DECISION-MAKING PROCESSES IN THE MANUFACTURING SECTOR:
THE INDEPENDENT LOCOMOTIVE INDUSTRY IN THE 19TH CENTURY

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Abstract

The thesis contributes to the debate about Britain's 19th century manufacturing development. It considers the capabilities and reasoning of the proprietors of the independent locomotive industry in making strategic policy decisions, and the tactical decisions for implementing them. It investigates historical practice rather than the modern theory of decision-making to develop a better understanding of behavioural rationality and its relationship to profit maximisation. Countering the criticisms of the Harvard School of business historians that Britain delayed implementing 'managerial capitalism', it is argued that a major contributory factor was the success of 'partnership capitalism'. Locomotive firms were multi-skilled partnership enterprises which provided for the withdrawal and recruitment of partners as age, experience and financial circumstances determined. As they increasingly employed general and specialist managers from the 1860s, it is concluded that incorporation of firms was solely motivated by the need for major re-capitalisation.

Addressing the Harvard School's further criticism that Britain was slow to implement the 'American system' of production, it is argued that the locomotive industry's vertically-integrated heavy manufacturing characteristics prevented mass-production economies of scale and scope. Although manufacturers recognised the need for component standardisation and greater batch production, the industry failed to control its market from the 1850s, the resulting design proliferation condemning it to small batch production. The loss of market control arose from the implementation of locomotive manufacture in British railway-owned workshops and the loss of design discretion to railway and consulting engineers, leaving the industry with a largely contract-only role. The industry experienced both a craft labour shortage, and a market which fluctuated widely through economic and political circumstance. It was divided between 'progressive' *specialist manufacturers and* 'craft' firms maintaining a broad manufacturing base, including locomotives, reflecting a tenacious will to survive, with sentiment and loyalty sometimes perceived to be more important than profit maximisation.

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Preface

A full understanding of the British contribution to the development of the world's railway networks has yet to be determined. The predominance of British capital in so many parts of Europe and the developing world in the 19th century, helped to expand Britain's engineering profession, construction industry and heavy manufacturing sector. British consulting and resident engineers helped to design and build many thousands of miles of line in each continent, which were equipped with bridges, track, signalling equipment, stations, depots and other structures manufactured in Britain and exported to the many railway locations.

Not least of these expanding manufacturing activities were the locomotive and rolling stock sectors that became amongst the largest parts of Britain's heavy manufacturing industry. The evolution of the firms engaged in these industries therefore form an important part of the country's economic development in the 19th century.

Since the early 1970s, the author has undertaken research into the history of the locomotive industry, which was independent of the British railway companies. He is pleased to have had this opportunity to consolidate all this research into a thesis which seeks to contribute towards a better understanding of decision-making, the progress of firms and Britain's locomotive manufacturing industry. It is hoped that the thesis will provide adequate acknowledgement of the contribution of the many proprietors, managers, foremen, craftsmen, tradesmen and labourers who were engaged in the industry during the 19th century.

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Author's Declaration

The research and the findings contained in this thesis have all been undertaken by the author alone. No part of this thesis has been previously submitted for consideration to either the University of York or any other university, and is therefore now submitted as "an original contribution to knowledge or understanding." Occasional references to the author's MA thesis, submitted to the University of Newcastle upon Tyne in 1984, have been fully referenced in the normal manner. No part of this thesis has been used in any publication.

Michael R. Bailey January 1999

1.0 Introduction

Business and economic historians have long considered the growth of entrepreneurship, business performance and the evolution of the firm from its 18th century 'family' origins to latter-day 'managerial' enterprises.[1] The development of Britain's manufacturing industry in the 19th century has formed an important focus for much of this research, which has examined whole market sectors and individual firms. Much consideration has been given to the quality of management in the attempt to provide a better understanding of the origins, growth and, sometimes, death of firms.[2] This thesis seeks to add to this debate through consideration of the decision-making capabilities of the proprietors of the independent locomotive manufacturing industry and its importance to the development of the firm.

The study of business history over the last quarter century has been much influenced by the 'Harvard' school of authors, notably Chandler, which has understandably taken the evolution of progressive American business as its bench-mark.[3] British authors since the work of Supple have recognised the importance of a more specific and analytical assessment of British business history from a comparative study of business structures to the importance of 'culture' on business behaviour.[4] While drawing on the fundamental assessments of Chandler into the development of business from 'personal' to 'managerial' capitalism, these studies seek in part to demonstrate that the peculiarities of the British case were a rational response to the growth of the country's industry.

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[1] The standard work has been R.H. Coase, 'The Nature of the Firm', Economica, Vol.IV, 1937, pp.386-405, which was developed by O.E. Williamson, The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting, New York, 1985; also, Economic Organisation: Firms, Markets and Policy Control, London, 1986. The subject has also been covered by P.J. Devine, 'The Firm' and 'Corporate Growth', in P.J. Devine, R.M. Jones, N.Lee and W.J. Tyson (eds), An Introduction to Industrial Economics, London, 1976; and K.D. George, C. Joll and E.L. Lynk, Industrial Organisation, Competition, Growth and Structural Change, London, 1991.

[2] For example, D.T. Jenkins and K.G. Ponting, The British Wool Textile Industry 1770-1914, Pasold Research Fund, 1975; R. Lloyd-Jones and A.A. LeRoux, 'Marshall and the Birth and Death of Firms: The Growth and Size Distribution of Firms in the Early Nineteenth-Century Cotton Industry', Business History, Vol. XXIV, 1982, No.2, pp.141-155; and Trevor Boyns and John Richard Edwards, 'Accounting Systems and Decision-Making in the mid-Victorian Period: The Case of the Consett Iron Company', Business History, Vol.37, July 1995, pp.28-51.

[3] Alfred D. Chandler Jr., The Visible Hand: The Managerial Revolution, Harvard, 1977; Alfred D. Chandler Jr., Scale and Scope The Dynamics of Industrial Capitalism, Harvard, 1990.

[4] B. Supple, Essays in British Business History, Oxford, 1977; J. Brown and M.B. Rose, Entrepreneurship, Networks and Modern Business, Manchester, 1993.

'Personal' or 'family' capitalism, which Chandler ascribes particularly to British business formation and development in the 19th century, was the form of entrepreneurial enterprise adopted by individuals and families who risked investment to innovate and exploit new technologies and services.[5] Chandler's definition of 'family firms', subsequently used in other papers, such as Church's essay on industrial capitalism, and the papers edited by Jones and Rose, refer to those in which the founders or their heirs have gone on to engage managers, but have continued themselves to hold executive positions and who exercised a decisive influence on policy matters.[6]

At the beginning of industrialisation, family firms provided kinship networks and personal connections which offered mutual trust, and helped to offset the uncertainties and risks of their developing markets. Such firms were appropriate in both scale and structure.[7] Prior and Kirby refer to the Quakers' regular Meeting House gatherings, which became the forum for discussions on investment and joint ventures, exploiting geographically dispersed pools of capital.[8] The rapid expansion of family firms in the early-mid 19th century contributed an extraordinary dynamism, particularly to the manufacturing sector. Their vertically specialised and horizontally fragmented industrial structure was particularly successful in securing for Britain her international competitive advantage. Jones and Rose argue that family firms maintained a longer-term perspective on their business than did managerial enterprises, and that they developed strong corporate cultures which yielded powerful competitive advantages. The family-owned business went on to outlive the industrial revolution and the 'second industrial revolution', and remains the predominant form of business organisation up to the present.[9]

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[5] Chandler, 1990, *op cit* (3), Part III, pp.235-392.
[6] Chandler, *ibid*, p.240; Roy Church, 'The Family Firm in Industrial Capitalism: International Perspectives on Hypotheses and History', Business History, Vol.35, No.4, 1993, pp.17-43; Geoffrey Jones and Mary B. Rose, 'Family Capitalism', Business History, Vol.35, No.4, 1993, pp.1-16.
[7] Church, *ibid*, p.19.
[8] Ann Prior and Maurice Kirby, 'The Society of Friends and the Family Firm, 1700-1830', Business History, Vol.35, 1993, p.67.
[9] Jones and Rose, *op cit* (6), pp.1-4.

The crucial factor in their on-going prosperity, however, was the generational transition from the entrepreneurial originators to their off-spring. There was a perceived advantage in young members of a family developing "an extensive tacit knowledge of their firm as they grew up, providing them with valuable expertise" when they themselves came to take decisions.[10] However, Lazonick believes that subsequent generations could not respond adequately to the challenges of technical change and that, regardless of relevant career credentials, they "stifled the growth of the enterprise and the development of organisational capability."[11] Payne goes further in arguing that their individualistic culture led owner-managers to take conscious decisions to "restrain the growth of the firm within the limits of existing managerial resources", thus restricting the growth of the firm reliant on internal managerial and financial resources.[12] Success in business often resulted from these strong personalities, for whom, Church believes, retirement represented a personal defeat.[13] Cookson's summary of the Yorkshire textile machinery industry has shown that there was a low survival of family firms in the early part of the 19th century, largely because of internal disputes or unsuitable heirs.[14]

These arguments concerning family firms have, however, inadequately drawn a distinction between the single-family firm and partnerships. Many of Britain's larger manufacturing enterprises in the 19th century were multi-skilled partnerships, and such partnerships were the organisational building-block of British business.[15] By their nature, partnerships shared the responsibility for the growth and health of their firms between their partners. They provided greater capital-raising potential to meet higher levels of investment, and were flexible enough to provide for the withdrawal and recruitment of partners as age, experience and financial circumstance determined. The effectiveness of this 'partnership capitalism' may have contributed to the slow introduction of 'managerial capitalism' in Britain, an argument which has been inadequately considered by previous authors.

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[10] *ibid*, p.4.
[11] W. Lazonick, Business Organisation and the Myth of the Market Economy, Cambridge, 1991, p.49.
[12] P.L. Payne, British Entrepreneurship in the Nineteenth Century, London, 1988, pp.40-43.
[13] Church, *op cit* (6), p.30.
[14] Gillian Cookson, 'Family Firms and Business Networks: Textile Engineering in Yorkshire, 1780-1830', Business History, Vol.39., No.1, 1997, p.3.
[15] P.L. Payne, 'Industrial Entrepreneurship and Management in Great Britain', in P. Mathias and M.M. Postan (eds), The Cambridge Economic History of Europe VII, Part I, 1978, p.192. Also, P.L. Cottrell, Industrial Finance, 1830-1914, London, 1980, pp.39-75.

The repeal of the 1719 'Bubble' Act in 1825 allowed firms to have more than six partners, which stimulated the raising of capital and the expansion of manufacturing industry.[16] However, Wilson has noted that until 1856 British company law encouraged and facilitated a highly individualistic business culture.[17] Entrepreneurs were forced primarily to form partnerships, as it was prohibitively expensive to set up joint stock companies. Much of the capital employed was working capital, which created an extensive 'web of credit' between industrialists, merchants, banks and acceptance houses, reinforcing the tendency to re-invest most profits.[18] Business networks, including manufacturing firms, were successfully established by Quaker 'dynasties', which were extended family enterprises whose beliefs developed a strong business culture.[19]

With its need for high levels of investment and risky markets, Britain's 'heavy' manufacturing industry in the 19th century was primarily formed of partnerships. The industry produced machinery, particularly steam engines, in small batches according to customer specification, and was composed of firms with a vertically-integrated workshop structure, quite unlike the small, repetitive production activities of the 'light' manufacturing sector. Partners had technical, production and commercial responsibilities, as well as the role, shared with their non-executive colleagues, of strategic planning. Reporting to them were senior clerks and foremen, who were themselves potential partners. This business structure generated novel problems of management. The effectiveness of 'partnership capitalism' in the British context can therefore be tested in part by considering the evolution of the decision-making capabilities of the heavy manufacturing industry.

The Harvard school tends to imply that the introduction of management required a wholesale restructuring of firms. Thus Chandler's works have concentrated on the development of

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[16] T.A. Lee, 'Company Financial Statements', in Business and Businessmen: Studies in Business, Economic and Accounting History, Liverpool, 1978, p.237.
[17] John F. Wilson, British Business History, 1720-1994, Manchester, 1995, p.56.
[18] S. Pollard, 'Fixed Capital in the Industrial Revolution in Britain', in F. Creuzet, Capital Formation in the Industrial Revolution, London, 1972, p.154.
[19] Prior and Kirby, *op cit* (8), pp.66-85.

'managerial capitalism', in which there was a three-tiered management structure requiring specialist managers with pre-determined responsibilities.[20] Such managerial hierarchies sprang up in large numbers from the mid-19th century with the growth of 'competitive managerial' capitalism in the United States, and from the late-century with the growth of 'co-operative managerial' capitalism in Germany. They did not become a major force in Britain until after the First World War. Yet it does not follow that British firms were necessarily poorly managed, as other business structures may have been just as effective. This thesis explores this possibility with regard to the independent locomotive manufacturers.

Chandler has described the salaried managerial class in the United States as becoming "the most influential group of economic decision makers", which demonstrated that effective administrative co-ordination could control external factors and permit "greater productivity, lower costs and higher profits than co-ordination by market mechanisms."[21] He describes the key to the success of managerial enterprises as being a "three-pronged investment" in production facilities large enough to exploit the economies of scale and scope, a marketing and distributive network, and a policy to recruit and train managers to undertake the strategic and tactical planning and control functions.[22] The German form of 'co-operative capitalism' was seen to be close to the American pattern, although Chandler argued that its cartels and collusion were often inefficient.[23]

In the British context, the introduction of specialist managers into firms was not dependent upon a change in the law, and, as discussed during this thesis, there were many examples in the early 19th century of managers being recruited to manufacturing by partnerships. However, the opportunity for developing this policy and creating full managerial enterprises only really came with the Companies Act of 1856, and the consolidating Companies Act of 1862, which provided for the establishment of joint-stock companies without the necessity of an enabling Act of Parliament, and with limited liability status. The intention of the

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[20] Chandler, 1977, and Chandler, 1990, *op cit* (3). Also, Alfred D. Chandler Jr. and Herman Daems, Managerial Hierarchies, Harvard, 1980, p.3.
[21] Chandler, 1977, *op cit* (3), pp.1/6.
[22] Chandler, 1990, *op cit* (3), p.8.
[23] *ibid*, pp.393-395.

legislation was to make possible the attraction of additional investment from shareholders who had no involvement in the enterprises, building on the experience of the railway companies. However, in practice, the investments of a large majority of the considerable number of firms which were incorporated in the years following the Acts were provided by their owner-proprietors seeking the greater security from the hazards of cyclical markets.[24] Payne sees this development of 'private limited companies' as "a typical British compromise", which, in perpetuating their ownership, actually discouraged wider investment.[25] Cottrell also notes that conversion to public companies was very slow, and largely remained the preserve of the large banking and utility organisations.[26] A small number of manufacturing firms took advantage of public status, but most proprietors sought to maintain their involvement with their companies, either through existing partnerships or through the new private companies. Yet we still know little of how the management of these firms was undertaken.

As noted above, Chandler's explanation for Britain's relative decline in the late 19th century, compared to the United States and Germany, is that entrepreneurs kept their family firms and passed them on to their heirs. This delayed the introduction of 'managerial capitalism' which would have provided the organisational capabilities needed for the 'second industrial revolution'.[27] Lazonick has developed this argument by claiming that Britain's 'proprietary capitalism' worked well until faced with the technological complexities and high fixed costs that developed from the late 19th century. It then lacked the managerial expertise to make decisions, which Lazonick blames on a reluctance of partners to become "reliant on, and potentially subservient to, a bureaucracy of technical specialists and middle managers."[28] Chandler notes, in particular, that in personally-owned and managed enterprises the proprietors sought to maintain an assured income rather than appreciate their assets, and that their dividends correspondingly depleted the level of investment that was available for long-

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24 Wilson, *op cit* (17), p.120.
25 P.L. Payne, 'The Emergence of the Large-Scale Company in Great Britain', Economic History Review, Vol.20, 1967, p.520.
26 Cottrell, *op cit* (15), pp.39-45.
27 Chandler, 1990, *op cit* (3), p.286.
28 Lazonick, *op cit* (11), pp.25-27, 45-49.

term growth.[29] On-going investment in capital equipment was necessary to exploit fully the economies of scale of improving production processes, and thus a policy of pursuing long-term profits based on long-term growth should have become more important.

An investigation into the development of proprietorial and management responsibilities in the heavy manufacturing industry should therefore be an excellent test of Chandler and Lazonick's views. It will also test the views of those historians who have alleged that the retardation of British industrial development was due to the wider issue of 'business culture'. Elbaum and Lazonick have suggested, for example, that business culture was one of the principal 'institutional rigidities' which hindered Britain's competitiveness.[30] Other historians have suggested that there was a 'gentrification' of industrialists in the latter part of the 19th century.[31] Such industrialists are said to have invested their wealth in landed estates rather than expanding and modernising their capital equipment,[32] but this is seen by Wilson to have little credibility.[33]

In pursuing a better historical understanding of business culture, recent research has considered the decision-making process and provision of management information in British business.[34] These studies have moved beyond the simple concept of profit maximisation towards an appreciation of behavioural rationality, both individually determined, and reflecting wider social forces. Some tentative conclusions have been drawn on the mixed motivations of entrepreneurs, the consequences of these on business performance through changing economic climates, and the development of managerial functions and responsibilities. However, much remains uncertain, and business historians' knowledge of

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[29] Chandler, 1990, *op cit* (3), pp.594/5.

[30] B. Elbaum and W. Lazonick, 'An Institutional Perspective on British Decline', in B. Elbaum and W. Lazonick (eds), The Decline of the British Economy, Oxford, 1986, pp.1-15.

[31] For example M.J. Wiener, English Culture and the Decline of the Industrial Spirit, 1850-1980, Cambridge, 1981.

[32] For example, Wiener, *ibid*, p.137, provides the example of Marshalls, the Leeds firm of flax spinners. Also, R.S. Fitton, The Arkwrights: Spinners of Fortune, Manchester, 1989, pp.182-184, refers to the acquisition of estates by the Arkwright family.

[33] Wilson, *op cit* (17), pp.115/6.

[34] For example, Boyns and Edwards, *op cit* (2), pp.28-51.

how businessmen undertook decisions, and the framework within which they were made, whether motivated by economic, cultural or social considerations, is very limited.[35]

Noting that, contrary to all the evidence, modern microeconomic text books maintain the notion that profit maximisation is central to the 'theory of the firm', Boyns and Edwards have highlighted the difference between the concepts of profit maximisation and long-term survival. They argue that, whilst some long-term profits may be a necessity for survival, it is not clear that profit maximisation and survival are synonymous.[36] Recognising that decision-makers act in a complex behavioural fashion, Simon and other behavioural theorists are pursuing the concept of bounded rationality, in which participants' behaviour is understood as being constrained by incomplete information.[37] They seek to determine "what the central frame of the decision is, how that frame arises from the decision situation, and how, within that frame, reason operates", and go on to call for micro-empirical studies to determine how the decision-making process was conducted in practice, and what the economic outcomes of that process were.[38]

A better understanding of 'business culture' and its relationship to profit motivation will, therefore, contribute to this debate, and lead to a better understanding of the strengths and weaknesses of partnership capitalism. This thesis seeks to determine this relationship through a detailed empirical study of the decision-making capabilities of the proprietors of one of the main sectors of British heavy manufacturing, the railway locomotive industry. It considers the historical practice rather than the modern theory of decision-making, and seeks a better understanding of managerial expertise as an example of bounded behavioural rationality. In particular, it seeks to analyse the relationship between profit maximisation and this type of business structure.

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[35] Post-Chandlerian Business History Seminar, University of Reading, 4th March 1994, reported by Boyns and Edwards, *ibid.*

[36] Boyns and Edwards, *ibid*, pp.30/31.

[37] Boyns and Edwards, *ibid*, quote, for example, M.L. Katz and H.S. Rosen, Microeconomics, Burr Ridge, Illinois, 1994.

[38] H.A. Simon, 'Rationality in Psychology and Economics', Journal of Business, Vol.59, 1986, p.S223.

To understand the evolution of proprietorial responsibilities, the thesis considers strategic decision-making relating to the development of marketing, sales, technology, design, manufacturing, management, skills and employment, and the tactical issues governing their implementation. It also considers the benefits and drawbacks of incorporation as private and public companies, and the objectives and motivations of their proprietors. It includes an assessment of management information systems, including accounting, which contributed to the process by which decisions were made, together with the economic outcomes of those decisions.

The thesis does not consider the new institutional theory of the firm, which Jones describes as being concerned with the historical relationship between organisational structures, resource allocation and the processes of equilibration.[39] Casson considers that, although the theory has succeeded in explaining where the boundaries of the firm were drawn, it has failed to relate these boundaries to what went on inside the firm.[40] He notes that as firms grew and diversified their boundaries shifted and internal organisations changed, but this growth and its consequences have, thus far, received little attention. Jones also concludes that the scope and limitations of theoretical 'transaction cost economics' of the 'New Institutional Approach' are both too ahistorical and too limited to explain all but a small proportion of business behaviour.[41] However, as the central theoretical questions of why firms exist and grow are increasingly being tackled through consideration of transaction cost economics, it is hoped that sufficient new evidence is presented here to guide the enquiries of economic historians pursuing the new institutional approach.

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[39] The most recent discussion and papers on the New Institutional Approach and Transaction Costs has been the dedicated issue of Business History, Vol.39, No.4, October 1997, Mark Casson and Mary B. Rose (eds). The issue includes S.R.H. Jones, 'Transaction Costs and the Theory of the Firm: The Scope and limitations of the New Institutional Approach', pp.10-25.
[40] Mark Casson, 'Institutional Economics and Business History: A Way Forward?' in Casson and Rose, *ibid*, p.151.
[41] Jones, *op cit* (39), p.24.

1.1 The Locomotive Industry

The British locomotive industry started in 1830 and underwent such an extraordinary growth that, by the end of the 19th century, it had become the country's third largest manufacturing activity, after textile machinery and railway carriage and wagon building, with a gross annual output of over £12million.[42] Nearly two-thirds of this activity was undertaken by the railways' own workshops. The subject of this thesis, however, is the sector which was independent of railway ownership, manufacturing locomotives for main-line railway and industrial customers, both at home and overseas. This sector, which itself grossed an annual output of £4.5million at the end of the century, was the world's largest locomotive export industry.[43]

Locomotive production was largely undertaken by firms in the heavy manufacturing sector, which pursued several markets with varying levels of specialisation. It began through the diversification of early manufacturing firms, which already had vertical integration of manufacturing processes and the administrative experience to take on this new market opportunity. Jenkins has noted similar diversification in relation to the textile machinery firms in this same period.[44] The heavy manufacturing sector developed from the late 18th century as factory-based activities employing multiple craft skills and metal forming techniques to produce robust machines and structures for the marine, colliery, iron, machine tool, textile and other industries.

Engines and other equipment were usually manufactured in small quantities, the many component variations for particular applications limiting batch production opportunities. The in-house development of machine tools, handling equipment and steam power extended the manufacturers' capabilities, both in terms of new product development and organisational efficiency. By its very nature, each item of equipment was designed, manufactured and

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[42] S.B. Saul, 'The Engineering Industry', in Derek H Aldcroft (ed), The Development of British Industry and Foreign Competition 1875-1914, London, 1968, Table 1, p.192.
[43] *ibid.*
[44] Jenkins and Ponting, *op cit* (2), p.302.

erected by skilled craftsmen, particularly millwrights, foundrymen, and boiler-makers, whose one-time independence and discretion over the labour process was being subsumed into the collective activities and hierarchical subservience of manufacturing firms.[45] Machinery manufacturers had the option of in-house production or buying-in their interchangeable components, the latter often being more cost effective. Cookson, for example, has shown the importance of the networking of the several component manufacturing firms in Yorkshire, each supplying the textile machinery industry on a 'hub and spoke' system.[46]

The output of heavy industry contrasts with the light manufacturing sector in the 19th century. The latter undertook quantity production of domestic ware, agricultural implements, firearms and, particularly, components for sub-assembly into larger industrial machines. The economics of repetitive component production by specialist producers, using unskilled labour, were very different from the production and erection of machines. Referring to the parallel situation in the United States, Scranton has drawn the distinction between the manufacturing characteristics of four levels of batch size, namely custom, batch, bulk and mass production.[47] He does not attempt to establish the boundaries between them, but he does highlight the growing economies of scale that is inherent as one moves from custom to mass production. Locomotive production had been born into a custom industry and developed, with varying degrees of success, into a batch industry.

The independent locomotive sector provides a case study of the relationship between entrepreneurial and behavioural characteristics in strategic decision-making in the heavy manufacturing industry. With our lack of understanding of how, historically, decisions were made, the conventional assertion that the sole motivation was profit maximisation will, for the locomotive industry, need to take account of the varied cultural as well as professional backgrounds of the proprietors. In the industry's early years, this culture, combining

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[45] For example, discussed by Chandler 1977, *op cit* (3), pp.269-272; A.E. Musson, 'Joseph Whitworth and the Growth of Mass-Production Engineering', Business History, Vol.XVII, No.2, 1975, pp.109-149; Saul, *op cit* (42), pp.186-237; and Diane K. Drummond, Crewe Railway Town, Company and People 1840-1914, Aldershot, 1995, pp.40-132.
[46] Cookson, *op cit* (14), p.4.
[47] Philip Scranton, Endless Novelty, Princeton, 1997, p.10.

enthusiastic engineer, anxious to improve upon successful innovation, and entrepreneurial businessman, with the acumen to create wealth and provide employment, was rarely found in one person, and partnerships were inevitably the way to combine these attributes.

The industry, which at any one time had between 25 and 35 partnership firms, was characterised by a wide divergence of entrepreneurial and managerial skills. These ranged from 'progressive' firms, which encouraged a large amount of equity and loan capital for investment, pursuing increases in productivity through improving capital equipment, employment and production procedures, to firms without such attributes, retaining instead their traditional craft-dependent working practices. In considering the decision-making attributes of the industry, it is therefore necessary to determine whether this diversity was generally symptomatic of partnership enterprises, and applied equally to all policy areas, or whether there were different motivations on some issues that gave rise to the diverging strategic decisions.

The establishment and development of large workshops in the 19th century called for personal attributes among proprietors which would encourage investors to provide sufficient equity and loan capital. Only by demonstrating sufficient return on that capital could proprietors stimulate further investment for expanded and modernised manufacturing facilities. From the mid-century, however, partnerships were limited in their ability to maintain sufficient levels of investment; these were heavily dependent upon sustained confidence, good profitability records and high collateral value of sites and capital equipment, not all of which could be guaranteed. The entrepreneurial flair of many of the first partnerships had to be renewed as their older members retired and were replaced with new partners, either from within family circles or by promotion through talent.

The opportunity to adopt limited company status, and thereby encourage further investment opportunities, followed the 1856 Joint Stock Companies Act and the consolidating Companies Act of 1862. Prais's assertion that limited company status fundamentally altered the forces affecting the size of firms can therefore be tested in regard to the locomotive industry.[48] The Company Acts not only allowed proprietors to attract further capital, but also provided the opportunity to attract new entrepreneurial talent. Understanding the changes in proprietorial culture and their decision-making capabilities, will help to explain the evolution of the industry during the 19th century. One line of enquiry, in particular, explores the extent to which proprietors sought to maintain control over their firms, either through continuing partnerships or through private limited companies, as Chandler suggests typified the British case,[49] or opted for public company status.

In addition to their entrepreneurial and engineering attributes, proprietors and their managers needed to draw on a third quality, namely strength of character coupled with sensitivity, with which to earn and maintain the respect of the labour force. This was a particular requirement of the locomotive firms as craft skills were eroded and repetitive tasks passed to un-skilled men. Too harsh an approach would lead to industrial strife, too soft an approach could engender such loyalty to the workforce that the motivation for maintaining employment levels in the short-term, and even remaining in business, became stronger than profit incentive alone. This third quality will need to be tested for the locomotive industry to ascertain the extent to which it provided an alternative motivation to profit maximisation.

Managers had been employed in manufacturing since the mid-18th century, and by the early 19th century they were in great demand as owner-managers struggled with the challenges of growing businesses.[50] Pollard believed that the "replacement of nepotism by merit became one of the more significant aspects of the growing rationalisation of industry" at that time, and that the managers "formed one of the most dynamic social groups of their age, responsible for initiating many of its decisive changes".[51] From the beginning of the railway era, the locomotive manufacturers were almost all partnerships, thus providing a case study of the benefits of managing partners, which Wilson describes as one of the more enduring

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[48] S.J.Prais, The Evolution of Giant Firms in Britain, Cambridge, 1976, p.33.
[49] Chandler, 1990, *op cit* (3), Part III, 'Great Britain: Personal Capitalism', pp.235-294.
[50] Wilson, *op cit* (17), p.27.
[51] Sidney Pollard, The Genesis of Modern Management, Cambridge, Mass, 1965, pp.174/185, quoted by Wilson, *ibid*, p.27, to illustrate attitudes towards professional managers.

solutions in the compromise between individualism and economic reality.[52] As the businesses grew, and delegated decision-making responsibilities became quite varied, this case study will examine the introduction of specialist managers who took over the responsibilities for strategic and administrative changes of the vertically-integrated operations.

As each of these operations could be regarded as a cost centre, they anticipated Chandler's first 'proposition' of the institutional changes towards "modern business enterprise".[53] The principal decision faced by proprietors, as the scale and scope of their operations expanded, was how to develop their administration through introduction of a management hierarchy (Chandler's second 'proposition'). The managerial responsibilities included interpretation of, and response to, cyclical market changes, raw material price movements, and the corresponding effects on employment policies and industrial relations. The locomotive industry, however, unlike the quantity-production light industries, had little opportunity to achieve the full benefits of administrative co-ordination, to which Chandler's subsequent management propositions were directed. The manufacturers' managerial responsibilities had to become increasingly technical and specialised in order to deal with demanding tactical and strategic decisions, on investment and use of assets, that were quite unlike those in the light manufacturing sector.

1.2 Previous Literature

Previous academic assessment of the independent locomotive industry, limited to a small number of papers and just one book, only goes a short way towards exploring these issues. An important contribution has been Saul's summary of the whole engineering industry from the 1860s until the First World War, in which he emphasises the handicap to the industry caused by the loss of the majority of the domestic main-line market to the railways' own

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[52] Wilson, *op cit* (17), p.27.
[53] Chandler, 1977, *op cit* (3), pp.6/7.

workshops.[54] Until the late 1870s, the home and export trades were comparable, but thereafter the export market became increasingly *important*. Saul also emphasises the further handicap to the industry due to the effects of the major cyclical demand for locomotives through the century.

Kirby has considered the issues of product proliferation in the British locomotive industry as a whole, as well as its record on technological innovation and divided structure.[55] The development of railway workshops in Britain had a major effect on the independent industry, not just through loss of market opportunity but through the proliferation of designs and standards that they generated. Kirby attributes this to the "autocratic temperaments" of the locomotive superintendents, which in one or two cases bordered on "certifiable megalomania".[56] The economic importance of the Scottish locomotive industry has been stressed by Vamplew, who outlines its development into the 20th century, from the beginning of which the North British Locomotive Company of Glasgow had become the largest in Europe employing over 8000 men.[57]

Cantrell's book is a 'Study of Entrepreneurship' of Nasmyth's Bridgewater Foundry, covering its first twenty years to 1857.[58] He considers the formation of the firm, its commercial organisation and patterns of trading, production methods, mechanical innovation and the labour force. Several issues raised by Cantrell need to be considered in the context of the whole locomotive industry to determine how representative Nasmyth was. These include the decision-making processes by which the firm was started up and subsequently expanded. They also include Nasmyth's radical labour policies as he sought to overcome a shortage of craftsmen, and which led directly to the introduction of a new generation of self-acting

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[54] Saul, *op cit* (42), pp.186-237.
[55] M.W. Kirby, 'Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineer's Paradise?', Business History, Vol.30, No.3, 1988, pp.287-305. Also, 'Technological Innovation and Structural Division in the UK Locomotive Building Industry, 1850-1914', in Colin Holmes and Alan Booth (eds), Economy and Society: European Industrialisation and Its Social Consequences, Leicester, 1991, pp.25-42.
[56] *ibid* (1988), p.288.
[57] Wray Vamplew, 'Scottish Railways and the Development of Scottish Locomotive Building in the Nineteenth Century', Business History Review, Vol.46, No.3, 1972, pp.320-338.
[58] J.A. Cantrell, James Nasmyth and the Bridgewater Foundry, Manchester, 1984.

machine tools operated by un-skilled men. It is clear from Cantrell's work that James Nasmyth was more than the self-styled, independent genius-inventor stressed in his autobiography.[59] Nasmyth was, in addition, one of the most successful engineering entrepreneurs of the 19th century, but he retired at the age of 48 claiming that his nervous system was showing signs of wear from his "long continued and incessant mental efforts."[60]

Lowe's comprehensive summary of each locomotive firm emphasises the large number which were engaged in the work.[61] Over a dozen histories of individual locomotive manufacturing firms have been written but, on the whole, these have been descriptive rather than analytical. This is largely true also of the two academic dissertations relating to locomotive manufacturers that have been submitted. Hayward's MSc dissertation largely considers the engineering development of William Fairbairn & Sons of Manchester,[62] whilst Davis' BA dissertation is a descriptive record of the Avonside Ironworks in Bristol.[63] Certainly, neither considers the decision-making processes or motivations that lay behind proprietorial strategies.[64] The most comprehensive of the other studies are those by Hills and Patrick, Clarke, and Lane, which provide useful summaries of the corporate progress of Beyer Peacock & Co., R.&W. Hawthorn and John Fowler & Co. respectively.[65] Although the authors provide evidence of some of the decisions taken, in the absence of an overview of the wider heavy manufacturing industry their narratives, targeted at an audience with a largely technical rather than business interest, provide limited critical assessment. The remaining company histories provide a descriptive or technical narrative.[66]

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59 *ibid*, pp.250-253. Also, Samuel Smiles (ed), James Nasmyth Engineer An Autobiography, London, 1883.
60 Cantrell, *ibid*, p.250.
61 James W. Lowe, British Steam Locomotive Builders, Cambridge, 1975.
62 R.A. Hayward, Fairbairns of Manchester, unpublished MSc dissertation, UMIST, Manchester, 1971.
63 C.P. Davis, Locomotive Building in Bristol, The Avonside Ironworks (1837-1882), unpublished BA Dissertation, University of Bristol, 1979.
64 During the preparation of this thesis it became known that David Boughey, of the School of Management, Royal Holloway, University of London, was researching for a thesis considering the independent locomotive manufacturers between 1860 and 1914. The initial emphasis of this work was to give substance to the notion of industrial clustering in providing competitive advantage, but as the work nears completion its title is now: 'Industrial Flexibility and International Competition: Railway Locomotive Engineering in Britain, 1860-1914'. It is expected that the thesis will be submitted later in 1999.
65 R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982; J.F. Clarke, Power on Land and Sea, Newcastle upon Tyne, nd but 1979; Michael R. Lane, The Story of the Steam Plough Works, London, 1980.
66 For example, Ronald N. Redman, The Railway Foundry Leeds: 1839-1969, Norwich, 1972.

The railways' own workshop facilities have similarly received insufficient enquiry, although a number of descriptive books have been published.[67] Only Drummond's detailed analyses of the Crewe workshops of the London & North Western Railway, and more cursory studies of other factories, have enquired into such issues as managerial strategies, worker responses and paternalism.[68] Direct comparison between railway-owned and independent workshops is not always relevant or even possible, as the former were fully integrated into the railways' corporate structure. Their workshop function was as much to provide maintenance as to undertake new manufacture, and their skills were also employed on wider areas of work than locomotive manufacture alone. Crewe's steel works, for example, supplied steel for a wide variety of railway applications in addition to locomotive components.[69] There are, however, a number of Drummond's conclusions that are directly relevant to the independent locomotive industry, and which provide evidence to explain some of the issues affecting it. These particularly include the related matters of labour recruitment, workshop organisation and supervision, and skill and the labour process, all of which were linked with the development of capital equipment and production processes. The relative geographical isolation of some of the railway workshops led to problems of recruitment and employment, solutions to which included paternalism. All of these matters need to be considered in relation to the more urban-based workshops of the independent manufacturers.

The histories of overseas manufacturers have mostly followed descriptive narrative forms.[70] The notable exception is Brown's history of the Baldwin Locomotive Works in Philadelphia,[71] in which he considers the growth of the American locomotive industry and the character of innovation in locomotive design, before analysing its management

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[67] A general summary of each workshop was provided in Edgar J. Larkin and John G. Larkin, The Railway Workshops of Britain 1823-1986, Basingstoke, 1988.
[68] Drummond, *op cit* (45), and two papers by Drummond, namely: 'Specifically Designed'? Employers' Labour Strategies and Worker Responses in British Railway Workshops, 1838-1914', Business History, Vol.31, No.2, 1989; and 'Technology and the Labour Process: A Preliminary Comparison of British Railway Companies' Approaches to locomotive Construction Before 1914', Perspectives on Railway History, Working Papers in Railway Studies Number One, Institute of Railway Studies, York, 1997.
[69] Drummond, *op cit* (45), p.48.
[70] American locomotive companies are summarised by John H. White Jr., A Short History of American Locomotive Builders in the Steam Era, Washington D.C., 1982.
[71] John K. Brown, The Baldwin Locomotive Works, 1831-1915, Baltimore, 1995.

procedures, workforce policies and developing manufacturing practices. This in-depth work considers many of the management and technical issues of locomotive manufacture, and the strategic decisions taken by its proprietors provide useful comparisons with those of their British counterparts. Of particular significance is Baldwin's approach to the problem of design proliferation which, as in Britain, threatened to escalate production costs through forcing small-batch production. The strong line taken by Baldwins in dealing with the railroad master mechanics' design aspirations whilst promoting component standardisation makes an interesting comparison with the British industry, which was so dependent upon the domestic railways and consulting engineers for its design detail.

No comparable detailed, analytical study of the German locomotive industry exists, although there are narrative studies. The most recent work is that by Lindner and Schmalfuß' on the Borsig locomotive works of Berlin,[72] whilst two pre-war histories of the large Henschel and Hanomag locomotive firms serve to provide much detail of their manufacture in the 19th century.[73] As Chandler and Daems have noted, German industry formed itself into federations or cartels with which to compete in the international market.[74] This included the locomotive industry, whose cartel benefited from the trade advantages of an assured home market, and which built on this strong market to compete with the British industry towards the end of the century. By contrast, the French locomotive industry was closest to the British pattern, being divided between the railway workshops and an independent industry, although both were much smaller in output. Crouzet's detailed summary of the industry confirms that it experienced the same demand fluctuations as those experienced in Britain and the United States, but it also suffered the loss of two of the larger firms from the Alsace region, following the Franco-Prussian war of 1871.[75] Annual exports ranged between 0 and 50 in the last quarter of the century.

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[72] Helmut Lindner and Jörg Schmalfuß, 150 Jahre Borsig Berlin-Tegel, Museum für Verkehr und Technik Berlin, 1987.
[73] Dr.-Ing. Kurt Ewald, 125 Jahre Henschel, Kassel, 1935; and Dr.phil.Dr.jur. Walther Däbritz und Baurat Dr.-Ing. E.H. Erich Metzeltin, Hundert Jahre Hanomag, Düsseldorf, 1935.
[74] Chandler and Daems, *op cit* (20), p.6.
[75] François Crouzet, 'Essor, Déclin et Renaissance de l'Industrie Française des Locomotives, 1838-1914', Revue d'Histoire Economique et Sociale, Vol.55, 1977, pp.112-209.

The absence of a detailed analytical study of the origin and development of the British independent locomotive industry in the 19th century is therefore long overdue. This study fulfils the need to assess the industry's managerial capabilities through the complex inter-relationship between its marketing, technological, design, production, management and employment policies, as well as its corporate development. The manufacturers' decision-making capabilities determined the effectiveness of their developing strategies with each of these policies, and their tactics in carrying them out.

1.3 Strategic Decision Making

By the end of the century, the diversity in the locomotive industry was very marked. The progressive firms, employing up to 3,000 men with advanced managerial and manufacturing procedures and a high degree of specialisation in locomotive production, contrasted sharply with the craft firms, employing several hundred men, and pursuing a broad market base of higher cost, small-batch orders for capital equipment. Throughout the century, the emphasis for all firms was on survival, the pursuit of which resulted in far more diverse organisations than was the case with their competitors in the United States and Germany.

By 1900, 26 large and medium sized independent firms were regularly making locomotives for the home and export markets (Appendix), compared to less than half that number in the United States making three times the output of the British industry (Section 1.4). It will therefore be helpful to compare how the cultural differences between the British proprietors and their counterparts in America affected corporate decision-making. Brown has determined that the failure rate of American locomotive firms was quite high, being unable to remain solvent during the extraordinary periodic downturns in the market.[76] Those that survived through superior decision-making strengths, were mostly incorporated firms, but the Baldwin works, the largest by far, remained a partnership. The company's progressive culture and ability to survive the market swings is explained by Brown as being due to a

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[76] Brown, *op cit* (71), pp.31-35.

distinctive business strategy that possessed its own internal coherence and logic. It minimised risks whenever possible while capitalising on opportunities for growth.[77]

A generation later, however, the American industry itself was faced with the cultural challenges of a major change in technology, during the transition from steam to diesel between 1920 and 1955. In considering the theory of the firm, Marx has analysed decision-making behaviour in the American steam locomotive industry during this period, which may have parallels with some of the attitudes in Britain's 19th century locomotive industry.[78] He notes that the manufacturers' managerial objectives were not directed towards profit maximisation alone, but were combined with diverse preferences for status, pecuniary awards and the steam technology itself. These preferences reflected vested interests in established production and marketing methods, including security and achieved status. Picking up Marx's theme, also in relation to the decline of the steam locomotive industry, Churella notes that if managers fail to modify their companies' cultures in response to technological change, then success may turn to disaster.[79] He cites the failure of the ALCo management to accommodate the change to diesel traction as due firstly to denial that change was taking place, and secondly the perseverance of the operational routines embedded in their old corporate culture.[80]

These contrasts within the American industry had their parallels in Britain. In spite of the relatively high 'survivability' of British locomotive firms during the 19th century, a cultural gulf developed between the 'progressive' firms and the 'craft' firms that retained their traditional working practices. The greater specialisation in locomotive production practised by the former gave potential benefits of larger batch production, which had to be balanced against the risks of being committed to an uncertain market. The move towards specialisation would have been a conscious decision and, as Payne has explained, it became

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[77] *ibid*, p.235.
[78] Thomas G. Marx, 'Technological Change and the Theory of the Firm: The American Locomotive Industry, 1920-1955', Business History Review, Vol.L, No.1, 1976, p.19.
[79] Albert Churella, 'Corporate Culture and Marketing in the American Railway Locomotive Industry: American Locomotive and Electro-Motive Despond to Dieselization', Business History Review, Vol.69, 1995, p.196.
[80] *ibid*, p.201.

"increasingly irreversible, for there takes place a concomitant growth of special mercantile relationships, highly skilled labour forces and the evolution of particular types of managerial talent that makes any return to an earlier, more flexible, position more expensive and difficult."[81] The 'craft' firms, on the other hand, were reliant on tactical decisions in order to survive, including diversification into alternative markets and the development of alternative employment policies. It is therefore germane to consider their motivations and attitudes to changes in production techniques, employment terms and marketing.

There were no moves towards amalgamation of the many locomotive firms still in production at the end of the century, which surpressed the opportunity for further production economies in the way that the American industry had evolved. Mergers were seen to be beneficial to certain sectors of British industry from the late 1880s. Hannah notes that an average of 67 firms were merged with others in each year between 1888 and 1914, although it did little to create an oligopolostic market structure in the country.[82] Indeed, almost all were horizontal combinations, essentially defensive measures by proprietors seeking the continuation of their businesses, and quite unlike the vertical mergers of the United States which gave closer harmonisation of industrial and financial undertakings.[83] Consideration of mergers within the locomotive industry will, therefore, help to illustrate further the cultural importance in decision-making in the manufacturing sector.

1.4 Market Development

The first consideration, which affected several of the industry's policies, was the development of the market, which was subject to extraordinary fluctuations during the 19th century. These were to have a significant influence on its strategic decision-making and were a strong factor in the industry's growing diversity. Demand, which varied for each geographic and

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[81] Payne, *op cit* (25), 1967 p.525.

[82] L. Hannah, The Rise of the Corporate Economy, 2nd Edition, London, 1983, pp.21/2.

[83] L. Hannah, 'Mergers in British Manufacturing Industry, 1880-1918', Oxford Economic Papers, XXVI, 1974, pp.1-20.

economic region, was the result of economic and political events quite outside the influence of the manufacturers. Long-term economic cycles and short-term market variations made profitable production difficult to maintain, and, with limited opportunities for scale economies through batch production, interpretation of market growth made investment decisions risky. The locomotive industry's main customers, the railways, were both capital-intensive industries, subject to the variations of the capital market, and major transport utilities, subject to national and, increasingly, international economic health and political stability. With these fluctuations having such an important influence on their affairs, the manufacturers' interpretation of the market, and their strategic and tactical response to the changes, became important elements in their policy making.

At its start-up in the 1830s, locomotive technology was dominated by British progress, although there was a rapid diffusion to America and continental European countries. These soon developed their own industries. After significant exports of locomotives from Britain, manufacturers in the United States took over their home market from the late 1830s, whilst manufacturers in Germany, France and Belgium dominated their respective home markets from the 1850s, and in Russia, similarly, from the 1890s. The locomotive markets beyond Europe and North America were dominated by the British industry, albeit facing increasing competition from the American and German industries in the 1890s (Section 2.5).

The industry's initial growth was to meet the demand of the new railways, which became the largest companies in Britain through to the First World War.[84] The loss of a large part of this market to the railways' own workshops from the 1840s was a major blow to the industry, which went on to seek a higher proportion of its market from overseas. By the end of the century, it was manufacturing 700 locomotives annually for those overseas markets, and a further 400 for its domestic industrial and residual main-line markets.[85] By comparison, the American industry manufactured 3000 locomotives annually, largely for its

[84] P. Wardley, 'The Anatomy of Big Business: Aspects of Corporate Development in the Twentieth Century', Business History, Vol.33, No.2, 1991, p.278.
[85] Analysis of production, Fig. 2, Chapter 2.

domestic market, but including export totals, of which the Baldwin company alone made 300.[86]

With the increasing loss of domestic main-line orders, the manufacturers' domestic market was limited and, by the 1870s, was made up of residual orders from the main line companies and industry's growing requirement for internal motive power. This emphasises the importance of the export market, which was made up of several distinct geographical and political sectors, each influenced to varying degrees by British capital exports. From the late 1850s, these investments increased significantly in the widening spheres of British influence around the world. Cottrell and Edelstein have calculated that 41%, and possibly as much as 44%, of all Britain's overseas investments between 1865 and 1914 were for railway projects,[87] and Edelstein and Kennedy have calculated that the amount of British money invested in overseas railways by 1870 was very nearly equal to that which had been invested in the British railway system itself.[88] However, in discussing the export of capital and all kinds of capital goods from Britain, Jenks could find no relation between the destination of exported capital goods and the apparent field of activity of British investment,[89] and it will need to be ascertained if this was true for the locomotive market. British capital exports fluctuated during the century, with railway investments following similar cyclical swings, and the market fluctuations may be explained by a correlation between capital export trends and the demand for locomotives.

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[86] John H. White Jr., A History of the American Locomotive, Baltimore, 1968, p.21; Also, Brown, *op cit* (71), p.45.

[87] P.L. Cottrell, British Overseas Investment in the Nineteenth Century, Studies in Economic and Social History, London, 1975, Fig.1, p.14; Also, Michael Edelstein, Overseas Investment in the Age of High Imperialism, The United Kingdom 1850-1914, New York, 1982, p.37.

[88] Edelstein, *ibid*, Table 3.1, p.48; Also J.J. van-Helten and Y. Cassis (eds), Capitalism in a Mature Economy: Financial Institutions, Capital Exports and British Industry 1870-1939, London, 1990, Table 5.4, p.104.

[89] L.H. Jenks, The Migration of British Capital to 1875, London, 1927, re-published 1963, p.175.

1.5 Marketing and Selling

Although demand patterns were difficult to determine, the long-term characteristics of the locomotive market were more readily perceived. The growth of the domestic main-line market in the 1830s was reversed from the 1840s with a gradual reduction in favour of the railway workshops, although a significant volume of domestic business remained at the end of the century. For the overseas market the initial dependence on agency representation gave way in the 1850s to a market more dependent upon direct contacts within the London commercial area. The start-up and growth of the industrial locomotive market from the 1850s gave rise to a third market category. The emphasis of all three categories was for the manufacturers to market themselves to ensure inclusion on tender lists, to provide themselves with the opportunity for quotations on time and price. Such fundamental commercial practices developed through the century, and it was incumbent upon the industry to adapt its marketing and selling strategies accordingly.

When the locomotive market began in the 1830s, the new railway customers were joint-stock companies or government-owned railways, for whom 'transparency' was important. The introduction of tendering and contracting was a major change for the industry, but as the market developed, tendering procedures by railways and consulting engineers became more demanding. The industry therefore implemented promotional marketing in addition to selling. The practices of the heavy manufacturing industry were thus transformed from those it had previously used for customers in the ship-building, colliery, iron, textile and other industries, which were usually family-owned or partnership firms requiring only informal, personal and often local contacts.

The overseas market, on the other hand, was initially the preserve of commission agents, who were extensively used by British industry as the link to its foreign customers.[90] Chapman writes that agents were the response to the enormous risks associated with

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[90] Payne, *op cit* (12), p.41.

exporting, particularly on matters of credit.[91] Payne argues that the employment of agents brought about a reliance on intermediaries which prevented industry from developing a close relationship with its customers.[92] Yet the growth of British foreign direct investments in the second half of the century, and the dominance of London in the affairs of many overseas railways, led to the growth of a strong London market for locomotives with the opportunity for direct marketing and selling by the manufacturers. The ways in which the manufacturers responded to these changing requirements, establishing new marketing practices, agency networks, and pricing and selling techniques, are important indicators of their responsiveness to the new order and their capacity to take decisions necessary to maintain or improve market share.

One such instance concerns trade associations. Wilson has noted that the price depression experienced by British industry from 1873 led to the formation of a number of trade associations, particularly in the iron and steel, textile, chemical and manufacturing industries, whose aims were to fix prices, allocate market quotas and liaise on technical matters.[93] The Locomotive Manufacturers Association was formed in this period, and a consideration of the ways in which the industry adapted to the market changes, particularly through this trade association, will provide further evidence of the adaptability of the industry.

1.6 Technology and Design

It was also incumbent upon the manufacturers to pursue long-term strategies through the development of locomotive technology and design. They lost the initiative from the 1850s, however, as their changing main-line market led them away from research and development to become a largely contract-only industry, manufacturing to the designs of their customers. Only the industrial sector, with its limited opportunities for technical advancement, remained

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[91] S.D. Chapman, Merchant Enterprise in Britain: From the Industrial Revolution to World War I, Cambridge, 1992, pp.129-166.
[92] Payne, *op cit* (25), pp.524/5.
[93] Wilson, *op cit* (17), p.99.

as an industry-led activity. It is therefore important to pursue the industry's decision-making processes to understand how it reacted to these market-led pressures, and to ascertain whether it might have done more to encourage its main-line customers to allow it to retain the initiative for technological innovation and design.

Previous studies of technology and design in the locomotive industry have been helpful, but not conclusive. In discussing technological innovation in the locomotive industry, Kirby argues that there were two "intensive bursts" in the years 1829 to 1841, and 1896 to 1911, with incremental progress in between.[94] This analysis needs more rigorous assessment, however, in order to understand the motivation for, and means of achieving, technological progress in locomotives. With the international nature of the locomotive market, this assessment will need to consider global advances in technology in order to assess and judge the contribution of the British independent industry.

The study of the history of technological innovation has broken new ground in recent theoretical studies. These consider, for example, the social construction of technology and technological thought, as well as the evolution of technological change.[95] Mokyr sought to demonstrate a Darwinian evolution in the process of technological change and determined that evolutionary models consist of "mutations, recombinations or hybrids, followed by selection,"[96] an apt description in the context of locomotive development. O'Brien, Griffiths and Hunt's analysis goes further in suggesting that the proper historical context for the consideration of technical change is both local and specific; innovations are either new products (or variations on old ones), or artefacts or processes designed to raise the quality of commodities, or techniques that lower production costs.[97]

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[94] Kirby, 1991, *op cit* (55), pp.24-42.
[95] Robert Fox (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996.
[96] Joel Mokyr, 'Evolution and Technological Change: A New Metaphor for Economic History?', in Technological Change, *ibid*, pp.63-83.
[97] Patrick O'Brien, Trevor Griffiths and Philip Hunt, 'Technological Change During the First Industrial Revolution: The Paradigm Case of Textiles, 1688-1851', in Technological Change, *ibid*, p.158.

Main-line locomotive technology showed evidence of all three processes, as it developed from an optional form of motive power, dependent upon the engineer to demonstrate an economic case for its use, to become a form of demand-led technology with railways requiring ever more demanding engineering and economic standards. To understand this transformation it is necessary to follow, as Picon proposes, the causal link between the need for technological advance of locomotives and the innovations which made it possible, particularly as they were achieved in a short period of time.[98] It will be demonstrated that the development of the first acceptable locomotive, upon which the start-up of the main-line railway era depended, was far from the result of indirect or deferred causality. It was prompted by personal ambition and reputation, and dependent upon invention, but which succeeded through innovation. Once the locomotive had proved itself, the economic incentive for greater speed and power drove technological and design improvements through generations of "mutations, recombinations and hybrids."[99]

The long-term development of all manufacturing firms depended on continued exploitation of new technologies and materials, and design progression to fulfil and stimulate market requirements. Innovative firms could license as well as exploit their inventions. In his discussion on entrepreneurship, Alford determined that many firms in the 19th century transformed an invention into a working design, but were unable to pursue its large-scale commercial exploitation. Often more likely was the eventual diffusion of the technique among a number of firms.[100] In the capital goods sector, this diffusion could have been promoted by the market through the tendering system, since firms were obliged to meet the, often quite detailed, specifications laid down by would-be customers.

The manufacturers were therefore faced with significant strategic decisions regarding, first, the depth of what is now known as research and development to stimulate new locomotive technology; secondly the risks associated with implementing innovation based on their own

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98 Antoine Picon, 'Towards a History of Technological Thought', in Technological Change, *ibid*, p.49.
99 Mokyr, *op cit* (96).
100 B.W.E. Alford, 'Entrepreneurship, Business Performance and Industrial Development', Business History, Vol.XIX, No.2, 1977, p.117.

work, balanced against the benefits that could be derived from issuing licences to others; and finally the level of design initiatives to improve or maintain market share. They were also faced with decisions regarding the balance between design-led business strategies, that is continuing to use their in-house design resources, and contract-led business strategies, manufacturing to the designs of railway customers and consulting engineers. None of these topics has been explored in any real depth. Even those aspects of the technology that have attracted the censure of historians merit further examination.

The economics of locomotive manufacture were affected by the large variety of designs, which were multiplied by the individual specifications of railway superintendents and consulting engineers. Zeitlin has stressed that British capital goods output generally was produced to customer specifications and that even quite specialised enterprises were forced to maintain a wide product range.[101] In investigating the proliferation of British railway locomotive designs, which led to a "chronic lack of standardisation", Kirby has pursued the twin explanation of a fragmented and relatively small market, and the likelihood that it was the "Empire-building propensities" of the locomotive superintendents which motivated the diversity.[102] Proliferation was partly caused by the continued existence of a large number of railways. In commenting on Chandler's 'Visible Hand', Channon has noted that mergers were surpressed by Parliament from the early 1870s, which removed the option of consolidation.[103] This, in turn, reduced the opportunity for larger locomotive batches.

Yet design proliferation was not unique to Britain, there being a similar problem amongst American railroads. Usselman has written about the "considerable discretionary authority" of the railroad master mechanics which not only gave them the freedom to dictate design specifications but also allowed them to shape the course of innovation.[104] As the railroads

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101 Jonathan Zeitlin, 'Between Flexibility and Mass Production: Strategic Ambiguity and Selective Adaptation in the British Engineering Industry, 1830-1914', in Charles F. Sabel and Jonathan Zeitlin (eds), World of Possibilities, Flexibility and Mass Production in Western Industrialization, Cambridge, 1997, p.244.

102 Kirby, 1988, *op cit* (55), pp.287-305.

103 Geoffrey Channon, 'A.D. Chandler's 'visible hand' in Transport History - A Review Article', The Journal of Transport History, 1981, p.59.

104 Steven Walter Usselman, Running The Machine: The Management of Technological Innovation on American Railroads, 1860-1910, unpublished PhD. thesis, University of Delaware, 1985, p.181.

expanded in the last quarter of the century, their technical departments became larger, more formalised and more bureaucratised.[105] Responsibility for technical matters passed to staff offices, which sought to limit change in the pursuit of standardisation. From this grew the practice of restricting locomotive contracts to one manufacturer, which therefore obtained scale benefits of production denied to the British industry.

Other locomotive markets were also subject to an extraordinary proliferation of designs. Saul has noted that the extensive use of British consulting engineers for overseas railways and the smaller domestic railways brought about this proliferation, preventing the manufacturers from exploiting what would have been substantial economies of scale in production.[106] This restricted their competitive position against the American and German manufacturers towards the end of the century. With consulting engineers taking a "baleful influence" on production practices, Saul believes that this market feature played a key role in the manufacturers' attitudes to mass production. Such was the deleterious effect of multiple designs and higher unit costs for the locomotive industry that a more detailed explanation of design proliferation needs to be sought, including comparisons with overseas industry.

1.7 Manufacturing

Locomotive progress in the 19th century was as much due to developments in manufacturing and production control methods as it was to technological and design evolution. As has been noted, the industry was first developed by manufacturers of capital equipment, whose craft skills and production methods were applied to a wide range of industrial equipment, and for whom locomotives were a diversification. The extent to which the locomotive industry merely took advantage of these production developments, or was itself instrumental in bringing them about, has been inadequately addressed in previous studies. The industry

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[105] *ibid*, pp.188-196.
[106] S.B. Saul, 'The Market and the Development of the Mechanical Engineering Industries in Britain, 1860-1914', in S.B. Saul (ed), Technological Change: The United States and Britain in the Nineteenth Century, London, 1970, pp.146-150.

represents a good case study to investigate the motivations for improvements in the heavy manufacturing sector generally, which will provide a better understanding of the process of innovation and proprietors' capital investment decisions.

The development of manufacturing during the century required major strategic decisions by the manufacturers, both in terms of accommodating the proliferating designs determined by its domestic and overseas markets, and in reducing craft-dependency through the introduction of self-acting machine tools. The different perceptions of the evolution of the locomotive market by the manufacturers gave rise to the industry's growing diversity. The 'progressive' firms sought to invest in capital equipment that would decrease the cost of batch production and encourage, as far as possible, the standardisation of component design. The 'craft' manufacturers, however, pursued a broad market base of capital goods, including locomotives, invested much less in equipment and maintained a higher dependency on craft skills.

With the major expansion in locomotive demand from the 1830s, the industry had developed its own production processes and requirements. As designs incorporated new technologies, and developed in size and power to meet the growing market requirements, the industry underwent radical and far-reaching changes. This enabled it to make components of increasing size, complexity and standardisation, to accommodate materials of increasing specification, and to reduce the unit cost of production.

Although this evolution was much constrained by the proliferation of designs from the 1850s, the manufacturers understood the scale benefits of specialisation, requiring both investment in self-acting capital equipment and the introduction of a new production culture. Saul has determined that manufacturing specialisation was still rare in Britain in the 1860s, but that the sectors that came closest to it were locomotive, textile machinery and heavy machine tool manufacturing.[107] He ascertained that by the 1870s there were about ten main-line locomotive manufacturers and a similar number for industrial types, but he did not

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107 Saul, *op cit* (42), p.186.

discuss the growing diversity between general heavy manufacturing firms and the evolving specialist firms. This diversity needs more rigorous assessment, and an understanding of the evolution of manufacturing processes for the different kinds of firms.

Chandler has reinforced the view of earlier economic and business historians that the technological advancements of the 1830s and 1840s were followed in the 1880s and 1890s by a 'Second Industrial Revolution'.[108] He rightly focuses on the extraordinary productivity improvements that took place in the second half of the 19th century, chiefly through the 'American System', in which new manufacturing and organisational processes led to mass production of finished goods with substantial unit cost reductions through economies of scale and scope. Chandler's criticism that Britain generally failed to invest in its capital-intensive industries to achieve America's high levels of efficiency turns on the interpretation of 'mass' production, which he defines as requiring technological and organisational innovation to permit "a small working force to produce a massive output."[109] Thus Zeitlin notes that by the end of the century, American firms were manufacturing large volumes of standardised equipment in contrast to the continued use of craft methods in Britain for the manufacture of customised products in small batches, which was the subject of comment on both sides of the Atlantic.[110] He has also emphasised, however, that certain sectors of British industry, such as the manufacture of textile and agricultural machinery, were well used to producing very large batches of standard components on special-purpose equipment, much of it designed by the firms themselves.[111]

Chandler failed to engage in this kind of argument in his comprehensive chapter on mass production. Thus he omits any mention of the heavy manufacturing sector, with its small-batch market for capital machinery, including locomotives, referring only to the repetitive production of finished goods and components in the light manufacturing sector.[112] Scranton's recent work on American 'specialist' manufacture, however, has done much to

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108 Chandler, 1990, *op cit* (3), p.62.
109 *ibid*, Part III, Great Britain: Personal Capitalism. Also Chandler, 1977, *op cit* (3), p.241.
110 Zeitlin, *op cit* (101), p.241.
111 Zeitlin, *ibid*, pp.248/9.
112 Chandler, 1977, *op cit* (3), Chapter 8, 'Mass Production'.

redress this emphasis.[113] He notes that the key issue for specialist manufacturers, including the locomotive industry, was the organisation of their production. The Philadelphia manufacturers, including the Baldwin Locomotive Works, strove to establish 'system' in industrial practice long before its general use in management parlance.[114] The Baldwin locomotive works also strove to accommodate design proliferation by standardising component production, as far as possible, within the many design envelopes demanded by their customers. Scranton thus concludes that locomotive construction was "systematized, but not standardized", which highlights the distinction between specialised and volume production to which Chandler avoided reference.[115] In considering the 'systematisation' of the British locomotive industry, it will be important not only to demonstrate that manufacturers understood production economy through specialisation and increasing batch size, but to ascertain if they sought to encourage railways to incorporate standard components in their diverse designs in the way successfully pursued by Baldwins.

It will also be necessary to consider developments in the labour process. Rolt has described the extraordinary advancement in 19th century manufacturing capability and production control procedures in both the heavy and light manufacturing industries.[116] Progressive development of machine tools transformed machining from a skilled activity, requiring experience and ingenuity, to an un-skilled activity, allowing batching of standard components with equipment that was more robust, faster and capable of more ambitious tasks. Major advances in forging and foundry equipment extended the range of metal-forming skills and the reliability of finished components. Improving production control procedures reduced component processing time, increasing productivity and decreasing production costs. Drummond links these developments with design proliferation, believing that particular manufacturing processes in each of the railway workshops, with different machine tools and other capital equipment, were used to meet the specific requirements of each design team. She further suggests that this proliferation was encouraged by railway managers to deter

113 Scranton, *op cit* (47).
114 *ibid*, p.99.
115 *ibid*, pp.81-107.
116 L.T.C. Rolt, Tools For The Job, London, 1965.

freedom of movement by skilled and semi-skilled men, as shortages of such skills would otherwise have resulted in wage competition. Drummond argues that there was collusion between the railway companies to prevent this.[117]

These findings have two implications for the independent manufacturers, which need to be considered. First is the effect on their capital investment programmes. What requirements did the manufacturers have to meet to allow them to tender for orders from main-line railways, each of which had its own component intra-standards and machining requirements? This problem was compounded by the consulting engineers' design proliferation for overseas railway specifications. The second implication is that independent firms could have followed a similar labour strategy to that of railway workshops. If they did not, were they themselves entering into competition for scarce labour skills, with corresponding labour migration and increase in wage-costs?

1.8 Employment and Industrial Relations

Labour relations were a severe test of managerial expertise. The growth of the locomotive manufacturing firms during the 19th century took them from small proprietorial concerns, with less than 100 craftsmen and labourers, to large private and public enterprises with workforces up to 3,000 strong. To accommodate such expansion the manufacturers pursued new labour policies, which both developed management skills and responsibilities and the transition of work skills from a fully craft-based to a partly 'factory'-based system. This was introduced against a background of improving terms of employment nationally, often arising from considerable industrial relations strife.

Whilst delegation of proprietorial responsibilities to managers was generally adopted throughout the industry, the evolution of employment policies most distinguished the growing diversity between the progressive and the craft enterprises. The shortage of skilled

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[117] Drummond, 1997, *op cit* (68), pp.32/3, Note 22.

labour throughout the century, with attendant higher wage expectations, was a major pre-occupation for the manufacturers. They resolved this shortage with varying emphasis on the development and acquisition of self-acting machine tools and other capital equipment, resulting in a divergence in the numbers of 'time-served' craftsmen employed by progressive and craft firms. The millwright, the smith and the foundryman had already developed skills to manufacture many forms of heavy machinery by the commencement of the railway era. The breadth of their practical and intellectual skills was essential for the development of early locomotive technology, but the extraordinary expansion of the market soon led to a shortage. The industry sought to overcome this by productivity improvements through radical changes in machine tool technology and manufacturing processes. Basic component preparation converted to 'factory'-based employment of un-skilled machinists.[118] However, the locomotive industry remained, on the whole, more dependent on skilled labour than repetitive manufacturing industries, with boiler-makers, foundrymen and fitter-erectors adapting their skills to improving techniques and equipment.

There have been several academic enquiries into the nature of skill and its application to manufacturing since Braverman first considered the matter in detail.[119] As they largely considered skill requirements in mass production industries, not all are relevant to the heavy manufacturing sector, which had to accommodate the on-going requirement for several craft skills whilst reducing the costs of routine machining tasks. The first issue for the manufacturers was to identify those repetitive activities which could be undertaken with new equipment by labour recruited for the purpose, and for whom training could be completed in just a few days. Much of their activities, however, would remained 'skilled', because no machine could be devised to carry them out.

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[118] For example, discussed by Chandler, 1977, *op cit* (3), pp.269-272; Musson, *op cit* (45), pp.109-149; Saul, *op cit* (42), pp.186-237; and Drummond, 1995, *op cit* (45), pp.40-132.
[119] H. Braverman, Labor and Monopoly Capitalism, New York, 1974; also A. Friedman, Industry and Labour, London, 1977; C. More, Skill and the English Working Class, 1870-1914, London, 1980; D. Gordon, R. Edwards and M. Reich, Segmented Work, Divided Workers, Cambridge, 1982; and M. Burawoy, The Politics of Production, London, 1985.

The second form of de-skilling, however, was motivated by different considerations on the manufacturers' part, namely the effective administration of design and technological developments, co-ordination of activities, planning of work programmes, and bulk ordering of raw materials and components - all work formerly undertaken by 'time-served journeymen'. As Drummond has pointed out, skill was more than just experience of metal-working and fitting, it included discretion and freedom to make decisions on the selection of materials and how the work was carried out.[120] The move towards a 'factory' system in a competitive environment meant that these responsibilities and functions would pass to the proprietors or their managers. The adaptation of craftsmen's skills, and the introduction and development of the factory system of production, were important considerations in the evolution of the locomotive industry. One aim of this study is to assess how well the manufacturers dealt with these issues.

A further important issue was the retention of staff. Pollard has described the move into 'factory' work as requiring a new culture among workers, which required them to adjust to the regularity and discipline of factory work.[121] Factory workers were said to have a 'restless and migratory spirit' and a stable, rather than a better labourer was usually worth more to a manufacturer. Pollard's paper, however, relies largely on evidence relating to repetitive factory work, such as in textile mills, and a better understanding is therefore sought as to how firms in the heavy manufacturing sector developed employment policies for un-skilled staff. However, the shortage of skilled craftsmen made it important for the locomotive firms to maintain loyalty, discipline and longevity of service through attractive employment terms. Rowe has demonstrated that hours of work, wage rates and productivity pay incentives in manufacturing establishments were all better than the provisions of the 1867 Factory Acts Extension Act, which was the first legislation to affect the manufacturers.[122] The requirement for employment incentives, including the provision of housing, extra-mural and

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120 Drummond, 1995, *op cit* (45), p.92/3.
121 Sidney Pollard, 'Factory Discipline in the Industrial Revolution', Economic History Review, 2nd Series, Vol.XVI, 1963-64, pp.254-271.
122 D.J. Rowe, 'Trade Unions and Strike Action in the North-East', in E.Allen, J.F.Clarke, N.McCord and D.J.Rowe (eds) The Strikes of the North-East Engineers in 1871: The Nine Hours League, Newcastle, 1971, p.52.

other community benefits, and whether employees enjoyed a higher level of paternalism than in light industries, are therefore important indicators of the manufacturers' response to the shortage.

Paternalism was an important issue with the locomotive factories. Joyce has determined that 19th century employers in certain factory towns secured a position of both ideological and cultural hegemony over their workforce.[123] It is likely, however, that this applied more to volume industries, employing largely un-skilled labour, in a relatively free market. By contrast, Revill has recently developed Drummond's point that railway companies shared many of the workplace strategies of industrial paternalism. Their workshop towns, such as Crewe, benefited from the provision of welfare, recreational and learning opportunities, and facilities which were partly the means by which workers created structures of self-help.[124] Unlike several of the railway workshops, however, the independent locomotive workshops were usually in existing urban areas, allowing most employees the opportunity of alternative employment. The extent to which these manufacturers were required to treat their workforce with equanimity, and the necessity for, and consequences of, company paternalism, therefore needs to be established.

In general, these matters were not, of course, wholly within the employers' control. 19th century industrial relations saw organisational growth, by both trades unions and employers federations, as pressures grew to preserve craftsmen 'closed shops' and introduce a shorter basic working week and higher wage rates. 'Friendly' societies amalgamated into regional and national trades unions, allowing pooled resources in support of local actions, presenting the manufacturers with industrial relations issues quite unlike the local ones to which they were accustomed. Southall notes that it was the urban manufacturing craftsmen that enjoyed real bargaining power in the mid-century, other groups being either too geographically

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[123] P. Joyce, Work, Society and Politics: The Culture of the Factory Town in Late Victorian England, London, 1980, p.92.

[124] George Revill, 'Railway Paternalism and Corporate Culture, 'Railway Derby' and the Formation of the ASRS', in Colin Divall (compiler), Workshops, Identity and Labour, Working Papers in Railway Studies, Number three, Institute of Railway Studies, York, 1998. Also Drummond, 1995, *op cit* (45), pp.186-208.

diffuse or too mobile to be effective.[125] The unions also provided unemployment benefit, sick pay and superannuation, which further reduced dependence on employers and increased union control.

However, McKinlay and Zeitlin have argued that between 1850 and 1890 there was an implicit accommodation between engineering employers and their skilled workers, all parties benefiting from British economic supremacy and relatively stable craft-labour employment.[126] It is important to consider the role of the locomotive manufacturers in the national employment disputes to test McKinlay and Zeitlin's thesis in respect of the heavy manufacturing industry. A comparison with the railway-owned workshops is also appropriate. Drummond has noted that these workshops, whose workforce was closest to the independent manufacturers' in skill and experience, had relatively trouble-free industrial relations, there being only three or four sectional strikes between 1838 and 1914.[127]

In seeking a better understanding of the contribution of partnerships to the development of 19th century heavy manufacturing, therefore, consideration is to be given to the entrepreneurial, technical and managerial attributes of proprietors and the developing expertise of their specialist managers. This enquiry into the independent locomotive industry will investigate their decision-making capabilities in developing strategic policies and in addressing the tactical issues they confronted in carrying them out. In particular, it will concentrate on the way the industry reached its decisions which led to the growing divergence between progressive firms specialising in locomotive production, and craft firms which maintained a broad market base. The different interpretations of the developing locomotive market, with its unpredictable demand fluctuations, resulted in a spectrum of policies on marketing and sales, technology and design, production and employment. This enquiry considers the issues determining the industry's divergence with each of these policies and how the manufacturers were conditioned by them in arriving at their decisions.

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[125] Humphrey Southall, 'Industrial Protest: 1850-1900', in Andrew Charlesworth *et al*, An Atlas of Industrial Protest in Britain 1750-1990, Basingstoke, 1996, p.61.
[126] Alan McKinlay and Jonathan Zeitlin, 'The Meanings of Managerial Prerogative: Industrial Relations and the Organisation of Work in British Engineering, 1880-1939', Business History, Vol.31, No.2, 1989, p.34.
[127] Drummond, 1989, *op cit* (68), p.8.

2.0 Development of the Locomotive Market

2.1 Introduction

The world's locomotive market grew throughout the 19th century as railway networks expanded. The development of the British locomotive industry's domestic and foreign markets was, however, determined largely by economic and political considerations, and by the structural changes within the British railway industry itself. The way in which the manufacturers interpreted the market developments, and acted upon them, was a major determinant in their success or failure. Their strategic decisions on investment, product diversification and employment were based on the interpretation, not only of long-term market trends, but also of the major fluctuations in demand that affected each geographic and economic region.

The locomotive markets were affected by several diverse influences, with which the manufacturers were initially unfamiliar, and several of which they had little means of predicting. The rate of railway growth in each country varied between the un-regulated network growth in Britain to the planned Government systems, including 'concession' networks, in several European countries. The increasing loss of much of the British main-line locomotive market to railway-owned workshops from the 1840s diverted much of the manufacturers' attention towards the growing overseas and industrial locomotive markets.

The early provision of portfolio capital for railway construction and equipment from the London market was subsequently emulated by other European capital markets. The nationalism that followed these changes, the political uprisings in Europe, the growth of national locomotive industries in major economic regions, and the increasing effects of import tariffs all influenced the potential for the British industry. The greatest influence in the second half of the century was the movement of the London capital market into foreign direct investments for railway schemes in the Empire and other areas that encouraged development capital, notably South America.

The major difficulty for the manufacturers in understanding the evolution of the locomotive market was in trying to predict the extraordinary fluctuations in demand with which the industry was faced throughout the century. The economic cycles of each world region greatly affected the market, which followed an often unpredictable demand pattern. The manufacturers' investment decisions had to anticipate the likely capacity requirements when demand was high, without over-providing when demand was low. The latter usually led to cash-flow problems and manpower reductions. They were thus required to monitor each changing market to predict potential demand, and the external influences that could divert that potential to their foreign competitors. Their use of representative agents to keep them informed of market potential followed the practices developed since the 18th century (Section 3.3). However, with the growth of foreign direct investment, based in London, market intelligence in this major economic sector became easier.

Figures 1 and 2 illustrate Britain's locomotive market, shown for main-line and industrial production, and for the home and overseas markets respectively.[1] They demonstrate the movement of the markets between periods of annual growth, followed by three or four years of (sometimes substantially) reduced output, before resuming its growth. The pattern of capital exports after 1855, itself closely following Britain's current account balance, reveals a reasonable correlation with these cyclical movements (Fig. 3).[2] This pattern of British trade and overseas investment followed an eight-twelve year boom/depression cycle, the so-called 'long swing', which was largely followed by the overseas locomotive market.[3] The health of British trade and overseas investment, in turn, accelerated or suppressed the British domestic economy. As the manufacturing sector was wholly dependent on railways for raw material

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[1] The locomotive production figures have been analysed for this thesis using a 'Windows'-based spreadsheet-derived software. The most reliable secondary-resource records known to be available, were used. These have been produced by members of the Stephenson Locomotive Society, and are lodged in the Society's library. The data spreadsheets, which include the reference sources and the market category analyses, have been deposited in the library of the National Railway Museum - Institute of Railway Studies room - and are available for general consultation.
[2] This graph is extracted from P.L. Cottrell, British Overseas Investment in the Nineteenth Century, Studies in Economic and Social History, Economic History Society, London, 1975, Fig.1, p.14, data prepared by Imlah and Simon.
[3] Cottrell, *ibid*, Chapter 3 'The Growth of the portfolio', 1855-1914, pp.27-40.

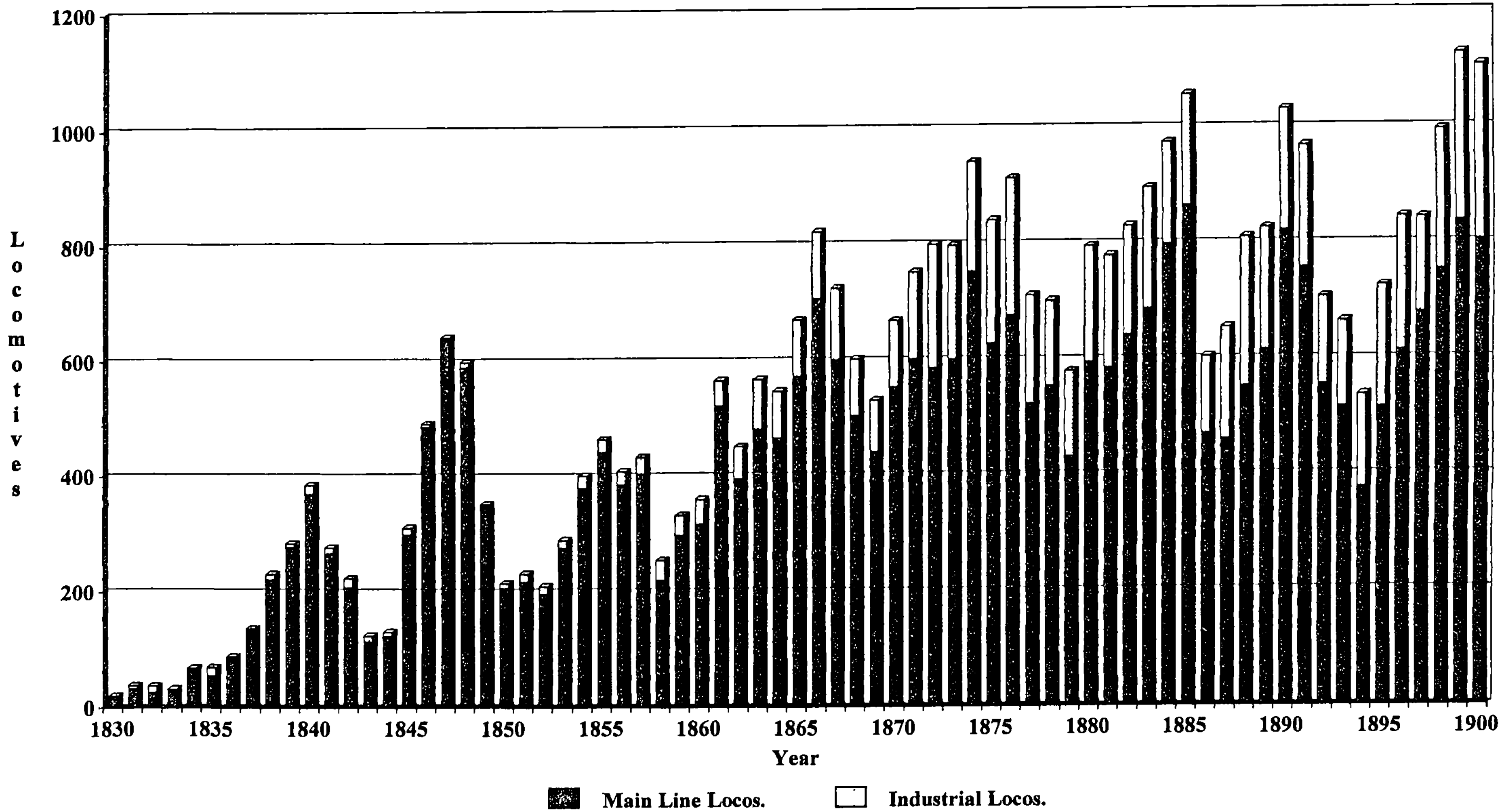

Fig.1 ANNUAL LOCOMOTIVE PRODUCTION by the Independent Industry

(Source: Analysis of locomotive production Note 1 p.51)

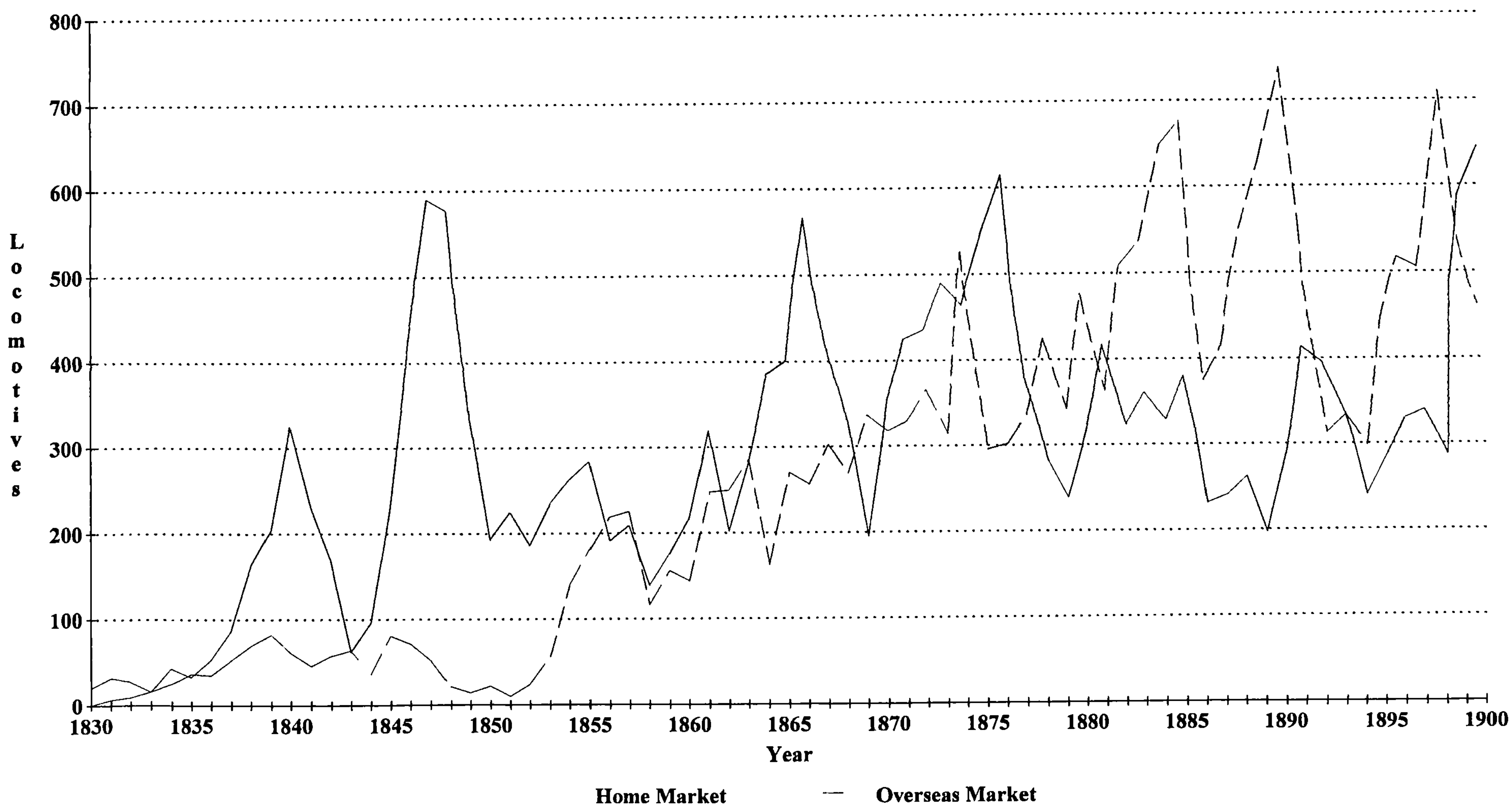

Fig.2 ANNUAL LOCOMOTIVE PRODUCTION for the Home and Overseas Markets

(Source: Analysis of locomotive production Note 1 p.51)

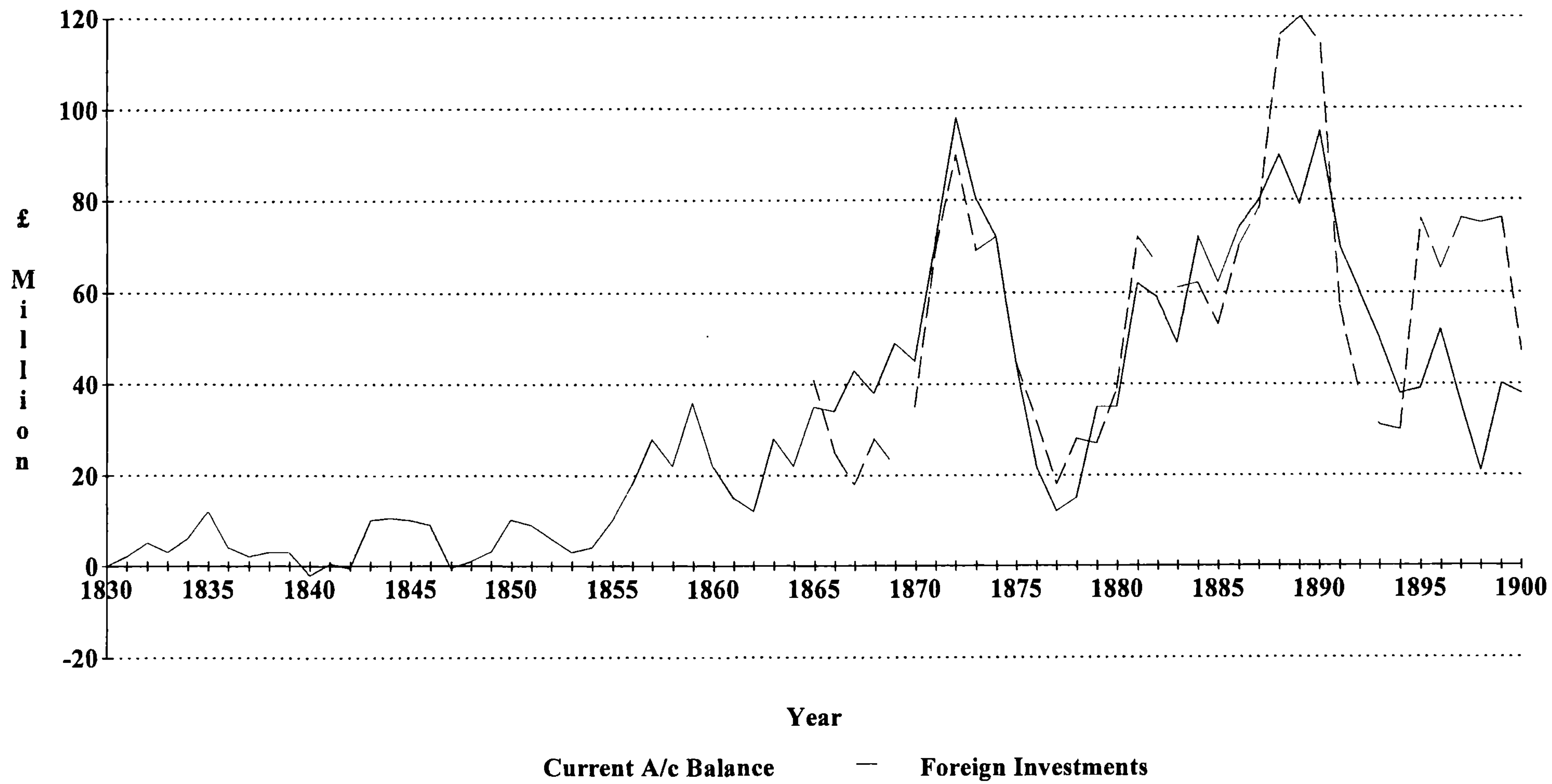

Fig.3 BRITAIN'S CURRENT ACCOUNT BALANCE AND VOLUME OF CAPITAL EXPORTS

(Source: P.L. Cottrell, British Overseas Investment in the Nineteenth Century, Studies in Economic and Social History, Economic History Society, London, 1975, Fig. 1, p.14; data prepared by Imlah and Simon) and finished product movements, the domestic railway industry was a barometer of the state of the economy, its rising and falling traffic patterns, in turn determining domestic locomotive requirements.

It is therefore necessary to investigate both the growth of the locomotive market, and its evolution through the demand fluctuations, to understand the context within which manufacturers' decisions were made. To provide sufficient capacity to meet peak demands, without surplus capacity when the market was low, required strategic decisions on investment and employment, and tactical decision-making about employment levels, to preserve scarce labour skills whilst maintaining profitability. This investigation will also provide an understanding of the market influences that led the industry towards structural and corporate changes, particularly in the second half of the century. The changes ranged between progressive specialisation through investment, to complete failure and closure.

2.2 Market Growth

From its start-up in 1830, the industry's output grew to over 1100 locomotives a year by the end of the century (Fig.1). It would have been considerably larger had the British main-line railway companies not undertaken their own locomotive manufacture from the 1840s. The growth in output was interrupted in each decade, as national, regional and world economic cycles and political events influenced growth in rail transport, resulting in considerable fluctuations in demand both to domestic and overseas markets (Fig.2). The British market showed no appreciable growth trend after the 1840s, but moved through the century in a series of cyclical peaks and troughs representing the residual requirements of the main line railway companies and the expanding industrial locomotive sector. The overseas market does show a significant growth through the century, and confirms Saul's statement (Section 1.2) that it exceeded the home market from the late 1870s. However, this growth is also punctuated by major fluctuations in seven to ten year cycles. The volatility of the world locomotive market is comparable with that of the North American market, which has been emphasised by Brown in his history of the Baldwin Locomotive Works.[4]

The market was principally composed of main-line railway locomotives, to which was added in the second half of the century a significant and growing number for industrial use (Fig.1). The main-line market, which developed in the 1830s and 1840s to meet the needs of the early railways in Britain, Europe and the United States, expanded considerably in the second half of the century as railways were developed in the Empire (particularly India), Latin America, the Middle East and the Far East, in addition to Britain itself.

It is clear that the rapid growth in the market was well understood by proprietors after 1830, as manufacturers already engaged in the heavy manufacturing sector, including industrial and marine engines, textile and other machinery, diversified into locomotive manufacture (Appendix). After just ten years, some 34 firms were manufacturing locomotives. The effects of the growing yet fluctuating market showed themselves in later years as firms started-up, diversified into, or withdrew from the industry. From the 1860s, between 25 and 30 large or medium-sized firms were engaged in locomotive manufacture at any one time, only a small proportion of which sought to specialise in the market (Fig.4). Whilst several manufacturers specialised in the industrial locomotive market, other firms in other manufacturing sectors also made small numbers of industrial locomotives, both for their own purposes and for supply to neighbouring companies when the market was buoyant and prices were high.[5]

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[4] John K. Brown, The Baldwin Locomotive Works, 1831-1915, Baltimore, 1995, p.12 and *passim*.
[5] James Lowe, British Steam Locomotive Builders, Cambridge, 1975, *passim*.

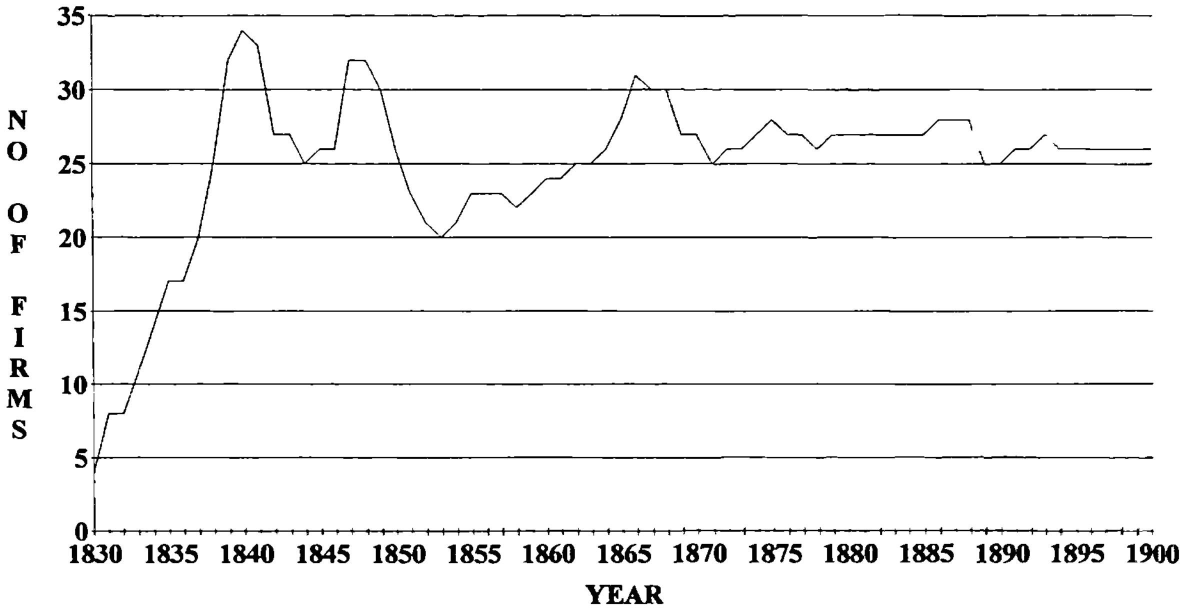

Fig. 4 Number of Firms in the Independent Locomotive Industry 1830-1900

(Source: List of Firms - Appendix)

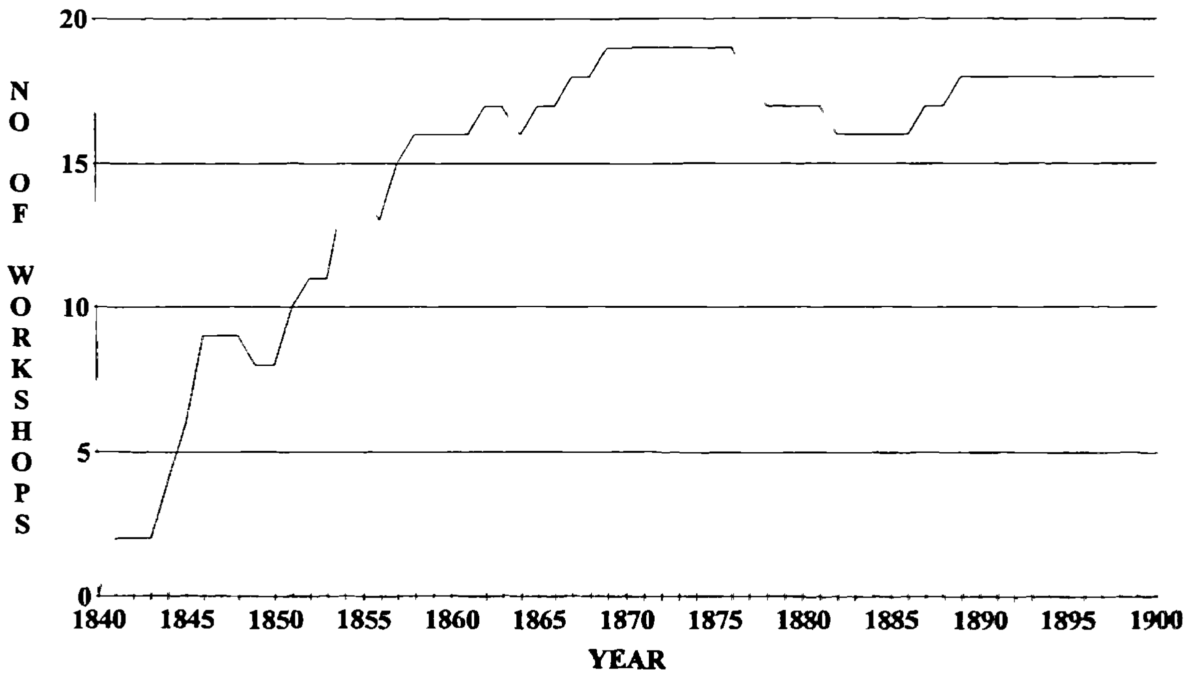

Fig. 5 Number of Railway-Owned Locomotive Workshops 1840-1900

(Source: James Lowe, British Steam Locomotive Builders, Cambridge, 1975)

2.3 United Kingdom Market

Until the mid-1840s, almost all locomotives for Britain and Ireland were made by the independent manufacturers, whose factories in Lancashire, Yorkshire and the north-east of England were well placed to meet the requirements of the new market. The gradual loss of much of the British main-line market to the railway workshops from the 1840s had major repercussions for the locomotive industry, which went beyond the simple contraction of market potential. The initiative gained by the railway workshops included technological and design progress, which left the independent industry to fulfil the residual locomotive orders on a contract-only basis and with a proliferation of designs specified by the railways themselves (Chapter 4).

The encouragement for the railways to develop their workshops was the direct result of insufficient capacity during the mid-1840s railway 'mania'. The extraordinary demand peak between 1844 and 1847 (Fig.1) could not have been predicted by the manufacturers, but even when the full extent of the demand was realised, the manufacturers were unable to increase their capacity quickly, and most were reluctant to invest in too much further capacity in anticipation of a subsequent market decline (Section 5.7). Delivery times lengthened unacceptably and prices rose substantially.[6]

The established railway companies became irritated at finding themselves in a long queue for locomotives alongside new railway companies which had yet to establish their services. The London & Birmingham Railway was so concerned to overcome the problem, that it sought an exclusive manufacturing agreement with the largest manufacturer, Robert Stephenson & Co. The railway's Secretary wrote: "I am desired to say, that our Company are prepared to deal with you for a supply of Engines to an extent that would probably make it worth your while to devote your Establishment to the execution of our orders exclusively. & with a view to a more prompt delivery of them than might under other circumstances be thought

[6] Analysis of production from the Order Books and Engines Delivered Books, R. Stephenson & Co. papers, National Railway Museum archives. Also Letter Edward Pease to E.J. Cooke (for R. Stephenson & Co.), Darlington, 11 mo [November] 29. [18]44, Institution of Mechanical Engineers Library, Crow Collection.

convenient."[7] With a very large order book, high prices and advanced payments, the Stephenson Company declined the proposal.

In order to meet the growth in their services, therefore, the larger railway companies embarked on their own locomotive manufacture. Using their existing maintenance and re-building workshops, they invested in new facilities and skills, such as boiler-making. This provided economies of scale through wider use of their workshop resources, but carried the risks of demand fluctuation without the opportunity to diversify into alternative markets when few new locomotives were required. The Grand Junction, London & South Western, Great Western and Glasgow, Paisley & Greenock Railways were amongst the first to commence locomotive manufacture. Joseph Locke, Engineer of the Grand Junction Railway, later wrote: "Then arose the question, whether this establishment [Crewe] could not be advantageously used, not only for the repair, but also for the construction, of engines. The plan was tried....... and the cost was found to be much less than the price they had formerly paid."[8]

From the 1850s more railway companies established their own locomotive workshops; about 18 were in being from the 1860s, outgrowing the activities of the independent firms (Fig.5).[9] By the beginning of the 20th century, their annual gross output, at £7.9 million, was 75% greater than the independent sector, although much of their work was related to maintenance and rebuilding.[10] Some railways, such as the London & North Western with its Crewe workshops, and the Great Western with its Swindon and Wolverhampton workshops, became fully self-reliant for locomotive provision. Other companies, such as the Midland Railway, with its Derby workshops, constrained their new-build capacity to meet a relatively constant demand, with peak requirements being met from the independent sector. The

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[7] Copy letter R. Creed (for the London & Birmingham Railway) to R. Stephenson & Co., Pease-Stephenson Collection, Durham County Record Office, Darlington Public Library, D/PS/2/64.
[8] Proceedings of the Institution of Civil Engineers, Vol.XI, 1851/2, pp.466/7.
[9] Fig.5 is produced from a spreadsheet analysis of opening and closing dates of railway workshops shown in Lowe, *op cit* (5), *passim*.
[10] First Census of Production 1907, quoted in S.B. Saul, 'The Engineering Industry', in Derek H. Aldcroft (ed), The Development of British Industry and Foreign Competition 1875-1914, London, 1968, Table 1, p.192.

smaller railways, however, remained fully dependent on the independent manufacturers for the provision of their locomotives.[11]

The culture that developed, with each railway establishing an identity through the design and construction of its locomotives, was peculiar to Britain. Although a small number of railways in France and elsewhere constructed their own locomotives, the large majority of the world's railways preferred the negotiating strength of independent supply. There were merits and disadvantages in self-design and manufacture, and a cultural divide grew up between the two industries. Once a railway had invested in manufacturing facilities, it retained and enlarged them, in spite of fluctuating demand that could result in costs rising above prices from the independent sector.

The railway workshops and their locomotives became symbols of the railways themselves, and particularly of the locomotive engineers, some of whom are described by Kirby as being "technical virtuosos with autocratic personalities". Kirby succinctly explains that "Lacking the economic motive for product differentiation in order to gain oligopolistic control of the market", the locomotive superintendents "were able to establish 'private empires' in which idiosyncrasies of design and the continuing proliferation of locomotive types could flourish" (Section 4.7).[12]

The incentive for the railway directors in sanctioning the continued operation of in-house locomotive production is partly explained by the prevailing accounting conventions.[13] New locomotives, which were authorised as direct replacements for old stock, were chargeable against revenue account, thus avoiding the need to increase the capital account, with its implications for shareholder approval and stock market evaluation. The same incentive also led to a strong 'second-hand' market, which offered a cheaper source of motive power, particularly during economic recessions. With minimal expenditure, old main-line

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[11] Analyses of production, *op cit* (1).
[12] M.W. Kirby, 'Product Proliferation In The British Locomotive Building Industry, 1850-1914: An Engineer's Paradise?', Business History, Vol.30, No.3, 1988, p.288.
[13] *ibid*, p.291.

locomotives, replaced by faster or more powerful types, were re-built in the railway workshops and 'cascaded' on to less demanding operations. Alternatively, they could be sold on the open market to other railways, industrial concerns and contractors, further reducing the home market potential for the independent industry.[14]

With the increasing loss of much of the main-line market after 1850, the home market might have reduced considerably but for the co-incident growth in the demand for industrial locomotives. The growth of British industry in the 19th century was largely dependent upon rail transport, for which large industrial sites required internal motive power. The market for small industrial locomotives expanded to meet the requirements of contracting, extractive, manufacturing, process, shipping and military operations in Britain and overseas. The market was industry-led, rather than customer-led, allowing the manufacturers to retain control and offer standard designs. Although all manufacturers were engaged in this market to some extent, several, particularly those in Leeds, Glasgow and Kilmarnock, took the strategic decision to specialise in industrial types.[15]

2.4 Export Market

The volume and strength of British capital in the development of overseas railway projects assisted the locomotive industry to develop and maintain a dominant position in the world market during the 19th century (Section 1.4). Until the 1850s, the investment in the growing railway networks in the United States and Europe was largely portfolio capital. There was, however, no link between the portfolio investments, mostly administered by the City of London commercial banks, notably Hambros, Barings, Schröeders and Rothschilds,[16] and the locomotive market. The dominance of British exports in the 1830s and 1840s was entirely due to Britain's technological and manufacturing lead (Chapters 4 and 5). The growth of manufacturing capability in the United States from the 1830s, and in the main

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[14] For example, A.R. Bennett, The Chronicles of Boulton's Siding, London, 1927, *passim*.
[15] For example Michael R. Lane, The Story of the Steam Plough Works, London, 1980, pp.146-154.
[16] Periodic listing of foreign railways from 1882 contained in The Railway Engineer, Vol.III onwards.

economic regions of Europe in the 1840s, coupled with the growth of the European capital markets, therefore gave rise to increasing competition from those regions.

From the 1850s, however, the emphasis of the strong British capital market shifted towards predominantly foreign direct investments for railway projects in the regions of the world which had little or no financial or administrative experience with public works. Manufacturers were able to take particular advantage of the substantial growth in locomotive demand arising from the development of these railways, whose head offices were based in London (Section 3.4). Marketing and selling was made easy by the close community of overseas railway head offices, consulting engineers and the manufacturers' own offices or agencies. Jones has recently emphasised how important foreign direct investment was, suggesting that these 'free-standing companies' were more deliberately managed, and their management concentrated in rather fewer hands than had previously been understood.[17] Many of the overseas railways established their head offices in the City of London. Wilkins has suggested that the typical City head office for a free-standing company was small, normally comprising a corporate secretary and a board of directors, and with a brass nameplate.[18]

The influence of the consulting engineering profession gave rise to a strong market focus for the manufacturers, but with the penalty of decreasing discretion in locomotive specification and design. Engineers, such as Sir Charles Fox, Sir John Hawkshaw and Sir Alexander Rendel, and contractors, such as Thomas Brassey and Sir Samuel Peto, were engaged to design and build the railways, and represent their clients in equipment procurement, including locomotives. The British civil and mechanical engineering professions played a major part in the development of railways in the Empire and other areas of the world, particularly South America. The engineers who worked for the railways took with them a

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[17] Charles Jones, 'Institutional Forms of British Foreign Direct Investment in South America', Business History, Vol.39, No.2, 1997, p.23; Also, T.A.B. Corley, 'Britain's Overseas Investments in 1914 Revisited', Business History, Vol.36, No.1, 1994, pp.71-88.
[18] M. Wilkins, 'The Free-Standing Company, 1870-1914: An Important Type of British Foreign Direct Investment', Economic History Review, 2nd Series, Vol.41, 1988, pp.259-282.

strong expertise and culture which favoured the British manufacturing industry, and directly benefited the locomotive industry.[19]

London thus became the world centre for the locomotive market, in which manufacturers maintained close contacts with railways and consultants through their own London offices or through agents (Section 3.4). Close contact was also maintained with the London-based representatives of colonial governments, or their agents, (particularly the Crown Agents for the less developed colonies towards the end of the century),[20] which sought to build railways to stimulate the development of underpopulated areas, and for which guaranteed annual dividend payments were often made. The market was a loose 'cartel' which effectively blocked the participation of the continental and American locomotive industries. There thus developed a *de facto* link between foreign direct investment and market opportunities for British industry.

The industry's diverse overseas market opportunities, which had to be understood and acted on accordingly by the manufacturers, may be summarised in ten categories:

- railways funded through foreign direct investment, whose head offices in Britain (usually London) had responsibility for the acquisition of materials, including locomotives, usually with the assistance of consulting engineers,
- railways funded through foreign direct or portfolio investment, with head offices in the country of operation, whose specification of materials rested with British consulting engineers,
- railways funded through foreign direct or portfolio investment, for which the acquisition of materials was undertaken directly by a British-trained Chief Engineer who maintained contacts with British suppliers, including locomotive manufacturers,

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[19] Anthony Burton, The Railway Empire, John Murray, London, 1994, *passim*.
[20] Crown Agents' papers, National Railway Museum archive, York.

- railways funded through foreign direct or portfolio investment, the acquisition of materials for which was undertaken by the Chief Engineer who pursued an open tendering policy,
- railways built for Colonial or other national governments, or the Crown Agents, financed by British capital (usually with guaranteed dividends), for which acquisition of materials was undertaken by British consulting engineers,
- railways built by Colonial or other national governments, financed by British capital, for which the acquisition of materials was undertaken by a British-trained Chief Engineer who maintained contacts with British suppliers, including locomotive manufacturers,
- railways built by Colonial or other national governments, financed by British capital, for which the acquisition of materials was undertaken by a Chief Engineer who pursued an open tendering policy,
- railways with minority British investment, but who engaged a British Chief Engineer or British consulting engineers, who favoured British suppliers, including locomotive manufacturers,
- railways with minority or no British investment, which pursued an open tendering policy,
- railways with no British investment, and for which the acquisition of materials was biased towards domestic industries by tariffs.

2.5 Competition from Overseas Manufacturers

Up to the 1870s, competition for the British locomotive industry was largely confined to industrial countries whose manufacturers developed their own expertise to meet domestic needs, or those of adjacent countries. In spite of the dominance of British railway finance,[21] British locomotives, designed and built for the well-made European railways, were unsuited to the cheaper, lightly-laid American track, which led to the development of a locomotive industry in Philadelphia and New York from the early 1830s (Section 4.8). From the late 1830s, American manufacturers dominated their domestic market, and went on to compete

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[21] L.H. Jenks, The Migration of British Capital to 1875, London, 1927, re-published 1963, p.75.

strongly against British manufacturers for the Canadian market, the characteristics of which were similar to those of the United States.

These technical differences could act against American manufacturers. A short-lived venture by the American Norris company to sell locomotives in Europe in the late 1830s and early 1840s failed to secure sufficient rewards to justify its continuation.[22] Although some of the Norris design characteristics were adopted by Austrian and German manufacturers, the early Europeanisation of the designs served to emphasise the distinctions between the American and European markets (Section 4.8). A manufacturing concession to the American Eastwick & Harrison company in Russia from the 1840s was more successful, however, and several hundred locomotives were manufactured there over twenty years.[23]

From the 1840s, French, Belgian, German and Austrian manufacturers took an increasing share of their respective home markets away from the British industry, and by the middle 1850s almost all of their national market requirements were met by the home industries. The withdrawal of the British locomotive industry from much of the western European market was due to the expansion of the capital markets of the western European nations (Section 2.7), the differing evolution of designs brought about by changing operating requirements (Section 4.8), and the tariffs imposed by countries to protect domestic manufacturing industries.

This last claim has been disputed. Aldcroft believed that it was highly improbable that tariffs were a major factor in Britain's trade losses against American and German competition,[24] but Broadberry has recently highlighted the high levels of tariffs imposed by both the United States and Germany to protect their domestic industries.[25] He notes that the fluctuating tariff levels in the United States remained high by international standards through to the First

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[22] Brian Reed, 'Norris Locomotives', Locomotives In Profile, Windsor, 1971, Vol.1, No.11.
[23] John H. White Jr., A History of The American Locomotive Its Development: 1830-1880, Baltimore, 1968, p.27.
[24] Derek H. Aldcroft, 'Introduction: British Industry and Foreign Competition, 1875-1914' in Aldcroft, *op cit* (10), p.22.
[25] S.N. Broadberry, The Productivity Race: British Manufacturing in International Perspective, 1850-1990, Cambridge, 1997, pp.138-142.

World War, although the German rates were much lower and closer to those of Britain. His ratio of overall duties to total imports, however, masks selectively high tariffs. Those for machinery and locomotives, for example, were fixed at 30% by the end of the century, which made Germany a 'closed country' for the British industry.[26]

The failure of the early export drive by US manufacturers did not deter later initiatives. From the mid-1870s, the American locomotive industry, which experienced a similar volatility in its large domestic market as the British industry, sought to use spare capacity when its domestic order books were low, by moving aggressively into exports. The industry, particularly the Baldwin firm, America's leading capital equipment company that became the world's largest locomotive manufacturer, significantly increased its sales efforts in markets hitherto dominated by the British industry, including Latin America, Far East and New Zealand.[27]

Competition also arose from the German locomotive industry which, expanding quickly after the 1871 unification to meet the needs of the rapidly growing domestic railway systems, helped the country's economy to grow initially at an average annual rate of 4.6 percent.[28] The larger manufacturers, such as Borsig, standardised their products to effect scale economies.[29] From the late 1880s, the manufacturers turned to export markets, using liberal credit-loan arrangements to compete with growing domestic locomotive industries in Russia and other eastern European countries, as well as with the British and American export industries in several other world markets.[30] The German manufacturers formed a cartel, for which the domestic railways made a practice of apportioning orders in accordance with the export trade achieved by individual firms in the previous year.[31] From the 1870s, the Swedish locomotive industry had become sufficiently large to meet most of its main-line

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[26] Evidence of J.F. Robinson (A Director of the North British Locomotive Co. Ltd.) before the Tariff Commission, reported in 'British Locomotive Building', The Railway Gazette, February 26th, 1909, p.281.
[27] Brown, *op cit* (4), p.xxv and p.46.
[28] Alan S. Milward and S.B. Saul, The Development of the Economies of Continental Europe 1850-1914, 1977, p.21.
[29] Rainer Fremdling, Chapter 4, 'Germany', in P. O'Brien (ed), Railways and the Economic Development of Western Europe 1830-1914, Oxford, 1983, pp.121-143.
[30] Aldcroft, *op cit* (24), p.20.
[31] Saul, *op cit* (10), pp.202/3.

requirements, and the Russian industry was, similarly, able to meet most of its domestic needs from the 1890s.[32]

The American locomotive industry had a relatively poor decade in the 1890s and, following a period of co-operation, eight of the smaller manufacturers amalgamated in 1901 to form the American Locomotive Company.[33] The new company claimed 46% of total American production against the 39% of the Baldwin Company. This marked the starting point for major investment programmes by both companies, which, as Kirby has pointed out, prompted the amalgamation in 1903 of the three Glasgow locomotive builders, Neilsons, Dübs and Sharp Stewart, to form the North British Locomotive Company (Section 7.6.6).[34] The defensive motivation for the merger was confirmed by a director of the new company "because it appeared to us that we could economise in production and expenses generally."[35]

2.6 Market Evolution 1830 - 1850

The decisions made by the locomotive manufacturers on investment, employment and diversification were taken on the basis of their interpretation of the evolving market. In the first twenty years of main-line railway operation, the industry dominated the home and European markets, and largely determined the pace of technological, design and manufacturing progress. Demand fluctuated widely, however, as railway development in Britain, America and Europe increased and slowed according to economic and political circumstance. The industry realised that it could not control what it soon saw as a high-risk market, in which it would have to participate only with caution, whilst maintaining involvement with other capital goods markets. The manufacturers, to varying extents, diversified into and out of locomotive work, whilst maintaining involvement with their more

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[32] E.L. Ahrons, 'The British Locomotive Builders and the European Trade', The Engineer, Jan. 9 1914, p.40.
[33] Brown *op cit* (4), pp.53/4.
[34] M.W.Kirby, 'Technological Innovation and Structural Division in the UK Locomotive Building Industry, 1850-1914', Chapter 2 of Colin Holmes and Alan Booth (eds), Economy and Society: European Industrialisation and its Social Consequences: Essays Presented to Sidney Pollard, Leicester, 1991.
[35] Evidence of J.F. Robinson, *op cit* (26), p.283.

established markets. Some firms risked too much involvement in locomotive work and failed altogether (Section 7.6.7).

Interest in railways grew quickly after the early dividends of the first main line railways, and with the ready availability of British capital to invest in railways in Britain, the United States, Belgium, France, Holland and the German states.[36] The market for locomotives increased correspondingly and the manufacturers diverted sufficient capacity to increase annual production to 100 by 1837. As the market continued to rise, further capacity was provided through capital investments in new machinery, recruitment of labour and additional heavy manufacturing firms diversifying into locomotive manufacture. By 1840, the industry had grown to 34 firms and production to 370 locomotives (Figs.1 and 4). This large increase in production was only possible through major decisions to introduce self-acting machine tools and employ unskilled labour, to overcome the shortage of craftsmen (Chapters 5 and 6).

This increase in demand, however, masked early variations in national markets. The American market, which had grown rapidly from 1831, was eliminated by 1838. The American financial crisis in 1837, primarily due to its accumulated indebtedness to London, caused railway building and, hence, demand for locomotives to reduce substantially. When financial stability returned and railroad building recommenced from 1838, the American domestic industry was able to meet the full requirements for motive power.[37]

The loss of the American market coincided with the market expansion in Britain and Europe.[38] The home market, in particular, was strong after the first railway 'mania' of 1836, when more than 1,000 miles of new railway were promoted in Britain alone.[39] Government and 'concession' railways in Belgium, France and the German states, which were largely dependent upon Britain for capital,[40] gave rise to a rapid market expansion for the British

36 Jenks, *op cit* (21), pp 73 88, also Cottrell, *op cit* (2), Chapter 2, 'Beginnings, 1815-1855', pp 17-25.
37 White, *op cit* (23), p 12
38 Analysis of production, *op cit* (1)
39 H.G. Lewin, Early British Railways, &c., 1801 1844, London n.d., but 1925, Chapter V, 1836-The Foundations of the British Railway System', pp.41 48.
40 Jenks, *op cit* (21), p 84

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[36] Jenks, *op cit* (21), pp.73-88; also Cottrell, *op cit* (2), Chapter 2, 'Beginnings, 1815-1855', pp.17-25.
[37] White, *op cit* (23), p.12.
[38] Analysis of production, *op cit* (1).
[39] H.G. Lewin, Early British Railways, &c., 1801-1844, London n.d., but 1925, Chapter V, '1836-The Foundations of the British Railway System', pp.41-48.
[40] Jenks, *op cit* (21), p.84.

manufacturers, which canvassed hard for orders around the European capitals (Section 3.2.2).

There was an abrupt decline in railway projects as Britain moved into recession in the early 1840s.[41] Trade with the near European countries declined both absolutely and relatively, and there was a cut-back in investment by the capital market, with dividends from continental securities returning to London rather than be re-invested in Europe. The decline was given momentum by the imposition of the "six hostile tariffs" by Russia, France, Belgium, Portugal, the United States and the 'Zollverein' (German states' customs union). With this substantial reduction in new railway projects,[42] demand for locomotives declined and the locomotive industry experienced the first downward movement of the market cycle that it was to experience for the remainder of the century. As new railway routes previously sanctioned were completed and equipped with locomotives, production fell by 1843 to less than a third of its 1840 peak (Fig.1). Nine firms either failed at this time or withdrew from locomotive manufacturing and returned to their original markets (Fig.4). Other firms also sought to increase their involvement in other heavy manufacturing markets, whilst persevering with the limited locomotive market.

The recession gave rise to £20-25 million of inactive capital in the City of London.[43] Investors continued to receive good dividends from railway companies, however, reviving interest in railway investment from 1844, which climbed rapidly to become the extraordinary railway 'mania' between 1845 and 1847. Unlike the European centrally planned railway networks, the British Government permitted a scramble for new routes to go unchecked.[44] Table 1 quantifies the mania years:

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[41] Cottrell, *op cit* (2), Chapter I, 'The Volume of Capital Exports, 1815-1914', pp 11-16, also Jenks, *op cit* (21), Chapter V, 'The Railway Revolution', pp.126-157.
[42] Lewin, *op cit* (39), Chapter IX, '1840-The Opening of Many Lines' &c., pp.77-96
[43] Jenks, *op cit* (21), p.128.
[44] Henry Grote Lewin, The Railway Mania and Its Aftermath: 1845-1852, London, 1936, *passim*

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Year	Acts of Parliament for Railway Construction	Capital Authorised £million	Total Actual Capitalization £million	Miles in Operation
1844	48	17.8	72.3	2148
1845	120	60.8	88.4	2441
1846	270	136.0	126.1	3036
1847	190	40.3	166.8	3945
1848	85	4.6	200.4	5127
1849	34	3.1	230.0	6031

Table 1 Railway Development in the U.K. 1844-1849[45]

This surge in British railway projects coincided with an expansion of railways in France, the Benelux countries and the German states. British investment in French railways increased at an extraordinary rate in 1845, 50 companies being authorised in that year, towards which at least £80 million was promised from London.[46] Also in that year, eight British owned companies, with London head offices, were formed with concessions to build and operate railways in Belgium.[47] In 1847, forty foreign railways were quoted on the Liverpool Stock Exchange, the second largest group after domestic railway companies.[48]

The extraordinary growth of railway schemes in these years led to a sharp increase in demand for locomotives, production of which nearly trebled to 300 in 1845, and doubled again in 1847 to a peak of more than 600 in the year (Fig.1). This large increase led to profound and lasting effects on the locomotive industry, which was not to see a return to such high production levels for another 20 years. More manufacturing firms were attracted to locomotive manufacture by the prevailing high prices, and existing firms sought to introduce or divert additional capacity. However, the industry as a whole, even with over 30 firms engaged in locomotive construction (Fig.4), was unable to provide sufficient capacity in such a short time (Section 5.7.2). The shortage of craftsmen further stimulated the introduction of new capital equipment that was not reliant on skilled labour, and significant improvements were made to production procedures that recognised the benefits of batch production (Chapters 5 and 6).

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[45] Jenks, *op cit* (21), p.129.
[46] *ibid*, p.146.
[47] *ibid*, p.151.
[48] Cottrell, *op cit* (2), p.24.

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Manufacturers increased their prices and demanded down payments to secure priority places in the lengthening production queues. Large orders were spread over several months, sometimes years (Section 5.7.2). The prices and the delays led directly to the commencement and development of locomotive manufacture in railway-owned workshops, and the consequential long-term reduction of much of the British main-line railway market (Section 2.3). The long delivery times and high prices, accentuated by the high value of the pound and import tariffs, stimulated the establishment and growth of domestic locomotive industries in the German states, France, Belgium and Austria, further suppressing future potential for the British industry.[49] As railway networks expanded, continental manufacturers copied and adapted British and American locomotive technology, expanding quickly to fulfil the requirements of their own countries and become formidable competitors to the British industry.

In the autumn of 1847, the British economy again went into recession; the financial problems brought about by the "tangled skein of credit disorders" adding to the strain already imposed by the corn and potato famines.[50] Well-established finance houses failed, including five Bank of England firms, and British investors sold some of their foreign government security investments. In 1848, the several political crises, in France and central Europe, also led to a considerable slowing of British investment in continental railways. With interest in railway schemes ending abruptly, locomotive orders dried up, considerably easing the pressure on the manufacturers and allowing them to catch up on their backlog of orders, which had built up to between two and three years.

The backlog was regained by 1850, but with a hesitant British market, now diluted by the railways' own workshop output, and an equally hesitant European market in the post-1848 political climate, locomotive production by the independent sector declined to 200 in the year (Fig.1). Manufacturers once again had surplus capacity which caused them to return to other markets. Some manufacturers withdrew from the locomotive business altogether to

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49 Article, 'Sketches of German Railways', The Railway Chronicle, October 11th 1845.
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[50] Jenks, *op cit* (21), p.153.

concentrate on their other markets, whilst other, quite large, firms failed to secure alternative markets and went out of business (Section 7.6). The drop in the market was so severe that the number of firms which continued in locomotive manufacturing dropped to 20 in the early 1850s (Fig.4).

2.7 Market Evolution 1851 - 1870

The characteristics of the locomotive market changed radically in the twenty years after 1850. Not only had the industry to witness the increasing loss of the domestic market to the railway workshops, it also had to accept that Britain's decreasing influence in the main economic centres of Europe would favour the continental manufacturers. The manufacturers therefore had to adapt their design and product strategies as the market focus shifted to the developing peripheral European countries and to the large potential of the early Empire railways, notably in India, as well as to the growing industrial locomotive sector.

In the mid-1850s, manufacturers that survived the depression years were cautious in their interpretation of these market developments, and opinions were divided. Some firms anticipated further severe fluctuations, and sought to maintain their broad, capital machinery market base and craft-based production methods. Other firms, some new to the industry, saw good opportunities in the developing market that warranted greater specialisation in locomotive manufacture (Section 5.7). As the new markets developed, these 'progressive' companies invested in new workshops and equipment, taking the number of firms back up to 30, which helped to double the industry's production capacity to 800 locomotives a year by the late 1860s (Fig.1).

The development of Britain's railways was slow to recover after the recession, both in terms of new routes and increased traffic, and development in the mid-1850s was at a rate considerably below that of the 1840s.[51] The demand for main-line locomotives was

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[51] Lewin, *op cit* (44), p.473.

correspondingly low, whilst an increasing proportion was manufactured in railway-owned workshops, sixteen of which were so involved by 1857 (Fig.5). Although the demand for industrial locomotives had begun to grow, overall production for the home market fell to 130 in 1858 (Fig.2).

With improving balance of payments, British investors sought to resume their interest in western European railways but, with the birth of the French 'Second Empire' in 1852, their investment was eroded by a resurgent French capital market, in particular the Crédit Mobilier.[52] In spite of nearly £40million of British investment, the French railway administration favoured French engineering industry, including locomotive manufacturers.[53] As Jenks has commented, "it was startling for Great Britain to be unable to command any market open to foreign competition which she chose to supply".[54] Many of the substantial European railway building programmes in the 1850s were railway concessions, financed and built through international syndicates formed by finance houses and railway-building contractors.[55]

Diverted from its dominant role in western Europe, the London capital market re-directed its portfolio investments to new railway systems in southern and eastern European countries, notably the Italian states, Switzerland, Spain and Austria, in competition with continental financial syndicates. Much of the investment was arranged through the strong British contracting industry, especially Brassey, Peto and Mackenzie.[56] Although there was no direct linkage between portfolio investment and locomotive supply, it would seem that by the mid-1850s British contractors were encouraging orders to British locomotive firms, in common practice with their continental counterparts.[57] There was no such link with Canadian railways, however, in spite of large portfolio investments, and British

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[52] Jenks, *op cit* (21), Chapter VI, 'Cosmopolitan Enterprise', and Chapter VIII, 'From Bill-Broker to Finance Company', pp.158-192 & pp.233-262.
[53] Cottrell, *op cit* (2), p.23, also Jenks, *op cit* (21), pp.162/3.
[54] Jenks, *op cit* (21), p.192.
[55] *ibid*, pp.176/7.
[56] Charles Walker, Thomas Brassey Railway Builder, London, 1969, pp.69-134 *passim*, also Jenks, *op cit* (21), p.253.
[57] Survey of locomotive works lists, *op cit* (1).

manufacturers competed with the United States firms, which dominated the north American market (Section 7.6.4).

Foreign direct investment increased during the 1850s, particularly for railways in Russia (post-Crimea), Australia and India, encouraged by 'guaranteed' government dividends.[58] With several railways in Holland also being financed through foreign direct investment in London, their locomotive requirements were largely met from Britain throughout the century.[59] Railway expansion in Europe, and the several new world markets, saw Britain's overseas locomotive production briefly exceed the home market in 1856/57. Although overall locomotive production remained at about 400 a year between 1854 and 1857 (Fig.1), production dropped by 40% in 1858, due both to a reduction in European demand, and a one third reduction in locomotives for the home market.

There then followed a period of sustained growth in output for the locomotive manufacturers through to 1866, that took their annual production to over 800 (Fig. 1). This included a four-fold increase in locomotives for Britain's main line and industrial railways, reflecting the country's increasing industrial production and expanding economy (Fig.2). The main-line requirements went well beyond the capacity of the railway workshops, indicating that, after twenty years experience, some of the larger railways understood the economic benefits of stabilising their workshop capacity at an economic and sustainable level of locomotive production. Their peak requirements were ordered from the independent firms, which thus bore the brunt of the demand variation for the home market. The exceptions, however, were the London & North Western Railway and, from 1864, the Great Western Railway, whose Crewe and Swindon workshops, respectively, were large enough to accommodate their peak requirements.

Locomotive orders from the major European economic centres declined, however, as French, Belgian, German and Austrian capital, with the encouragement of their national

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[58] Jenks, *op cit* (21), pp.193-198.
[59] Milward and Saul, *op cit* (28), p.210.

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[55] *ibid*, pp.176/7.
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[58] Jenks, *op cit* (21), pp.193-198.
[59] Milward and Saul, *op cit* (28), p.210.

governments, gave preference for their national industries, including the locomotive manufacturers. Although French capital, led by the Crédit Mobilier, dominated railway development in Italy and Spain, as well as in France itself,[60] the collapse of the Crédit Mobilier in 1867, and the Prussian war of 1870 interrupted further French expansion.[61]

The strong British market coincided with a more sustained growth in demand for locomotives for countries beyond western Europe. Railway companies were formed to build railways in Russia, Scandinavia, South America, Canada and India with the encouragement of the host governments, to entice the large reserves of the London financial market, often with dividend guarantees, as a means of developing the economies of the countries concerned.[62] Following the Companies Act of 1862, a series of finance companies were formed, based on the French Crédit Mobilier system, to pursue the new investment opportunities.

British investment in India, particularly for railways, developed at an extraordinary rate in the wake of new government policies after the 1857 'mutiny'. It became so high in the early 1860s that it caused alarm as the British interest rate began to rise. The annual investment in Indian railways, mostly encouraged by the 'guarantee' system, is summarised for the decade in Table 2:

Year	Amount £millions	Year	Amount £millions
1858	5.50	1864	3.80
1859	7.15	1865	5.40
1860	7.58	1866	7.70
1861	6.50	1867	7.00
1862	5.80	1868	4.50
1863	4.78	1869	4.40

Table 2 Investment in Indian Railways 1858-1869[63]

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60 *ibid*, pp.244-247.
61 Jenks, *op cit* (21), p.172 and Milward and Saul, *ibid*; also Stefano Fenoaltea, Chapter 3, 'Italy', in P.O'Brien, *op cit* (29), pp.49-120.
62 Jenks, *op cit* (21), p.195, and Chapter VIII, *op cit* (52).
63 Jenks, *ibid*, p.219.

As the extensive railway routes in India were constructed and opened, the demand for locomotives quickly developed into the second largest market, after the home market, for the British locomotive industry. This new market was again cyclical, however, generally following the railway investment pattern, but a year behind as the new routes were opened and traffic expanded. 200 locomotives were constructed in 1867, for example, following the high investment year of 1866, but had dropped to only 50 locomotives in 1870 as the new building programme slowed down.

Between 1860 and 1876, some £50 million was loaned to the governments of the Australian colonies, chiefly for railway construction and other public works.[64] The sparseness of the population and the low service levels, however, meant that locomotive requirements, all supplied from Britain, were generally no more than 20 per year.

Following the Crimean War, the Russian economy was stimulated by capital from several western European financial centres, including London, which was partly used to build government-owned and concession railways.[65] Some railways, such as the Dunaberg-Vitebsk, were British-owned.[66] Other companies were funded by French, German and Austrian interests, and locomotive orders were generally, but not always, placed in the country with the prevailing financial interest. Several large orders were received by the British industry, over 150 being manufactured in 1870.

The growth of the British economy was badly interrupted by the failure of the Overend Gurney & Co. discount bank in 1866, with debts of £10 million.[67] The effects on the railway contractors (Peto & Betts failed with debts of £4 million) and on the domestic railway building programme were felt for some three or four years afterwards. The collapse revealed that much of the railway building boom in the 1860s had only been possible by an expanding credit system that could not sustain itself. Contractors had been willing to take

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[64] Jenks, *ibid*, p.231.
[65] Article, 'Russian Railways', Engineering, Vol.IX, May 13 1870, pp.331/2.
[66] The Railway Engineer, *op cit* (16), *passim*.
[67] Jenks, *op cit* (21), sub-chapter, 'The Failure of Overend Gurney & Co.', pp.259-262.

shares in the railway companies for whom they were building, or to raise loans, which the new finance companies had proved eager to provide.[68] The collapse put an end to the raising of capital by contractors for railway construction purposes. The resulting loss of confidence, and its effects on the country's economy, led to a substantial falling off of locomotive orders. Annual production for the home market dropped by two-thirds to less than 200 locomotives between 1866 and 1869.

The fluctuations in the locomotive market further widened the views of the manufacturers between those which remained cautious about its development, and those which anticipated its long-term development. This divergence resulted from strategic decisions that the locomotive firms took from the 1850s on investment for increased locomotive production, employment and the extent of product diversification (Chapters 5,6 and 7). The more cautious firms reduced their dependence on locomotive work and maintained a big involvement in marine, colliery, process and manufacturing steam engines and other machinery, for which their 'craft' skills were well suited for small batch production. The 'progressive' firms invested in increased production capacity and further labour-saving capital equipment to reduce their dependence on craft skills, and allowing them to employ unskilled labour in numbers appropriate to the buoyancy of the market.

2.8 Market Evolution 1871 - 1900

As the market developed in the last three decades of the century, the manufacturers experienced an overall growth in the market for locomotives which was interrupted by three periods of low demand that severely tested their ability to remain profitable (Fig.1). The period also saw increasing competition from American and European manufacturers (Section 2.5). The growth in the size of railways and in the traffic they handled led to an increase in batch sizes which favoured the progressive manufacturers, whose continued investment in

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[68] P.L. Cottrell, 'Railway Finance and the Crisis of 1866: Contractors' Bills of Exchange, and the Finance Companies', The Journal of Transport History, Vol.III, New Series, No.1, 1975, pp.20-38.

capital equipment allowed cost reductions to be made to the disadvantage of the 'craft' firms (Section 5.7).

From 1870, there was a major expansion of London-based foreign direct investment in railways in both the Empire and all other regions of the world, particularly South America. Several railways in Europe, including those in Scandinavia, Holland and Russia, were either British-owned, with their head offices in London, or retained strong proprietorial contact with British manufacturers. The London market for locomotives gave every opportunity for manufacturers to monitor the progress of demand in each country, although the economic and political influences on world railway development continued to create extraordinary fluctuations in demand that were largely impossible to predict.

Britain's economy recovered strongly in the early-mid 1870s, in spite of major increases in raw material prices following the Franco-Prussian War (Section 7.2), and the 1873 financial crash in Vienna.[69] Locomotive output achieved new highs of more than 900 a year in 1874 and 1876 (Fig.1). In the latter year, a record 600 were made for the home market, a third being for industrial use, reflecting the high level of Britain's industrial activity. There was also a short-term boost in the western European market arising from extraordinary needs from Germany in the aftermath of the Franco-Prussian war, and nearly 500 locomotives were made for western Europe in the mid-1870s.[70]

From 1873, the upward trend in Britain's export income was reversed, and capital values fell in the so-called 'Great Depression'.[71] The country's surplus capital that had been re-invested abroad, including railway schemes, all but disappeared by 1876, and for the next generation, the country's overseas investments were limited to the 'secondary export of capital'. Britain's 1878 liquidity crisis is described by Collins as amongst the worst in the nineteenth

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69 Cottrell, *op cit* (2), p.36.
70 Ahrons, *op cit* (32), p.40.
71 Jenks, *op cit*, (21), Chapter XI, 'At the End of the Surplus'; also, A.E. Musson, 'The 'Great Depression' in Britain, 1873-1896: A Reappraisal', Economic History Review, Vol.12, 1959-60, pp.199-228.

century.[72] The resulting short-term adverse trade swing slowed manufacturing output, and locomotive production dropped by a third to below 600 in 1879, of which the domestic market accounted for only 40 per cent.

The effects were worse in certain markets. Following the boom market for Russian locomotives up to 1876, for example, British investment in Russian railways, and hence locomotive orders, fell sharply. The vacuum was filled by continental investors, particularly those in Germany. In 1884, following a 'rapprochement', Germany made available a £15million loan to Russia, which was seen as being "essentially a railway loan" for which there would be "some large orders for rails and railway appurtenances of all kinds".[73] With Russia's locomotive industry unable to keep up with demand, the loan led to some large orders for the German industry, to the exclusion of the British manufacturers.

The British industry's overseas markets were, however, broadly based from the 1870s. British investment in the railways of Argentina was extensive and, by the end of the decade, twenty-seven of the country's thirty-four railway enterprises were British controlled.[74] The locomotive market for South America as a whole reached between 30 and 70 per year by 1880. The strong Indian market in the mid-late 1870s did most to off-set the declining domestic market, with a record of over 250 locomotives being exported there in 1880. Further markets arose from expanding railway projects in Australasia and the Middle East, and new railways in southern Africa and the Far East.

British manufacturers experienced their first concerted competition outside Europe from the American locomotive industry, during the 1870s. In the wake of the 1873 American economic panic, and a reduction in its domestic market, the American industry competed for export orders. Even after the recovery of the American market in the mid-late 1870s, modest inroads continued to be made in markets previously considered to be 'British'. These

[72] Michael Collins, 'English Bank Lending and the Financial Crisis of the 1870s', Business History, Vol.32, No.1, 1990, pp.198-224.
[73] Article, 'The Recent Russian Loan and Railway Business', The Railway Engineer, Vol.5, No.8, August 1884, pp.205/6.
[74] J. Fred. Rippy, British Investments in Latin America, 1822-1949, Minneapolis, 1959, p.33.

were notably railways in Australasia and Latin America, where the nature of certain routes, constructed to the more demanding, low expenditure standards of American railroads, favoured American designs over British ones (Section 4.8).[75] The export of American locomotives between 1875 and 1879 was equal to 20% of the British export total.[76]

In the early 1880s, Britain's capital exports and trade recovered strongly (Fig.3). Australia benefited particularly, about half of all overseas investment being directed there in the late 1870s, and a quarter in the 1880s, mainly to expand the 'pastoral economy' and for railway construction.[77] There was a large increase in locomotive demand, particularly for India, South America and Australia, and more than 100 were also made for railways in France, which its domestic industry could not fulfil.[78] Production increased each year, to reach over a thousand locomotives for the first time in 1885 (Fig.1). British manufacturers again faced capacity limitations and quoted longer delivery times and higher prices. Taking advantage of the strong world demand, and with reduced home demand, American manufacturers expanded their locomotive exports, which increased to 30% of British-made exports in the early 1880s.[79] After 1885, however, the American industry switched production back to a rejuvenated domestic market, exports falling to 15% of the British total.

In 1886, there was another downturn in Britain's economy which depressed the locomotive market, the industry experiencing a 40% drop in production from the previous year, to 600 locomotives. Whilst the home market fell, also by 40%, the fall in overseas demand is more difficult to explain given the rapidly expanding volume of foreign investment (Fig.3). Cottrell suggests that there was a short-term drop in the volume of capital exports in 1885/6, a pause in the 'long swing' rise in overseas investments, particularly to the Empire and to Argentina, through to 1890.[80] Saul's brief survey of the engineering industry makes no

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75 Brown, *op cit* (4), p.45.
76 Analysis of production, *op cit* (1), compared with editorial, The Railway Engineer, Vol.XIV, March 1893, p.66.
77 Cottrell, *op cit* (2), Chapter 3, 'The Growth of the Portfolio, 1855-1914', p.37.
78 Ahrons, *op cit*, (32).
79 Analysis *op cit*, (76).
80 Cottrell, *op cit* (2), p.35.

comment about the sharp drop in production, even though it features in his graph of locomotive sales by the nine largest independent manufacturers.[81]

A five-year trade recovery began in 1887, stimulated by Britain's expanded foreign investment programme which reached £120 million in 1890, the highest figure in the century (Fig.3). A major beneficiary was Latin America in which, by 1890, the nominal capital in a hundred railway enterprises was approximately £164 million.[82] A large network of rail routes spread throughout the sub-continent, particularly Argentina, for which the British industry manufactured nearly 350 locomotives in 1890. Another expanding market was in the Far East, particularly Japan and China, in spite of growing competition from American and German manufacturers. The Australasian market, however, was reduced by competition from America, and by the small Australian locomotive industry (Section 4.8).

The British domestic main-line and industrial markets also strengthened in the late 1880s, and reached 400 locomotives annually in 1890/91, the highest for a decade (Fig. 2). However, in the early 1890s, confidence in foreign securities was shaken by the Barings Bank crisis, the financial panic on Wall Street and other international banking-related problems.[83] Once again, Britain's economy and overseas investments went into a sharp downturn, depressing railway operations and locomotive demand. Production fell to just over 500 in 1894, half that of four years earlier, and the lowest since 1869 (Fig.1). The home market fell by 40% from the 1891 figure, the majority being industrial locomotives. Other markets were also weak, although production for the Indian, South American and Japanese railways held up over the two years to carry the industry through the lean period.

The steep drop in British investment overseas was accompanied by more aggressive competition for capital goods, particularly from the United States and Germany, in some of Britain's areas of high investment. Both countries increased their share of overall imports into Argentina, for example, from about 8% in 1885/86 to over 13% in 1901-03, whilst the

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[81] Saul, *op cit* (10), Chapter 7.
[82] Rippy, *op cit* (74), pp.38/39; also Cottrell, *op cit* (2), p.38.
[83] Cottrell, *ibid*, p.39.

British share fell from 36.7% to 33%.[84] The American locomotive industry competed aggressively in Latin America, Far East, New Zealand and parts of Australia, and between 1890-92 its export total rose to nearly 40% of the British export figure.[85]

The British economy strengthened from 1895 with the ending of the 'Great Depression', and returned to a boom period by the end of the century, with overseas investment regaining some of its lost ground. Foreign direct investment in South American railways alone exceeded £300 million by the Edwardian decade.[86] Britain's high industrial output generated unprecedented rail activity and, with railway expansion programmes resuming in all world markets, demand for locomotives rose substantially. In 1899, the industry's output exceeded 1100 for the first time, equally divided between the home and export markets (Fig.2), including 300 industrial locomotives, reflecting the extraordinary growth of Britain's industrial sector.

With both the independent sector and the railway workshops working to capacity, the industry as a whole was unable to meet the demand, leading to rising prices and lengthening delivery times. Orders were lost to American and European manufacturers. An order for 18 locomotives in 1896 from Japan, for example, was transferred to a French firm, with a consequent loss of the 10% deposit, when the English manufacturer's delivery time slipped back unacceptably.[87] For the first time since the earliest railway era, three British railways, the Midland, Great Northern and Great Central, acquired locomotives from American manufacturers.[88]

Although the market remained buoyant into the Edwardian era, and the manufacturers continued to retain full order books, the loss of these orders had long-term effects for the British industry, which lost its dominance in the world market from this time. A

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[84] S.B. Saul, Studies in British Overseas Trade 1870-1914, Liverpool, 1960, Table X, p.39.
[85] Analysis *op cit*, (76).
[86] Corley, *op cit* (17), pp.71-88.
[87] Consular Report No.427, Presented to Parliament June 1897, reported in The Railway Engineer, September 1897, Vol.XVIII, pp.276-279.
[88] Ahrons, *op cit* (32), p.307.

contemporary American report calculated that the value of British locomotive exports dropped from $9 million in 1890 to $7.3 million in 1900, whilst in the same decade the value of American exports had risen from $1.3 million to $5.6 million.[89] For some countries, such as Japan, American companies manufactured almost as many locomotives as British firms.

The progressive manufacturers were generally successful in their pursuit of strategies to provide sufficient capacity to meet the growth in locomotive demand, and to improve their production facilities to provide the economies of batch production. The extraordinary surge in production at the end of the century was, however, partly created by a backlog arising from the protracted 'lock-out' dispute of 1897 (Section 6.5), which coincided with the high demand from the world markets. By the end of the century, the progressive firms were able to accommodate the sharp fluctuations in demand by a policy of employing unskilled labour according to demand, which minimised the risk of losing their skilled labour (Section 6.3). The craft firms, however, without this high proportion of unskilled labour, were placed in severe difficulties when demand was low, since they could ill afford to employ men for whom they had no work.

2.9 Conclusion

The strategic decisions taken by the locomotive industry in the 19th century were influenced directly by perceptions of its changing markets. Whilst the manufacturers controlled the industry's development in its earliest years, their subsequent decisions on expansion and capital investment, technological and design development, and employment were all conditioned by a market which, after 1850, it no longer controlled. The domestic market, in particular, for which the industry had previously provided all requirements to its own designs, gradually became a residual market consisting of designs undertaken by the railways themselves (Chapter 4).

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89 'British and American Exports of Locomotives', Railroad Gazette, Vol.33, Feb.1st 1901, quoted in Brown, *op cit* (4), Note 63, p.265.

It was the inability to predict the extraordinary fluctuations in demand throughout the century that made strategic decision-making so difficult for the manufacturers. The risk to firms through over-commitment of investment, producing funding problems when demand was low, underlay the manufacturers' caution. It led directly to the industry's divergence between firms dependent upon craft skills, avoiding major capital expenditure, and the progressive firms which were stimulated to develop new capital equipment to reduce craft dependency (Section 5.5). Employment policies for these firms were premised on the increasing use of un-skilled labour, which could be laid off and recruited according to the strength of the market (Section 6.3).

These diverging policies, and the determination to survive the periods of low demand, led the manufacturers to base their corporate decisions, both of company structure and product diversification, on a combination of long-term growth in the locomotive market and a cautious interpretation of shorter-term demands. The raising of capital, through continued partnership status or through conversion to limited liability companies, was based upon this cautious interpretation (Section 7.6). All firms relied on diversification to varying degrees, in their bid to survive through the periods of low locomotive demand. Several diversified away from the industry permanently, whilst others went out of business altogether through failure to provide alternative markets.

Although the industry's dominance in the markets of America and the major European economic centres was lost to their home industries through tariff imposition and the increasing influence of European capital, the strong British capital market developed new locomotive markets through the major foreign direct investment programmes. The London market became the dominant influence for the locomotive industry, not only through direct contacts with the many overseas railways, but also with their consulting engineers. The increasing influence of the London-based engineering offices included their greater involvement in locomotive design, which further reduced the technological and design discretion for the industry (Section 4.5).

Jenks' conclusion that he could find no relation between the destination of exported capital goods and the apparent field of activity of British investment (Section 1.4), therefore has limited application for the locomotive industry. It was true that in countries, such as the United States, Germany and France, which protected their home industries with tariffs, British portfolio investment was not able to generate benefits for British manufacturing industries. However, the relationship between foreign direct investment and the locomotive industry in other parts of the world, particularly in the Empire and South American countries, illustrates a close liaison between manufacturers and the railway companies, focused on London.

The manufacturers thus based their strategic decisions on their perception of the evolving locomotive market, and with some anticipation of the consequences of its volatility. They sought to reduce the uncertainties of locomotive demand, and the attendant risks to their business, through marketing and selling policies. These policies developed through the century as their major opportunities passed from domestic and European demand to London-based overseas markets.

3.0 Marketing and Sales

3.1 Introduction

In the 1830s, the rapid growth of the locomotive market and the number of firms diversifying into locomotive manufacture (Section 2.2) introduced the need for marketing and selling practices as competition between manufacturers intensified. In contrast to the proprietorial or agency contact, which had been the normal selling practice for the heavy manufacturing industry, the proprietors were faced with the tactical decisions of marketing themselves to their potential railway customers in order to be included on the lists of favoured firms which would be asked to tender for orders. The introduction of 'transparent' tendering and contracting was required by the new main-line railways, which were joint stock companies or government-owned networks.

The manufacturers had to learn and adapt existing marketing and selling procedures, based on reputation for product quality, specification and design, as well as acceptable price, delivery terms and payment arrangements. They were required to learn new marketing techniques, aimed at raising and maintaining awareness about their products among railway customers or their representatives, to prompt enquiries of the manufacturer, or allow him to obtain a hearing on product sales. Although marketing and selling to home railways was often undertaken by the proprietors themselves, that to the railways of America and Europe was largely undertaken through commission agents, upon whom the manufacturers were dependent.

The competitiveness of the market depended upon the relationship between fluctuating demand and the capacity available to meet that demand. In adapting to market movements, the manufacturers sought to attract orders by offering better delivery quotations through parallel production scheduling, as well as through price and payment arrangements. When the market was strong, prices would rise and delivery dates would be spread to provide the best medium-term production schedule (Section 5.7) and cash-flow projection (Section 7.3). When the market was weak, not only did prices fall and delivery dates become more critical, but the manufacturers made comparison with other machinery markets which could offer better returns on the use of men and equipment. The decisions on complete or partial diversification played an essential role in the prosperity, and even survivability of firms (Section 7.5).

The manufacturers had to adapt to the changing market through the century. Tendering procedures for the reducing British railways market remained largely the same, although they had to accommodate the growing influence of the locomotive superintendents. The loss of markets in America and the major European economic centres, however, and the rise in the importance of the London market, shifted the marketing emphasis towards direct contacts in the capital with railway and government representatives and consulting engineers. For this purpose new offices were obtained, or representative agents appointed.

The loss of much of the manufacturers' technological and design discretion from the 1850s (Sections 4.3 - 4.5), brought about a change from a production-led to a market-led business. The manufacturers had very limited opportunities to offer technical progress as a marketing incentive, and relied instead on production quality and delivery reliability to keep their places on tender-lists. The economic benefits of their strategic decisions in favour of greater batch production (Section 5.7.3) were reflected in tender prices, but the proliferation of designs for both the home and overseas markets reduced opportunities to capitalise on them.

3.2 Proprietorial Contact

The evolution of marketing and selling responsibilities during the century, from predominantly proprietorial control to its delegation to senior managers and commission agents, is a prime example of the adaptability of 'partnership' enterprises. Such was the growth of the market, that partners quickly limited themselves to marketing contacts, usually at senior levels, whilst delegating negotiations and tender preparations to their senior aides. The proprietors' experience in developing contacts with railways, and the factors that led them towards delegation, therefore provide evidence of the evolution of management capabilities in the heavy manufacturing industry.

Marketing and selling of capital goods had been undertaken since the 18th century. Matthew Boulton, for example, prior to his partnership with James Watt, had developed an agency network throughout Europe to generate sales of his hardware articles since the 1770s.[1] Marketing, however, was an infant concept. Although the agents undertook some 'market research' amongst potential customers, including governments, it paved the way for Boulton and Watt to undertake 'sales' tours for their pumping and factory engines, negotiating price, installation and after-sales commitments.[2]

Prior to 1830, manufacturers, customers and agents were usually sole proprietors or small partnerships, contact between whom often developed close personal relationships. The proprietors of the Butterley Company: "took a personal hand in selling their products", spending a good deal of time in London,[3] and when William Fairbairn visited Switzerland and France in 1823 he obtained extensive orders for water-wheels, mill-gearing and other manufactured items.[4] With the limitations on proprietors' time, however, representative agents were appointed to sell capital goods. By 1807, a sales agency was acting on the Butterley Company's behalf, and from 1810 Boulton and Watt received most of its overseas orders through London, Liverpool or Bristol merchants.[5]

The manufacturers of capital equipment who first diversified into locomotive manufacture, continued to pursue proprietorial sales contact with their customers. Following its success at the Rainhill Trials of 1829, Robert Stephenson & Co. was invited to manufacture the first locomotive fleets for the early main-line railways. With the Stephenson company unprotected by patent cover, however (Section 4.2), other manufacturers saw immediate

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[1] Jennifer Tann, 'Marketing Methods in the International Steam Engine Market: The Case of Boulton and Watt', Journal of Economic History, Vol.38, 1978, p.364.
[2] *ibid*, p.372.
[3] Philip Riden, The Butterley Company 1790-1830, Chesterfield, 1973, p.43.
[4] R.A. Hayward, Fairbairn's of Manchester, unpublished MSc thesis, UMIST, 1971, pp.1.18, 2.10 and 2.12.
[5] Tann, *op cit* (1), p.364.

market potential. Several offered locomotives speculatively to the railways, the most tenacious being Edward Bury who offered his first locomotive to the Liverpool & Manchester Railway as early as March 1830.[6]

The railway directors acquired some locomotives from other experienced manufacturers on the grounds of on-going trial of a new technology, but George and Robert Stephenson, who had responsibility to their railway clients for design and specification, sought to direct orders to their own Newcastle and Newton-le-Willows factories (Section 7.6.2). Mounting pressure from other manufacturers, particularly Bury, brought about extraordinary episodes on the Liverpool & Manchester, London & Birmingham and Grand Junction Railways, in which the directors divided between those who favoured direct ordering of locomotives from the Stephensons and those who sought to introduce an open tendering system.[7]

The acrimonious boardroom battles, which continued until 1836, degenerated into a trial of strength between the Stephensons and Bury and their supporters. Robert Stephenson was distressed by the severity of the personal attacks upon him. He wrote:[8]

> "Our enemies viz Rathbone and Cropper [London & Birmingham Railway Directors] are raising a hue and cry about our having an Engine to build at Newcastle - they say another article will be brought out by [Dr. Dionysius] Lardner on the subject - They half intimate that I shall withdraw either from the Railway or the Engine Building - The revenge of these people is quite insatiable - This distresses me very much."

Although the Stephensons lost influence on all three railways, and Bury was contracted by the London & Birmingham Railway to provide its motive power, the resolution of the struggle was the introduction of a formal and open specification, tender and contract system. This marked the beginning of 'transparent' competition for all manufacturers, which had to market themselves to achieve and maintain a place on the list of favoured firms kept by each

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[6] Lieut. Peter Lecount, A Practical Treatise on Railways &c., Edinburgh, 1839, p.377.
[7] Minutes of the Liverpool & Manchester Railway Board, PRO Rail 371; London & Birmingham Railway, London and Birmingham Board Committees, PRO Rail 384; Grand Junction Railway Board, PRO Rail 220, *passim* 1830-1836.
[8] Letter Robert Stephenson to Michael Longridge, London, 26th January 1835, Darlington Public Library, Pease-Stephenson collection, D/PS/2/67.

railway or consulting engineer, to ensure that invitations to tender would be received. Obtaining a contract was then dependent upon the tender price, delivery times and payment details (Section 3.6).

The extraordinary growth of the industrial locomotive market in the second half of the century called for its own, different marketing and selling techniques. It was driven by the demand for inexpensive motive units with common specifications and economies of scale from batch production, with design initiative in the hands of the manufacturer (Section 4.5). Industrial locomotives were more akin to the component supply market than the capital goods market, and were sold with demanding price and delivery terms. As the main-line and industrial markets diverged, therefore, manufacturers had to adapt their marketing and selling techniques accordingly.

3.2.1 United Kingdom Market

The ending of the Stephensons' domination of locomotive supply resulted in a rapid expansion of proprietorial approaches from the growing number of manufacturers promoting their firms and seeking invitations to submit tenders. As early as 1837, Robert Stephenson involved himself in the selling activities of Robert Stephenson & Co. He requested a briefing from his Head Clerk: "of the present state of your orders and future prospects of completion - for my guidance in making further negotiations."[9] Stephenson's high reputation as a consulting engineer, however, meant that he was too preoccupied with those duties to remain fully responsible for marketing and sales. With none of his fellow partners acting in an executive capacity, responsibility for marketing and sales rested with the Head Clerk, with the considerable assistance of the firm's representative agent, Edward Starbuck (Section 3.3.1).

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[9] Post-script to letter, Robert Stephenson to E.J. Cook, 16th June 1837, Library of the Institution of Mechanical Engineers, Crow Collection.

For other firms, however, proprietorial contacts with the larger railways was a dominant feature of the locomotive industry for 20 or 30 years. High-profile proprietors, such as Charles Beyer, Edward Wilson, John Sharp and Walter Neilson could command respectful audiences from senior railway managers, to ensure their firms were included on tender lists. Personal contacts with smaller railways often encouraged direct sales without formal tendering procedures. This was in marked contrast to the American industry which was dominated by commission agents until 1872.[10] Not until this practice was swept away by the manufacturers acting in concert (Section 3.7) were they able to develop proprietorial representation, backed up by salesmen who travelled across North America on sales tours. The partners themselves then negotiated financial matters with the railway Presidents.

In Britain, proprietors of the smaller manufacturers, and those seeking to build reputations, also worked hard to gain access to tender lists and to sell directly when the opportunity arose. In 1865, for example, John Fowler negotiated directly with William Martley, locomotive engineer of the London Chatham & Dover Railway to obtain an order for his new Leeds factory and secure a footing in the home market.[11]

In the 1850s it was not unusual for 12 or 15 companies to be invited to tender, but by the 1890s ten companies was more usual.[12] Some regrettable statements were made to gain access to a tender list. In 1846, Arthur Jones of Jones & Potts wrote to his partner: "Mr. Slaughter [of Slaughter, Gruning & Co.] has been soliciting work from Mr. Stephenson and recommends his engine as very vastly superior to ours....... I said I thought Mr. Slaughter might have adopted a different way of obtaining orders than by pulling other people's engines to pieces - this he agreed to."[13]

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[10] John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, pp.42/3 & 50/51.
[11] Michael R. Lane, The Steam Plough Works, London, 1980, p.138.
[12] For example, Minutes of the Midland Railway's Locomotive Committee, PRO, Rail 491/168-192, *passim*.
[13] Letter Arthur Potts to John Jones, London, March 31st 1846, R. Stephenson & Co. archive, National Railway Museum, Folder 19.

In some cases, a close supplier/customer relationship developed where a locomotive superintendent had previously been engaged by a manufacturer. Benjamin Connor, the Works Manager for Neilson's Glasgow works, became the Caledonian Railway's Locomotive Superintendent in 1857. Whilst the railway regularly built locomotives at its own works, further new-build requirements were met from the nearby Neilson factory, no doubt influenced by Connor's relationships with the personnel there.[14]

From the 1860s, with the passing of the first generation of proprietors and the significant increase of locomotive sales, direct proprietorial promotion was delegated to head clerks, London managers and representative agents (Sections 3.3 and 3.4). Throughout the century, however, proprietors of industrial locomotive firms retained close contacts with their British customers, for whom they made much other equipment, such as colliery machinery.

3.2.2 Overseas Markets

Up to the 1860s, overseas visits by proprietors were important initiatives in developing and maintaining goodwill with customers, including government departments. William Fairbairn made several visits between the 1830s and 1850s, to Sweden, Russia and Turkey, the resulting sales including locomotives for his Manchester factory.[15] With Robert Stephenson's civil engineering work allowing him limited opportunity to visit European railways, he engaged, in 1840, the services of a representative agent, Edward Starbuck, to undertake the considerable marketing and selling work required on the continent (Section 3.3.1). Their successful working relationship brought about several visits by Stephenson to railways on the continent and to Egypt, in which he combined consultancy advice with promotion of his Newcastle factory.

Following Starbuck's death in c1856, he was replaced by Charles Manby, the Executive Secretary of the Institution of Civil Engineers, whose Westminster address was adjacent to

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[14] John Thomas, The Springburn Story, London, 1964, pp.85-96.
[15] Hayward, *op cit* (4).

the Stephenson office. Manby's seniority and international reputation would, itself, have been a signal to customers of the importance placed on them by the Stephenson Company.[16] Manby, who had the status of a proprietor rather than an agent, subsequently moved his office into the Stephenson property, whilst continuing as Honorary Secretary to the Institution.

Return visits to Newcastle were also encouraged as part of the marketing effort. In 1841, Robert Stephenson & Co. received a visit from the Hamburg Railway engineer, which was "for the purpose of seeing my new Engine, ... in order that he may be enabled to give an opinion to his Directors as to the propriety of having their Engines constructed on our new plan. - You will please to give him every information that he may require........"[17]

The close relationships with some of its customers developed by Beyer Peacock & Co., arose out of personal visits by Charles Beyer. As early as 1857, in a letter referring to the potential for further orders, G.H. Stieler, representing the Swedish railways, signed off: "Many compliments to your associates from Your faithful friend."[18] In 1863, Beyer undertook a continental tour, and met Brouwer von Hagendorp who was responsible for ordering locomotives on behalf of the Dutch railways. He laid the foundations for a successful supplier/customer relationship against increasing competition from the German Borsig company.[19] Von Hagendorp paid a return visit to the Gorton Foundry, from which orders were secured.

The personal connections of locomotive engineers, whose career moves promoted them to positions with manufacturers, consulting engineers and overseas railways, played an influential part with the overseas market. In a letter to their English agents, the Sydney &

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[16] For example, letter, Charles Manby (for R. Stephenson & Co.) to Carl Pihl (for the Norwegian State Railways), 30 December 1858, Beyer Peacock & Co. archive, Museum of Science & Industry in Manchester, Ref. MS0001/258.
[17] Letter, Robert Stephenson to Edward Cook, London, 2 Oct 1841, Deutsches Museum Library, Munich, Ref.1981-19.
[18] Letter, G.H. Stieler to Beyer Peacock & Co., Gothenberg, 16th March 1857, Beyer-Peacock archive, *op cit* (16), Ref. MS0001/255.
[19] R.L. Hills and D. Patrick, Beyer, Peacock Locomotive Builders to the World, Glossop, 1982, p.45.

Goulburn Railway, the first in Australia, passed on the opinion of its engineer, James Wallace, who had just taken up office on arrival from England, that the first locomotives: "should be procured from, if possible, either Messrs. R. Stephenson, Messrs. Fairbairn or Messrs. Sharp Roberts and Co."[20] Similarly, Robert Bennett, formerly Beyer Peacock & Co.'s Works Manager, who was appointed Chief Mechanical Engineer to the New South Wales Government Railways, maintained a close relationship with Beyer Peacock, no doubt aided by his familiarity with personnel and procedures at Gorton.[21]

3.3 Agents

The use of representative agents by the manufacturers was, until the 1850s, an important feature of the industry's overseas marketing and selling activities which did much to ensure their success. With the market moving away from America and the major European economic regions, however, and the shift in emphasis towards the London market (Section 2.4), overseas agency representation declined in favour of London managers or, for the smaller firms, London agencies. The different characteristics of the industrial locomotive market throughout the century meant that proprietors and senior managers were required to negotiate for sales with commission agents representing railways and industrial concerns. The procedures for dealing with agents, and the problems that arose, are further evidence of the tactical decision-making responsibilities of the proprietors and their senior managers.

3.3.1 Representative Agents

The employment of representative agents was not as widespread as for other capital goods, such as textile machinery. Farnie, for example, states that both home-based and foreign agents exclusively represented textile machinery manufacturers in particular geographic

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[20] C.A. Cardew, 'Copy of Centenary Notice of the Opening of the Sydney and Parramatta Railway', RSCo archive, *op cit* (13), Folder No.7.
[21] Hills and Patrick, *op cit* (19), pp.56/65.

areas.[22] Representative agents undertook marketing work, canvassed orders, negotiated contracts, arranged shipments, insurance, payment arrangements and document translations, and represented their principals on other matters such as patent royalty payments. They represented only one locomotive manufacturer, but often represented other firms for other forms of goods, rails for example, which did not conflict with their locomotive interests. Commission payments could be quite high in buoyant years; E.B. Wilson & Co., for example, paid out £11,500 in commissions in 1857.[23]

The extraordinary success of Robert Stephenson & Co. in the 1840s and 1850s was largely due to its London-based agent, Edward F. Starbuck. He represented the company for all its products, including marine engines and bridges, as well as locomotives, and negotiated many continental contracts and some British ones. He was highly regarded by Stephenson, whom he represented personally on matters relating to royalty payments,[24] and who proposed, unsuccessfully, in 1842 that he should become a partner of the company. He pre-deceased Stephenson, who left a large sum of money to Starbuck's children in his will.[25]

Although the Stephensons first had contact with him in 1834, Starbuck represented R.B. Longridge & Co. from 1837, for whom he obtained some notable European orders. In 1840, however, Stephenson reported to Joseph Pease: "You have probably heard that Longridge and Starbuck no longer carry on business together, the latter intends commencing a commission business in his own account and has applied to me to allow him to act for RS & Co more particularly on the Continent where he has already been instrumental in establishing a connection for Longridge & Co in the Locomotive department."[26]

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[22] D.A. Farnie, 'The Textile Machine-Making Industry and the World Market, 1870-1960', Business History, Vol.32, No.4, 1990, p.151.
[23] Letter, Charles Manby to R. Stephenson & Co., Westminster, June 8 1858, Crow Collection, *op cit* (9).
[24] Examples of Starbuck's agency work for R. Stephenson & Co. have survived in his papers and copy Letter Book, Jan. - Aug. 1844, Tyne & Wear County Record Office, Starbuck papers, including letter Robert Stephenson to W.H. Budden, London, 18 Sep 51, Ref. 131/45.
[25] Schedule 16, Schedule of Pecuniary Legacies, Probate Document for Robert Stephenson, Science Museum Library, Stephenson papers, Ref. MS.2033/95.
[26] Letter Robert Stephenson to Joseph Pease, London, 24 Oct 1840, Pease-Stephenson Collection, *op cit* (8), Ref. D/PS/2/56.

Starbuck knew the locomotive market well, and the right price and contractual terms with which to win orders. In 1844, for example, he wrote: "I am inclined to think we may be very firm in price & time of delivery, & where any increased dimensions are asked need not dread adding £50 or £75."[27] He also kept close attention to the activities of competing manufacturers and their agents. He wrote, also in 1844: "I believe Hawthorn has either gone or is just starting for Silesia,"[28] and later observed: "I hear Samuelson [Sharp Bros.' agent] has not made himself very popular with many of the Continental R.W. Co."[29]

Starbuck earned respect from Stephenson over a contract for ten locomotives for the South Eastern Railway in 1850, although his commission was greater than the profit at a time of recession and low prices. "If he had not gained access to the Chairman [of the South Eastern Railway] after a very great deal of trouble, we should have been shut out from tendering, and that at a time when we were almost standing still for want of an order."[30]

Starbuck was paid 5% commission on all locomotives sold in Europe and re-imbursement of travel and accommodation expenses. There were occasional disagreements over commission entitlements, and in 1846 clarification was necessary on orders obtained from British railways. Stephenson considered that he was: "Entitled to half Commission on those Home Contracts negotiated through him......but where the orders were negotiated by the Factory, without his intervention....... no Commission should be allowed."[31] This was further clarified the following year when Stephenson agreed his entitlement to the commission: "on all transactions that may spring from his having obtained the first order or be the continuation of the original introduction."[32] Stephenson paid Starbuck 15% commission for his work in

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[27] Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 8 August 1844, letter book., Starbuck papers, *op cit* (24).
[28]Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 4th April 1844, letter book., Starbuck papers, *ibid.*
[29]Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 17th April 1844, letter book., Starbuck papers, *ibid.*
[30] Letter, Robert Stephenson to W.H. Budden (for R. Stephenson & Co.), Westminster, 18 Sep 1851, Starbuck papers, *ibid*, Ref.131/45.
[31] Letter, J.E. Sanderson (for Robert Stephenson) to W.H. Budden (for R. Stephenson & Co.), Westminster, 6" February 1846, Starbuck papers, *ibid*, Ref.131/42.
[32] Letter, J.E. Sanderson (for Robert Stephenson) to W.H. Budden (for R. Stephenson & Co.), Westminster, 22 Jany 1846, Starbuck papers, *ibid*, Ref.131/44.

retrieving patent royalty payments (Section 4.6). Although Stephenson was by far his largest principal, Starbuck also represented about six other organisations, and his annual income was £4000 in the busy years.[33]

The development of certain overseas railways, with head offices in their home countries, saw the recruitment of representative agents covering large geographic areas. Some of the larger manufacturers already employed agents to represent their engineering business, and those agents took on additional work as railway schemes got under way. In Australasia, diplomacy as well as commercial flair were pre-requisite qualities, as responsibility for locomotive orders rested with the colonial governments. William Fairbairn & Sons' agent, based in Melbourne, Victoria by 1855, was described as being "a gentleman of much enterprise and on the best terms with both the Government and Corporate Authorities".[34]

From 1878, Beyer Peacock & Co. engaged a representative in Australia with a remit to cover every state, including Tasmania. His replacement in 1894 received an early letter from the company stating: "If we decide to continue our Australian agency", indicating uncertainty at a particularly poor time for the locomotive industry.[35] The tenacity shown by Robert Fairlie in marketing his patent locomotive design (Section 4.5) also led him to engage an agent, who represented him throughout Australasia.[36] Agents were supplied with albums of photographs and folios of tracings to assist them in their marketing and selling endeavours.

Competition from American manufacturers increased from the 1870s (Section 2.5), with the Baldwin Locomotive company engaging representative agents in Havana, Rio de Janeiro, Melbourne and Yokohama. The firm's partners also travelled abroad to secure business. In 1885, Baldwin's sales efforts included the circulation of 'broadsides' in Spanish announcing price cuts for both railway and sugar plantation locomotives.[37]

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[33] E.F. Starbuck commission statements 1845-55, Starbuck papers, *ibid*, Refs.131/53 and 131/54.
[34] Letter, Wm. Fairbairn & Son to Messrs. C.J. Hambro' & Son, Manchester, 20th July 1855, Hambro's Bank Ltd. loan papers archives, Guildhall Library, London, Hambros papers, Ref. MS.19158.
[35] Copy correspondence, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/546.
[36] Engineering, Vol.XIV, p.15, July 5th 1872.
[37] Brown, *op cit* (10), pp.45/6.

3.3.2 Commission Agents

Other agents, representing industrial concerns, railways and even governments, obtained locomotives on the best terms for their principals. These 'commission' agents, based both in Britain and overseas, were engaged to obtain a wide range of railway, mining and other industrial equipment, and would visit manufacturers with 'shopping lists' of requirements. Commission agents were similarly used in the United States in the 1850s, soliciting bids for locomotives for railroads with long credit terms or through partial payment in stocks.[38]

Many European railways were represented by commission agents in the 1830s and 1840s, and manufacturers sought to satisfy themselves about the advisability of doing business with some of them. Starbuck wrote in 1844: "I entirely agree with you that before we come to close quarters with parties such as Mons. Hirsch or Mons. Vogts a reference is requisite & such I shall certainly require before any operations are entered on."[39] Occasional difficulties over commissions were encountered where representative agents obtained orders through commission agents, and, in the 1840s, the Stephenson Company sometimes found itself paying two commissions.[40]

Commission agents were adept at ascertaining competing prices from manufacturers. In 1851, William Bird & Co. advised its principal, Hambros, that: "Stevensons' [sic] price at present in consequence of his having received some orders wd be £2000 pr Locomotive & tender........ but there are other makers of precisely similar Engines at full £400 or £450 less in price."[41]

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[38] *ibid*, p.19.
[39] Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 15th June 1844, letter book., Starbuck papers, *op cit* (24).
[40] Letter, J.E. Sanderson (for Robert Stephenson) to W.H. Budden (for R. Stephenson & Co.), *op cit* (31). Also, letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 25th March 1844, letter book., Starbuck papers, *ibid.*
[41] Letter, Wm. Bird & Co. to C.J. Hambro & Son, London, 12 January 1851, Hambros papers, *op cit* (34), Ref. MS.19129.

Commission agents were frequently evident in industrial locomotive sales, particularly for overseas customers. They negotiated discounts on list prices, payment, delivery and other contractual terms. Many of the agents were London-based, but others were in Glasgow, Liverpool, Manchester and elsewhere in the country and overseas. Maintaining contact with these agents was an important marketing effort for the industrial locomotive manufacturers.

Some of the London-based agents specialised in certain countries or parts of the world, and were, no doubt, themselves in competition with each other to represent their respective principals. Some names recur in the manufacturers' order books; Messrs. Fry, Meirs & Co., for example, appear frequently as representing a number of smaller South American railway and industrial concerns from the 1850s. Messrs. Mathieson & Co. represented several Spanish-speaking industrial organisations in the 1880s, before diversifying into the Far East market, where they represented railways in Japan and China. Black Hawthorn & Co. supplied tank engines to about 40 agencies, several with repeat orders, in the last 30 years of the century.[42]

3.4 The London Locomotive Market

In addition to several domestic railways, the establishment of overseas railway head offices and their consulting engineers in London from the 1850s, arising from the foreign direct investment programmes (Section 2.4), focused the manufacturers' attention on that city. They established offices in the capital to develop and encourage contact with decision-makers in the railway and government organisations, engineering consultancies and agents. This close contact did much to ensure that only British firms were approached to tender for locomotive contracts for such a large railway and industrial market. The dependence on London managers, working closely with their senior workshop colleagues, was a further demonstration of the devolution of decision-making within the partnership and limited company enterprises.

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[42] Analysis of manufacturers' Works lists prepared by the Industrial Locomotive Society.

By the 1860s, London had become the world centre of main-line and industrial locomotive tendering and contracting for both the home and overseas markets. Many railway companies operating in Africa, Latin America, India and other Asian countries had their head offices there, as did their consulting engineers, on whose recommendation tender invitations were made (Section 3.6.1). Government organisations, with remits to acquire capital goods, including locomotives, were also based in London. These included the India Office, and, from the 1870s, the Crown Agents and Agents-General for the Australasian colonies. London was also the base for many representative and commission agents engaged in locomotive acquisition (Section 3.3).

Robert Stephenson & Co. had led the way in demonstrating the advantages of a London office as early as 1840. In addition to Edward Starbuck's London office, Stephenson played an important proprietorial role for the firm in tandem with his Westminster civil engineering business. When part of the Stephenson premises were sold to allow expansion of the adjacent Institution of Civil Engineers in 1868, one-third of the site's asset value was recorded in favour of Robert Stephenson & Co.[43]

Many of the larger manufacturers had a London office, whilst others opted for representative agents. Companies as small as Dick Kerr & Co. and Thomas McCulloch & Sons, both of Kilmarnock and specialising in industrial locomotives and other industrial equipment, had a London office and a London representative respectively.[44]

Manufacturers' order books show the complexity and diversity of the overseas markets achieved through London, with orders from railway companies and industrial users, obtained both directly and through commission agents, and others from national and provincial

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[43] Report from the Council of the Institution of Civil Engineers Upon the Building Question &c., Presented at a Special General Meeting of Members & Associates on the 7th April 1868, Institution of Civil Engineers archives, register No. 213.
[44] Engineering, 25th May 1883 and 9th July 1886, shown in Russell Wear, 'The Locomotive Builders of Kilmarnock', Industrial Railway Record, No. 69, January 1977, pp.346/369.

government representatives. The latter would be shown as being for: "The Secretary of State for India", "The Colonial Government of Cape of Good Hope", or "The Crown Agents for the Colonies", whilst in 1870 the Agent-General for Victoria procured fourteen locomotives for the colony's North Eastern Railway.[45]

American and European manufacturers did not seek London representation to tap into the potential market until the end of the century. No evidence has been found to explain their decision, but it is likely that the London market was seen as a cartel for British manufacturers into which it would have been difficult to break. The concentration of their effort was on the markets not represented in London, namely the railways and industrial concerns of North America, Germany, Austria, Belgium and France, and railways in other countries financed by them (Section 2.5).

Signs that London's dominance was to change came in 1895. Japan's railways had developed in the 1880s and 1890s, predominantly on the main island of Honshu, with British expertise and financial involvement.[46] Their equipment had been acquired by the Japanese Government through the London market, to the corresponding benefit of the British locomotive manufacturers. However, in 1895, perhaps under pressure from manufacturers in other countries, the Japanese took over direct responsibility for the acquisition of railway materials. A British Consular Report of 1897 stated:[47]

> "British manufacturers have hitherto practically had a monopoly in furnishing rails, locomotives, rolling stock &c., but it would require renewed exertions on their part to continue to be the purveyors in this line........ Up to the end of 1895, Government requisitions and indents were sent en bloc to London, and the materials required were purchased by Government agents under very rigid inspection and supervision. Since the end of 1895 all requisitions have been issued from the head railway office in Shinbashi, and this will probably continue to be the system adopted."

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[45] Engineering, Vol. IX, April 22nd 1870, p.270.
[46] Steven J. Ericson, The Sound of the Whistle, Railroads and the State in Meiji Japan, Council on East Asian Studies, Harvard, 1996, pp.32-36.
[47] Consular Report No.427, Presented to Parliament, June 1897, reported in The Railway Engineer, Vol. XVIII, September 1897, pp.276-279.

The prolonged industrial dispute of 1897 (Section 6.5), and the consequential back-log of locomotive orders in the buoyant economy of the late 1890s (Section 2.8), opened the door for American and European manufacturers to break into traditional British markets. Burnham Williams & Co., the then proprietors of the Baldwin Locomotive Works opened a London office, and were rewarded with orders for several overseas railways and six British railways. The Schenectady Locomotive Works engaged London agents, Messrs. Sanders & Co. to represent them, and they too were rewarded with an order.[48]

3.5 Marketing Methods

Business promotion through proprietorial or agency contact was soon restricted by market volume and the introduction of tendering procedures. Promotion through marketing was a new discipline, which had to be learned and improved upon. The methods adopted supplemented the personal contacts that the proprietors, and their senior managers and agents were pursuing. Published and other printed material both informed and ensured a commonality of technical detail put forward by the managerial and agent teams, this being an important requisite in the delegation process. Whilst the success of the personal marketing contacts led to a perception that participation at international exhibitions would have limited impact, trade fairs, in Britain and overseas, became an important outlet for the promotion of industrial locomotives.

3.5.1 Published Material

With the introduction of formal tendering and contracting in the 1830s, manufacturers sought to raise or increase awareness of their developing capabilities. The Stephensons responded to their defeat by Edward Bury (Section 3.2) by writing a detailed description of their *Patentee* locomotive, accompanied by good-quality arrangement drawings. Written by

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[48] Brown, *op cit* (10), p.208. Also Minutes of the Locomotive Committee of the Midland Railway, 1895-1899, PRO, Ref. Rail.491/182.

William Marshall, one of Robert Stephenson's subordinate engineers, the 67-page description was published as part of Thomas Tredgold's steam engine treatise published in 1838.[49] Understanding the marketing potential, the work was 'off-printed' as a separate volume, to promote awareness of the Stephenson company's lead in locomotive development, although there is no evidence that copies were specifically forwarded to railway companies.[50]

This was followed in the 1840s and 1850s by several other books, in which competing manufacturers emulated the Stephenson company by having their own designs featured in them. Templeton's 1841 book, for example, included a description and engravings of a locomotive designed by Kirtley & Co.[51] A number of the books were re-published in Europe and North America, promoting awareness in overseas markets.

The Stephensons also benefited from the technical assessment of their locomotives by the French engineer, Guyonneau De Pambour, the two editions of whose publication were translated into English.[52] R.&W. Hawthorn responded by promoting its own 71-page publication on experiments carried out on two of its locomotives on the Newcastle & Carlisle Railway.[53] By 1850, books provided examples of best practice from several companies. Tredgold's work of that year included examples of locomotives built by Sharp Bros., Bury, Curtis & Kennedy, R.&W. Hawthorn and R. Stephenson & Co., and another of Thomas Crampton's patent design (Section 4.5).

A 12-page booklet was produced by R.&W. Hawthorn to accompany the appearance of one of its express locomotives at the Great Exhibition,[54] but manufacturers of main-line locomotives generally did not produce catalogues until later in the century. This was in

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[49] Thomas Tredgold, The Steam Engine: Its Invention and Progressive Improvement &c, London 1838.
[50] Description of the Patent Locomotive Steam Engine of Messrs. Robert Stephenson and Co. Newcastle-upon-Tyne, London, 1838.
[51] William Templeton, The Locomotive Engine Popularly Explained &c., London, 1841.
[52] Guyonneau F.M. De Pambour, Practical Treatise on Locomotive Engines Upon Railways &c., 1st Edition, London, 1836, and 2nd Edition, London, 1840.
[53] R.&W. Hawthorn, Experiments by R. and W. Hawthorn of Two Locomotive Engines &c., Newcastle-upon-Tyne, 1840.
[54] R.&W. Hawthorn, R. & W. Hawthorn's First-Class Passenger Locomotive Engine, 'The Hawthorn', London, 1851.

contrast to the component manufacturers, which regularly produced illustrated catalogues. The Salter Company, for example, which made industrial spring balances, including those for locomotive safety valves, was issuing illustrated catalogues by 1870.[55] William Fairbairn & Sons and Nasmyth Gaskell & Co., both produced catalogues of their standard machined castings and machine tools, but not of locomotives or other steam engines.[56]

The proliferation of main-line locomotive designs, required by railway companies and consulting engineers (Section 4.7), made classification in a product catalogue more difficult. The tendering system generally negated such a need anyway. This contrasts with the greater dependency on more regularised designs in the United States. The Baldwin locomotive works began issuing illustrated catalogues in 1872, providing: "a series of descriptions of the various classes of engines now made, each type being illustrated by a photograph and tables being given of the principal dimensions of the various classes (forty in number) and of the duties which they were capable of performing". The book was: "got up in a style very unusual in works of this kind, and in excellent taste."[57]

Industrial locomotive manufacturers, however, with their several standard designs, regularly produced catalogues. An early example was a 17-page "Illustrated Description of Some of the Tank Locomotives etc.", constructed by Fletcher, Jennings & Co., published in London on the company's behalf about 1870.[58] In 1892, Peckett & Sons produced: "an elegant little catalogue" containing: "illustrations and short descriptions of 25 different types of main line and tank engines". Pecketts were said to keep several locomotives: "in stock or progress", the catalogue thus being: "useful for customers requiring locomotives at short notice".[59]

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[55] Brochure of the Salter Co., c1870, retained in the Staffordshire Record Office, Ref. CXD.4721/J/1/1.
[56] Examples of Nasmyth Gaskell & Co.'s machine tool catalogues from 1839 and 1849 have survived, in A.E. Musson, 'James Nasmyth and the Early Growth of Mechanical Engineering', Economic History Review, Vol.X, 1957-58, p.125; also Hayward, *op cit* (4), p.2.10.
[57] Brown, *op cit* (10), p.34. Also, Engineering, Vol. XIV, November 15th 1872, pp.335/6.
[58] George Ottley, A Bibliography of British Railway History, HMSO, 2nd Edition, 1983, entry 2963.
[59] The Railway Engineer, Vol.XIII, November 1892, p.315.

Photographs were used as a marketing aide by several manufacturers. Beyer Peacock & Co. began taking photographs in 1856, from when most types were photographed on completion at Gorton Works.[60] The company and its agents maintained albums of prints to show to prospective customers.[61] Baldwins had begun circulating lithographs of its engines from the early 1850s, but changed to photographs after 1860.[62] It was later common practice for British manufacturers to produce 'data' cards with photographic prints of locomotives accompanied by their basic dimensions.

Main-line locomotive manufacturers did not advertise, either in Britain or overseas. This again contrasted with the approach of the American industry, whose firms regularly advertised in the railroad trade press and other specialist periodicals. The Baldwin Company, at least from the 1880s, was also advertising in foreign railway publications, and subscribed to newspaper clipping services in London, Paris and St. Petersburg.[63]

Industrial locomotive manufacturers, however, regularly advertised in trade periodicals, this being an important part of their marketing efforts for their whole range of products. Advertisements appeared both in general periodicals, such as *Engineering*, and in specialist periodicals such as *Iron* which catered for the iron and steel industry. Advertising probably began in the 1860s, and by the 1880s, manufacturers such as Dick, Kerr & Co., Grant Ritchie & Co. and Barr Morrison & Co. were regularly advertising their locomotive and other general engineering products.[64]

Published articles about locomotive factories may also have been regarded as a form of publicity, although how much marketing benefit was derived is questionable. Robert Stephenson & Co. played host to *Illustrated London News* after completion of its new

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60 Hills and Patrick, *op cit* (19), p.26 and *passim*.
61 Beyer Peacock archive, *op cit* (16), photographic collection, and Ref. MS0001/546.
62 Brown, *op cit* (10), p.34.
63 *ibid*, pp.34/43-45.
64 Wear, *op cit* (44), *passim*.

erecting and machine shops in 1864, which were elaborately illustrated.[65] In 1887, *The Railway Engineer* carried an illustrated article about Peckett & Sons' Atlas Works in Bristol. It may well have been company inspired from some of the phraseology used, including a welcome for: "any visitors, be they buyers or not....".[66]

3.5.2 International Exhibitions

Although trade exhibitions developed in the late 18th and early 19th centuries, the first major opportunity for locomotive manufacturers to market their products was London's Great Exhibition of 1851. This was a turning point for two reasons. It was the first exhibition to promote international trade as, hitherto, although free trade had been seen as an economic ideal, manufacturing countries had been nervous to expose their home industries to foreign competition. Secondly, previous exhibitions had focused on technological advance rather than marketing. As Greenhalgh outlines, although British industry considered that it led the world, it recognised the growth of industry in Europe and North America and, by inviting nations to take part in the friendly competition, sought to out-sell it.[67]

The Commissioners of the Great Exhibition had little or no experience of promotional events, and for a time there was a lack of response to their invitations. Robert Stephenson, one of the Commissioners, wrote at the beginning of 1851:

> "I promised Col Reid. when there was a probability of there being a lack of exhibitors to send an Engine or two and I had in my mind the notion of sending the old Engine with what the Stockton & Darlington was opened - the Rocket and one of our last improvements.... Being a Commissioner I did not after some reflection think it right to force any thing upon the commission of substance...."[68]

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[65] 'Stephenson's Locomotive Manufactory at Newcastle-on-Tyne', The Illustrated London News, October 15th 1864, pp.392-394.
[66] The Railway Engineer, Vol. VIII, No.10, October 1887, pp.304-309.
[67] Paul Greenhalgh, Ephemeral Vistas. The Expositions Universelles, Great Exhibitions and World's Fairs, 1851-1939, Studies in Imperialism, Manchester, 1988, p.10.
[68] Letter, Robert Stephenson to Edward Starbuck, Suez, 1 Jany 1851, RSCo archive, *op cit* (13), Folder 18.

Stephenson's words reflected little understanding of marketing benefits that could be derived from the Exhibition and, in the event, he did not send any locomotive, old or new. Indeed, only five manufacturers exhibited locomotives in their own name, namely: R.&W. Hawthorn, Kitson Thompson & Hewitson, E.B. Wilson, William Fairbairn & Sons and George England & Co. Only Hawthorn appears to have seen the marketing potential, its: "first-class patent passenger locomotive", with "several novelties", being accompanied by a 12-page descriptive booklet (Section 3.5.1). The other manufacturers exhibited tank locomotives, none representing outstanding examples of design.[69]

Thomas Crampton, however, renowned for his patent locomotive designs (Section 4.5), exhibited one of his express locomotives, *Folkstone*, built by Robert Stephenson & Co. for the South Eastern Railway. He saw opportunity to promote his designs amongst interested railway and locomotive manufacturers, and the Stephenson Company may have indirectly benefited from his initiative. With different motivation, two railways exhibited locomotives, including the London & North Western Railway with another of Crampton's patent locomotives, *Liverpool*. This had been built by Bury Curtis & Kennedy, which, however, went into liquidation during the year (Section 7.6.7).

The Great Exhibition sparked considerable international interest, and in the second half of the century the numbers, frequency and scale of international exhibitions grew significantly. In 1855 a bigger event was held in Paris to begin a cycle of exhibitions in Paris, London, Vienna and America.[70] Although the railway audience was global rather than European, being representatives of administrations from around the world, the British locomotive manufacturers participated in only a limited way. Some major firms, such as Beyer Peacock & Co. and the Vulcan Foundry Ltd., never exhibited locomotives at any of the international exhibitions.

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[69] Official Catalogue of the Great Exhibition of the Works of Industry of All Nations 1851, p.34, Section II Machinery, Class 5, 'Machines for Direct Use, Including Carriages, Railway and Marine Mechanism'.
[70] Greenhalgh, *op cit* (67), pp.3-24.

Foreign manufacturers, on the other hand, particularly those in France, Belgium, Germany and Austria, were constantly striving to develop their European markets and, for them, the exhibitions provided an important marketing medium. Two locomotives from Belgium and one from France were shown at the Great Exhibition, including one from John Cockerill & Co. which put on a major exhibition and was awarded a 'Council Medal'.[71]

For the continental manufacturers, the exhibitions circumvented the London market, as opportunities developed in the Far East and South America. At the 1867 Paris Exhibition, the Würtemberg manufacturer, Kessler, exhibited one of 20 locomotives it had built for the East India Railway.[72] This rare example of an Indian order not being undertaken by a British manufacturer, sent a clear message to the British industry. Indeed, Campbell noted at the time, in referring to both the Indian locomotive and another built by Schneider & Co. for the Great Eastern Railway in Britain, that: "These two engines afford incontrovertible proof of the possibility of getting English designs carried out abroad quite as well as at home, and at a cheaper rate......"[73]

The British railway supply industry, as a whole, had only a minimal involvement with the exhibitions, which, at the 1867 Paris Exhibition, was cause for official comment:[74]

> "In the English section, although in individual cases the 'exhibits' are unsurpassed, if not unequalled, the Exhibition, as a whole, does not come up to the standard of what might have been expected, either in numbers or in importance of the objects exhibited. In it there are neither goods engines, railway carriages, vans nor goods trucks; nor, with the exception of some steel springs, are there any specimens of the various locomotive and carriage fittings which are exhibited in such numbers by other nations."

By the Vienna Exhibition of 1873, the lack of participation by British manufacturers was the subject of critical public comment:

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[71] Official Catalogue, *op cit* (69).
[72] Sir. D. Campbell Bart., Reports on the Paris Universal Exhibition 1867, Presented to both Houses of Parliament, London, 1868, Vol.IV, 'Containing Reports on... Railway Apparatus', p.512.
[73] *ibid*, p.487.
[74] *ibid*, p.516.

> "It is a matter for regret that in such a collection of locomotives as that now to be found at the Vienna Exhibition, the makers of Great Britain, France and the United States are not fairly represented....... Germany and Austria are both large exhibitors, and Belgium is fairly represented; but we miss the names of those makers who have gained England its reputation for locomotive engineering......."[75]

Later in the year, *Engineering* was moved to issue a warning to the manufacturers:

> "..... The Exhibition at Vienna, more strikingly than any other, has shown the British manufacturer how great the producing, and how much greater are the imitating powers of the leading Continental makers, and it has taught him the salutary lesson that maintaining the lead is no longer the comparatively easy matter that it was, even at the period of the Paris Exhibition in 1867. Never before have the Continental nations put out their strength as at this Exhibition, and never has so grand an occasion arisen for the study and consideration of the actual position England holds among manufacturing countries. It has shown us that, harder pressed in the great race than ever before, she still, in the main, holds her own, and must continue to do so......"[76]

The manufacturers themselves would perhaps have regarded these comments as naive, disregarding both the commercial realities of the European market (Section 2.5) and the significant deviations in scale and design of the continental locomotives (Section 4.8).

By 1900, the international exhibitions had become very large affairs dominated by continental interests. Some 68 locomotives were shown in Paris that year, of which just five were from Britain. Four of those were railway designed and built, the attendant publicity benefiting the railways as carriers, but with no opportunities for generating manufacturing interest. As at the previous Paris Exhibition of 1889, Neilson & Co. was the only British company to attend, exhibiting an express locomotive for Holland.[77]

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[75] 'Locomotives at the Vienna Exhibition No.1', Engineering, Vol.XV, June 6th 1873, p.404.
[76] 'The Vienna Exhibition', Engineering, Vol. XVI, November 7th 1873, p.381.
[77] British Official Catalogue Paris - Exposition Universelle de 1900, published by the Royal Commission; Group VI Civil Engineering and Transportation, Class 32, 'Railway and Tramway Plant', p.171, 'Locomotives and Rolling Stock'.

3.5.3 Trade Exhibitions

Industrial locomotive firms, mostly involved in the manufacture of mining, colliery and other industrial equipment, and other types of steam engine, regularly exhibited at trade exhibitions. They initially attended the international exhibitions, but gained most benefit from the growing number of trade fairs in Britain and overseas from the 1870s.

Their first endeavours were at the London and Paris International Exhibitions in 1862 and 1867. The long-established Lilleshall engineering company exhibited its first locomotive in London and, after building only a few industrial locomotives, exhibited an "express passenger" locomotive at the Paris Exhibition, for which it was awarded a silver medal. It derived no benefit, however, and re-built it for sale as a colliery tank engine.[78] Henry Hughes & Co., and Ruston Procter & Co. both received 'honourable mentions' for their tank engines at the 1867 Paris Exhibition.[79] Hughes also exhibited a tank engine at the Vienna Exhibition of 1873, as did Fox Walker & Co., the only British manufacturers present.

An early trade fair was the first Russian industrial exhibition, held in Moscow in 1872. Nine locomotives were exhibited, of which five were of Russian manufacture, telling a sceptical world that Russian manufacturing had come of age. One locomotive was from Germany ("without doubt the best in the Exhibition"), and two from Britain, a narrow-gauge Fairlie locomotive built by Sharp Stewart & Co., already in service in Russia, and a 3-year old crane locomotive built by Dübs & Co., also in Russian service. The ninth was a 25 year-old locomotive exhibited for historical purposes.[80]

The number of trade fairs, both in Britain and overseas, increased considerably from the 1880s. In 1883, two manufacturers, Fowler & Co. and Dick Kerr & Co., exhibited at the

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[78] James W. Lowe, British Steam Locomotive Builders, Cambridge, 1975, p.380.
[79] Dunod (ed), Ernest Taillard (Text), Exposition Universelle de Paris de 1867, Chemins de Fer Les Locomotives et le Materiel de Transport, 2 volumes, Paris 1867, p.171, XXXI and XXXII.
[80] Engineering, Vol.XIV, September 1872, p.172.

Engineering and Metal Trade's Exhibition in London.[81] The latter company also exhibited a locomotive at the Calcutta International Exhibition of 1883-84, where it gained five medals for the various railway items it exhibited.[82] R.&W. Hawthorn Leslie exhibited one of its crane tanks at the Adelaide Exhibition in South Australia in 1887.

The marketing policies of the British main-line locomotive manufacturers were, therefore, quite different from those of their continental competitors and from the industrial market. Their limited reliance on printed material and exhibition promotion reflected their dependence on personal contacts within the London market, in which their primary objective was inclusion on tender lists. The marketing efforts of the industrial locomotive manufacturers, however, were much closer to those of the industrial components and other capital goods industries, being dependent upon catalogues and presence at trade fairs.

3.6 Sales

Selling locomotives called for tactical decision-making in accordance with the prevailing market intelligence, raw material prices and anticipated production programmes. With the rapid growth in the locomotive market, the immediacy of the tendering process required increasing delegation of responsibilities for pricing, delivery quotation and methods of payment. Guidelines were laid down by the proprietors and agreed with senior managers and representative agents who became adept at reading the market, demonstrating the reliability of this delegation.

3.6.1 Invitations to Tender

After 1836/7, the tender/contract system for locomotive acquisition was widely used by Britain's main-line railways, although some smaller railways and early overseas lines

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[81] The Railway Engineer, Vol.IV, September 1883, pp.231-238.
[82] Engineering, 9th July 1886, shown in Wear, op cit (44), p.346.

continued to obtain their requirements without wide comparisons of price or availability. The larger, London-based overseas railways would also issue invitations, either directly, or through their consulting engineers, or through one of the government agencies. Other invitations from overseas railways were obtained by representative agents.

Some of the largest British main-line railways offered full 'transparency' by advertising in journals, such as *The Railway Times*, providing the opportunity for any manufacturer to tender.[83] It is likely, however, that tenders were only seriously considered from firms with whom they regularly contracted. Over time, railway companies responded to changes in the manufacturing sector by dropping under-performing firms and including firms which had impressed with locomotives for other railways, or which had been brought to their attention by their marketing efforts.

As tender invitations became more detailed, and as railway companies became more demanding with their design and material requirements (Section 4.5), manufacturers were invited to see arrangement drawings and specifications at the railway offices. The invitations were accompanied by a deadline for receipt of tender. An early example was in 1839 when I.K. Brunel, Engineer to the Great Western Railway, wrote to manufacturers:[84]

> "I am instructed to inform you that the Directors of the Great Western Railway are desirous of receiving offers for the immediate supply of a certain number of locomotive Engines and Tenders to be made according to drawings and specifications which are prepared for the inspection of yourself and of the other manufacturers to whom copies of this circular have been addressed...... I enclose a printed copy of the specification to enable you to apply to the above, but the drawings can be seen at the Engineer's office at the Company's station at Paddington and copies will be furnished if your tender is accepted."

Some invitations to tender contained considerable detail and required much time and thought by the manufacturers. In 1844 Robert Stephenson & Co. received: "......what you most

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[83] In a random year, 1875, The Railway Times carried four series of advertisements for three railway companies, viz. Midland Railway, Great Northern Railway and South Eastern Railway, being invitations to tender for batches of locomotives.

[84] Multiple letter, I. K. Brunel, Engineer, Great Western Railway, to locomotive manufacturers, London, 4th March 1839, R SCo. archive, *op cit* (13), Folder 15.

appropriately term the little Volume from the Rhenish R.W. Co. it is being translated....... but even to a good Translator these documents require much care & time."[85]

Some railways were unable to anticipate their locomotive requirements in good time and, finding themselves with an urgent need, appealed to manufacturers for early quotations and deliveries without going to tender. Often, this would be achieved by substituting other customers' locomotives. Charles Beyer, of Beyer Peacock & Co., wrote in 1857: "They want five passenger Engines at Warsaw immediately and I offered them by telegraph the 5 of Talabot's [for the Lombardo Venetian Railway] we have standing here in the yard."[86] In 1863, he received an urgent enquiry from the Inverness & Aberdeen Junction Railway: "If the Inverness Rw. wants Goods Engines, they can have two first class one's [sic] at once. The two Egyptian engines are nearly finished and we can replace them in time for the Pasha."[87]

Some smaller railways speeded up the tendering process by requesting prices and delivery times for small numbers of locomotives of existing designs. In 1857, Charles Beyer wrote: "I have had a visit today from Mr. Needham Engineer of the Dundalk and Enniskillen Rw. and have to give them a tender for 2 Engines and Tenders...... by tomorrow afternoon. They have [also] asked Fairbairns and Sharp..."[88]

Industrial locomotives for larger customers in Britain were also obtained through the tendering system, but with the design initiative resting with the manufacturers, modified to meet the specific requirements of the customer. The large market for small industrial locomotives, however, was dominated by customers or commission agents applying for current prices and discount possibilities of standard locomotives.

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[85] Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 17th April 1844, letter book., Starbuck papers, *op cit* (24).
[86] Letter, Charles Beyer to H. Robertson, Manchester, Sept: 8/1857, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/255.
[87] Letter, Charles Beyer to H. Robertson, Manchester, February 22nd 1863, Beyer Peacock archive, *ibid*, Ref. MS.0001/256.
[88] Letter, Charles Beyer to H. Robertson, Manchester, Sept: 8/1857, *op cit* (86).

3.6.2 Submission of Tenders

Invited manufacturers submitted tenders which included specifications, indicating materials and relevant design characteristics, general arrangement tracings, numbers of locomotives offered towards the desired fleet requirement, estimated delivery dates and price per locomotive. Some railways provided standard tender forms to allow direct comparison between manufacturers. In other cases manufacturers had their own standard tender forms, which benefited them when frequent tenders were being prepared. The complex mix of tenders were considered by the Boards of directors, or their nominated committees, with the advice of their engineering superintendents or consulting firms. Negotiations over points of detail often preceded contract signing. The system in the United States, by comparison, appeared less regulated. Once a railroad had defined its requirements, Baldwins prepared a formal proposal accompanied by a detailed set of technical specifications, which served as a basic contractual agreement.[89]

A less formal tendering system was applied on some of the first continental railways in the 1830s and 1840s. Manufacturers submitted tenders, without formal invitation, when they learned about procurement intention. Prices, delivery and payment terms were negotiated by agents, and sales could be encouraged by reduced prices at times of low demand. Railways which developed close relations with manufacturers became adept at negotiating beneficial terms. Edward Starbuck, the Stephenson Company's agent, played a central role in such negotiations, and built up a significant expertise in selling to the continental railways, either directly or through commission agents. In August 1844, he wrote to his principal:[90]

> "..... you may have heard direct from the Cologne Minden Co. regarding 2 Engines they purpose taking, 2 of you - 2 of Sharp & Co - 2 of Borsig, Berlin - 2 of [Cockerill] Seraing - to test the qualities of each maker! Now on their writing I recommend your allowing me to reply....... for I am quite au fait at all the maneuvres [sic] of this Company."

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89 Brown, *op cit* (10), pp.42/3.
90 Letter, E.F. Starbuck to E.J. Cook (for R. Stephenson & Co.), London, 8 August 1844, letter book, Starbuck papers, *op cit* (24).

Some tenders were made directly through proprietorial contact and without competitive bids. In September 1846, for example, Gilkes, Wilson & Co., which was then seeking to re-start locomotive manufacturing encouraged by the buoyant market, wrote to the Stockton & Darlington Railway:[91]

> "Referring to thy conversation with our E. Gilkes...... respecting our building a Locomotive Engine for the Stockton & Darlington Railway Comp., we beg to say that in accordance with thy proposal we are prepared to commence with an Engine similar to Robt. Stephenson & Co's patent Engine on the following terms That when the Engine is completed she is to be taken by the Ry. Co at the current price, should they so incline, that should they not incline to take her we shall be then at liberty to sell her to any other party....."

New characteristics or component features occasionally prompted letters of reference to assist with a tender. In 1867, Beyer Peacock & Co. obtained a detailed letter from the Norwegian Government Railway regarding the capabilities and performances of the narrow-gauge locomotives on their Drammen line, which they forwarded with their tender for similar locomotives for Adelaide, South Australia.[92]

A successful patent design was a strong selling point for a manufacturer. The Stephenson Company promoted its 'long-boiler' patent design in the 1840s (Section 4.5): "We enclose you Extract from the York & North Midland R.W.Co. on the working of Engines similar to the one now required by you, which as you are probably aware, is our patent plan & cannot be supplied by any other maker."[93]

Manufacturers were usually willing to pursue sales opportunities, from wherever they arose. In 1863, for example, Charles Beyer wrote:[94]

> "Yesterday I had a private letter from Mr. Wilson W[est] M[idland] Rw., saying he thought he could sell for us the 2 Llangollen Tank Engines if we

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[91] Letter, Gilkes Wilson & Co. to John Pease (for Stockton & Darlington Railway), Middlesbrough, 9th month 2nd 1846, Stockton & Darlington Railway papers, PRO, Rail 667/773.
[92] Letter, C. Pihl, Jernbane-Direktøren (Norway) to Beyer Peacock & Co., Kristiania, 30th Novr. 1867, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/261.
[93] Letter, E.F. Starbuck to Eastern Counties Railway, London, 27 May 1844, letter book, Starbuck papers, *op cit* (24).
[94] Letter, Charles Beyer to H. Robertson, Manchester, February 22nd 1863, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/256.

> had them still on hand. I wrote him we could make two in 3½ months and price was £2,050 and if he could sell them for us we shall be glad to pay him a commission for his trouble....."

Although the international exhibitions were largely marketing opportunities, an unexpected exception occurred at the 1862 London Exhibition, where Neilson & Co. had exhibited the Caledonian Railway's large passenger locomotive designed by their former Works Manager, Benjamin Connor. The Viceroy of Egypt was so taken by: "Its striking appearance with its magnificent wheel" that he bought it and shipped it to Alexandria. After successful trials, two more examples were ordered, a rare example of a British railway-designed locomotive export.[95]

Occasionally, manufacturers had locomotives on hand resulting from 'frustrated' orders when customers withdrew from contracts. They were offered to other potential customers, usually at a discounted rate. In 1847, for example, Robert Stephenson & Co. offered to the York, Newcastle & Berwick Railway: "3 Goods Engines & Tenders..... which were ordered by a Railway Company who have requested us to substitute for them, engines of a different construction."[96] Some locomotives could be difficult to re-sell. In 1866, John Fowler & Co. had four locomotives on its hands when the Irish Midland Railway could not raise the purchase money. Built to the Irish track gauge, they could only be offered cheaply to another Irish line, and were eventually sold to the Waterford & Kilkenny Railway.[97]

The poor reliability of certain components up to the 1850s was acknowledged by manufacturers and customers alike. It was normal practice for tenders for batches of locomotives, particularly export orders, to include provision for "duplicate" components such as cylinders and crank-axle wheel-sets. In the event of failure, they could be replaced, avoiding the locomotive being out of use for a long period. They were separately priced and generated significant additional revenue for the manufacturers. Improvements in material

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[95] Thomas, *op cit* (14), pp.95/96.
[96] Letter, W.H. Budden, Ppro R. Stephenson & Co., to Edw. Fletcher Esq. (York, Newcastle & Berwick Railway), Newcastle upon Tyne, 5 Octr. 1847, York, Newcastle & Berwick Railway archive, PRO, Rail 772/96.
[97] Lane, *op cit* (11), p.139.

technology, and in the railways' own repair-facilities in the 1840s and 1850s, gradually reduced the requirement for duplicates. By the end of 1861, only one order received by Robert Stephenson & Co., required duplicates. This was for an Italian railway which had inadequate facilities for major repairs.[98]

3.6.3 Price Quotation

Most manufacturers kept detailed records of the direct costs of locomotive production (Section 7.2). These formed the basis of their 'list prices' which were generally determined on the long-established cost plus percentage basis. In the 18th century, Boulton and Watt had calculated its steam engine prices by keeping close records of manufacturing costs and adding on approximately 30% profit margin for home orders and 100% for overseas orders.[99]

As early as 1834, Robert Stephenson & Co., having costed in "Trade Expences" as a common 15% of manufacturing costs to accommodate its overheads, then added a standard 25% charge to determine its target price. The latter charge accommodated agency fees, where applicable, and the firm's profit.[100] In 1878, Beyer Peacock & Co. employed a similar method, applying a common 20% 'profit' margin to its cost figures to determine its list prices. This probably included an allowance for agency fees as, in 1863, the company had applied a 10% profit margin in a direct quotation to the Great Eastern Railway.[101]

List prices were based on standard fittings and recommended materials, but all manufacturers would vary quotes for specification changes. In the 1830s, Robert Stephenson & Co. and Charles Tayleur & Co. recommended copper fireboxes, which had longer operating lives than

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[98] List, 'Orders on Hand', prepared by R. Stephenson & Co., Dec.27th 1861, Pease-Stephenson Collection, *op cit* (8), Ref. D/PS/2/75.
[99] Tann, *op cit* (1), p.384.
[100] Cost & Profit Notebook of R. Stephenson & Co. (probably prepared by Wm. Hutchinson), Bidder Papers, Science Museum Library, Ref. Arch:Bidd 27/8.
[101] List Prices of Engines & Tenders, including 25% Profit, fob in this country (but calculated as 20% profit throughout), Beyer Peacock archive, *op cit* (16), Ref. MS.0001/546. Also letter, Charles Beyer to H. Robertson, Manchester, January 21st 1863, Beyer Peacock archive, *ibid*, Ref. MS.0001/256.

wrought iron ones, but had a higher first cost (£100-£120 compared to £20-£30). To compete with other manufacturers, they were obliged to quote also for wrought iron.[102] In 1878, Beyer Peacock's policy was that "Slight deviations or modifications" to its specifications incurred no extra charge, whilst significant changes, such as "crucible cast steel" crank axles instead of "best selected Yorkshire scrap iron" should be charged for at cost price.[103]

Changes in raw material costs (Section 7.2) were promptly reflected in list price changes and, subject to the competitive situation, passed on to the customer. In its 1878 policy statement, Beyer Peacock & Co. instructed its Australian agent that variations in list prices due to raw material costs would be made in four stages of 2½%, to a maximum of 10%. The changes were communicated from Gorton by a simple telegraphic message; "five up", for example, requiring a 5% increase on list price.

Whilst most of the communications between the proprietors, agents and factory managers were by correspondence, the urgency of many of the sales matters led to early use of telegraphic communication. The earliest recorded use of the telegraph was by Robert Stephenson & Co. in 1853, but most, and probably all manufacturers used the telegraph by the end of the century.[104]

Negotiated prices depended upon current market conditions. Manufacturers increased prices at times of high demand, but reduced them with low demand to stimulate orders. In 1854, for example, Thomas Fairbairn, on behalf of William Fairbairn & Sons, sought to increase an order for four locomotives for the Lancashire & Yorkshire Railway to as many as 15 or 20

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102 Michael R. Bailey, Robert Stephenson & Co. 1823-1836, unpublished MA thesis, University of Newcastle-on-Tyne, 1984, pp.300/1.
103 Beyer Peacock & Co. instructions to its Australian agent, W.S. Brewster, Feby 27 1878, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/546, pp.228-232.
104 E.F. Starbuck Account Sheets, Tyne & Wear Record Office, Starbuck papers, *op cit* (24), Ref.131/66. The telegraphic address for Robert Stephenson & Co. was "Rocket", Newcastle-on-Tyne, as set down on a brochure, "The "Rocket" Oil Engine, R. Stephenson & Co. Ltd., n.d. but 1893, Science Museum.

as: "prices will rise during the next couple of years."[105] In 1878, reductions to Beyer Peacock's list prices were permitted at the discretion of its Australian agent when negotiating for orders and in "severe competition" with other manufacturers. These were, again, to be in four equal stages to a maximum of 10%. If a commission agent was involved in the sale, then a consequential increase on the list price would be imposed. Manufacturers of main-line locomotives closely guarded their list prices from competitors. Beyer Peacock & Co. instructed its agent: "In no case must you show or give copies of the prices list we have sent..... but keep it strictly private....."[106]

Where a close proprietorial relationship had developed, a gentlemanly negotiation over price would take place. Charles Beyer, for example, who became friendly with Carl Pihl of the Norwegian Government Railway, sought to justify a major increase in price for comparable locomotives between £1200 quoted in 1858 and £1400 in 1865, explaining: "At that time we were in the wrong and would have lost money had we obtained your order and the price we now ask I expect will yield no more than an ordinary trade's profit."[107]

List prices were reduced for large batch orders, for which progressive manufacturers well understood the economy of scale benefits through acquisition of materials and sub-components, and from manufacturing economy (Section 5.7.3). Beyer Peacock & Co. encouraged orders of more than six locomotives by "small" reductions on list prices. However, not until the 1870s did the larger railways, particularly in India, regularly take advantage of large batch production, making significant list price reductions possible.

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105 Letter, Thomas Fairbairn (for William Fairbairn & Co.), to George Wilson (Deputy Chairman of the Lancashire & Yorkshire Railway Company), Wilson Papers, Manchester Public Library, Local Studies Unit, quoted in Hayward, *op cit* (4), pp.2.57/58.
106 List Prices of Engines & Tenders, Beyer Peacock archive, *op cit* (101), p.228.
107 Draft letter, C.F. Beyer (for Beyer Peacock & Co.) to C. Pihl, Norwegian State Railways, Manchester, Aug 9/65, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/259.

3.6.4 Methods of Payment

There were substantial risks and benefits for manufacturers when arranging payment terms for their locomotive business. Adequacy of working capital was essential to avoid unnecessary interest payments or, at worst, insolvency. The proprietors, senior managers and agents developed an expertise with which to interpret the locomotive and financial markets, in order to take the necessary tactical decisions on payment terms to maximise their liquidity opportunities.

In the earliest years of locomotive contracts, payment was made by Bills of Exchange for which credit fell due after a stated time. This was usually three months, but could be fixed at any time from a week to 12 months and reflected the strengths and weaknesses of both the locomotive and money markets. Contracts usually specified that half the price should be paid when the locomotive was delivered and the balance on satisfactory conclusion of the proving mileage (Section 3.6.6). For large locomotive orders, multiple payments would be made, phased during the delivery programme.

At times of peak demand when delivery times were extending, manufacturers not only increased prices but also required an advance payment to secure delivery within an acceptable time. In 1838, Robert Stephenson & Co. resolved: "...... that with all future contracts an advance of one third be stipulated."[108] In 1844 the company wrote to the Saxon Bavarian Railway: "..... our practice as you are aware is to receive about one third of the amount of the order on its being given, & cash for each shipment, deducting the amount advanced from the last......"[109] The advance may have been increased later that year, as the company's Head Clerk received the advice: "..... I cannot doubt but it will be your care to follow up the well known exhortation "make Hay while the sun shines."[110]

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[108] Entry, 10m [Oct] 20th 1838, Partners' Minute Book, R. Stephenson & Co. archive, Science Museum.
[109] Letter Edwd. J. Cook, Ppro Rob't Stephenson & Co. to the Directors of the Saxon Bavarian Railway, Newcastle, 5th May 1844, copied into E.F. Starbuck's letter book, Starbuck papers, *op cit* (24).
[110] Letter, Edward Pease to E.J. Cooke (for R. Stephenson & Co.), Darlington, 11 mo [November] 29. [18]44, Crow Collection, *op cit* (9).

By comparison, the Baldwin Company in the USA did not go nearly as far with its advance payment requirements. In the 1830s it required half payment when a locomotive was half completed, and the remainder on delivery. During periods of low demand, Baldwins accepted half payment on completion, with the balance due six months after delivery.[111]

The advances greatly assisted the manufacturers' cash-flow, assisting them with bulk purchase of raw materials and components. In 1858, for example, Beyer Peacock & Co. received; "£9,090 on account from the Madras [railway]. Money never so plentiful as at present."[112] It also allowed the larger manufacturers with lengthening order books to reach agreements with other manufacturers to undertake subcontracted orders (Section 5.7.2).

When funding for railway companies was difficult or when small railways were starting-up, they offered part-payment in shares. In 1857, for example, Sharp Stewart & Co. agreed to accept half-payment for two locomotives for the Dundalk & Enniskillen Railway in preference shares on delivery, and the other half with a 12 months bill.[113] As Brown notes was also the case for Baldwins in America, these 'credit' sales posed serious cash-flow risks to the manufacturers, who were obliged to balance a low order book with a shared risk with their customers.[114] In the early 1850s, Baldwins were obliged to accept total payment in the stock of some railroad companies. The practice does not seem to have been widely used in Britain, other than at times of low demand. In 1858, when manufacturing more than one locomotive per week, Robert Stephenson & Co. rejected a call from the London-based owners of the Turkish Smyrna Railway for half payment in shares for six locomotives.[115]

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111 Brown, *op cit* (10), pp.12/13.
112 Letter, Charles Beyer to H. Robertson, Manchester, July 13th 1858, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/256.
113 Letter, Charles Beyer to H. Robertson, Manchester, Sept: 8/1857, Beyer Peacock archive, *ibid*, Ref. MS.0001/255.
114 Brown, *op cit* (10), pp.12/13.
115 Letter, Charles Manby to R. Stephenson & Co., Westminster, June 8th 1858, Crow Collection, *op cit* (9).

Payment for locomotives for overseas railways whose offices were not based in London were, typically, "Terms net cash payable in London on presentation of Bills of Lading" which normally safeguarded the manufacturers from the potential of bad debts. For "Firms of undoubted stability" a manufacturer would forward the invoice and Bills of Lading through its bankers with a draft bill of, say, "30 days for the full amount including shipping charges, bank exchanges and insurances."[116] Overseas railway companies would be expected to pay the shipping companies for the freight on discharge of the locomotives at the destination port.

Continental firms made payment available through an international banking house. Robert Stephenson & Co., for example, received an "acceptance" to its "draft for £1070" which its agent, Edward Starbuck, would: "probably negotiate..... to Messrs. Rothschild & Sons paying the Amount when received to Messrs. Glyn & Co. to your acco't as usual."[117]

3.6.5 Delivery Times

Attractive delivery dates were usually as important as price when competitive tenders were being considered. Manufacturers developed an expertise in anticipating locomotive demand, with which to balance production schedules with their perception of market price. When demand was high, production capacity was increased as far as possible through a combination of facility expansion and recruitment (Sections 5.7.2 and 6.3.1), which required a 'lead' time to implement. The judgement required of the proprietors and their senior managers was thus a combination of this estimated lead time, and of locomotive production scheduling for parallel deliveries to two or more customers.

Locomotive manufacturing times decreased only gradually during the century, improvements in manufacturing techniques and production practices being offset by larger and more complex designs (Section 5.7). Six months for delivery of the first locomotive was normal at

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116 Bailey, *op cit* (102), p.232.
117 Letter, E.F. Starbuck to R. Stephenson & Co., London, 23rd February 1844, Crow Collection, *op cit* (9).

first, but this reduced to about five months by the 1870s-1880s.[118] At times of low demand, manufacturers would reduce anticipated delivery times in an effort to win orders. Beyer Peacock & Co. stated in 1863 that: "We can deliver any kind of Engine, provided they are our scheme in 3½ months, that is as fast as an engine can be made."[119] In the 1894 slump in orders, Beyer Peacock & Co. was quoting 3½ - 4 months for delivery.[120]

Competitive delivery dates could win or lose orders. Beyer Peacock & Co. lost an order in 1855 as: "Kitsons of Leeds have got the order by promising an earlier delivery."[121] Once railways and industrial customers had decided to proceed with an order, they usually wanted early delivery dates. The largest manufacturers anticipated this urgency by quoting relatively early delivery dates for the first two or three locomotives and spreading the remainder with deliveries over several months, or even years. This allowed them to build locomotives for up to, say, six customers simultaneously. It also had the advantage that urgent orders for similar locomotives could be substituted at a premium rate to the railway concerned. Main-line railways responded to the prospect of long delivery times by dividing their orders between two or three manufacturers. This practice was gradually discontinued for all but the largest orders, as manufacturers' production capacity increased (Section 5.7.2).

Manufacturers were generally bad at maintaining their predicted delivery dates, and through the century railways sought to introduce penalty clauses in their contracts to encourage adherence to the agreed programme. In the 1840s, manufacturers were defensive about delivery dates in communications with their customers, a view undoubtedly influenced by the unpredictable changes in demand (Section 2.6). With demand for its products and prices both increasing, the Stephenson Company accepted a large number of orders for which it had insufficient manufacturing capacity (Section 5.7.2), and it became notoriously bad on

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[118] Locomotive contracts retained in the archives of 19th century British railway companies, for example South Eastern Railway, PRO, Rail 635/225-230.
[119] Letter, Charles Beyer to H. Robertson, Manchester, February 22nd 1863, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/256.
[120] Beyer Peacock & Co., instructions to its Australian agent, W.J. Adams by Sept. 27/94, Beyer Peacock archive, *ibid*, Ref. MS.0001/546.
[121] Letter, Charles Beyer to H. Robertson, Manchester, June 13th 1855, Beyer Peacock archive, *ibid*, Ref. MS.0001/256.

delivery dates. Edward Starbuck wrote, however: ".... it is not Messrs. Robert Stephenson & Co.'s custom to allow the Insertion of a clause (in a contract) giving a penalty when the Engines are not ready to the day named. We are exceedingly punctual in the performance of our Contracts to their spirit & à la lettre - but the penalty clause you will be good enough to resist in future, if in your power."[122]

In 1883, the manufacturers came under intense pressure from the Secretary of State for India to accept a penalty clause in respect of the Indian State Railways, which led to a flurry of meetings, proposed penalty definitions and arguments between the members of the Locomotive Manufacturers Association (Section 3.7). The manufacturers sought definitions that did not leave themselves open to penalties for reasons outside their control, due to changes in design or specification by the customer, late deliveries of components or raw materials, or problems with shipping arrangements. They eventually agreed that a member's tender for an Indian contract could include a penalty clause, but subject to a further compromise exclusion clause and the agreement of all the LMA members on each occasion. The clause read:[123]

> "If the Contractor shall have been delayed in the execution of any part of the work by alteration in design, or by any other cause which the Secretary of State in Council shall consider to have been beyond the Contractor's control, or may admit as reasonable cause for extra time, the Secretary of State in Council will allow such addition to the time for the delivery thereof as he may consider to have been required by the circumstances of the case."

3.6.6 Other Contractual Requirements

In addition to price, payment terms and delivery times, locomotive contracts also specified place of delivery, guaranteed 'proving' mileage, delivery and commissioning. These were, again, important to win contracts, and the judgement for offering competitive terms fell on

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122 Letter W. Winfield (for E.F. Starbuck) to Mons. F. Kunitz (agent in Hamburg), London, 30 April 1844, Starbuck papers letter book, *op cit* (24).

123 Entry for December 12th 1883, First Minute Book of the Locomotive Manufacturers Association 1875-1900 (LMA Minute Book), Railway Industry Association Collection, National Railway Museum.

the proprietors and their senior managers. The willingness of manufacturers to improve upon standard terms of contract could assist them to win contracts over other firms with, for example, the commissioning and the training of overseas railway operating and maintenance personnel.

Early tenders specified either "delivery" at the factory or at a port, with an additional sum to cover shipping costs,[124] but as the railway network developed, contracts usually specified rail delivery to a main centre of operations.[125] Overseas locomotives were occasionally quoted for delivery "at the works", although the normal arrangement was "free on board" (fob) a ship in a nominated port, for which customers would arrange shipment through an agent. When overseas railways requested delivery at a port near their operations, manufacturers would arrange "carriage, insurance and freight" (cif), the cost being included in the contract price.[126]

From the earliest contracts in the 1830s, provision was included for the first 1,000 *miles* of satisfactory operation before final payment was made. This 'proving mileage' became a regular contractual requirement, but was increased to, typically, 2000 or even 3,000 miles by the end of the century.[127] Although expertise in locomotive technology quickly devolved throughout Britain, overseas railway expertise took longer to develop. Locomotive delivery became a major concern for manufacturers who had to send responsible superintendents to undertake discharge, transport and erection of the locomotives, train the railways' personnel, occasionally set up a maintenance workshop and remain for the proving mileage.

Manufacturers' costs in having experienced superintendents away from the factory for months at a time would have been quite high, but there is no evidence to confirm that this

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124 For example, tenders for Locomotive Engines for the London & Birmingham Railway, PRO, Rail 384/265-269.
125 B.S. Stafford, Memorandum, 'Engines pr Railway', Locomotive Department, London & Birmingam Railway, 15/1/39, recording detail of locomotives being delivered to the London & Southampton, London & Brighton and London & Croydon Railways, Dendy-Marshall Collection, the Newcomen Society.
126 General Specification of Locomotives built by Messrs. Beyer Peacock & Co. Gorton Foundry, Manchester, Beyer Peacock archive, *op cit* (16), Ref. MS.0001/546, p.232.
127 For example, locomotive contracts, *op cit* (118).

cost was added to the contract price. Thomas Wardropper, one of Robert Stephenson & Co.'s senior foremen, accompanied the company's first locomotive to the St. Petersburgh & Tsarskoe-Seloe Railway in September 1836.[128] He worked continuously in the Russian capital until at least the following February when he wrote to Newcastle: "There has not been anything said about a further agreement yet but..... if I stop another winter here....."[129]

Robert Weatherburn spent several years overseas as a roving representative engineer for Kitson & Co., discharging, delivering and commissioning locomotives in Russia, Austria, Denmark, Germany and France. He recorded his pioneering experiences with locomotive deliveries and setting up maintenance facilities, which served to emphasise the importance of such personnel in the export market of the locomotive manufacturers.[130]

3.7 The Locomotive Manufacturers Association

Until the 1870s there had been no moves by the manufacturers towards any form of association. It is likely that this was partly through lack of perceived need and partly because most manufacturers continued to see locomotive manufacturing as part of the wider heavy engineering industry. There had been three attempts to form an association of locomotive builders in the USA in the 1850s and 1860s, with a price-fixing motivation, but they had all failed.[131] The use of commission agents by American railroads had been the cause of their concern, and the formation of the Locomotive Builders Association (LBA) in 1872 succeeded in forcing railroads to order locomotives directly from manufacturers. An attempt to collude on prices again failed however, and the LBA was wound up the following year.

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128 Diary of Thomas Wardropper, 28th September 1836 to 28th January 1837, Tyne & Wear County Record Office.
129 Letter, Thomas Wardropper to William Hutchinson (Head Foreman for R. Stephenson & Co.), Trotsky Bridge [near St. Petersburgh] 16th February 1837, in private possession of Mr. R. Longridge of Darlington and York, and quoted with permission.
130 Robert Weatherburn, 'Leaves from the Log of a Locomotive Engineer', The Railway Magazine, Part I, Vol.XXXI, July-December 1912, p.289, to Part XXX, Vol.XXXVI, January-June 1915, p.240, *passim*.
131 Brown, *op cit* (10), pp.50/51.

In contrast, the motivation that led to the formation of the Locomotive Manufacturers Association (LMA) was the protection of the home market from railway workshop competition. The British market had expanded after 1870 (Section 2.8), leading to lengthening delivery times and rising prices. The Lancashire & Yorkshire Railway (LYR) found this unacceptable and, at a time when consideration was being given to amalgamation with the London & North Western Railway (LNWR), it contracted with the latter for six locomotives to be made at Crewe Works. These were completed in 1871, a rare example of inter-railway co-operation for locomotive manufacture.

No opposition was raised by the independent manufacturers, probably because of their lengthening order books. A further 37 locomotives in several orders, built for the LYR at the LNWR's Crewe Works, were delivered up to 1874, again without comment from the manufacturers. In March 1875, however, the LYR sent out an invitation for 50 locomotives, towards which the LNWR tendered to manufacture 25.[132] The independent manufacturers, whose orders were 100 fewer in 1875 than in 1874, thus shortening delivery times, were alerted to the danger of a lost order by the LNWR tender.[133] In the words of the LMA's opening memorandum:[134]

> "Some time in the month of April 1875, information was received that the London & North Western Railway Company had entered into competition with the locomotive manufacturers of the country, and had undertaken to construct a number of engines for the Lancashire & Yorkshire Railway Company. In consequence of this information, Mr. E. Sacré, of the Yorkshire Engine Company, entered into communication with the various firms in England and Scotland, with a view to gathering their opinion upon the legality of the action......"

The manufacturers' proprietors met in April and resolved: "It is the opinion of this meeting that it is now necessary to take steps for the protection of engineers and others against the competition of railway companies as manufacturers for sale."[135] Under the chairmanship of

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132 Draft letter, Messrs Hargrove, Fowler & Blunt (solicitors for the locomotive manufacturers) to the Secretary of the London & North Western Railway, n.d. but 4th May 1875, in LMA Minute Book, *op cit* (123).
133 Analysis of manufacturers' records, Chapter 2, Reference 1.
134 Opening entry, April 1875, in LMA Minute Book, *op cit* (123).
135 Minutes for 29th April 1875, LMA Minute Book, *ibid.*

John Robinson of Sharp Stewart & Co., the manufacturers collectively obtained the services of Counsel, and on the 4th June the LMA was formally established.[136] Application was made, in the name of the Attorney-General, to restrain the LNWR in the High Court of Justice (Chancery Division), and judgement was made in December 1875 in the LMA's favour through a "perpetual injunction" against the LNWR.[137]

The LMA members met again in March 1876 and confirmed their intention to continue the Association: "..... with a view to any action it may be necessary to take for the mutual protection of the interests of its members."[138] As early as January 1877, the LMA's Parliamentary advisers let it know of the actions of the Great Eastern Railway (GER) which proposed to provide locomotives for the London, Tilbury & Southend Railway (LTSR). The GER fought long and vigorously in the High Court and Appeal Court to be allowed to fulfil its agreement with the LTSR, and not until May 1880 did the House of Lords confirm the injunction in the LMA's favour.[139]

The legal battle served to strengthen the LMA, which then diversified its activities into a wider trade association representing its members on several issues of common concern. By 1889, it described its "Object" as being "To overcome the evils resulting from excessive competition, by means of a friendly combination of the principal firms in the trade."[140] Not all manufacturers were members. There were fourteen firms in its early years, but only ten firms from the early 1880s to the end of the century, namely:

Beyer Peacock & Co.	Nasmyth Wilson & Co.
Dübs & Co.	Neilson & Co.
Hunslet Engine Co.	Sharp Stewart & Co.
Kitson & Co.	Robert Stephenson & Co.
Manning Wardle & Co.	Vulcan Foundry Ltd.

136 Minutes for June 4th 1875, LMA Minute Book, *ibid.*
137 Minutes for December 16th 1875, LMA Minute Book, *ibid.*
138 Minutes for March 31st 1876, LMA Minute Book, *ibid.*
139 LMA Minute Book, *ibid, passim.*
140 Private Memorandum and Agreement of the Locomotive Manufacturers' Association, adopted at a meeting in London, April 11th 1889, retained in the National Railway Museum archives.

The LMA campaigned on both legislative and commercial issues. Early in its existence it dealt with the imposition of tonnage dues for deck shipments which would increase the price of exported locomotives,[141] and dissuaded the Great Western Railway from re-gauging and exporting 26 broad gauge locomotives to Russia in competition with the new-build potential for LMA members.[142] It also considered such diverse issues as penalty clauses in contracts for late deliveries, the undertaking of metal tests to satisfy customers and insurers over safety requirements, and the inspection of locomotives on delivery overseas.[143]

The LMA produced and printed a 'Private Memorandum and Agreement entered into by sundry firms in the Locomotive Building Trade &c', and which was several times re-issued as 'The Amended Rules of the Locomotive Makers' [sic] Association'.[144] It set out lengthy rules that bound the members to a cartel, requiring each member to advise the value of all tenders it proposed to make to the LMA Secretary, who would determine average tender quotations. The difference between the lowest and average price for each order was to be added to the actual tenders of each member, as a means of weighting the quotations to provide support for the smaller companies.

The cartel was strengthened from 1894 following the sharp downturn in the home and overseas markets (Section 2.8). Members were then required to include an allowance of 2½% in their tender quotations. The allowance was to be passed by the successful company to the LMA Secretary, who would then distribute the sum amongst the unsuccessful member companies in agreed proportions, to offset their tendering costs. Further modifications were made in the mid-1890s, including an increase in the allowance to 5%, as the LMA sought to prop up its weaker members. In spite of the rapid expansion in demand from 1898, and the resulting rise in prices (Section 2.8), it failed to secure the future of Robert Stephenson & Co., which went into liquidation the following year (Section 7.6.7).

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141 Minutes for March 31st 1876, LMA Minute Book, *ibid.*
142 Minutes for November 23rd 1877, LMA Minute Book, *ibid.*
143 LMA Minute Book, *ibid, passim.*
144 Printed Memoranda and Rules (of the Locomotive Manufacturers Association) 1889-1898, Railway Industry Association Collection, National Railway Museum archives.

3.8 Effectiveness of Marketing and Selling

The locomotive industry adapted well to the changing market opportunities through the century. The industry's success in its first 20 years had been due to its competitive marketing and selling, as well as its progressive design and manufacturing developments (Chapters 4 and 5). With the gradual loss of its design discretion from the 1850s, however, the market moved away from technological initiatives and component innovations, to focus on production methods and available capacity. These were the determinants for price and delivery quotations. The industry trebled its output in the second half of the century (Fig.1), as it experienced the transition from a production-led to a largely market-led business, and the replacement of its early markets by the dominant London market.

Marketing, which had begun as an infant concept in the 1830s, was successfully developed by the manufacturers and their agents. By the mid-century, they had gained sufficient experience to understand that such effort as was necessary should be directed principally towards maintaining a place on the tender lists of railway companies, government agencies and consulting engineers. This experience had also told them that, unlike consumer products, their efforts would have no effect on the volume of demand. Scranton makes this point about the American locomotive industry, noting that Baldwins sent no fewer than 16 locomotives to the 1893 Chicago Exposition, but that the marketing effort "came to naught."[145]

The manufacturers' marketing efforts were developed principally by delegating responsibility for contacts to managers and agents working in the close-knit London market. These British firms vied with each other for inclusion on tender lists without regard to overseas competition. The market became the exclusive preserve of the British manufacturers and was an effective cartel which, until the end of the century, kept out European and American competition. Through their many contacts with the anglophile railway companies and

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[145] Philip Scranton, and Walter Licht, Work Sights: Industrial Philadelphia, 1890-1950, Philadelphia, 1986, quoted in Brown, *op cit* (10), p.262, note 31.

engineers, the manufacturers could maintain their competitive position with limited benefit from promotional material and exhibitions. The experience of the few manufacturers that had taken part in the early exhibitions had persuaded them that promotional marketing gave only limited returns.

As overseas competition developed in the 1880s and 1890s, however, the industry was shown to lack promotional marketing experience, in contrast to the continental and American industries. As British manufacturers sought to pursue new customers in the developing open market, notably in Latin America and the Far East, undertaken from financial centres other than London, they were faced with a need to develop new marketing strategies. Manufacturers were faced with direct competition, from American and German manufacturers in particular, as the influence of the London market, outside of its Empire interests, began to decline. Their lack of experience of exhibitions, trade fairs and advertisements thus put them at a disadvantage. Their lack of promotional material, notably catalogues, a consequence of the proliferation of main-line locomotive designs, was also a problem.

The manufacturers showed themselves to be astute in selling locomotives in the competitive market. In spite of their reducing opportunity for product initiative, and the proliferation of customer-led designs, their tactical decisions on prices, methods of payment, production and delivery scheduling showed an awareness of the market opportunities as they arose. Although at first many proprietors and their agents were personally involved in preparing tender documents or in direct selling, the expansion of the market, and its concentration in London, saw these responsibilities delegated to London managers in consultation with their workshop colleagues. This necessary delegation, to ensure up to date knowledge of sales opportunities, raw material prices and production scheduling, well illustrates the evolution towards 'managerial' responsibilities within 'partnership' or 'limited company' enterprises.

Although the Locomotive Manufacturers Association had arisen out of a threat to the industry's domestic market, in the 1880s and 1890s it increasingly provided a forum for the protection of its members in a wider market context; this eventually developed into a cartel. The cartel served to accommodate the inefficiencies of the smaller, craft-based firms (Section 5.7.4), and the consequent raising of prices at a time of increasing international competition, particularly from the American and German industries, was indicative of an industry that had got out of touch with wider railway developments after years of dependency on the London market.

In contrast to the main-line market, the industrial locomotive sector successfully developed marketing and selling expertise in the British and London international market. The specialisation of several firms in industrial manufacture reflected the different proprietorial approach that was required. The industry was more akin to the component supply industry and marketed itself accordingly. Although perceiving little benefit from the international exhibitions, following its minimal involvement in Paris (1867) and Vienna (1873), the manufacturers did perceive opportunities from the specifically targeted trade fairs around the world. The very competitive nature of the market, and its close relationship with the supply of other industrial capital goods, led to vigorous marketing, both through trade catalogues and trade fairs, targeted at customers and commission agents alike.

Through their close association with their railway and industrial customers, the manufacturers were fully conversant with their developing expectations for improved locomotive performance and economy. The gradual withdrawal of technological and design discretion as Britain's larger railways and consulting engineers developed their own capabilities during the century was to convert the industry from a manufacturing-led to a largely customer-led business.

4.0 Technology and Design

4.1 Introduction

The heavy manufacturing industry had developed from the 18th century through its ability to innovate with new technologies and designs. The industry's partnerships had formed through combinations of technical and business expertise to develop machines and structures that fulfilled its customers' requirements. Such combinations brought about the emergent locomotive industry, which rapidly developed thermodynamic and material technology, and made available improving designs to an eager railway industry. Until the 1850s, the effectiveness of the manufacturers' marketing and selling efforts were sustained by offering products that met the developing aspirations of their railway customers.

As the potential of technological and design development became evident, main-line railways sought to improve the speed, haulage capability and economy of their locomotive fleets. By the end of the 1830s, they began to take their own initiatives for improvements based on the extensive operating experience they had gained. During the 1840s, through increasing loss of initiative, manufacturers began to experience a shift from a product-led to a demand-led business. The introduction of railway workshops (Section 2.3) was accompanied by the introduction of drawing offices and technical development teams which took over the initiative for locomotive improvement and design, and increasingly subordinated the manufacturers to largely contract manufacture. Similarly, from the 1850s, discretion to innovate and design locomotives for the overseas markets was increasingly removed from the manufacturers as the role of the consulting engineers widened to include responsibility for design (Section 2.4).

The locomotive industry well understood these market changes, but responded to them with diverging strategic policies. The manufacturers decided either to retain their development and design capability, and retain their broad heavy engineering market base, or to move towards greater specialisation in the largely sub-contracted locomotive market, but with a limited design capability. In order to understand how the manufacturers' undertook these important strategic decisions, and how they responded to their subordinated role, requires two broad technical issues to be addressed. These are the motivation, influences and innovatory processes of technological and design evolution, and, the reasons for design proliferation and consequent lack of manufacturing economy.

Such enquiry needs to distinguish between conceptual developments, relating to thermodynamics, materials and components, and design innovation which was generally developed in response to external influences and market requirements. It includes consideration of the manufacturers' contribution to invention, and the benefits they derived through patent protection, licensing and royalty income.

The independent locomotive industry was subject to three major market-based transitions in the century, which withdrew its discretion to innovate. The first arose from the emergence of a railway's right to specify the type and design of locomotive best suited to its requirements (Section 3.2). The introduction and development of tendering and contracting in 1835/6, gave locomotive superintendents increasing influence in specification and design. By the early 1840s, the manufacturers were responding to the rapidly developing railway requirements whilst pursuing further innovation, and at the same time seeking component standardisation with which to contain manufacturing costs (Section 5.6).

The second transition arose from the commencement of locomotive manufacture in railway-owned workshops (Section 2.3). The increase in number and capability of these workshops in the 1840s and 1850s, was accompanied by an expansion of both technological and design expertise. Railways' own designs and specifications became more detailed, and, over time, their developing expertise curtailed manufacturers' opportunities for technological and design development.

The third transition, from the 1850s, arose from the increasing involvement in locomotive design and specification of the London-based consulting engineering firms, representing the growing numbers of overseas railways (Section 2.4). The introduction of railways into India, Australasia, the Middle East and South America, was under the direction of consultants, such as Fox, Hawkshaw and Rendel, whose growing expertise further curtailed manufacturers' freedom for design initiatives.

There were eight major technological developments during the century, of such economic benefit that they were quickly adopted internationally. Indeed, the locomotive was not a specific machine but a generic form, within which were considerable opportunities for thermodynamic, material, mechanical and design innovation. In addition, locomotive design was itself a dynamic process which accommodated developing requirements for size and performance capability, together with evolving specifications for different traffics, track standards, track and loading gauges, operating speeds and gradients. Locomotive design progressed through several significant innovations, which were scale and performance related, and built on the opportunities of technological advancement, as well as meeting market demands.

As railway and consultancy design teams began to dominate locomotive progress from the 1850s, the resulting proliferation of designs became an overriding characteristic of the British locomotive industry, which substantially reduced its opportunities for standardisation and the manufacturing economies of large batch production (Section 5.7.3). Kirby's assessment that the development of railway design expertise had itself led to this design proliferation (Section 1.6), thus needs to be considered in more depth, to determine the extent to which the three market-based transitions were responsible.[1]

By the last quarter of the century, the locomotive industry's technological and design progress was judged increasingly against the designs of the overseas industries, notably of America and Germany. The very different economic and technical backgrounds of both industries were built on design practices which diverged from their British origins in the

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[1] M.W. Kirby, 'Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineer's Paradise?', Business History, Vol.30, No.3, 1988, pp.287-305.

1830s and 1850s respectively. As locomotive markets became more internationalised towards the end of the century (Section 2.4), the comparative merits of the British, American and German design schools were brought sharply into focus. This comparison thus provides a better measure of the technological and design progress of the British industry, than an insular consideration of locomotive technology for the London-based market.

4.2 Origins of the Main-Line Locomotive

The partnership structure of the heavy manufacturing industry readily allowed diversification into locomotive development through the combination of technical and material knowledge, craft experience and entrepreneurial drive. Such was the urgency to develop the first main-line locomotives, that tactical decisions were taken to pursue innovatory features, whilst relying on existing skills and materials. The immediate design success was tempered by the inadequacy of the materials and railway requirements for further improvements, which quickly called for strategies for systematic enhancement of locomotive technology, design and materials.

The research and development programme between 1828 and 1830, that led to the main-line locomotive, was one of the most remarkable in the history of engineering.[2] Through the tenacity of Robert Stephenson, a unified programme was carried out, combining new technological principles, design features and material developments. It conducted systematic examinations of major components, and innovatory features were tried on a series of experimental locomotives. The motivation for Stephenson's programme was to provide motive power suitable for inter-city operation on the Liverpool & Manchester Railway, stimulated by the strong claims made for locomotive operations by his father, George

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[2] Michael R. Bailey, Robert Stephenson & Co. 1823-1836, unpublished MA thesis, University of Newcastle on Tyne, 1984, pp.130-148.

Stephenson, the railway's Engineer.[3] It culminated in the prototype *Planet* locomotive, the progenitor of the 'Stephenson'-type adopted by the world's railways for more than a century.

Whereas locomotive design arrangements had previously been advanced empirically and on an experimental basis, with millwrights and fitters using sketch drawings to prepare and fit components, Stephenson's development programme included the services of a design draughtsman for the first time.[4] Arrangement drawings introduced design techniques to accommodate components within the space and weight constraints of the early locomotives. By the completion of the development programme in the early 1830s, the foundations of drawing office design work had been laid, which led on to more detailed sub-assembly and component drawings for manufacturing purposes.

Design, materials and construction methods were required to keep in step for successful innovation, and the extraordinary speed of Stephenson's programme had outpaced the availability of suitable materials and satisfactory methods of construction. During the 1830s, therefore, the early manufacturers were under considerable pressure to develop more reliable materials and new manufacturing methods, as well as to pursue further design innovation. The most significant material improvements related to crank-axles, wheels, fireboxes and firetubes, the frequent failures of which had led to considerable anxiety by the railways, not least when accidents occurred.

Better quality wrought iron, a more robust design and better forging and machining methods were necessary to overcome crank-axle failures. By 1839, John Moss, the Chairman of the Grand Junction Railway, reported to a Parliamentary Select Committee that: "we had many accidents in the first instance of axles breaking, but we have not had any for some time."[5] Even after the crank-axle improvements, failures occasionally occurred until the adoption of

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[3] Michael R. Bailey, 'George Stephenson - Locomotive Advocate: The Background to the Rainhill Trials', Transactions of the Newcomen Society, Vol.52, 1980-1981, pp.171-179.
[4] Michael R. Bailey, 'Robert Stephenson & Co. 1823-1829', Transactions of the Newcomen Society, Vol.50, 1978-1979, pp.109-138.
[5] First Report from the Select Committee on Railways Together with the Minutes of Evidence and Appendix, Ordered by the House of Commons to be Printed 26th April 1839, Question 418, 22nd April 1839, p.23.

the inside and mixed frames in the 1840s (Section 4.5). Similarly, it took nearly four years to improve design, materials and casting techniques to provide a wheel free from stress fracture problems. Firebox and firetube failures were directly attributable to unsuitable materials, and when copper plate and brass sheet, respectively, were confirmed as preferable, new industries had to be established to produce sufficient quantities to meet the new demand (Section 5.3.4).

The Stephenson development programme introduced several new technological and design features, none of which were protected by patents, in spite of George Stephenson's early experience of patents, which were vested with the Stephenson Company on its formation in 1823.[6] There was, therefore, no deterrent to imitation and, as early as 1824, Stephenson's partner, Edward Pease, had felt nervous about protecting locomotive designs from the interests of potential competitors:[7]

> .....if it be possible we must have GS to adopt some improvements for these Engines & get a new patent, I mean to write him in a day or two to enter a caveat in the patent office, for improvements, for I cannot doubt such is the enquiry about Railway & any but these engines will be a most important thing & ought to leave us no small sum for either making or Licences.

Stephenson's neglect in the 1820s seems prompted by an arrogant belief that, as the country's leading railway engineer, there was no need to take out patents. A contributory factor may have been the extraordinary pace of events, both Stephensons being so taken up with the supervision of surveying, route construction and mechanical research and development work, that they allowed no time to brief a patent agent. Thus, by the completion of the programme, other manufacturers, notably Edward Bury (Section 3.2), had begun to take an interest, and a period of imitation and further innovation took place.[8] Only then did the Stephensons realise that their opportunity for protection had been lost.

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[6] Stephenson's first patent (No.3887 of 28th February 1815) was joint with Ralph Dodds, and his second (No.4067 of 26th November 1816) was joint with William Losh.
[7] Letter, Edward Pease to Thomas Richardson, Darlington, 10 M 23: 1824, Hodgkin Collection, Durham County Record Office, Darlington Public Library, Ref. D/HO/C 63/5.
[8] Bailey, *op cit*, (2), pp.160-185.

Three design 'schools' emerged in the early 1830s as the Stephensons' two main competitors took advantage of their neglect. In addition to the main Stephenson school, with its sandwich frames, rectangular fireboxes and, from 1833, three axles, Bury developed a variation with wrought iron bar frames, 'D'-form fireboxes and two axles. The third school, pursued by Timothy Hackworth, continued with the incremental development of the 1820s 'colliery'-type locomotive, better suited to mineral haulage than main-line operation.

In 1830, as a defensive response to the challenges of their competitors, rather than as a strategic policy, the Stephensons began to take out patents for their further, but relatively less important, inventions. In developing a new type of wagon axle, Robert Stephenson revealed a lack of patenting experience when he wrote to his father:[9]

> I hope you will think it well over, but as it is new and likely to answer, let us take a patent for it, the patent cannot cost much and if [it] does get introduced upon Railways a very small additional price on each carriage would produce a great deal of money -

Stephenson took out a patent the following summer,[10] followed a month later by his father's first solo patent, for a wrought iron spoked wheel.[11] Thereafter, novel design features were increasingly patented, firstly by the independent manufacturers, but, subsequently, also by railway-employed locomotive engineers. 19 patents were taken out in the first decade, some relating to component improvements, such as wheels, others relating to whole locomotive schemes.[12]

The first significant patent, taken out by Robert Stephenson in 1833, sent a clear message that he had learned the lesson of his previous failure.[13] The patent introduced the features of a three-axled locomotive, which, to emphasise the point, was known as the *Patentee* type. It

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[9] Letter, Robert Stephenson to George Stephenson, Stone Bridge, Nov.8th 1830, R. Stephenson & Co. archive, National Railway Museum, York, Folder 18.
[10] Patent Specification No. 6092, Enrolled 11th July 1831.
[11] Patent Specification No. 6111, Enrolled 30th August 1831.
[12] Analysis of Patents in the Science Reference Library of the British Library.
[13] Provisional Patent No. 6372, Enrolled 26th January 1833, later a final Patent Specification No. 6484, Enrolled 3rd December 1833.

was adopted by several manufacturers, in addition to the Stephenson Company, and it is likely that Stephenson received significant royalty payments, although no evidence has been found to indicate their extent.

Thus, by the introduction of the trunk railway building programme in the mid-1830s, proven locomotive designs were available to railways, but largely in the gift of the Stephenson and Bury companies. The influence of the two 'schools' was such that engineers of new railways specified one or other of the two types in their tender invitations, allowing other manufacturers to gain a relatively inexpensive way of entering locomotive manufacture.

4.3 Development of Thermodynamic Technology

A fundamental strategy for locomotive manufacturers was the search for improving thermodynamic technology, which would allow for increased efficiency through reduced fuel cost. Consideration of this technological progress through the 19th century will, therefore, allow an understanding of how the manufacturers pursued this goal, and under what circumstances they lost the initiative to the development teams of British railways and overseas manufacturers.

Stephenson's first, *Planet* class, locomotives have been shown to have had a draw-bar thermal efficiency of about 2%.[14] Development work was undertaken by both manufacturers and railway workshop teams, and by the end of the century, a four-fold increase in efficiency was achieved. Cheaper fuel, through the substitution of coal for coke, in addition to the efficiency increase, gave a larger reduction in fuel costs, although it has not been possible to quantify this reduction. The developmental work was conducted empirically, as the scientific principles of thermodynamics were not fully understood. Only towards the turn of the

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[14] Michael R. Bailey, 'Learning Through Replication: The *Planet* Locomotive Project', Transactions of the Newcomen Society, Vol.68, 1996/7, pp.109-136.

century were scientific experiments carried out, that led to the introduction of superheating with its further increase in thermal efficiency.[15]

Improvements to thermal efficiency were achieved through the following thermodynamic developments:

Steam Expansion Valve Gear: The potential for reduction in steam use through variable expansion, for its most economic use with speed, load and gradient, had been understood since 1828,[16] but, although the manufacturers improved the early, cumbersome valve gears, the search for a variable cut-off mechanism required considerable technological evaluation and design work.

The first improvement, in 1840, arose from experimentation in railway service, when the Liverpool & Manchester Railway's superintendent, John Dewrance, modified locomotives to allow steam expansion, and increased the blast-pipe diameter resulting in a: "sweeter draught, which did not tear the fire to pieces".[17] Dewrance's experiments, which reduced coke consumption by over 50%,[18] not only made a major contribution to locomotive technology, it also demonstrated that manufacturers, without day to day operational contact, could lose initiative in locomotive development. This message was reinforced when Dewrance was entrusted to design and build locomotives in the company's Liverpool workshops, the first railway-built examples.[19]

In 1842, Robert Stephenson & Co. derived the variable cut-off 'link' motion, which was demonstrated to Stephenson himself using a small wooden model.[20] Criticising certain parts

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[15] J.N. Westwood, Locomotive Designers in the Age of Steam, London, 1977, pp.132/3.
[16] Robert Stephenson's *Lancashire Witch* locomotive in 1828 had been built with a primitive form of cut-off apparatus; referred to in Bailey, *op cit* (4), p.126.
[17] Railway Magazine, 27th November 1841.
[18] R.H.G. Thomas, The Liverpool & Manchester Railway, London, 1980, p.166.
[19] The locomotives were just preceded by one 'new' locomotive rebuilt from parts of older engines in the Grand Canal Street Works of the Dublin & Kingstown Railway, K.A. Murray, Ireland's First Railway, Irish Railway Record Society, Dublin, 1981, pp.186/7.
[20] Practical Mechanic and Engineer's Magazine, Glasgow, 1846. Correspondence, The Engineer, Vol.29, Jan-Jun 1870, pp.7-394, *passim*. American Machinist, February 11th 1904, p.178.

of its action, he requested a full-sized model to confirm its potential: "If it answers it will be worth a jew's eye and the contriver of it should be rewarded".[21] The successful trials of the 'Stephenson' link motion, which was not, however, patented (Section 4.6), quickly led to general use of variable cut-off valve gears, a number of different forms being introduced by other manufacturers, notably Daniel Gooch on the Great Western Railway in 1843, Egide Walschaert on the Belgian State Railways in 1844, and David Joy as an independent venture in 1879.[22]

The Coal-Burning Firebox: The next major technological advance was the development, in the 1850s, of the coal-burning firebox, which met statutory smoke emission bans.[23] The motivations for the switch from coke were the reduction in fuel and maintenance costs and line-side fires, and it is notable that all development work was carried out by railway development teams, rather than by the independent manufacturers. Comprehensive in-service trials, during the 1840s and 1850s, were undertaken by locomotive superintendents, the research incurring incremental design improvements of fireboxes manufactured in railway workshops. Joseph Beattie (1808-1871) of the London & South Western Railway, James McConnell (1815-1883) of the London & North Western Railway and James Cudworth (1817-1899) of the South Eastern Railway each developed large and complex coal burning fireboxes, which they patented in their own names.[24]

Without the in-service trial opportunities available to the railway teams, the independent manufacturers were unable to contribute to the programmes. In 1857, however, Beyer Peacock & Co. saw the commercial opportunities of the coal-burning firebox, and reached

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[21] Letter, Robert Stephenson to Edward J. Cook (for R.Stephenson & Co.), Westminster, 31 Aug 1842, Library of the Institution of Mechanical Engineers, Crow Collection.
[22] Brian Reed, 150 Years of British Steam Locomotives, Newton Abbot, 1975, pp.40-49.
[23] The Liverpool & Manchester Railway Act (Geo IV, c xlix, 5 May 1826) for example directed: "That the Furnace of every Steam Engine to be erected or built...... shall be constructed on the Principle of consuming its own smoke". The provision was to be enforced by fines of between £5 and £20.
[24] Reed, *op cit* (22), pp.50-52. Also, E.L. Ahrons, The British Steam Railway Locomotive 1825-1925, London, 1927, pp.131-136.

agreement with Beattie to tender for locomotives incorporating his design.[25] The arrangement was short-lived, however, as the definitive coal-burning firebox, incorporating a brick-arch and firehole deflector plate, was derived by the Midland Railway during trials in 1859/60. The features were already known, although not previously arranged as a coherent design, and there was no opportunity for patent protection. The breakthrough was announced to the Institution of Mechanical Engineers in 1860,[26] and the design was adopted by all European manufacturers, ending the use of coke.

Compound Locomotives: The potential for improved efficiency through the 'compound' use of exhaust steam in a further, low-pressure cylinder provided the next research effort, again by railway development teams, particularly in countries, such as France, that lacked cheap coal.[27] In 1876, a prototype compound locomotive was made by Anatole Mallet (1837-1919) for the Bayonne & Biarritz Railway, and shown at the 1878 Paris Exposition. The fuel-saving potential soon led to the introduction of compound locomotives elsewhere in France and Germany. Mallet read a paper to the Institution of Mechanical Engineers in 1879,[28] prompting several British railway locomotive superintendents to pursue compound development programmes, which took several forms, leading to a number of patents.[29]

Compound development programmes were carried out by independent manufacturers in France (Société Alsacienne de Constructions Mécaniques - SACM), and the United States (the Baldwin Locomotive Works' 'Vauclain' type), with the close co-operation of railway locomotive engineers.[30] By the 1890s, compounding was more widely used on European

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[25] First Minute Book, Beyer Peacock & Co., p.40, 10 January 1857, Beyer Peacock & Co. archive, Museum of Science & Industry in Manchester, Ref. 0001/X. Also quoted in R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982, p.32.
[26] Mr. Charles Markham of Derby, 'On The Burning of Coal Instead of Coke in Locomotive Engines', Proceedings of the Institution of Mechanical Engineers, 1860, p.147-176.
[27] Westwood, *op cit* (15), pp.107-124.
[28] M. Anatole Mallet, of Paris, 'On The Compounding of Locomotive Engines', Proceedings of the Institution of Mechanical Engineers, 1879, pp.328-363.
[29] For example, a tandem compound design patent was taken out by W.H. Nesbitt, Locomotive Superintendent of the North British Railway, No.16,967 of 1884.
[30] J.T. van Riemsdijk, 'The Compound Locomotive, Part I 1876-1901', Transactions of the Newcomen Society, Vol. XLIII, pp.1-17.

than on British railways, who remained equivocal in its application.[31] The higher maintenance costs of compound locomotives were generally thought to be greater than the savings from reduced coal consumption, and were generally less acceptable because of the conditions under which they were required to work.[32]

Oil-Burning Fireboxes: Again prompted by high coal costs, oil-burning trials were undertaken in 1868 on the French Chemin de Fer de l'Est, but the cost of oil was greater than coal, and the project was abandoned.[33] Liquid fuel refining in the 1880s provided a residual fuel oil which was adopted on the Grazi-Tsaritsin Railway in Russia.[34] Although there was little economic incentive to pursue oil-fuel burning in the 19th century, an embarrassing surplus of oil from the Great Eastern Railway's gas-making plant in the1880s, led it to experiment with the fuel, which was adopted for use on several dozen express locomotives.[35]

Superheating: The scientific principles of thermodynamics were first pursued in the 1890s, although superheating was not adopted until the early years of the twentieth century. The German engineer, Wilhelm Schmidt (1858-1924), experimented with stationary engines, before the first locomotives fitted with superheaters were built in 1898, by Henschel & Sohn and the Stettin Maschinenbau A.G. Vulcan. The major improvement in thermal efficiency with a low maintenance requirement quickly endeared it to the world's railways. Superheating has been recognised as: "the greatest step forward in steam locomotive technology since the days of Stephenson", and was quickly and extensively fitted to British locomotives from the mid-Edwardian era.[36] Its introduction did much to displace the need for compounding, particularly in Britain.

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[31] Ahrons, *op cit* (24), pp.243-262.
[32] J.T. van Riemsdijk, Compound Locomotives, Penryn, 1994, p.9.
[33] Bulletin de la Société Industrielle de Mulhouse, No.744, 1971, pp.79/80.
[34] Ahrons, *op cit* (24), pp.311/312.
[35] Michael R. Bailey, 'The Oil-Burning Locomotives of the Great Eastern', The Railway World, Vol. 21, No.243, August 1960, pp.238-241 & 253.
[36] Westwood, *op cit* (15), p.132.

This survey thus illustrates that the independent locomotive industry played no further part in thermodynamic development after the introduction of the link motion in the early 1840s. As a direct consequence of the greater role of the railway development teams and the subordination of the industry to a largely 'sub-contracting' role, it carried out no further research and development work. This was in marked contrast to the European and American industries, which maintained their development roles, in close co-operation with their railway customers and with technical institutes. Even if the manufacturers had wished to pursue their thermodynamic work through co-operative ventures with British railway development teams, they were effectively prevented by the aspirations of the railway superintendents building on the strengths of their workshop teams.

4.4 Development of Material Technology

The development of materials to meet new component requirements was as important to design development as arrangement and detailing. Keeping material technology in tandem with design progress had been a major problem for the manufacturers since the 1820s.[37] The manufacturers initiated material technology development whilst pursuing locomotive design development. As designs evolved, their implementation was slowed until suitable materials were available, sometimes requiring new raw material and component supply industries. By its nature, material development depended on strategies negotiated with both the supply industries and their railway customers. Consideration of material progress will, therefore, allow an understanding of how the manufacturers pursued these strategies, and under what circumstances they lost initiative to the British railway development teams and overseas suppliers.

The rapid growth of the locomotive industry in the early 1830s, placed unprecedented demands on its material suppliers, particularly the iron industry, in terms both of quality and

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[37] Bailey, *op cit* (2), pp.102-119.

quantity. The suppliers had to develop materials that could meet demanding specifications on strength, stress and weight. In 1839 for example, locomotives supplied to Austria had to undergo an hydraulic boiler test of three times their working pressure under the supervision of "a learned Professor", which required strengthened copper firebox plates.[38]

The manufacturers therefore worked closely with suppliers to develop materials of requisite strength that could demonstrate safety and economy to the railways. The failure of several components in the first decade of operations, however, was of such concern that railway locomotive superintendents began to specify materials for particular applications. These were especially high quality iron grades, such as that from Low Moor (Bradford), and other grades from Yorkshire and Staffordshire (Section 5.4.1). By 1850, the superintendents of the largest railways had developed personal contacts with suppliers, and became quite specific in their material requirements for most locomotive components. One example in 1847 required: "best Lowmoor plates" for the boiler, smokebox and front tube plate, "best Staffordshire iron plates" for the ashpan, and "best copper plate" for the firebox.[39]

For industrial countries with a relative scarcity of good quality iron ore, such as Germany, imports of iron products from Britain incurred heavy import tariffs. The German iron industry therefore undertook considerable development work to convert its iron to steel. Its more durable characteristics and higher tensile strength offered the prospect of longer life, reduced maintenance and replacement costs, and weight reduction. Each type of steel had different tensile characteristics, however, which had to be independently developed for industrial use, including locomotive components. These early forms of steel were beset with metallurgical problems, which required considerable development work for over a quarter of a century before becoming a safe and cost-effective alternative to wrought iron.

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[38] Letter, James Haslam to Messrs. Jones & Potts, Vienna, 10th June 1839, Robert Stephenson & Co. archive, *op cit* (9), Folder 19.

[39] 'Specification for 6 Wheeled Engine' (Customer not recorded), Northumberland County Record Office, NRO 630, nd, but c1847.

The potential uses of steel were considered early by the railway industry, in close collaboration with the developing British steel industry. The LNWR's Locomotive Superintendent, John Ramsbottom (1814-1897), introduced a Bessemer steel-making and rolling plant into Crewe Works in 1864.[40] Ramsbottom's assistant, Francis Webb (1836-1906) undertook research and development work into steel boilers and fireboxes that was keenly watched by other locomotive and consulting engineers. A further steel plant, for the Horwich locomotive works of the Lancashire & Yorkshire Railway, began production in 1886.

From the 1850s, therefore, the British and German steel industries and, from the 1860s, the larger British railway workshops were in the forefront of development work for the several kinds of locomotive steel. The subordinated role of the independent industry from this time, however, meant that it had no opportunity to participate in this work. Its knowledge of the use and working of steel resulted from experience gained from orders which specified the use of each steel grade, the introduction of which is summarised below:

Steel Tyres: The Krupp company of Essen developed crucible cast steel for tyres in 1851.[41] Trials confirmed its hard-wearing properties, but considerable research was necessary to minimise fracture problems. Krupp set up an agency in London to promote sales of the tyres, the first imports being in 1856, whilst, in 1859, Naylor & Vickers of Sheffield began supplying them to the LNWR. Cast steel was then widely specified by railways in Britain, France and Germany as, in spite of its higher initial expense, costs were less over the longer life of the tyres. Bessemer steel, and an improved rolling mill by George & Co. of Rotherham in 1864, provided cheaper rolled steel tyres. Although they were quickly brought into general use by the British steel industry, metallurgical problems persisted, and, as late as 1876, tyre fractures remained the subject of enquiry and research.[42]

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[40] Edgar J. Larkin and John G. Larkin, The Railway Workshops of Britain 1823 - 1986, Basingstoke, 1988, pp.167/8.
[41] Ahrons, *op cit* (24), pp.163/4.
[42] William W. Beaumont, 'The Fracture of Railway Tires', Proceedings of the Institution of Civil Engineers, Vol.XLVII, 1876, Paper 1453, Part I, pp.68-9.

Steel Axles and Motion Parts: The Krupp company also developed axles of crucible cast steel, the first examples being shown at the Great Exhibition of 1851. British railways were wary of them, because of a high failure rate, particularly of crank axles, the material being brittle and less able to withstand running forces. Axle steel was supplied for forging into crank and straight axles, and Ahrons suggests that caution by British locomotive manufacturers arose out of lack of metallurgical understanding. Unlike the German firms, they were inexperienced in working the steel to ensure perfect homogeneity.[43]

Motion parts, particularly piston rods, valve spindles, slide-bars and connecting rods were switched to steel with the same caution following the first use of Krupp steel in 1862. Forged Bessemer steel axles were introduced by Naylor & Vickers in 1866, but, although successful trials were carried out, there was no major cost benefit, Yorkshire wrought iron axles being only slowly displaced over the following twenty years.[44] As late as 1884, Beyer Peacock & Co. retained an option for the use of wrought iron:[45]

> .... in cases where the selection of materials for axles..... is left entirely to us, we shall use mild steel of good quality, instead of wrought iron..... but you need make no increase in your prices over those which you have been in the habit of quoting for iron. If however crucible steel made by Vickers, or Krupp, or any other special steel is specified, you must quote the additional price as at present arranged for steel.......

Rolled Steel Frames and Boilers: The introduction of Bessemer steel plate rolling mills in the 1860s, made possible rolled steel frames and boiler plate. From 1867, frame plates could be rolled in one piece, offering considerable cost savings over wrought iron sectional frames welded under steam hammers (Section 5.5.2). Locomotive superintendents were particularly cautious about adopting steel plate for boilers, however, as the plates pitted more quickly than wrought iron. After considerable development work and trials by the LNWR's Crewe Works, confidence was gained, and steel boilers became generally specified from the late

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43 Ahrons, *op cit* (24), pp.163/4.
44 *ibid*, p.165.
45 Memorandum, Beyer Peacock & Co. to their Australian Agent, Mr. Brewster, July 10th 1884, Beyer Peacock & Co. archive, *op cit* (25), Ref. 0001/546, p.235A.

1870s.[46] By 1886 Webb stated that: "Since commencing to make steel plates, we have made in the [Crewe] works 2752 locomotive boilers....... [and] 230 stationary and marine boilers, and of all the material used, not a single plate has ever failed."[47] Their introduction permitted higher steam pressures, rising from typically 120 lbs. to 175 lbs. per square inch in 15 years, providing a significant economic justification for their use.[48]

Rolled Steel Fireboxes: Firebox steel was first made in Sheffield in 1860, and trial fireboxes were made in 1862 by Daniel Adamson & Co. of Hyde. Trials with different kinds of plate, however, revealed that, when worn, they became too weak for the screwed stays, and frequently gave way: "with a loud report when on the road."[49] Although steel fireboxes were cheaper than the normal British copper type, overall costs were higher due to their short life.[50] After several trials, including a major series undertaken by the LNWR in 1872-73, British railways remained unconvinced about steel fireboxes. In spite of widespread use in North America, locomotive superintendents persisted in specifying copper fireboxes until well into the 20th century. As late as 1927 Ahrons concluded that: "The riddle of the failure of the steel firebox in British locomotive practice still remains unsolved."[51]

This survey confirms that the independent locomotive industry played no further part in material development after its pioneering work in the 1830s and 1840s, being a further example of responsibilities passing to the railway development teams and consulting engineers. When inviting tenders for locomotives, they specified both the steel grades and a short-list of suppliers to the manufacturers, who were then required to provide the necessary capital equipment and expertise to work the materials (Section 5.5.3). The European and American locomotive industries were also dependent upon steel supplies from specialist firms, such as Krupp and Pennsylvania Steel, with whom they co-operated on development

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[46] Ahrons, *op cit* (24), pp.205-207.
[47] Paper, F.W. Webb to the Institution of Naval Architects, 1886, quoted in C.J. Bowen-Cooke, British Locomotives, London, 1893, pp.91/2.
[48] The Engineer, 13th August 1886.
[49] Ahrons, *op cit* (24), p.206/7.
[50] J. Edward Darbishire, 'Modern Locomotive Design and Construction', The Railway Engineer, Vol. IV, No.10, October 1883, pp.245-249.
[51] Ahrons, *op cit* (24), p.207.

work, although as early as 1873, the Baldwin company acquired its own steel works to reduce its dependency on external supplies.[52] In Britain, however, the lead in steel development for locomotives remained vested with the railways, particularly Crewe Works, working closely with the British steel industry.

4.5 Evolution of Locomotive Design

The manufacturers' initiative in promoting the early locomotive types, set the bench-marks for design evolution until the 1840s. In accordance with the market growth and development, their design strategy was both to increase the power, speed and economy of main-line locomotives, and to develop new types to suit each new kind of railway and industrial operation, as determined by railway or consulting engineers. The strategy was sharpened by the increasingly competitive nature of the locomotive market (Section 2.2), and several of the design and component innovations were patented (Section 4.6).

The advent of British railway workshops, however, saw design initiative gradually pass to them as their drawing offices and development teams experimented with new arrangements. The 1840s also witnessed the rise of talented independent engineers, who sought to license their patented arrangements. The growth of the consulting engineering firms from the 1850s, took further design initiative away from the manufacturers in respect of locomotive types for the several new kinds of railway around the world. The choices confronting the manufacturers, therefore, were to seek to maintain their own design initiatives, offer licensing deals to independent patentees, or become passive designers limited to the detailing of customers' designs for manufacturing purposes. The extent to which the manufacturers were able to pursue a combination of these options, and the effects on their long-term ability to promote new products, can be judged from a review of design evolution through the century.

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[52] John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, p.40.

By the time locomotive design was considered by Parliament's Select Committee on Railways in 1839, the evidence was a re-iteration of the arguments between the adherents of the Stephenson and Bury types (Section 4.2).[53] This drew attention away from the improvements in reliability that had taken place, through better materials and construction methods. Trains now kept better time: "owing to the engines being themselves in much better order, very much improved, and owing to their getting a better supply of coke." The engines had been much improved: "Not in principle, but they are better made."[54]

The Bury type largely stagnated because of his adherence to two axles, and, although in 1846 railway pressure forced him to introduce three-axle variants, they were less good than the Stephenson locomotive, and the design type was discontinued on the demise of the Bury firm in 1851 (Section 7.6.7). His bar-frame, however, had become firmly established in North America, being better suited to the poorer track and more adaptable for railways in developing countries (Section 4.8). After 1850, the Stephenson type dominated locomotive design development for railways in Britain, and overseas railways of British influence.

When the larger railways set up their workshops from the mid-1840s, however, locomotive superintendents supervised drawing offices which produced distinctive locomotive designs, manufacture of which was frequently shared between their workshops and the independent firms. An early example was James McConnell's passenger locomotive type for the LNWR in 1851, the class of 40 being shared between Sharp Stewart & Co., Kitson & Co. and the railway's own Wolverton workshops.[55] The 1840s also saw the introduction of entrepreneurial engineers, such as Thomas Crampton (1816-1888), whose inventiveness led to several lucrative patents (Section 4.6), and who encouraged several railways to specify his designs.

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[53] Select Committee On Railways, *op cit* (5); and Second Report, *ibid*, to be Printed 9th August 1839. The third, 'Hackworth', design type had been limited to a few north-east manufacturers, and was discontinued after 1850.
[54] Evidence of Hardman Earle, Director of the Liverpool & Manchester and other railways, *ibid*, Questions 5003/4, p.230.
[55] Ahrons, *op cit* (24), p.94.

As the capability of railway drawing offices grew, tender invitations were accompanied by more detailed arrangement drawings. Whereas the earliest specifications of 1836 had been listed on two foolscap pages and were accompanied by two or three arrangement drawings,[56] by 1864 they took up, typically, 14 double foolscap pages and were accompanied by more than 50 component and arrangement drawings.[57]

Locomotive weights and axle-loads increased as main line track improved, and greater tractive power was achieved through more wheels and higher boiler pressures. Design development was, therefore, directed towards increases of size and enhanced specification as well as through innovation. In a major paper in 1883/84, Edward Darbishire identified the several demand-led requirements which had influenced locomotive design in the previous 20 years:[58]

> First, undoubtedly, is the enormous development of traffic, demanding every day more and more powerful engines to conduct it. The passenger traffic...... in carrying third class passengers by all trains, gave an impetus to travelling which has resulted in an immense increase in the weight of trains, which, moreover, are run at higher speeds than formerly. Local or suburban traffic has developed as facilities have been taxed to meet the demand for engines to suit the special conditions of this traffic. Goods traffic is worked at higher speeds than formerly, and, on many of our leading lines, through goods trains are run at a higher rate of speed for long distances without a stop. In fact, in all directions the tendency has been to require heavier and more powerful engines for all classes of traffic....

Substantial overseas railway developments also increased locomotive performance requirements, for which specifications and detailed arrangement drawings were increasingly prepared by consulting engineers. For example, locomotives specified in 1854 for the Sydney and Goulborn Railway, the first in Australia, were to the LNWR designs of James McConnell, who was also the line's consultant.[59] The consulting firms recruited locomotive

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[56] 'Specification of Locomotive Engines for the London & Birmingham Railway', July/August 1836, PRO, Rail 384/265-269.

[57] For example: 'Specification of ten 0-4-2WT locomotives for the South Eastern Railway', prepared by James Cudworth, Locomotive Superintendent, PRO Rail 635/225 (Locomotives built 1864 by Slaughter Gruning & Co.).

[58] Darbishire, *op cit* (50), Vol. IV, pp.217-221.

[59] J.G.H. Warren, A Century of Locomotive Building By Robert Stephenson & Co 1823/1923, Newcastle on Tyne, 1923, p.410.

designers and superintendents from both British railways and manufacturers. Edward Snowball, for example, Robert Stephenson & Co.'s talented Chief Draughtsman, was recruited as Superintendent of the Scinde Railway in India, although he was subsequently attracted to a career with Neilson & Co.[60]

From the 1850s, therefore, the manufacturers became increasingly restricted in their scope for design innovation, but, as they witnessed improved arrangements and components from their larger customers, they were able to pass these on to their other, smaller railway customers, subject to any patent licensing arrangements. The following summary of design innovations outlines the several changes in market requirements, and highlights the transition of design initiative from the independent industry to the railway, independent and consulting engineers:

'Long-Boiler' Type: This design type, which was patented and introduced by Robert Stephenson & Co. in 1841, was motivated by fuel economy.[61] The long-boiler provided an increased heating surface, whilst minimising: "the escape of a large quantity of waste heat up the chimney."[62] Its distinctive boiler/wheel layout, also introduced inside plate frames, vertical slide valves and boiler feed-pump eccentric drives.[63] Although constructed under licence by several manufacturers in Britain and on the Continent (Section 4.6), it was more widely adopted by European railways, particularly in France and Germany, than in Britain.

Mixed Frame Type: The mixed frame locomotive, or 'Crewe Type', with inside bearings for the driving axle and outside bearings for carrying axles, was the first design initiative taken by a railway engineering team. Developed by the Grand Junction Railway in the early 1840s, it was taken up by independent manufacturers, notably E.B.Wilson and Kitson, Thompson &

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[60] John Thomas, The Springburn Story, Dawlish, 1964, p.103.
[61] Patent No. 8998, of 23rd June 1841.
[62] Printed Report, 'Mr. Stephenson's Report to The Directors of the Norfolk Railway', Westminster, January 21, 1846, Retained in a scrap book thought to have belonged to George Stephenson, Institution of Civil Engineers Library, Ref. 04.
[63] Warren, *op cit* (59), Chapter XXVI, pp.346-357.

Hewitson.[64] It circumvented the Stephenson 'long-boiler' patent, and became popular amongst several railways in Britain, for whom the latter type was less suitable at higher speeds.

Crampton Type: A radical departure in locomotive design occurred from 1842 when Thomas Crampton (1816-1888) pursued his own design programme, leading to patents, licensing and royalty income (Section 4.6).[65] Whilst employed by the Great Western Railway (GWR), Crampton patented a 'single-driver' locomotive, whose large, rear-mounted wheels were a characteristic. Although not taken up by the GWR, a few manufacturers in Britain and, more particularly, several on the continent did manufacture the type.

Balanced Locomotives: In the 1840s, increased speeds were constrained by yawing motion, which led the Manchester-based engineer, John Bodmer (1786-1864), to pursue balancing the reciprocating mass of wheels and motion by counter-forcing the piston action. He worked closely with Sharp Roberts & Co., which built a small number of his locomotives,[66] until the simpler expedient of adding balancing weights to driving wheel rims, developed on the Eastern Counties Railway, became widespread.

Main Line 'Tank' Locomotive Type: Significant economy, through all-up weight reduction, was achieved for short-distance operations, by eliminating the tender, and accommodating coke and water on the locomotive itself. Apart from a few experimental 'tank' locomotives, the first true tank design was introduced by Charles Tayleur & Co. in 1846, and taken up by Sharp Bros. and Jones & Potts in the following two years.[67] These were the fore-runners of many main-line tank locomotives for secondary duties (Fig.6).

Industrial 'Tank' Locomotive Type: The widely-adopted design type from the mid-19th century was the industrial tank locomotive for the expanding industrial market sector

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[64] D.H. Stuart and Brian Reed, The Crewe Type, Locomotives In Profile, Vol.2, Windsor, 1972.
[65] Ahrons, *op cit* (24), pp.70-73.
[66] *ibid*, pp.60-62.
[67] *ibid*, pp.83-84.

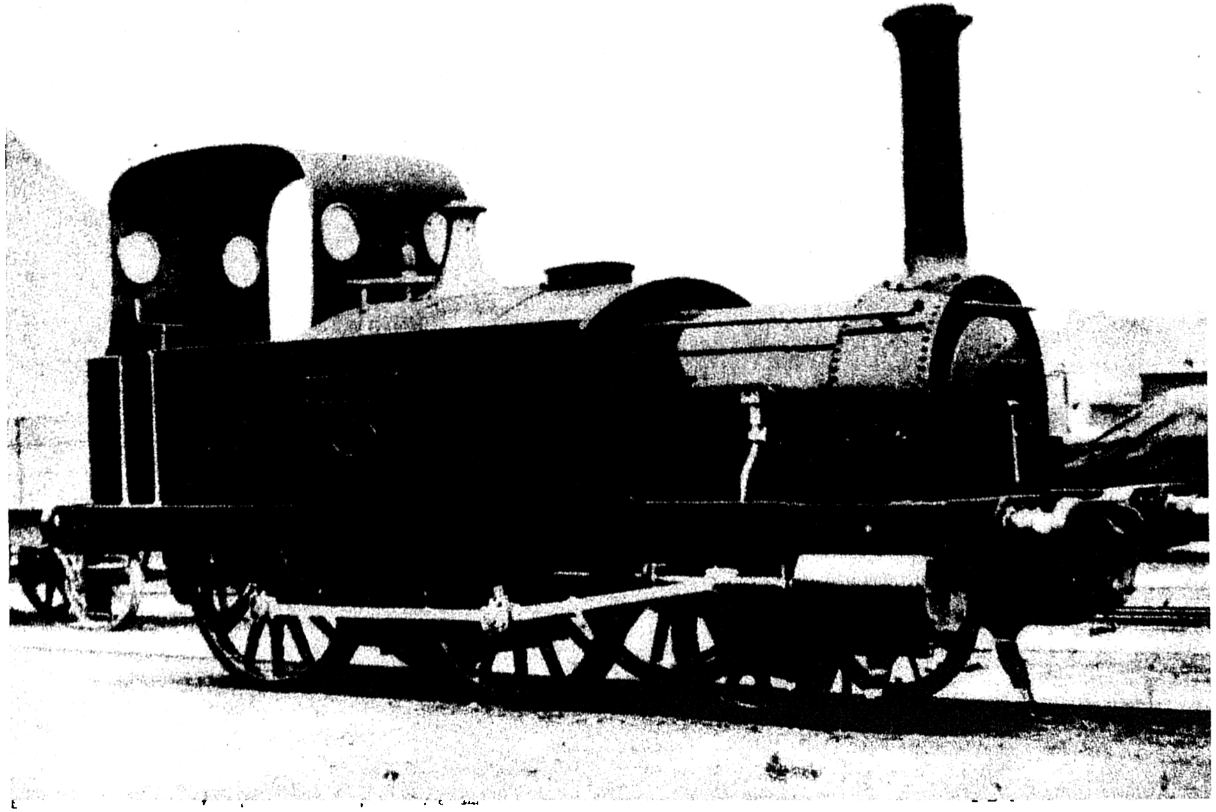

Fig.6 **EXAMPLE OF A MAIN-LINE TANK LOCOMOTIVE (Neilson & Co., 1860, for the Morayshire Railway)**

(Photograph: Courtesy the Mitchell Library, Glasgow)

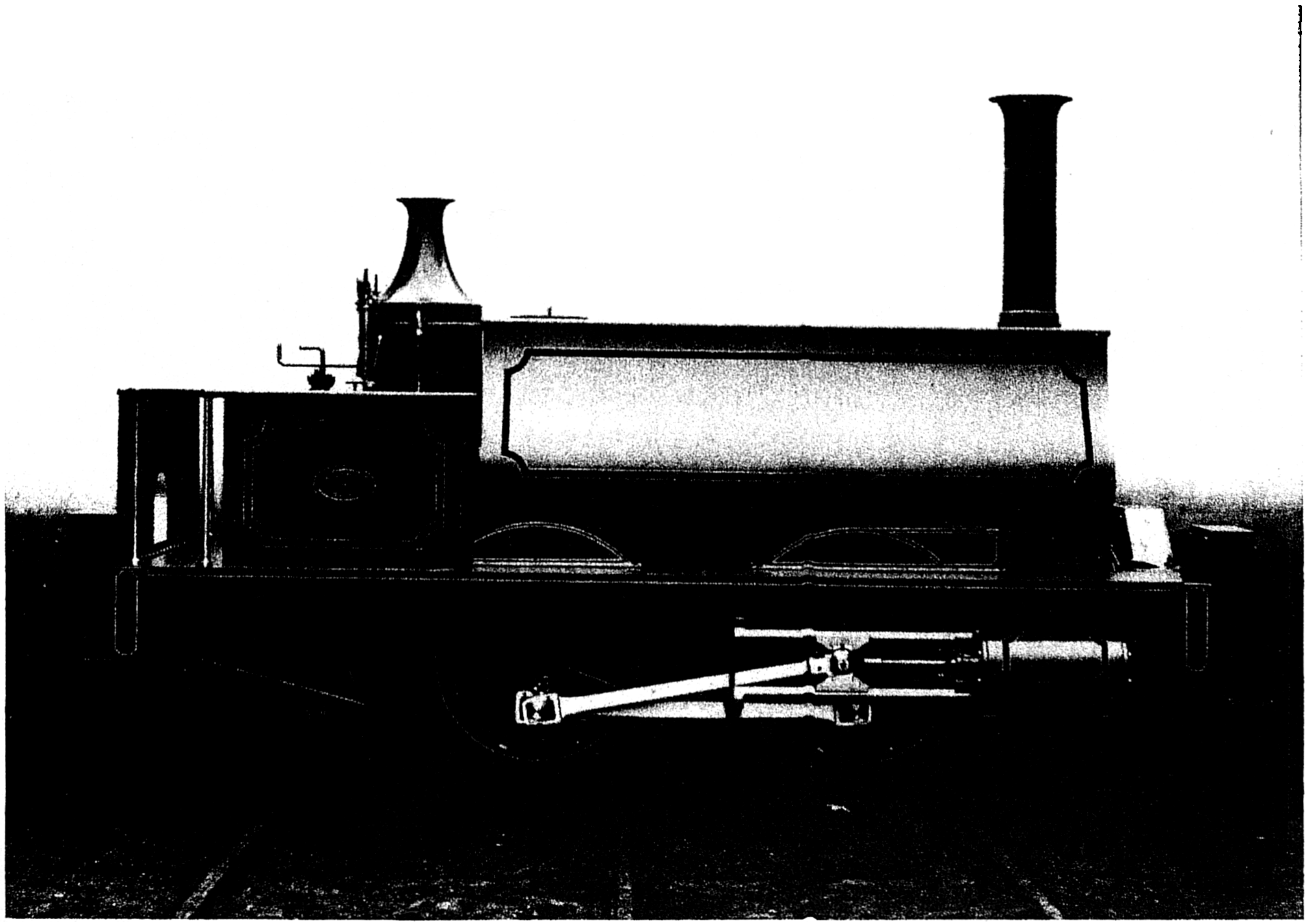

Fig.7 EXAMPLE OF AN INDUSTRIAL-USE TANK LOCOMOTIVE (Neilson & Co., 1867, for Messrs. Rigby & Beardmore)

(Photograph: Courtesy the Mitchell Library, Glasgow)

(Section 2.3). The light-weight, un-complicated, short wheel-based locomotives, were competitively priced. The first standard examples, manufactured by Manning Wardle & Co. in 1858,[68] were followed by examples from several other manufacturers who retained full design control, allowing a high degree of standardisation whilst accommodating customer variations (Fig.7).

Narrow Gauge Locomotive Type: Narrow gauge railways, which were cheaper and more flexible than standard gauge for certain applications, opened new opportunities for the manufacturers. Robert Stephenson & Co. and Slaughter Gruning & Co. constructed the first 3ft 6in gauge locomotives for Norway in 1862, but an 1866 design by Beyer Peacock & Co. set the standard for narrow gauge main-line development.[69] Narrow gauge industrial lines in Britain and overseas developed extensively from the 1860s, further expanding opportunities for the independent industry, which adapted designs for several different gauges.

Mountain Railway Types: From the 1860s, steeply graded mountain railways, beyond reliable adhesion, called for a new type of locomotive. The consulting engineer, John Fell (1815-1902), developed and patented a 'centre-rail' adhesion system for application to the Mont Cenis Railway in Alpine Italy.[70] He licensed British and continental manufacturers to build the locomotives, which were subsequently employed on mountain railways around the world. A mountain railways rack system was also patented, in 1886, by Herman Lange (1837-1892), Chief Engineer and Joint Manager of Beyer Peacock & Co. and James Livesey (1831-1925), consulting engineer to several South American railways, who had himself been trained by Beyer Peacock.[71]

Condensing Type: The introduction of the Metropolitan Railway's underground services in 1863, required a condensing apparatus to minimise smoke nuisance for passengers and train crew. The first locomotives, provided by the GWR with crude condensing equipment, were

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[68] L.T.C. Rolt, A Hunslet Hundred, Dawlish, 1964, p.26/32.
[69] Hills and Patrick, *op cit* (25), p.49.
[70] Ahrons, *op cit* (24), pp.319/320.
[71] Hills and Patrick, *op cit* (25), p.74.

soon replaced by the Metropolitan Railway's own fleet, designed and built by Beyer Peacock & Co.[72] The simple condensing apparatus, which returned exhaust steam to the water tanks, was adopted throughout the steam era.

Articulated Type: In 1864 the consulting engineer, Robert Fairlie (1831-1885), patented his double-bogie, double-boiler locomotives for use on secondary routes with sharp radii, particularly overseas.[73] After initial hesitation of the 'double-Fairlie's' novel design, by both railways and consulting engineers, he formed, in 1869, the Fairlie Engine & Steam Carriage Co., which ceased within a year after only five locomotives had been built.[74] Thereafter, he energetically promoted the type, and licensed six British independent manufacturers and others in Europe and the United States to manufacture them. By 1875, Fairlie had received orders from 41 railways around the world with gauges ranging from 2ft to 5ft 3in.[75]

In 1868, a first articulated locomotive was built to the patented design of Jean Meyer (1804-1877), an Alsatian consulting engineer. The type became more popular in the 1890s when the Hartmann Works in Germany and Kitson & Co. began to build variants for particular applications on steeply-graded mountain lines. A further articulated type, patented by Anatole Mallet (Section 4.3) in 1884, was first adopted for narrow-gauge use, but was later adapted for main lines, and in the 20th century became the most widely adopted of all the articulated types.

Manufacturers increasingly lost the opportunity to design main-line locomotives as specifications produced by consulting engineers became increasingly detailed. In 1884, for example, Robert Stephenson & Co. manufactured some 2ft 6in gauge tank engines for the steeply-graded Antofagasta Railway, to the 'general design and specification' of its consulting

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[72] Ahrons, *op cit* (24), p.153-155.
[73] Patent No. 1210, Enrolled on 12th May 1864.
[74] Ahrons, *op cit* (24), pp.314-316.
[75] The manufacturing of Fairlie's locomotives was contracted out to several firms, namely, Sharp Stewart & Co, Avonside Engine Co., Yorkshire Engine Co., Vulcan Foundry Ltd., R.&W. Hawthorn, and Neilson & Co., Engineering, April 9 1875, p.302.

engineer, Edward Woods.[76] They incorporated Webb's compound system, Joy's valve gear, Cleminson's patent radial axle-box, Adam's bogie, Friedmann's injector and Hancock's 'inspirator'. The Stephenson Company undertook only the detailing work, prior to manufacture.

However, manufacturers did retain the capability for preparing new arrangements where, for example, consulting engineers issued 'Heads of Specifications' only. In such cases, they would undertake sufficient arrangement work to enable them to tender, leaving full detailing work to be undertaken once a contract had been awarded. In 1880, for example, James Livesey invited tenders for eight tank locomotives on behalf of the Chilean Tal Tal Railway.[77] The invitation explained that: "As time is of the utmost importance, an outline specification only is given, so that manufacturers can adopt such patterns, dies, and templates as they may have. The tender to be accompanied with an outline tracing, and a detailed specification."

It is thus apparent that manufacturers' design strategies for main-line locomotives were conditioned by their developing markets, and that they were obliged to accept an increasingly passive role in design innovation from the 1850s. Their drawing offices retained the facility to undertake arrangement work for their smaller customers in Britain and overseas, from whom they received broad specifications only. In this respect, the 'craft' firms, which retained a broad market base (Section 1.3), manufacturing small batches of machinery and engines, were better placed than the 'progressive' firms which specialised in larger batch production of pre-specified locomotive designs. Although the larger British railway drawing offices provided manufacturing drawings, all other contracts, particularly those for overseas, required detailing work, which was undertaken by the manufacturers' own drawing offices.

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[76] Darbishire, *op cit* (50), Vol.V, No.7, July 1884, pp.178-181.
[77] James Livesey's Specification Book, 1878-1882, Livesey & Henderson Collection, Institution of Mechanical Engineers Library.

Industrial locomotive manufacturers retained full control over their design work, albeit forming a few standard types, but which often involved additional detailing work to accommodate varying track gauges and other customer requirements.

4.6 Patents

The importance for manufacturers to adopt patent protection for novel locomotive design features, had been well illustrated by the Stephensons' omissions in the late 1820s (Section 4.2.). Patent law was an important legal procedure for inventors, providing them with a period of exclusivity to protect themselves from imitators and pursue financial exploitation, through manufacture and sale, or through licensing royalties. In his survey of English patenting and invention between 1760 and 1850, Sullivan has suggested that patents merely indicated the potential profits inventors perceived they could make from inventions.[78] MacLeod has noted that there was no theoretical debate concerning the nature of invention, and the patenting process was a largely anonymous activity. Only in the 1850s and 1860s did the patenting process become the subject of considerable controversy and a platform for the popularisation of 'heroic' inventors.[79]

As with other industrial sectors, the number of railway, particularly locomotive, patents grew markedly, and, by 1850, represented the second largest industrial category after textile machinery.[80] The 374 railway patents in the 1840s were two and half times more than in the 1830s, representing some 8 per cent of the total. The majority of patents, however, could demonstrate neither technical nor financial benefit and were not taken up, and only a handful produced significant incomes for the patentees.

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[78] Richard J. Sullivan, 'The Revolution of Ideas: Widespread Patenting and Invention During the English Industrial Revolution', Journal of Economic History, Vol. L., No.2, June 1990, pp.349-361.
[79] Christine MacLeod, 'Concepts of Invention and the Patent Controversy in Victorian Britain', in Robert Fox (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996, pp.140/1.
[80] Sullivan *op cit* (78), Table 1, Compiled from Bennet Woodcroft, Subject Matter Index of Patents of Invention, London, 1857.

The most successful early patent was taken out by Robert Stephenson in 1841, for his company's 'long-boiler' locomotive type (Section 4.5), with which he demonstrated a determination to maintain a design lead over Edward Bury and other aspiring manufacturers.[81] The partners of Robert Stephenson & Co. minuted:[82]

> Rob. Stephenson having stated that he has some improvements in Locomotives in view which he apprehends it would be to the advantage of this concern to take out a patent for, he is encouraged to effect the same in his own name on our behalf.

No discussion was recorded regarding sharing the royalties, and it would seem that the partners were content that their interests would benefit from an increase in orders for the Newcastle factory. Stephenson received all royalties personally over the patent's 15 year life.

The 'long-boiler' type was widely adopted in Britain and Europe, with manufacture initially being limited to the Stephenson Company for the British market, and to British and foreign firms for the European market, royalty negotiations for which were handled by Stephenson's agent, Edward Starbuck (Section 3.3.1). When the market was low in 1843 and early 1844 (Section 2.6), Stephenson resisted all approaches from manufacturers seeking to make 'long-boilers' for the British market. Starbuck wrote curtly to Messrs. Kitson, Thompson & Hewitson:[83]

> You are probably aware that he [Robert Stephenson] has already repeatedly stated to Parties both in England & on the continent his objection to this permission [to adopting his patent arrangement of Engine] & his interests have been so injuriously affected by the circumstance of other manufacturers having offered & undertake to make Engines on his patent arrange't that he is compelled to adhere to this decision......

Relationships with other manufacturers became strained over matters of infringement. When, without agreement, R.&W. Hawthorn, the Stephenson Co.'s neighbours in Newcastle,

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[81] Patent Specification No. 8998, Enrolled 22nd December 1841.
[82] R. Stephenson & Co., Partners' Minute Book, 29th April 1841, R. Stephenson & Co. collection, Science Museum, London.
[83] Copy letter, E.F. Starbuck to Messrs. Kitson, Thompson & Hewitson, London, 17 June 1844, letter book, Starbuck papers, Tyne & Wear Record Office.

began making a long-boiler locomotive in the spring of 1844, the Stephensons' Head Clerk promptly wrote:[84]

> Gentlemen Having been credibly informed that you are about Exporting one or more Locom've Engines, upon a construction which embraces our Patent, & which is a manifest infringement of it, we feel called upon for the protection of our interest, to protect against such use being made by yourselves or any other Engine Builders of our Patent right & to state that we cannot consent to your delivery of such Engines. The writer will be in Newcastle in the early part of next week, & will then be glad to receive any communication you may be disposed to make upon this subject."

Hawthorns at first denied any infringement, but, after a meeting with Stephenson, they conceded the point, agreeing to a £50 royalty per locomotive. Stephenson felt: ".... very strongly the shameful manner he has been treated by H. & Co. in denying in the first instance..... the infringement....." [85] Hawthorns later objected to the agreement and claimed that the positioning of their rear axle was sufficiently different from the patent to make it void. The Stephenson Company promptly sought legal advice, which found in its favour. Starbuck wrote:[86]

> ".... as a matter of Equity H & Co must know themselves wrong - as a matter of Law the high opinion of Webster [barrister] makes them so. The maintenance of our just Right in this question will have great weight on the Continent, such affairs give a prestige much in favour of the Inventor".

The poor relationships between the two companies was thus further strained, but the litigation confirmed to the industry as a whole the full strength of a patent. As the locomotive demand rose in the 'mania' years of 1845-47, however, the Stephenson Company could not keep up with the demand, and allowed orders to pass to other manufacturers in return for royalty payments.

Different royalties were negotiated by Starbuck for each market. He offered French manufacturers an agreement to make any number of locomotives for £1,000, or £50 for each

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[84] Copy letter, E.J. Cook (for R. Stephenson & Co.) to R.&W. Hawthorn, London, 28th May 1844, Starbuck letter Book, *ibid.*
[85] Copy letter, E.F.Starbuck to E.J. Cook, London, 11th June 1844, Starbuck letter book, *ibid.*
[86] Copy letter, E.F.Starbuck to E.J. Cook, 8 August 1844, Starbuck letter book, *ibid.*

one made.[87] In Holland he obtained £25 for each locomotive, whilst noting that the Dutch patent laws lapsed if a patent was not exercised for 2 years.[88] In 1846, the royalty was: "£10..... an Engine...... including everything - Wheels &c", the latter being duplicate components (Section 3.6.2).[89] In 1854, the Paris & Orleans Railway was charged £10 per locomotive for a fleet of 26. Three smaller orders in the same year generated a royalty of £30 per locomotive, suggesting a stepped rate of £30 each for less than ten, and £10 above that number.[90]

Keeping track of licensees' output, and of manufacturers who sought to infringe the patent, was a time-consuming activity for Starbuck, who checked all orders to claim Stephenson's royalties, of which he, in turn, received a 15% commission. Starbuck's commission accounts show that Stephenson earned several thousand pounds in royalties, particularly in the peak year of 1846 when he grossed over £12,000.[91] In the reduced market conditions of 1848, Stephenson looked back at his substantial income over the previous four years and paid Starbuck a gratuity of £500 over and above his commission.[92]

The Stephenson Company had won few friends with its rigid application of the patent rights. This helped to persuade other manufacturers, notably Sharp Brothers and E.B. Wilson, to develop the alternative, 'mixed-frame' types that, without the royalty premium, could be more competitively priced.[93] These were judged to be significantly better than the 'long-boilers' under British, higher speed operating conditions. The use of 'long-boilers' in Britain was, therefore, limited, but this contrasted with Continental railways, particularly France, Belgium, Holland and Germany, whose slower operating speeds made them popular long after the patent had expired.

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[87] Copy letter, E.F. Starbuck to Emile Martin, 5 Feby 1844, Starbuck letter book, *ibid.*
[88] Copy letter, E.F. Starbuck, for Self & Rob't Stephenson, to Dudok Van Heel, 6th February 1844, Starbuck letter book, *ibid.*
[89] Letter, J.E. Sanderson (for Robert Stephenson) to W.H. Budden (for R. Stephenson & Co.), Westminster, 6" February 1846, Starbuck Papers, *op cit* (83), Ref. 131/42.
[90] E.F. Starbuck's accounts, *ibid*, Ref. 131/73
[91] E.F. Starbuck's accounts, *ibid*, Ref. 131/53.
[92] Letter F.E. Sanderson (for Robert Stephenson) to E.F. Starbuck, Westminster, 13 Nov 1848, *ibid*, Ref. 131/81.
[93] Ahrons, *op cit* (24), pp.76/7.

Although the Stephenson Company's link motion of 1842 (Section 4.3) was such an important technological step, it was not patented.[94] William Howe, who helped develop the valve gear, gave evidence to a patent tribunal in 1851 stating: "I do not think there was ever one [patent] applied for. There seemed to be a doubt whether it would act effectively or not at the time."[95] The tribunal, which enquired into precedence of expansion valve gear, arose out of action by John Gray (1810-1854), patentee of the 'horse-leg' valve gear of 1839,[96] against the LNWR for its use of the Stephenson link motion. Gray's gear may have influenced Stephenson's decision not to patent the link motion, although its form was sufficiently novel. The tribunal, which denied Gray's claim, was seen by the Stephenson Company as being: "of the utmost importance, not only to railway companies, but also to manufacturers, [and] it is desirable to use every exertion to prevent a claim which I think is unjust."[97] The link motion became the most widely used valve gear and, had it been patented, would undoubtedly have brought considerable income to Stephenson.

The extraordinary profits of the 'long-boiler' patent gave incentive to engineers, without a manufacturing affiliation, to patent their inventions, the first being Thomas Crampton.[98] A prolific and popular inventor, he took out several patents, including one for his 'Crampton'-type of 1842 (Section 4.5). He licensed manufacturers in Britain[99] and the United States, but the type was not seen to offer advantages over normal express types and only about 25 examples were built in each country. Nearly 300 were constructed by licensed manufacturers in France and Germany, however, from which Crampton received significant royalties.

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[94] Warren, *op cit* (59), pp.359-370.
[95] R.T. Smith, 'John Gray and His Expansion Valve Gear', Transactions of the Newcomen Society, Vol. 50, 1979/80, pp.139-154.
[96] Patent No. 7745, Enrolled 26th January 1839.
[97] Letter, W.Weallens (for R. Stephenson & Co.) to Howe, quoted by N.P. Burgh in letter to The Engineer, Vol.XXIX, p.7, Jan 7. 1870.
[98] C. Hamilton Ellis, 'Famous Locomotive Engineers, XV, Thomas Russell Crampton', The Locomotive, Vol.XLVI, No.571, March 15 1940, pp.67/8.
[99] Notably the London & North Western Railway, Tulk & Ley, Bury Curtis & Kennedy, Kitson Thompson & Hewitson and E.B. Wilson.

The Patent Law Amendment Act of 1852, which limited each patent to a single invention rather than a cluster as hitherto, was preceded by a Parliamentary Select Committee and succeeded by an extraordinary controversy, during which a strong abolitionist movement was formed.[100] Following enactment, however, many patents were taken out for improvements to locomotive components, a small proportion being taken up, some licensed to manufacturers and earning royalties for their inventors, others prompting the establishment of new companies forming an important expansion of the component supply industry. The Act also separated British and Colonial patents, which then required separate registration.[101]

Reflecting the reduction in design and technological discretion for the manufacturers in the 1850s, there was a shift in locomotive-related patents to independent engineers, motivated by potential profits, to railway locomotive superintendents, following their technological development work such as for coal-burning fireboxes and compounding types (Section 4.3), and to consulting engineers, following their work on articulated and mountain types (Section 4.5). The majority of patents were however, related to components, the following being a summary of the main ones:

Steam-Injector: The most important component was the steam injector, patented throughout Europe and North America by the French engineer, Henri Giffard (1825-1882) in 1859.[102] It allowed water to be fed into the boiler at any time, a marked improvement over feed-pumps which required locomotives to move to pump water. It also allowed an increase in boiler size, hitherto limited by a secure water supply. In competition with Robert Stephenson & Co., Sharp Stewart & Co. secured sole rights for its British manufacture, including those for export.[103] The firm supplied thousands of injectors to British locomotive manufacturers. On expiry of the licence in the 1870s, Sharp Stewart introduced their 'Atlas'

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100 MacLeod, *op cit* (79), pp.140-145.
101 Copy memorandum by J.W. Barlow, Ralph Peacock's notebook, Beyer Peacock Collection, *op cit* (25), Ref. MS0001/70, p.18.
102 British patent No. 1665, Enrolled on 23rd July 1858.
103 Ahrons, *op cit* (24), p.132, also quoting from Kneass, Practice and Theory of the Injector, John Wiley & Sons, New York, nd. Also, Mr. John Robinson, of Manchester, 'On Giffard's Injector for Feeding Steam Boilers' Proceedings of the Institution of Mechanical Engineers, 1860, pp.39-51, and 'Supplementary Paper, pp.74-82.

injector, in competition with others patented by Gresham & Craven, and Davies & Metcalfe.[104]

Water Pick-up Apparatus: John Ramsbottom developed the apparatus for LNWR express trains to pick up water on the move providing a significant saving in time and operating costs. Patented in 1860, it was first used only by the LNWR, but in the 20th century it was adopted by several other railways in Britain and a few overseas.

Radial Axles: To overcome the route limitations of long wheel-based locomotives, lateral moving 'radial' axles were introduced in 1863 by the British engineer, William Adams (1797-1872), and about the same time, by Wöhler, Locomotive Superintendent of the Lower Silesian Railway. Adams' basic design was adopted extensively, but with several improvements, most particularly by Webb on the LNWR, and by Bottomley, whose patented design of 1881 was adopted by Sharp, Stewart & Co. and other manufacturers.[105]

Continuous Brakes: The most significant of the 'proprietary' patents was a group of over twenty taken out in the United States by George Westinghouse (1846-1914) between 1869 and 1873, following his development of the continuous air brake system.[106] He experienced particular difficulty introducing the system in the United States, which required a consensus amongst railroads and industry-wide co-operation. Only through the encouragement of national standards by the Master Car-Builders' Association and a series of trials, was a standard agreed upon in the late 1880s.

Westinghouse was advised of the British requirement for automatic braking by James Dredge (1840-1906) the Editor of Engineering, prompting Westinghouse to develop, patent and introduce the triple-valve air brake system.[107] Reaching a consensus on a standard braking

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104 Darbishire, *op cit* (50), Vol.V, No.3, March 1884, pp.58-63. Also Ahrons, *op cit* (24), pp.133-142.
105 Ahrons, *op cit* (24), pp.160/1 & 225/6.
106 Steven Walter Usselman, 'Air Brakes for Freight Trains: Technological Innovation in the American Railroad Industry, 1869-1900', Business History Review, Vol.58, Spring 1984, pp.30-50.
107 Article, 'The Westinghouse Brake', The Railway Magazine, Vol.1, 1897, pp.362-369.

system in Britain was just as difficult as in the USA. The larger railways researched and developed a variety of alternative systems, in an endeavour both to improve upon the Westinghouse performance and to avoid being dependent upon a major component supplier. The Board of Trade directed railways to introduce automatic braking for passenger services (but not for goods services), and the two systems that were generally adopted in the 1880s and 1890s, were the Westinghouse brake and the vacuum brake.

Many small component patents were taken out, an example being for india-rubber pads fitted into coupling rods and axle boxes, to allow freedom of movement on curved track. The patent, promoted by the Fairbairn Company, received only limited application.[108] Several components were patented in Britain by overseas suppliers, an example being the 'Jerome Patent Packing' anti-friction metallic rings that were developed in the USA and, by 1885, were licensed to five British locomotive manufacturers.[109]

This survey of locomotive and component patents confirms that the conclusion of the 'long-boiler' patent in 1856 marked the end of design initiative by the independent locomotive industry. Thereafter, invention, expressed through patents, was mostly the pursuit of independent and railway-employed engineers. Of those that went on to production, the majority were manufactured under licence, whilst others gave rise to new component industries. The lack of inventive effort by the manufacturers after 1850, adds further evidence of their move away from developmental design, and their growing dependence on customer-led designs for manufacture.

This lack of inventive output contrasts with the United States, France and Germany, whose locomotive industries remained prominent inventors. Patents taken out by American manufacturers provided them with important competitive advantages, and were used to

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108 Patent No. 2273 of 1855, referred to in R.A. Hayward, Fairbairns' of Manchester, unpublished thesis, UMIST, 1971, p.2.57.
109 Namely, Dübs & Co., Neilson & Co., Beyer Peacock & Co., Robert Stephenson & Co. and R.&W. Hawthorn Leslie & Co., see The Railway Engineer, Vol. VI, No.7, July 1885, pp.203/4.

forestall competitors either through high royalties or refusal of manufacturing rights.[110] Baldwins alone took out fifty-three component patents between 1877 and 1900, and one major design patent for its four-cylinder 'Vauclain' compound type (Section 4.3).

4.7 Standardisation

The progress in locomotive design in the 1830s and 1840s fulfilled the railways' requirements for greater speed, haulage and economy, but the proliferation of manufacturers (Section 2.2) resulted in incompatible components for similar locomotive types. Manufacturers were cautious to expand their production capacity too quickly due to the fluctuating demand, and railways were obliged to spread their orders across several firms to avoid lengthy delivery times (Section 5.7.2). The resulting lack of component standardisation concerned the larger railways, which prompted their preparation of specification drawings, and added emphasis to the standardisation of bolt threads.

This gradual withdrawal of design discretion from the manufacturers was stepped up as railway and consulting engineer teams took on more design work, particularly after the 1850s. In spite of a recognition by the 'progressive' manufacturers, from that time, of the benefits of production-led rather than customer-led standardisation, their proprietors were unable to discourage this growing trend. The consequential proliferation of locomotive designs from both railways and consulting engineers significantly restrained batch size and the opportunity for production economy in the second half of the century (Section 5.7.3). This strategic failure by the industry to retain responsibility for design initiative was in marked contrast to the experience of the American and European industries (Section 4.8), which prompts enquiry into the initiatives that manufacturers pursued towards standardisation.

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110 Brown, *op cit* (52), pp.60/1 & 87/8.

The cost benefits of standardisation and component interchangeability had been considered since Daniel Gooch's *Firefly* design for the GWR in 1840 (Section 5.6.1).[111] By the end of the 1840s, the major manufacturers were well aware of the production benefits of standardisation, and their designs generally adopted common components. As more locomotive superintendents developed specifications for their railways, however (Section 4.5), opportunities for standardisation reduced. To discourage this trend, from 1848, E.B.Wilson & Co. offered only three standard designs, for passenger, goods and secondary duties, persuading their customers to adapt their specifications to those designs, for which there was a competitive price incentive.[112] If the customer so much as required a clack-box to be altered from the basic design, he was surcharged up to £25 for the alteration.

As railways and, later, consulting engineers developed their design capabilities, locomotive designs multiplied within each type, according to the perceived requirements of each line. Although each locomotive superintendent sought to standardise, his perception was limited to the internal needs of each railway, without regard to national standards. The developing intra-standardisation was thus a consequence of the growth of railway workshops, each pursuing the needs of its parent railway. The largest number of locomotives of one type was the DX class goods locomotive of the LNWR, of which 943 examples were made, mostly at the Crewe workshops. Each locomotive was identical with the others in the class, which represented the first example of large scale batch production.[113]

With the rise in intra-standardisation, the drift away from national standard designs became all too evident, and in 1855 Daniel K. Clark, an authority on locomotive design, wrote:[114]

> .....probably five distinct classes of locomotive would afford a variety sufficiently accommodating to suit the varied traffic of railways, whereas I suppose the varieties of locomotives in actual operation in this country and elsewhere are very nearly five hundred in number. Everyone cannot be right,

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111 Cdr. John Mosse, 'The *Firefly* Locomotive of 1839', Transactions of the Newcomen Society, Vol.62, 1990-91, pp.97-112.

112 R.N. Redman, The Railway Foundry Leeds, Norwich, 1972, p.12.

113 Ahrons, *op cit* (24), p.123.

114 D.K. Clark, Railway Machinery: a Treatise on the Mechanical Engineering of Railways, London,1855, p.vii.

> and most of them must be wrong, and it would be for the best interests of railways if the proper authorities could be unanimous in the selection of a good number of classes to uniform patterns to be adopted in future practice.

The consequences of locomotive design proliferation were small batches and high unit costs of production (Section 5.7.3). It was a major factor in the economics of locomotive provision in the 19th century, and in the competitiveness of the independent industry against overseas competition later in the century. In his enquiry into design proliferation, Kirby concluded that there were four contributory factors, namely:[115]

- a heavily decentralised railway system, where a minimum of workshop facilities was essential for efficient operations due to the unreliability of the first locomotives, which acted as a powerful encouragement for the proliferation of locomotive classes. This factor, however, does not take account of the fact that overseas railways were equally decentralised, each with their own workshops for the repair of similar early locomotives, but which did not venture into their own manufacture. Continental and American manufacturers moderated design proliferation by transferring innovation from large customers to smaller ones (Section 4.8).

- the development of technology, in which the innovative process itself contributed towards product proliferation, with standardisation only becoming meaningful in the 20th century, using improved machine tools, new methods of workshop organisation and developments in metallurgy. As discussed in Sections 4.3 and 4.4, however, thermodynamic and material innovation were important steps in locomotive evolution, which were applied to the benefit of all designs. Innovation was not, of itself, a cause of design proliferation.

- the market for railway services, in which a proliferation of passenger classes occurred to meet the changes in passenger to train weight ratios between the fastest express services and the ordinary passenger services. There was such an expansion through the

[115] Kirby, *op cit* (1), pp.287-305.

introduction of fast express, fast goods, and suburban services (Section 4.5), but it was relatively modest, and could be fulfilled by just a few standard classes. However, the development of further locomotive design types made more ambitious routes possible with steeper gradients and sharper curvature, which could be accommodated by narrow gauge or mountain type motive power.

- the independence of locomotive superintendents, who established "private empires" in which design idiosyncrasies and proliferation of types could flourish, and who became a law unto themselves with locomotive design. This was undoubtedly true, being a consequence of the growth of railway workshop "empires" each undertaking developmental and design work. Intra-standardisation practices gave little incentive for co-operation between railways, even though standardisation was generally encouraged through the Technical Committee of the Railway Clearing House. Exceptions were few, such as the Somerset & Dorset Joint Railway designs undertaken by the parent Midland Railway. The legal rebuff by the Locomotive Manufacturers Association, to the LNWR's manufacture of locomotives for the Lancashire & Yorkshire Railway in the 1870s, further removed incentive for design co-operation between railways (Section 3.7).

In her discussion on technology and the labour process, Drummond concluded that locomotive design proliferation prompted diversification in production practices amongst railway workshops, and led to collusion regarding labour relations and labour market benefits.[116] It was thus partly a consequence of a perceived advantage in maintaining internal labour markets among skilled workers. The consequences of the design proliferation on the independent industry, in terms of standardised component production, batch sizes, and production practices, are considered in Chapter 5.

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[116] Di Drummond, 'Technology and the Labour Process: A Prelimiary Comparison of British Railway Companies' Approaches to Locomotive Construction Before 1914', in Colin Divall (ed), Perspectives on Railway History, Working Papers in Railway Studies, No.1, Institute of Railway Studies, York, 1997, p.28.

Similar proliferation occurred with the consulting engineers' overseas designs, further diluting the manufacturers' ability to contribute to main-line locomotive standardisation, even for comparable markets, such as India (Fig.8). From as early as 1873, standardisation of Indian locomotive designs was considered on several occasions by the India Office, but it was not achieved until the Edwardian era, because of divided opinions between the consulting engineers in England and the locomotive superintendents in India. The consulting engineer, Sir Alexander Rendel, wrote in 1894:[117]

> It appears that the Locomotive Superintendents of India concur in one thing only, and that is, that what Consulting Engineers to the Secretary of State and to the Companies send out to them is more or less wrong.

The lack of standardisation compared to American practice has been highlighted by Rosenberg who felt that manufacturers indulged in: "needless proliferation of designs and specifications", which prevented the organisation of mass production and impaired export competitiveness.[118] Brown, however, identifies only partial standardisation within the American locomotive industry.[119] From the 1850s, in spite of manufacturers' initial resistance, master mechanics with the larger railroads began to prepare their own specifications for design, materials and fittings. In the absence of widespread railway workshop manufacturing, however, most of the smaller railroads remained reliant on the locomotive industry. Manufacturers were not prepared to forgo their design capability, and made a 'virtue out of necessity' by imitating the designs for the larger railroads and making them available to their smaller customers. This was acceptable to the master mechanics because of the scale benefits from this partial standardisation. The master mechanics maintained contact with each other and, in 1868, even founded an Association to try to curb a growing diversity in design.

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[117] Statement by Sir Alexander Rendel, November 1894, quoted in H.C. Hughes, 'India Office Records', The Journal of Transport History, Vol.VI, No.4, November 1964, p.245.
[118] N. Rosenberg, 'Economic Development and the Transfer of Technology: Some Historical Perspectives', Technology and Culture, Vol.11, 1970, p.561.
[119] John K. Brown, *op cit* (52), pp.63-85.

Fig.8 EXAMPLE OF A MAIN-LINE LOCOMOTIVE FOR INDIA (Neilson & Co., 1880, for the Indian North Western Railway)

(Photograph: Courtesy the Mitchell Library, Glasgow)

The Institution of Mechanical Engineers, founded in 1847, had similarly provided a British forum for debate on design innovation. In spite of economic incentive for standardisation, locomotive superintendents secured and maintained a status with their peers, towards which individual design characteristics were important, and for which employment of competitors' designs had no place. Through the medium of the Institution, and the Scottish Institution of Engineers and Shipbuilders, locomotive superintendents were well aware of design progress, and there is further evidence of close relationships between them in the form of regular correspondence in the last two decades of the century.[120] In his 1884 summary of locomotive design, Darbishire succinctly sums up the diversity:[121]

> "It would be, of course, impossible to expect unanimity of opinion amongst engineers even of the same country and training, but when we compare their practice we can only wonder how so many different forms and types of engines can have been produced, and such different means adopted to attain the same object."

The proliferation of British locomotive designs in the nineteenth century, and the lack of component standardisation did much to increase the unit costs of locomotive production (Section 5.6). The continued requirement for small batches of non-standard types allowed the 'craft' manufacturers to remain in the locomotive business, where larger batch runs of standard types would have favoured the 'progressive' manufacturers. The continued proliferation of independent firms was thus conditioned by the imbalance in the economics of locomotive production due to the lack of standardisation. For overseas sales, the effective cartel created by the dominant influence of the London market (Section 3.4), largely shielded the high cost of production from comparison with the American and European industries. From the 1880s, however, the greater exposure to competition from these industries revealed both the higher costs of production and the inadequacies of design for some overseas railways.

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120 M.W.Kirby, 'Technological Innovation and Structural Division in the UK Locomotive Building Industry' in Colin Holmes and Alan Booth (eds), Economy and Society: European Industrialisation and its Social Consequences, Leicester University Press, 1991, p.35, citing correspondence in the Great Western Railway archives, PRO Rail 254/52.
121 Darbishire, *op cit* (50), Vol.5, No.9, September 1884, pp.259/260.

4.8 Competing Designs in the Overseas Market

The insulation of the London locomotive market was brought sharply into focus from the 1880s as new markets opened up in countries, such as Japan, that were not dependent upon one economic influence (Section 2.8). British locomotive designs for overseas use were perceived by some observers to have diverged unacceptably from the best standards of American and German practice. Central to this debate, therefore, was the responsibility for designs, and the extent to which the locomotive industry was in a position to influence them, or remained as a passive sub-contractor.

Many of the overseas markets were in developing countries, often with challenging topography, and with limited funds with which to open up their respective territories. Their railways were usually laid with slow-speed track and tight horizontal radii, closer in character to American railroads than to European routes. American designs developed quite independently from European ones, the early focus for which had been the 1839-1844 attempts by the Norris company to develop European markets (Section 2.5). Their lack of success in Britain, and the early Europeanisation of the American type in Germany and Austria, were as much a lesson for the American manufacturers about the two distinct market characteristics, as for European manufacturers with export aspirations.

The introduction of railways to developing countries in the 1850s again focused attention on the divergent locomotive types in Britain and America, but it took someone of the stature of Walter Neilson (1819-1889), proprietor of Neilson & Co., to understand fully the characteristics of the American locomotive. Following a visit to the USA in 1856/7, he brought back locomotive drawings showing current design practice, which he exhibited at a meeting of the Institute of Engineers in Scotland. The designs greatly impressed him, especially the 4-4-0 type which he described as:[122]

> a gay, jaunty-looking vehicle - very different from the sombre, business-like machine of the old country...... The American eight-wheeled truck engine is a

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122 Thomas, *op cit* (60), p.86.

> beautifully balanced and steady machine remarkably easy on a bad road and much safer than an English engine under similar circumstances..... We may predict that the time is not far distant when we may look to our friends across the Atlantic with the expectation of learning something from them even in railway engineering.

Neilsons manufactured locomotives for the Nova Scotia Railway employing many American features.[123] For the most part, however, consulting engineers, acting for overseas railways, did not seek to learn about American practice and pursued British types with which they were familiar from their training and careers. Most particularly, by the 1870s and 1880s, many overseas locomotive designs were being precisely specified by the design teams of the large consultancies such as Livesey, Fox, Rendel and Hawkshaw. In 1881, for example, Livesey's office issued a three page specification for materials alone, for two engines for the Buenos Ayres Great Southern Railway. The overall specification was accompanied by at least 155 separate drawings.[124]

The continuing adoption of 'British' locomotive practices for most overseas railways became a contentious issue after 1870, following an uneasy decade of comparison with American locomotive practices in certain parts of the world, notably South America.[125] Design variations were two-fold, namely suitability for well-graded or poorly-graded track, and the employment of short-life and long-life materials.[126] American manufacturers used bar-frame locomotives, guided by a leading bogie truck, for use on poorly-laid track with sharp vertical and horizontal curvatures, characteristic of early railways in Canada, South America, Australasia and Africa (Fig.9). British designs were better suited to higher speeds on well-laid track not initially provided in the developing countries (Fig.10). British designers also had insufficient experience in wood-burning fireboxes, and comparative fuel consumption featured large in the debate.

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123 More detail is being learned about these locomotives from the underwater archaeological project 'Operation Iron Horse'. Artefacts now deposited at the National Railway Museum, York.

124 James Livesey Specification Book 1878-1882, Specification No. 27, September 16th 1881, Livesey & Henderson collection, *op cit* (77), (Locomotives built by the Yorkshire Engine Co.).

125 Summarised in a booklet, American v English Locomotives, Correspondence, Criticism and Commentary, No ed., but clearly inspired by W.W. Evans, Leeds, 1880.

126 Zerah Colburn (posthumus publication), Locomotive Engineering and The Mechanism of Railways &c., London and Glasgow, 2 Vols., 1871.

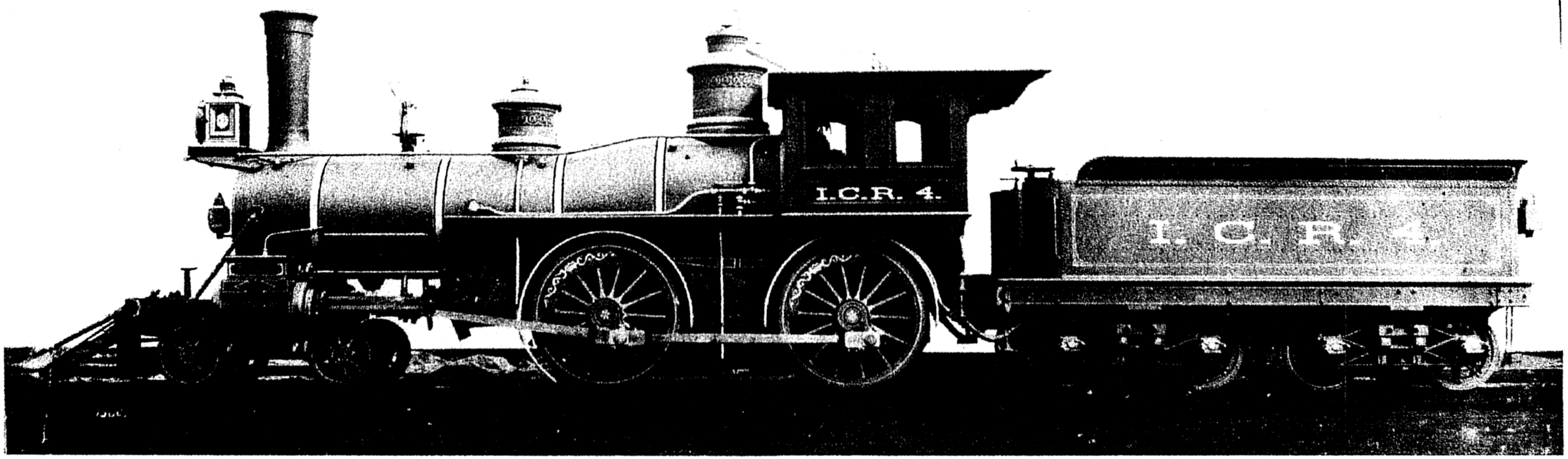

Fig.9 EXAMPLE OF AMERICAN-TYPE LOCOMOTIVE MANUFACTURED IN BRITAIN (Dübs & Co., 1882, for the Canadian Inter Colonial Railway)

(Photograph: Courtesy the Mitchell Library, Glasgow)

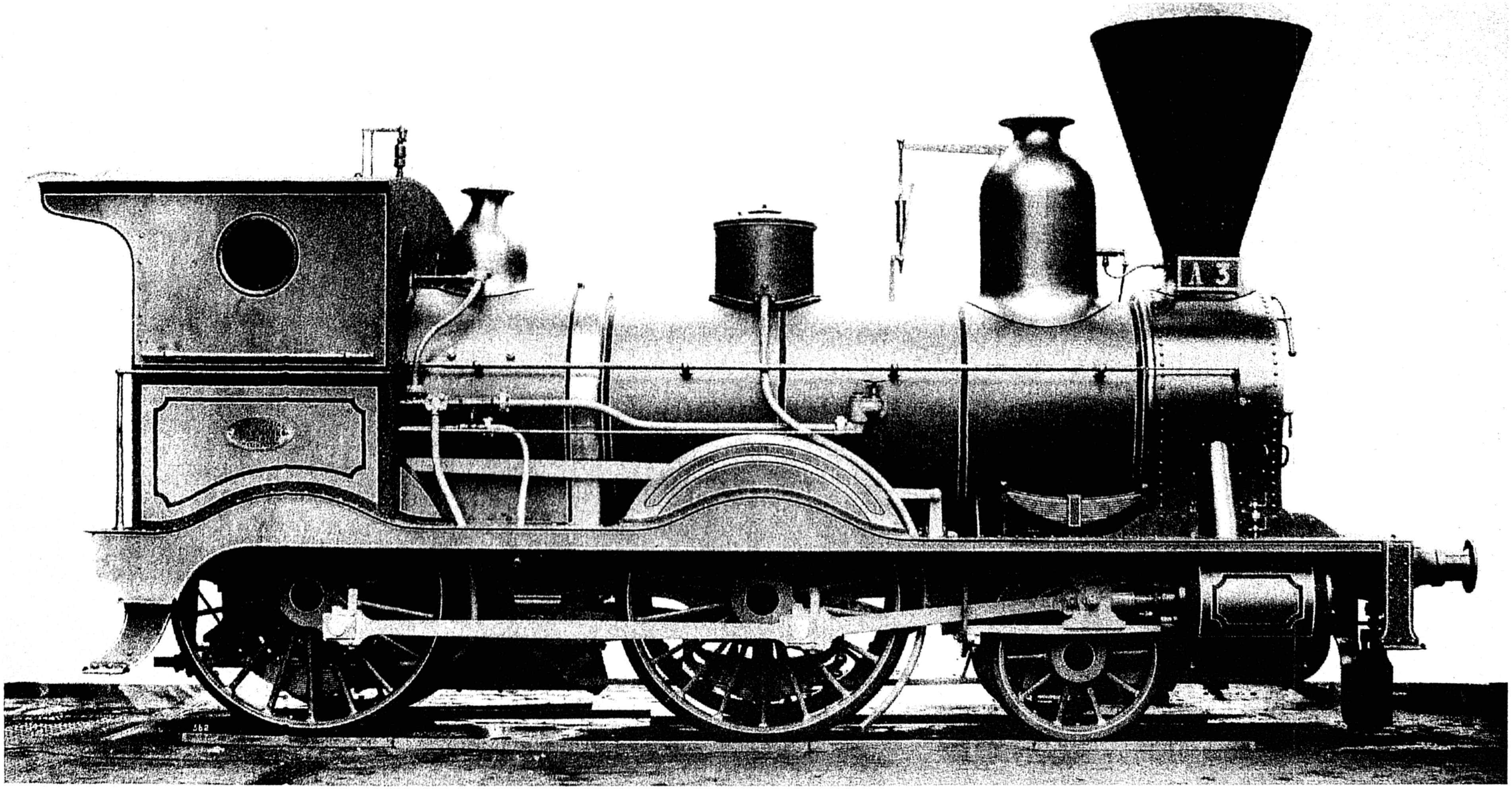

Fig.10 EXAMPLE OF BRITISH-TYPE OVERSEAS MAIN-LINE LOCOMOTIVE (Sharp Stewart & Co. Ltd., 1870, for the Russian Rybinsk-Bologoye Railway)

(Photograph: Courtesy the Mitchell Library, Glasgow)

The differences between American and British types were highlighted in 1878-1880, regarding the suitability of designs for railways in Victoria and New Zealand. Extensive correspondence, accompanied by several opinions, both published and private, criticising British locomotive design practice, was assembled as a 79-page booklet by an American engineer, W.W. Evans of New York.[127] The core of the booklet was a letter by Evans to the Agent-General for New Zealand in London, which preceded locomotive orders for the colony. These were largely awarded to American manufacturers, although there is no evidence of Evans being rewarded as their agent.

Evans' evidence followed the successful trial of American locomotives in New Zealand, an extract from a report by the Commissioner of Railways stating:[128]

> They [American locomotives] have now proved themselves to be both good and economical, and for attention to detail in design and general excellence in workmanship they stand out first in our catalogue of locomotives. American engines I thoroughly believe to be more suited for our lines than anything we can get built in England.

The matter was brought to the attention of Neilson & Co. and the Vulcan Foundry Ltd. by the London agents of the New Zealand Railways, to whom Neilson & Co. responded stating:[129]

> The ordinary American type of engine, such as is in use in America, is, we have not the slightest doubt, better adapted for railways as now constructed than the engine used in this country. It is more flexible, and adapts itself better to the line than our excessively rigid engines. It has also the advantage of being less costly, though, we quite believe, equally efficient in its details, by reason of these being of simpler construction, and frequently of cheaper materials. We need not tell you that, although holding these views, it would be needless our attempting to persuade our locomotive superintendent [i.e. Consulting Engineer] to adopt even a modification of the American type, as you will be well aware of the vast amount of prejudice that would have to be overcome.

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127 American v English Locomotives, *op cit* (125).

128 Report of the Commissioner of New Zealand Railways to the New Zealand Minister for Public Works, July 24th 1878, *ibid*, p.23.

129 Letter, Neilson & Co., Glasgow, 27th November 1878, to Messrs. Hemans, Falkiner, and Tancred, Agents for New Zealand Railways, *ibid*, pp.23/24

The Vulcan Foundry wrote in similar vein:[130]

> ...... we should like to know whether our transatlantic competitors built these particular engines to a specification and drawings supplied, or whether the design and carrying out of details was a matter left entirely to themselves.
>
> We suppose the latter, in which case we submit the comparison between ourselves and the American builders is most unfair.
>
> We are prepared to admit that the American type of engine...... is certainly better adapted to the nature of the curves and permanent way usually prevailing in our colonies than the rigid wheel-base of our English engines; but such is the absurd conservation existing in this country that any departure from existing types would not be entertained....... If English builders are compelled to adhere to a particular type and specification of an engine, they surely cannot be held responsible for its performance or failures.

Evans' booklet, published in Leeds, was clearly designed to be available to British locomotive engineers generally, and particularly those engaged with consultancies. It was also available to engineering journals, through whose columns the on-going debate was continued.[131]

The growing divergence of British and American designs was well summarised by Barnes in 1893:[132]

> In the United States, long train runs, high wages, sharp competition and high rates of interest define the method of railroad operation..... In other countries, generally speaking, the distances are short, competition small, wages low, and money rentals moderate..... The average weight of an American goods train for level roads is not far from 1,350 tons.... a foreign goods train is approximately 450 tons. So then, in the United States, heavy trains, high wages, sharp competition and high rates of interest fix the main distinctive feature of American locomotive practice, which is the greater hauling power of the locomotives. The greater power is obtained in two ways; first by using locomotives of greater weight, and second, by forcing the boilers to a degree almost unknown elsewhere....

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130 Letter, Vulcan Foundry Co. to Messrs. Hemans, Falkiner and Tancred, Lancashire, 28th November 1878, *ibid*, pp.24-26.
131 For example, editorial: 'Superiority of American Locomotives(?)' - The American Engineer, Vol.1, No.7, August 1880, pp.247/8.
132 David L. Barnes, 'Differences Between American and Foreign Locomotives', Paper for the International Engineering Congress of the Columbian Exposition, 1893, summarised in The Railway Engineer, Vol.XV, March 1894, pp.78-80.

Comparison with European locomotive designs centres on the different operating characteristics from those in Britain. Unlike the British trains of moderate length and weight, run at high speed to accommodate passenger traffic on crowded routes, continental operations were longer and heavier, and run at slow or moderate speed, often with frequent and heavy gradients.[133] British manufacturers monitored design evolution of the German, French, Austrian and Belgian industries through regular features in technical journals and the appearance of locomotives at international exhibitions (Section 3.5.2). They were, however: "filled with wonder at the multiplicity of parts and the complicated form of each piece, which seem to be features inseparable from Continental designs..... " which seemed to result from: "the Continental system of training engineers entirely in the technical schools, where it is impossible to gain the practical workshop experience which is given by our system of apprenticeship....."[134]

From the 1850s, the eight major manufacturers in the German union[135] had maintained full control over locomotive design development in conjunction with their predominantly state-run railway customers, and in close co-operation with State and University technical departments. With minor exceptions, none of the German railways manufactured locomotives, relying entirely on the independent companies, between whom competition was intense.[136] In 1909, it was observed that: "The State by way of assisting the manufacturers does not encourage the railways to build their own engines, but prefers to keep the manufacturers going."[137]

The issues relating to the differing designs of locomotives in Britain, the United States and Germany were brought sharply into focus in 1902 when the three Glasgow firms, Neilson & Co., Dübs & Co. and Sharp Stewart & Co., wrote a joint letter to the Times newspaper. They were prompted by Lord George Hamilton, Secretary of State for India, who stated that

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133 Darbishire, *op cit* (50), Vol.IV, No.9, September 1883, pp.217-221.
134 Darbishire, *op cit* (50), Vol.V, No.9, September 1884, pp.259/260.
135 Borsig of Berlin, Maffei of Munich, Esslingen Works, Hartmann of Chemnitz, Egestorff of Hanover, Karlsruhe Works, Woehlert of Berlin and Vulcan of Stettin.
136 Karl-Ernst Maedel, Die Deutschen Dampflokomotiven Gestern und Heute, Berlin, 1965, *passim*.
137 The Railway Gazette, Vol.X, Feb.26th 1909, p.281.

locomotive orders for India in the three previous years had been given to American and German companies as British manufacturers were unable to provide the right engine at the right price, for which: "they only had themselves to blame". The manufacturers' letter responded:[138]

> With the commencement of American competition for Indian locomotives........ all engines ordered for India were of the British type modified, of course, to suit local and climatic conditions, and British builders were asked to build these types only. When the American builders began to compete they were allowed to offer their own type of engine.....
>
> It follows, therefore, as far as design is concerned, the Americans were allowed to supply a cheaper engine than British builders.
>
> As to materials employed in the construction, the British builders are compelled to obtain certain materials from two or three makers whose products have been found to give the most satisfactory results in working, but which are not unnaturally costly. Were the American builders in all cases restricted to the same makers?.........
>
> You, Sir, treat the matter, rightly we believe, as one of national importance, and we suggest that Lord George Hamilton should send a small commission to India to inquire into the results with the American engines there.......
>
> As to German competition, as the two orders recently sent to Germany are the first that have been given for locomotives it has yet to be proved that 'Germany can serve her (India) better than England in the matter of locomotives'...........
>
> It would be interesting to know what makes of material are to be accepted in the case of the German engines. We can buy German tyres, axles, etc. much cheaper than we can get them in this country, but so far we have not desired and have not been invited to use these materials in the construction of engines for India......

The manufacturers' frustration, revealed in the Times letter, adequately sums up the effects that had been created by the consulting engineers' strong hold on design development for overseas railways. It also serves to confirm the extent to which the manufacturers had

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[138] Letter, Neilson Reid & Co., Dübs & Co., Sharp Stewart & Co. Ltd., to the Editor, The Times, quoted in Thomas, *op cit* (60), pp.208-210.

become dependent upon the specifications of their customers or their representative engineers, and to highlight the extent to which the progress of British industry had deviated from the developing practice of its competitors.

4.9 Conclusion

Prior to the railway era, the heavy manufacturing industry had developed on the basis of improving technologies and materials, and design progression which fulfilled and stimulated market requirements. It was well able to progress locomotive technology and design, from a crude travelling machine to an economic form of inter-city motive power. Robert Stephenson's pioneering work between 1828 and 1830 was an "intensive burst" of innovation (Section 1.6), that made the locomotive available to an expectant railway industry. The introduction of tendering and contracting procedures (Section 3.2) resulted in the rapid diffusion and steady, empirical progress of thermodynamic and material technology. Design progress, through "mutations, recombinations and hybrids" (Section 1.6), was determined by the expanding speed and load haulage requirements of main-line railways, the evolution of rail routes in developing countries and industry's internal motive power requirements.

The locomotive industry's strategies were, therefore, to pursue further technological and design progress, whilst, from the 1840s, encouraging railways to accept standardised types. From the 1850s, however, the industry lost the initiative in the development of thermodynamic and material technology. From then until the introduction of scientific enquiry in the 1890s, empirical advancement through trial was achieved by railway development teams, particularly the LNWR's Crewe workshops, in close collaboration with the steel industry. This lost initiative, contrasted with the industries of Germany, France and America, whose manufacturers co-operated closely with railways and technical institutions throughout the century.

The loss of design discretion had even greater impact on the industry's long term competitiveness in the world market. The withdrawal of that discretion from the home market, in favour of railway design teams, and the overseas market, in favour of consulting engineers, left the manufacturers with little opportunity to innovate. The larger railways saw the firms as extensions of railway workshops, to which they supplied manufacturing drawings, leaving no room even for detailing work. An industry that had once benefited from exclusive manufacturing rights and licensed income from its own patents, was subordinated to a contract rôle, negotiating the best terms with which to employ the rights of other patentees.

The main-line locomotive industry was unable to persuade its railway customers, or influence their consulting engineers, to depend upon the manufacturers for technological, material and design progression. Once the railway and engineering "empires" were developed, the manufacturers had to adopt compromise strategies which saw them play a passive role in this progression. Design work was either eliminated, where railways supplied manufacturing drawings, or was limited to arrangement and detailing work. The resulting proliferation of designs brought about a multitude of small batch production runs, which significantly increased the costs of locomotive manufacture.

Kirby was correct in his assessment of the "chronic lack of standardisation" (Section 1.6), as being the result of a fragmented market and an almost inevitable consequence of so many locomotive superintendents in charge of design and development teams. Had the independent industry not been forestalled in its ambitions, the standard designs of E.B.Wilson & Co., Robert Stephenson & Co., and Sharp Stewart & Co. may well have gone on to become the benchmarks for British domestic locomotive design development, emulating the German and American industries.

The formation of the Locomotive Manufacturers Association in 1875 (Section 3.7), should have allowed the manufacturers to speak with unanimity with the consulting engineering profession regarding overseas locomotive standardisation, particularly for market groups such as the Indian railways. There was no such dialogue,[139] however, and, in spite of its criticisms of a number of designs, the industry appears to have had no success in changing the design procedures for overseas locomotives. Although aware of the unsuitability of many British "rigid" designs, the manufacturers were subordinated to designing locomotives according to specifications that left little room for initiative.

In spite of its dominant position in the world locomotive market at the end of the 19th century, therefore, the independent industry had been largely subordinated to the rôle of manufacturing contractors to the designs of its railway customers and their consulting engineers. Although main-line locomotive manufacturers had limited opportunity to innovate, most firms retained a design capability for other markets, such as for marine, colliery and industrial engines, and continued to offer a design facility. Indeed, the industrial locomotive sector retained full design capability for its standard products, alongside its many other forms of capital machinery. The diminution of technological and design initiative made more difficult the development of locomotive production processes, which became the manufacturers' primary concern. The twin challenges of investment and production engineering advancement thus determined their long-term future.

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139 Minute Book, 1875-1900, Locomotive Manufacturers Association, Railway Industry Association collection, National Railway Museum.

5.0 Manufacturing

5.1 Introduction

The Chandlerian debate on the progression from craft to 'American-system' mass production methods draws no distinction between the heavy capital goods sector and the repetitive production of domestic items and interchangeable industrial components. By the commencement of the railway era in 1830, Britain's manufacturing industry had already divided between semi-skilled repetitive production and the craft-based production of capital goods. As Zeitlin has recently re-iterated, the concept of scale economies from volume production had been well understood and practised since the first decade of the 19th century, when Marc Brunel's sequential operation block-making machinery was made by Maudslay, Sons & Field.[1] The processes were well learned and adopted by the textile industry, for example, which required regular provision of interchangeable, replacement components.[2]

The manufacture of capital goods, on the other hand, both custom-designed products and customised variations of standard products, had been undertaken under the 'factory' system since the 18th century. The development of their components relied on material enhancements and the progressive ingenuity of specialist machine tools and craft manufacturing disciplines. Opportunities for 'batch' production economies were limited by their small numbers and design variations. The manufacturing processes for both capital goods and standardised components were both to change substantially during the century, and their respective skills and practices followed complementary evolutionary paths.

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[1] Jonathan Zeitlin, 'Between Flexibility and Mass Production: Strategic Ambiguity and Selective Adaptation in the British Engineering Industry, 1830-1914', in Charles F. Sabel and Jonathan Zeitlin (eds), World of Possibilities: Flexibility and Mass Production in Western Industrialization, Cambridge, 1997, p.242. Also, K.R. Gilbert, The Portsmouth Block-Making Machinery, London, 1965, and K.R. Gilbert, 'The Control of Machine Tools - A Historical Survey', Transactions of the Newcomen Society, Vol.XLIV, 1971-72, p.121.
[2] Gillian Cookson, 'Family Firms and Business Networks: Textile Engineering in Yorkshire, 1780-1830', Business History, Vol.39, No.1, 1997, p.4.

Locomotive manufacturing was developed by the capital machinery industry, whose craft skills were readily adapted to the new requirements. Following the practice of that industry, each locomotive was, at first, individually made with its own uniquely-fitted components. The industry quickly learned the benefits of multiple, standardised component production but, from the 1840s, was confronted with the conflicting aspirations of volume production and design proliferation, which reduced the opportunities for heavy and volume production practices to converge.

In spite of the promotion of standard designs by the larger manufacturers in the 1840s, the subsequent loss of design initiative and the resulting proliferation of designs (Section 4.7), reduced batch sizes and increased production costs. The strategic and tactical issues addressed by the proprietors to reconcile these pressures, whilst accommodating the developing material and design technologies, forms the theme for this chapter. This consideration includes the cyclical variations in the locomotive market, which encouraged most firms to maintain an involvement in other forms of capital equipment, in order to provide a more consistent level of work for their men and machines (Section 7.5).

The introduction of a common locomotive design in the 1830s saw the industry pioneer the use of arrangement and manufacturing drawings, with which to ensure consistency of component manufacture. The introduction of this discipline removed an important responsibility from the craftsmen, and thus became, itself, a significant part of the industry's movement away from craft-dependency. Within twenty years, however, with responsibility for design being passed to railway and consulting engineer drawing offices (Section 4.5), the main-line locomotive sector was largely converted into a contract manufacturing business. All design work for the industrial sector, however, and detailing work for overseas main-line orders remained with the manufacturers.

The strategic decisions taken by the proprietors included consideration of what facilities to provide for in-house component production and what components to buy-in from sub-contractors. The growth of the specialist sub-contracting industries was, itself, an important part of the development of the locomotive industry, which did much to answer the need for economies in multiple production. Although this marked the interface between the volume and capital goods industries, the manufacturers moved, in part, to take over some of the volume production work, and thus diversify their activities away from being wholly capital-goods based.

The provision of specified raw materials, in sufficient quantities and at minimum unit costs, required daily negotiation and tactical decision-making by the proprietors or their managers. As the industry got under way, its material requirements created new supply industries, whilst from the 1860s, the gradual change to steel supplies required close co-operation between the industry and the steel suppliers. Although British railways and consulting engineers on behalf of overseas railways took over the responsibility for material development and specification, the manufacturers' retained the freedom to negotiate satisfactory supply arrangements, the economies of scale of their purchasing power being reflected in their tender quotations.

The development of capital equipment, particularly of machine tools, had far-reaching effects on locomotive manufacture during the century, that took it from a wholly craft-based industry to one with the potential for substantial cost benefits from standard component production. Self-acting machine tool development was motivated by a shortage of skilled craftsmen, which increasingly allowed the employment of un-skilled men. Many of the manufacturers were, themselves, pioneers in the development of the self-acting tools, forging and casting equipment and, throughout the 19th century, several firms developed more sophisticated tools to meet their specialised requirements.

There were between 5,000 and 6,000 components in a steam locomotive,[3] with several opportunities for volume production of standard and interchangeable components. The industry well understood the economies from batch processing but, against the background

[3] Diane K. Drummond, Crewe Railway Town, Company and People 1840-1914, Aldershot, 1995, p.105, and John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, p.173.

of design proliferation, such opportunities depended upon railways conceding the use of standard components. The development of British railways' drawing offices, with their own intra-standardisation policies, together with the influence on overseas locomotive design exercised by consulting engineers, suppressed interchangeability opportunities and challenged manufacturers' freedom to pursue production economies.

Brown writes that, in common with Britain's railways, the American locomotive industry was similarly customer-driven in terms of its design requirements but, in contrast, the Baldwin Locomotive Works succeeded in accommodating the volume production of interchangeable components with this design proliferation.[4] Comparing British and American practice will therefore help to understand the causes of the limited volume production of standard components by Britain's manufacturers.

Production capacity was a strategic judgement for the manufacturers, for whom investment in workshops and capital equipment had to balance both a predicted locomotive market share and a share in other product markets. Consideration of this judgement is discussed in Section 7.5. The cyclical demand swings, however, with some extraordinary year on year changes (Fig.1), gave rise to short-term capacity shortages and surpluses. These reflected directly on manning requirements and profitability, requiring difficult tactical decisions by the manufacturers, whose options including short-term investment in, or leasing of new production facilities, sub-contracting locomotive orders and diversification into and out of alternative markets.

The transformation from craft to multiple production took place in different ways and at different rates, leading to a growing divergence between the manufacturers and a 'two-speed' industry by the last quarter of the century. This divergence was a key distinction between 'progressive' manufacturers, which invested more in capital equipment to provide batch production economies, and pursued the largest orders at more competitive prices, and 'craft'

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[4] Brown, *ibid*, p.xxviii

manufacturers which pursued small batch orders using their craft-based skills and equipment. The divergence related as much to labour policies as to capital investment and business strategy, as discussed further in Chapter 6.

5.2 Manufacturing Drawings

The introduction and development of drawing techniques were essential steps towards systematic design and manufacturing progression. The manufacturers embarked on this strategy both as a means to accelerate the preparation of locomotive arrangements, formerly the empirical pursuit of the millwrights, and as a means of co-ordinating and directing design strategies that had hitherto been fragmented. The evolution of manufacturing drawings, however, gave production economies through the introduction of standard components, with the potential for interchangeability. This evolution, which took away from the millwrights the discretion for component formation, became a significant part of the manufacturers' strategy to reduce dependency on the craft skills, motivated by their shortage and lengthy apprenticeship.

The first requirement in the development of standard components was the progression from arrangement drawings to component manufacturing drawings. Although Robert Stephenson & Co. had introduced arrangement drawings in 1828 (Section 4.2), the millwrights, pattern-makers and fitters, who made the first locomotives, applied their craft skills without working drawings. This practice prevailed for several years with a number of early firms, and a former employee of R.&W.Hawthorn recalled the method used as late as 1845:[5]

> On ordinary foolscap sheets the work to be done was calculated and the size of boilers required, diameters of cylinders and length of stroke stated. The parts were sketched by hand alongside the calculations in sufficient detail to enable the millwright or pattern-maker to lay them down full size and to make the pattern for the founder. Copies of every part were hand sketched and afterwards the sheets were stitched together........

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[5] J.F. Clarke, Power on Land & Sea, Newcastle upon Tyne, nd but 1979, p.14.

From the 1840s, the introduction of standard designs and components, using templates and gauges (Section 5.6), imposed upon the craftsmen the discipline of standard parts production based on dimensioned, working drawings. The preparation of these drawings and workshop tracings, became an important part of the manufacturing process, for which teams of draughtsmen developed a new design craft. This was in marked contrast to American locomotive building which lagged well behind British practice. Through to the early 1850s, each of Baldwin's locomotives: "was constructed without much reference to those which were built before or those which would come after it. Complete drawings were almost unknown."[6]

As locomotive design work for Britain's larger main-line railways was increasingly taken over by their own drawing offices (Section 4.5), more detailed arrangement and component drawings were supplied to the manufacturers, whose draughtsmen were eventually limited to preparing tracings for workshop use.[7] Consulting engineers representing overseas railways and, towards the end of the century, locomotive superintendents of the larger colonial railways, usually supplied only arrangement drawings to the manufacturers with their invitations to tender. Once a contract was awarded, working drawings were prepared by the manufacturers' draughtsmen, with the option of using existing templates and gauges, as far as could be accommodated by the design. These drawings were submitted for approval before moving to the detailing and tracing work.[8]

5.3 Bought-In Components

The economics of component provision were important strategic considerations for the locomotive manufacturers. Before committing major investment in specific workshops for

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[6] Obituary of Charles T. Parry, Report of the Proceedings of the Twentieth Annual Convention of the American Railway Master Mechanics Association, Chicago, 1887, p.200, quoted in Brown, *op cit* (3), p.170.
[7] The introduction of women tracers was begun by Dübs & Co. in the 1860s. Michael S. Moss and John R. Hume, Workshop of the British Empire, London, 1977, p.46.
[8] Douglas Gordon, 'The Building of a Locomotive', The Railway Magazine, Vol.IX, 1901, p.113.

component production, they considered the benefits of buying them, in a finished or semi-finished state, from specialist sub-contractors. Decisions to invest in foundries, forges, non-ferrous shops and boiler shops depended on their several heavy engineering markets, and not just on potential locomotive business (Section 7.6). Although they undertook all smith, fitting and erecting work, large components could either be made in the factory or bought-in, depending on the facilities available. Whilst most manufacturers had boiler shops, for example, some smaller firms found it more cost-effective to contract their boiler-making out to other firms.

In the early 1830s, Robert Stephenson & Co. bought-in boilers from the Bedlington Iron Co. to supplement those made in-house.[9] This overcame a shortage of boiler-makers (Section 6.3.1), but may also have been seen by the Bedlington Manager, Michael Longridge, as a form of forward integration with the Stephenson Company, of which he was also a partner. Later in the century, Andrew Barclay & Sons had bought-in all its boilers before investing in boiler-making facilities.[10]

As specifications by railways and consulting engineers became more detailed during the century, they increasingly determined which components and raw materials were to be sub-contracted, together with their suppliers. By the 1860s, these included proprietary components, such as safety-valve spring-balances or injectors, to be bought-in from a patentee or licensee. Buying-in large quantities of components and materials required manufacturers to have a good working relationship with suppliers, as prices depended upon the wider number of orders and their consequent negotiating strength. By the 1880s, locomotives could require, typically, 32 separate orders for components and raw materials bought in from 16 different suppliers and sub-contractors.[11]

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[9] Michael R. Bailey, Robert Stephenson & Co. 1823-1836, unpublished MA thesis, University of Newcastle upon Tyne, 1984, pp.296/7. Also, letter, Harris Dickinson (for R. Stephenson & Co.) to Edward Pease, Newcastle upon Tyne, 10 mo.21.1830, Pease-Stephenson Collection, Durham County Record Office, Darlington Public Library, Ref. D/PS/2/52.
[10] Moss and Hume, *op cit* (7), p.77.
[11] Analysis of Order E515, of Neilson & Co., February 1880, in Fittings and Materials Order Book, Vol.17, Neilson & Co. Collection, Business Records Centre, University of Glasgow, Ref. UGD10/3/1.

5.3.1 Iron Castings

The employment of ferrous foundries depended on the volume of casting work to meet overall market requirements, but evidence is lacking regarding a throughput threshold above which it was profitable to establish a foundry. At the start of its business in 1823, Robert Stephenson & Co.'s factory was located adjacent to the Burrell foundry, of which George Stephenson was a partner, and from which it would obtain its castings.[12] As early as 1824, however, there was frustration with this arrangement and the partners minuted:[13]

> It appearing to this meeting that we labour under considerable disadvantages in not being able to found our own Cylinders & other cast metal articles, it is resolved, that an adjacent piece of ground, about 1800 square yards.... be purchased.... to erect a foundry upon..... It is contemplated that this extension of our works, may involve a Capital equal but not exceeding the sum already invested in our Engine manufactory.

Following the foundry's opening, George Stephenson resigned from his Burrell partnership.[14] In spite of the foundry undertaking substantial quantities of track and other general castings, its profitability was evidently marginal, and, following a drop in locomotive orders in 1832, the partners decided: "That the Foundry shall immediately be given up, & the castings in future purchased from [various] Founders."[15] The run-down and write-off of stock led to a loss of over £2200, and the utensils were sold to the Burrell Foundry, from whom the Stephenson Company obtained most of its castings for the next 30 years.[16] Only after taking over the Burrell site in the 1860s, did the Stephenson Company again undertake its own casting.

Although most locomotive manufacturers went on to install their own foundries, and several adopted the name 'Foundry' rather than 'Works' as if to emphasise its provision, others continued through the century to buy-in their castings. The Hunslet Engine Company, for

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[12] Bailey, *op cit* (9), p.17.
[13] Minute Book of R. Stephenson & Co., 1823 - 1848, Science Museum Collection, Ref. 1947/134, pp.19/20.
[14] Advertisement, Newcastle Chronicle, 15th October 1825.
[15] Stephenson Co. Minute Book, *op cit* (13), p.35, 20 Oct 1832.
[16] Foundry Account and Balance Sheet, R. Stephenson & Co., March 30th 1833, Pease-Stephenson Collection, *op cit* (9).

example, initially bought-in its castings from its adjacent competitor, Manning Wardle & Co.[17] The unusually close co-operation of the two firms probably arose from the close family ties between their respective managers, but later in the century the arrangement ended and Hunslets obtained its castings from elsewhere.

5.3.2 Iron Forgings

Heavy forgings were beyond the capability of the first manufacturers, and had to be obtained from specialist ironworks. Locomotive axles, in particular, were supplied by ironworks equipped with water-driven, and later steam-driven helve-hammers, which were also used for other large marine and colliery forgings, such as ships' anchors and wagon axles. The Bedlington Iron Company was the first supplier of locomotive axles to Robert Stephenson & Co. from the 1820s, and later to R.&W. Hawthorn and Timothy Hackworth. The demanding strength and reliability requirements of main-line axles took some time to fulfil.[18] After initial problems with some of the Liverpool & Manchester Railway wagon tyres, which had been rolled and forge-welded at Bedlington, George Stephenson wrote to Michael Longridge that the tyres were:[19]

> scarcely at all welded. This says very ill for your Blacksmith's work and alarms me very much about the axletrees; For, should one of them break you are quite aware how serious an accident it would be. It is the cranked axletrees of the Engines to which I allude. The axletrees should all be numbered at your Works, and the name of the Maker inserted in a book.

The several crank-axle failures in the earliest years of main-line operation (Section 4.2) imposed upon the Bedlington Company the need to improve iron quality and forging methods. It required improvements in axle design, better forging and the use of 'best-quality' scrap iron to produce the most robust axles.[20] As the demand for locomotive axles grew in

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17 L.T.C. Rolt, A Hunslet Hundred, Dawlish, 1964, pp.32/38.
18 Report by Thomas Davison, 'Description and Valuation of Bedlington Ironworks in the County of Durham and Northumberland', quoted in Evan Martin, Bedlington Iron & Engine Works 1736-1867, Newcastle upon Tyne, 1974, p.35.
19 Letter George Stephenson to Michael Longridge, Liverpool, Oct.11th 1830, Phillimore Collection, Institution of Mechanical Engineers Library.
20 Description of The Patent Locomotive Steam Engine of Messrs. Robert Stephenson and Co., London, 1838, p.35.

the 1830s and 1840s, ironworks in Yorkshire, Staffordshire, South Wales and elsewhere equipped themselves accordingly. The Brunswick Iron Works near Wednesbury patented and made locomotive axles by forging "central and radial bars together, at a single heat, their hardness, tenacity, safety, and durability are incomparably greater than those produced by the old process."[21]

Other forgings were also provided by the ironworks and forwarded to the manufacturers for machining. Recalling his time at Bedlington, Robert Rennie wrote:[22]

> I had worked at the little forge, or water wheel, as it was called, before going to the big forge. We made all the small forgings for locomotives, such as straight axles, large and small links, double eyes, motion bars, connecting rods, cross-heads and piston rods.

The invention of the steam-hammer by James Nasmyth was a major technical advance, which considerably reduced forging time and cost following its introduction in the mid-1840s.[23] It became cost-effective for manufacturers to undertake their own forging and, from the late 1840s, they invested in steam hammers and took on teams of forgemen (Section 5.5.2), correspondingly reducing their intake of forgings from the ironworks.

5.3.3 Steel Forgings and Castings

Crucible steel springs and keys, introduced during Robert Stephenson's development programme in 1828 (Section 4.2), were bought-in from specialist craftsmen. Laminated steel springs for horse-drawn carriages had developed from c1770, and the spring-making techniques were 'coveted' by the spring-makers.[24] The Newcastle firm of French & Donnison supplied the earliest parts to the Stephenson Company, although other craftsmen later

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[21] Article, Railway Times, Vol.I, August 4th 1838, p.413.
[22] Letter, Robert Rennie, Weekly Chronicle, 24th October 1908, with description of crank-axle making in 1848.
[23] Samuel Smiles (ed), James Nasmyth Engineer, An Autobiography, London, 1883, pp.239-251. Also J.A. Cantrell, James Nasmyth and the Bridgewater Foundry, Manchester, 1984, Chapter VI, pp.134-180.
[24] Gordon S. Cantle, 'The Steel Spring Suspensions of Horse Drawn Carriages (Circa 1760 to 1900)', Transactions of the Newcomen Society, Vol.50, 1978-9, p.25.

supplied boiler-tube ferrules, springs and keys.[25] Most manufacturers had insufficient volume of business to employ their own spring-makers, and specialist firms usually supplied locomotive and rolling stock manufacturers. Thomas Turton & Sons of Sheffield became a major supplier, although in 1848 it appeared to employ only few craftsmen when it apologised to Jones & Potts for a delayed delivery: "which has arisen from the circumstance of our foreman having been the subject of a severe attack of the prevailing [un-readable] as well as one of the others of our best workmen in this department of our business."[26]

As specifications became more detailed, railways set down particular manufacturers from whom springs should be obtained. In the 1870s, for example, Hudswell Clark & Rodgers made industrial locomotives with springs from "the best Sheffield spring makers".[27] In 1880, the South Eastern Railway specified springs from Charles Cammell & Co., Thomas Turton & Sons or John Spencer & Sons, which allowed manufacturers to negotiate prices, obtaining scale economies through combination of orders.[28]

The first manufacturers to buy-in Krupp's cast crucible steel tyres (Section 4.4) included Robert Stephenson & Co. which fitted them to a Great Eastern Railway locomotive exhibited at the London International Exhibition. Naylor & Vickers of Sheffield began supplying cast steel tyres in 1859, and other companies followed. From 1864, rolled Bessemer steel tyres were introduced by George & Co. of Rotherham, but with on-going reliability problems, some railways and consulting engineers preferred high-quality cast-steel tyres. The Patent Shaft and Axletree Company of Wednesbury was still supplying cast tyres at the end of the century.[29] The high cost of tyres led larger railway companies to purchase them directly and make them available to the manufacturers for fitting. The annual tyre requirements for a fleet

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[25] Bailey, *op cit* (9), Appendix IX.

[26] Letter, Thomas Turton & Sons, Sheffield, to Messrs. Jones & Potts, Oct. 19 1848, Library of the Institution of Mechanical Engineers, Ref. IMS 246/7.

[27] Ronald N.Redman, The Railway Foundry Leeds 1839-1969, Norwich, 1972, p.38.

[28] Specification of a 4-wheel Coupled Bogie Tank Engine, South Eastern Railway, Ashford, Oct.18 1880, PRO, Rail 635/230.

[29] Anon, 'A Modern Forge of Vulcan', The Railway Magazine, Vol.II, January-June 1898, pp.171-178.

of locomotives became so large that the railways' own purchasing power could lead to significant price reductions.[30]

Although other steel castings were also bought in, the hesitant introduction of cast steel generally for locomotive components (Section 4.4) gave no incentive to the manufacturers to invest in their own steel foundries. Even with the introduction of cast steel wheels after 1884, the manufacturers bought them in from specified foundries in Sheffield and elsewhere.[31] Only in 1899, did Beyer Peacock & Co. become the first independent manufacturer to establish a steel foundry, over 30 years after the LNWR's pioneering plant at Crewe Works.[32]

The introduction of forged Bessemer steel for axles and motion parts in 1866 (Section 4.4) saw the sourcing of axles return to outside suppliers, beginning with Naylor & Vickers. Cost comparison between bought-in steel axles and in-house forged wrought iron axles initially gave only limited incentive to the introduction of the former. In spite of their high first cost, some railways and consulting engineers became keen on the strength and long-life advantages of steel axles. In 1872, for example, the Midland Railway specified steel crank-axles from Taylor & Co. of Leeds for a batch of forty locomotives to be built by Dübs & Co.[33]

5.3.4 Non-Ferrous Components

In its earliest years of trading, Robert Stephenson & Co. bought in brass, bronze and gun-metal castings for axle and motion bearings, and boiler fittings. More than £3000-worth of castings were acquired in the eight years to 1831, prompting the company to establish its own brass foundry the following year.[34] As locomotive production increased, the volume of

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[30] For example, Specification of Ten Tank Engines for the South Eastern Railway, 9th February 1864, PRO, Rail 635/225.
[31] E.L. Ahrons, The British Steam Railway Locomotive 1825-1925, London, 1927, p.286.
[32] R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982, p.80. Also, Drummond, *op cit* (3), p.48.
[33] Engineering, Vol.XIII, January 26th 1872, p.63.
[34] Bailey, *op cit* (9), Appendix IX

brass, bronze and gun-metal castings and other non-ferrous formations that was required, persuaded manufacturers to establish their own brass foundries.

Boiler tubes were a major requirement for the locomotive industry. Initially, copper and wrought iron tubes were formed in the manufacturers' workshops using sheet materials,[35] but from 1834, sheet brass tubes were introduced, the formation and soldering of which was a repetitive, mass-production activity.[36] As boilers became larger and locomotive orders increased, the Birmingham copper and brass industry was encouraged by the manufacturers to develop its brass-rolling and tube-making skills by diversifying into locomotive tube manufacture, and reduce unit costs.[37]

Seamed and soldered tubes with flanged ends were produced from 1834/5, whilst the first seamless, brass tubes were made in Birmingham by Charles Green in 1838. To ensure accuracy of dimension for its boiler tubes, Nasmyths Gaskell & Co. sent a template to the Cheadle Copper & Brass Co., near Birmingham:[38]

> through which you will please to pass the Locomotive tubes which we lately ordered & they must be made so close to the gauge that one cannot rattle them upon it.

By 1860, 4,500 tons a year of seamless tubes were being made in Birmingham for the locomotive industry.[39] One of the largest manufacturers was Thomas Bolton & Sons who made tubes in their Birmingham premises until 1858, when manufacture was transferred to Oakamoor in Staffordshire. Recent archaeology has shown that Boltons' close neighbours in Birmingham, John Wilkes & Co. supplied boiler tubes to Neilson & Co. in 1857.[40]

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[35] *ibid*, pp 289/290.
[36] Patent Locomotive, *op cit* (20), p.10.
[37] John Morton, Thomas Bolton & Sons Ltd. 1783-1983, Ashbourne, 1983, p.35.
[38] Copy letter, Nasmyths Gaskell & Co. to the Cheadle Copper & Brass Co., Patricroft, 13 December 1838, Letter Book 3, p.351, Nasmyth Collection, Eccles Central Area Library.
[39] Samuel Timmins (ed), Birmingham and the Midland Hardware District, 1866, quoted in Morton, *op cit* (37), p.35.
[40] Tubes from ship-wrecked Neilson-built locomotives recovered during 'Operation Iron Horse' project off the coast of Islay, Scotland in 1980's. Now retained in the National Railway Museum, York.

Early locomotive specifications left the manufacturers to negotiate for tube supplies. In 1852, a Midland Railway specification merely stated that the tubes should be: "Brass, about 200 in number and 2 inches diameter, No 10 Wire Guage [sic] at the Fire Box end, and No 13 Wire Guage [sic] at the Smoke Box end......."[41] However, in the fast-expanding boiler-tube market, copper producers approached railway companies directly to negotiate supply arrangements. In 1860, the Midland Railway received a "letter from the Broughton Copper Company Manchester asking to be allowed to supply Tubes for the Engines Messrs. Fairbairn & Co. are building for this Company." The company resolved "That this request cannot be complied with."[42] Railways later provided a list of approved tube suppliers with whom the manufacturers were to negotiate. The South Eastern Railway, for example, stated that:[43]

> The tubes shall be of brass solid drawn, made by Allen, Everitt & Sons, [John] Wilkes [& Co.], Mapplebeck & Co., the Broughton Copper Co., or the Birmingham Battery Co......

Brass safety-valve spring-balances were adopted from the 1830s, for which the manufacturers turned to the makers of industrial spring weighing balances. George Salter & Co. of West Bromwich, manufacturers of springs and weighing machines since the 1770s, supplied the earliest spring-balances, and developed a succession of designs, including patented features, in step with boiler developments. The patent 'Salter' spring-balance was the most widely used type on British made locomotives.[44]

'Clock-face' boiler-pressure gauges were patented and introduced in 1847 by S.Smith of Nottingham, with the public endorsement of George Stephenson.[45] A more successful clock-face gauge was patented in 1849 by Eugène Bourdon of Paris, manufacture in Britain

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[41] Midland Railway, Specification for Goods Engines and Tenders inserted in the Minutes of the Locomotive Committee, 3rd February 1852, PRO, Rail 491/168.
[42] Midland Railway, Minutes of the Locomotive Committee, 20th March 1860, PRO Rail 491/170.
[43] South Eastern Railway, Specification of a 4-Wheeled Coupled Bogie Tank Engine, Oct 18 1880, PRO, Rail 635/230.
[44] Patent Specification 7724, July 9th 1838.
[45] Open letter by George Stephenson, Chesterfield, Oct 15th 1847, published in "the daily papers", quoted in Samuel Smiles, The Life of George Stephenson, London, 1857, pp.449-450, and subsequent editions.

being licensed to Charles Dewrance.[46] Whilst other manufacturers, also supplied to the manufacturers, the 'Bourdon' gauge became the most widely used, and was often specified by railway companies.[47]

Other patented components specified by railway companies and engineering consultants, included injectors, introduced in 1860 and manufactured by Sharp Stewart & Co., licencees to Henri Giffard, with subsequent competition from Gresham & Craven and Davies & Metcalf (Section 4.6).[48] Manufacturers of proprietary continuous brake equipment were the Westinghouse Brake Company, established in 1881 (Section 4.6),[49] and Gresham & Craven, licensees of the Vacuum Brake Company's equipment.[50] Proprietary steam sanding apparatus was also fitted.

The component supply industry was, therefore, an integral part of locomotive production, and an important consideration for manufacturers' investment strategies. Although cost studies of component supply were undertaken from time to time, there is no evidence that they formed part of business plans considering investment in workshops and capital equipment (Section 7.6). From the 1830s, however, the volume supply of interchangeable, mass-produced components, such as boiler-tubes and springs, was a clear recognition of the economies of scale that could be achieved from specialist suppliers. This example of volume component production supplying to a capital equipment industry highlights the distinction between the heavy and light manufacturing sectors that was omitted by Chandler in his consideration of the 'American' system of manufacture (Section 1.7).

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[46] Patent No. 12,889, enrolled in UK on December 15th 1849, quoted in Zerah Colburn, Locomotive Engineering and the Mechanism of Railways, London, 2 Vols., p.79.
[47] For example, South Eastern Railway, Specification of a 4-Wheeled Coupled Bogie Tank Engine, Oct 18 1880, PRO, Rail 635/230.
[48] Article, 'Messrs. Gresham and Craven's Works', The Railway Magazine, Vol.I, July-December 1897, pp.252-255.
[49] Article, 'The Westinghouse Brake', The Railway Magazine, Vol.I, July-December 1897, pp.362-369.
[50] Article, 'The Vacuum Automatic Bake', The Railway Magazine, Vol.XII, January-June 1903, pp.104/5.

5.4 Raw Material Supply

The locomotive industry created new demand patterns for raw materials, both in terms of innovation in the first years of production (Section 4.2) and the gradual introduction of steel later in the century (Section 4.4), and in terms of fluctuating supply requirements. Negotiations for the provision of adequate supplies of specified materials, in line with market fluctuations, at prices that would allow profitable fulfilment of orders, was a major, on-going tactical decision-making requirement for the manufacturers.

From the 1850s, as responsibility for specification and design passed increasingly to the railways, supply fragmentation reduced opportunities for predicting long-term material requirements and, correspondingly, the opportunity for negotiating the best unit prices. The problem was compounded not only by the unpredictability of the locomotive market, but also by the movement of raw material prices, reflecting the nation's wider economic health. In particular, was the manufacturers' need to balance the acquisition of materials at prices anticipated when locomotive contracts were signed, against the working capital requirements for lengthy material stock-holding (Section 7.3). By 1880, locomotive manufacture required, typically, twelve types of materials of differing specifications, from five different suppliers.[51]

5.4.1 Rolled Iron and Steel

The introduction of main-line locomotives in the 1830s, increased the demand for wrought iron plate for boilers, frames and tanks, the suppliers for which diversified from other markets. In addition to its forged components (Section 5.3.2), Robert Stephenson & Co.'s initial requirements for wrought iron plate, bar and sections were all met by the Bedlington Iron Company. From its origins as a nail-making centre, the ironworks had expanded in the early 19th century, under its manager, Michael Longridge, into an iron-rolling site.[52]

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[51] Analysis of Order E515, of Neilson & Co., February 1880, in Fittings and Materials Order Book, Vol.17, Neilson & Co. Collection, *op cit* (11), Ref. UGD10/3/1.

[52] C. Evans, 'Manufacturing Iron in the North-East During the Eighteenth Century: The Case of Bedlington', Northern History, Vol.28, 1992, pp.178-196. Also Martin, *op cit* (18).

Although there was no formal business link between the two companies, Longridge's partnership with the Stephenson Company suggests an early form of forward integration, through which he could justify his dual role to the ironworks' owners, Gordon & Biddulph of London.

Bedlington's earliest endeavours with boiler plate were not wholly successful however, as its quality and thickness often varied beyond acceptable tolerance, and from 1829 the Stephenson Company began to supplement supplies with Staffordshire and Yorkshire plate.[53] Although specific evidence is lacking, it would seem that the loss of most of the Stephenson iron business from the mid-1830s prompted Longridge to establish R.B.Longridge & Co., which began locomotive production in 1837. As this company was supplied with iron from the adjacent Bedlington Ironworks, which in 1839 could roll 10,000 tons of bar and boiler-plate, it was a closer form of forward integration than the Stephenson Company arrangement had been.[54]

"Best Yorkshire Iron" was established as the best quality for boiler-plate, the first use of which was in 1830, when the Stephenson Company's Head Clerk wrote: "I have ordered a lot of Plates from Low Moor, & have seen two gentlemen from that concern to-day, who promise to do the best they can for us -"[55] Initially, boiler size was limited by the narrowness of the plate that could be rolled,[56] but from 1833, Lowmoor rolled larger plates, allowing larger boilers to be made.[57] Plates were usually sheared to shapes and dimensions supplied by the boiler makers.[58] The tough, low sulphur Lowmoor iron, "The Best Wrought Iron in

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[53] Letter George Stephenson to Robert Stephenson, Liverpool, 8 January 1828, Institution of Mechanical Engineers Library.
[54] Report by Thomas Davison, 'Description and Valuation of Bedlington Ironworks in the County of Durham and Northumberland', quoted in Martin, *op cit* (18), p.35.
[55] Letter, Harris Dickinson (for R. Stephenson & Co.) to Edward Pease, Newcastle Upon Tyne, 10 Mo 21.1830, Pease-Stephenson Collection, *op cit* (9), D/PS/2/52.
[56] R. Stephenson & Co. ledger 1823-1831, *passim*, R. Stephenson & Co. Collection, National Railway Museum archive, York.
[57] Notebook by Christopher Davy, Vol.2, 1836, p.70, privately owned by E. Lomax and quoted with permission, recording details of the Stephenson Company's products as recorded on a visit to the Newcastle factory in 1836.
[58] W.K.V. Gale, The Black Country Iron Industry, London, 1966, p.97.

the World",[59] carried a £5 per ton premium in the middle of the 19th century.[60] Comparable iron, for high-specification components, including boilers, was produced by the adjacent Bowling Ironworks and, from the 1850s, three Leeds firms produced a near comparable quality, the Farnley Iron Co., Monk Bridge Iron Co. and Taylor Bros. & Co.

By the 1860s, railways were specifying short-lists of boiler-plate suppliers, leaving the manufacturers to negotiate prices which would be reflected in their quotations. A Midland Railway specification for tank engines, for example, required: "Boiler barrel, outside firebox and smoke-box plates, also rivets, stays, and hoops, to be of the best Yorkshire iron, of Low Moor, Bowling, Taylor's, Cooper's, or Farnley Iron Company's make."[61] Other iron plate, particularly for frames and for tenders, would be specified of less expensive make, such as (Best) Staffordshire or (B Best) Glasgow make.[62]

Large quantities of wrought iron, rolled to a variety of cross-sections, were the raw material of the smiths, who forged many large and small components from wheels to handles. The iron was usually rolled from scrap iron, but the introduction, in the 1840s, of case-hardening for wearing surfaces such as tyres and slide-bars, determined the use of Low Moor or Bowling iron.[63] Wrought iron tyre bars were rolled straight, in lengths suitable for wheelwrights to form and weld into tyres for differing diameter wheels[64]

Although round iron bars for piston rods were generally converted into blistered steel from the early 1840s,[65] and cast steel motion bars and outside coupling rods were made of Bessemer steel by the 1860s,[66] the switch from wrought iron to steel was slow, determined

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59 Charles Dodsworth, 'The Low Moor Ironworks Bradford', Industrial Archaeology, 1965, pp.122-164.
60 R.A. Mott, 'Dry and Wet Puddling', Transactions of the Newcomen Society, Vol.49, 1977-78, p.157.
61 Advertisement, 'Tank Engines for the Midland Railway', Engineering, Vol.VIII, Oct.8 1869, p.239.
62 For example, Contract between Messrs. Sharp Stewart & Co. and the South Eastern Railway Company for the construction of twelve goods engines, 17th May 1878, PRO, Rail 635/229.
63 John Bourne (ed), A Treatise on the Steam Engine &c., London, 1846, p.227.
64 For example, order placed by Benjamin Hick to the Bowling Iron Works, 25th July 1836, was for "8 Engine tire bars 16.0 ft long for 5.0 wheels", Benjamin Hick Order Book, 1833-1836, Museum of Science & Industry in Manchester Archives.
65 Bourne, *op cit* (63), p.227.
66 Advertisement, *op cit* (61).

largely by the specifications of the railways and consulting engineers, following trials of different grades (Section 4.4). Fig.11 illustrates this slow change by showing the value of materials bought-in by the Vulcan Foundry in the latter part of the century.[67] Not until 1893 was the intake of steel greater than that of wrought iron plate, and there was no perceptible change in the use of bar iron through to the end of the century.

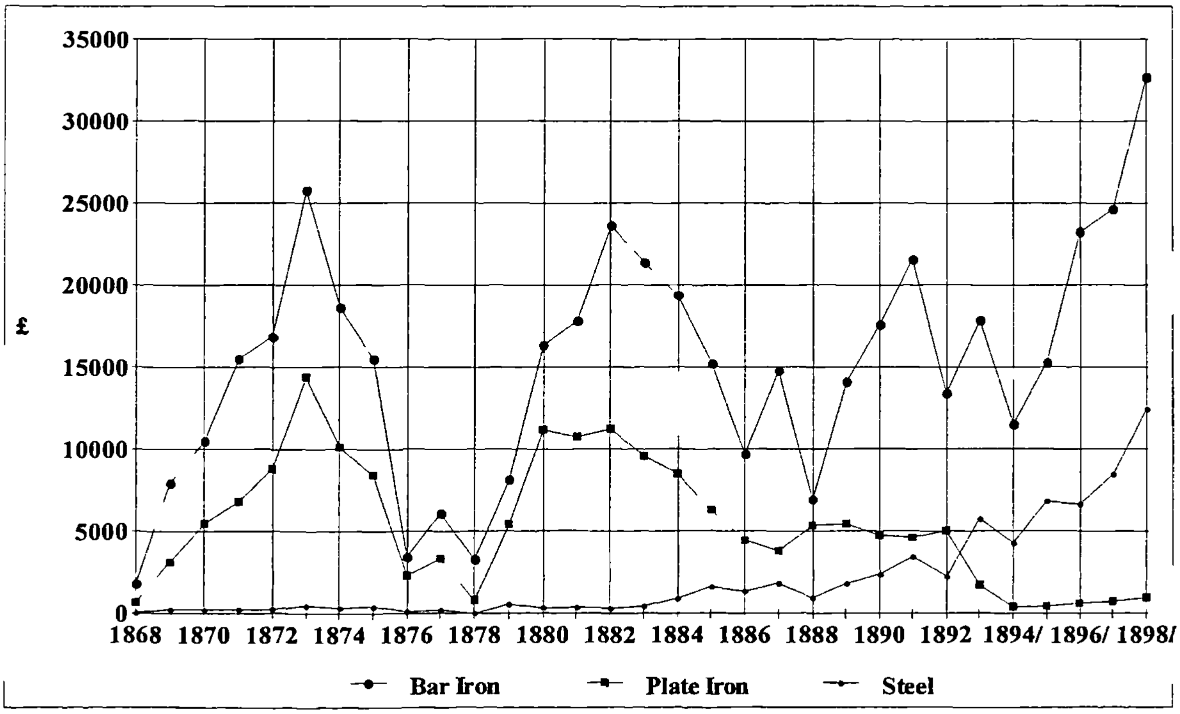

Fig. 11 Vulcan Foundry Quantities of Iron and Steel Used 1868-1899

(Source: Vulcan Foundry Co. Ltd. Ledger and Journal 1864-1900)

5.4.2 Pig Iron

Most locomotive manufacturers had their own foundries and bought-in supplies of several grades of pig iron for their castings. It was a rule in casting engine components, such as cylinders, "that the greater the number of the kinds of iron entering into the composition of any casting, the denser and tougher it will be."[68] Supplies were therefore obtained from

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[67] Ledger, 1864-1889, and Journal, 1864-1900, Vulcan Foundry Co. Ltd. Collection, Archives of the National Museums & Galleries on Merseyside, Refs. 1970/37/4/1 & 1970/37/4/2/1.
[68] Bourne, *op cit* (63), p.227.

several blast furnace companies around the country according to prevailing availability and price of the required grades. During Robert Stephenson & Co.'s brief operation of its foundry to 1832 (Section 5.3.1), it purchased iron from 21 different suppliers and agencies in the West Midlands, Scotland, South Wales, Yorkshire, Tyneside, Bristol, Hull and Liverpool.[69]

5.4.3 Non-Ferrous Materials

Firebox construction, in the early 1830s, created the need for an entirely new copper-plate industry (Section 4.2).[70] Copper producers, such as Thomas Bolton & Sons of Birmingham, developed rolling mills to meet the new demand. With the predominant use of copper for fireboxes and tubeplates throughout the century, in spite of trials with steel plates (Section 4.4), the copper-plate industry grew significantly with several firms participating, especially Boltons, which established large rolling mills in Widnes to supply the locomotive industry.[71]

The manufacturers carried out trials of several copper alloys to provide brass, bronze and gun-metals suitable for locomotive bearings and other wearing surfaces and fittings. There were considerable variations in bearing life between the manufacturers, as much due to surface quality as the varying composition of the metal.[72] The introduction of the harder wearing phosphor-bronze in the 1870s introduced a new chemistry. The Vulcan Foundry, for example, had derived six copper-alloy compositions for phosphor-bronze for different components by 1885.[73]

It is thus apparent that the locomotive industry provided significant benefits to other areas of the country through the economic 'multiplier' effects of raw material supply. New industries were established and existing industries substantially enlarged to meet the expanding

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[69] Bailey, *op cit* (9), Appendix IX.
[70] *ibid*, pp.298-301.
[71] Morton, *op cit* (37), pp.66/7.
[72] Bourne, *op cit* (63), p.227.
[73] Vulcan Foundry Cost Book, 1870-1939, Vulcan Foundry Co. Ltd. Collection, *op cit* (67), Ref. 1970/37/6/3.

requirements of both the independent and railway factories. In the absence of evidence, it is not known how accomplished the suppliers were at dealing with the fluctuating demands, or how adept the manufacturers were at negotiating prices and maintaining adequate supply arrangements. They were, however, fully aware of the prevailing prices of raw materials (Section 7.2), and the larger manufacturers had the opportunity of their greater purchasing power to obtain better unit prices.

5.5 Capital Equipment

Investment in capital equipment allowed the manufacturers to expand both their volume of production and production capability. From its earliest years, the industry was faced with the twin pressures of needing increased production capacity to meet rising demand, and the reducing availability of skilled craftsmen. In its first twenty years, the industry, as part of the wider heavy manufacturing sector, was in the forefront of the design and manufacture of machine tools and other capital equipment, which made possible employment of un-skilled labour (Section 6.3).

From the 1850s, diverging strategies between 'progressive' and 'craft' manufacturers, formed a key theme in the industry's corporate development (Section 1.1). The former were sufficiently encouraged by the long-term market potential to provide improving equipment for multiple locomotive production, whilst the 'craft' manufacturers, maintained a broad manufacturing base, for which the inherent skills of their workforce would continue to use more basic equipment.

Up to the 1820s, progress had been made by manufacturers, such as Henry Maudslay (1771-1831), Joseph Clement (1779-1844) and James Fox (1789-1859), in developing machine tools to undertake basic metal-cutting tasks.[74] Finishing work, as James Nasmyth (1808-

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[74] L.T.C. Rolt, Tools for the Job, London, 1965, Chapter 5, pp.92-121.

1890) noted, was undertaken by hand: "nearly every part of a machine had to be made and finished...... by mere manual labour; that is, on the dexterity of the hand of the workman, and the correctness of his eye, had we entirely to depend for accuracy and precision in the execution of such machinery as was then required."[75]

In 1823, Robert Stephenson & Company's factory was equipped with machine tools and a factory-engine, made by its own millwrights to enhance their craft skills.[76] They began with simple machine tools,[77] but ingenuity was required for certain machining requirements, including crank axles.[78] The rapid expansion of the locomotive market in the early-1830s (Section 2.2) posed extraordinary production problems as, although arrangement drawings were used (Section 4.2), each locomotive was individually made through the millwrights' finishing skills using components which were not necessarily interchangeable.[79] This practice provided opportunity for material and layout improvement trials, and a quick response to component failure problems. Reflecting on his apprenticeship at the Stephenson factory in 1837, Bruce recalled that:[80]

> wheels were driven on to their axles by sledge hammers....... and only hand labour was available for the ordinary work of the smith's shop and boiler yard....... riveting by machinery..... was unknown..... there were shear-legs in the yard, by which a boiler could be lifted on to a truck, and there were portable shear-legs in the shop, by skilful manipulation of which...... wonders were done in the way of transmitting heavy loads from one part of the shop to another.

'Duplicates' of larger components, such as driving wheel sets, were made to suit each locomotive order, but otherwise components that broke in service were not easily replaced, and had to be re-manufactured or replaced by railway maintenance teams.

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75 J. Nasmyth, 'Remarks on the Introduction of the Slide Principle and Machines Employed in the Production of Machinery', in R. Buchanan, Practical Essays on Mill Work, 3rd Ed., revised by G. Rennie, 1841, pp.393-418.

76 Bailey, *op cit* (9), p.31.

77 Michael R. Bailey, 'Robert Stephenson & Co. 1823-1829', Transactions of the Newcomen Society, Vol.50, 1978-79, pp.109-138.

78 Bailey, *op cit* (9), p.306.

79 Bailey, *op cit* (9), Chapters 10 and 11.

80 (Sir) George B. Bruce, Presidential Address, Proceedings of the Institution of Civil Engineers, 8th November 1887.

5.5.1 Self-Acting Machine Tools

In the early 1830s, locomotive manufacturing played as important a part in the development of machine tools, as marine and industrial engines, and textile, paper-making and mining equipment. Nasmyth later wrote that: "Shortly after the opening of the Liverpool & Manchester Railway there was a largely increased demand for machine-making tools. The success of that line led to the construction of other lines concentrating in Manchester; and every branch of manufacture shared in the prosperity of the time."[81]

To overcome the immediate shortage of skilled craftsmen, manufacturing was transformed by the introduction of self-acting and improved machine tools, which could be operated by un-skilled machinists. Manchester manufacturers, notably Richard Roberts (1789-1864), Joseph Whitworth (1803-1887), William Fairbairn (1789-1874) and James Nasmyth were the primary innovators, contributing to both their versatility and standardised use.[82] The slotting machine, in particular, developed by Roberts through Sharp Roberts & Co., reduced considerably millwrights' time on locomotive components.[83] Whitworth noted that the planing machine reduced the labour cost of cast iron surface preparation from twelve shillings per square foot by hand, to just a penny per square foot.[84] Several manufacturers, such as Sharp Roberts & Co. and Nasmyth Gaskell & Co., were also engaged in locomotive manufacture, and were particularly innovative in machine tool development to reduce machining time for locomotive components. In 1840, Nasmyth: "contrived several special machine tools, which assisted us most materially...... to effect the prompt and perfect execution of this order [of twenty locomotives]".[85]

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[81] Smiles, *op cit* (23), p.199.
[82] Rolt, *op cit* (74), Chapter 5, pp.92-121. Also S.B. Hamilton, 'Sixty Glorious Years: The Impact of Engineering on Society in the Reign of Queen Victoria', Transactions of the Newcomen Society, Vol.XXXI, 1957-59, pp.184-187.
[83] W. Steeds, A History of Machine Tools 1700-1910, Oxford, 1969, p.69.
[84] Proceedings of Institution of Mechanical Engineers, 1856, p.130.
[85] Smiles, *op cit* (23), p.238.

Light line-shafting, wheels and belts, powered by a central winding engine, became the usual form of machine-shop power transmission.[86] Because of the risk that engine or boiler breakdown would shut down the machine shop, Nasmyth preferred small steam engines to power individual machine tools,[87] and in 1854, Beyer Peacock & Co. installed wall engines connected directly to shafting.[88] Joseph Beattie (1808-1871), Locomotive Superintendent of the London & South Western Railway patented a wheel lathe, although Sharp Brothers developed an improved version.[89] In 1841 it was officially acknowledged that the rapid development of machine tools had: "introduced a revolution in machinery, and tool-making has become a distinct branch of machines, and a very important trade, although twenty years ago it was scarcely known."[90]

In the economic boom years of the mid-1840s, an independent machine tool industry developed in major manufacturing areas, notably Lancashire and the West Riding of Yorkshire, to meet the requirements of textile, colliery, ship-building and steam engine manufacturers, as well as the locomotive industry. The strong demand for locomotives, in particular, led to: "an increased stimulus to the demand for self-acting machine tools", which arose because the demand for skilled labour was greater than the supply and because of the men's: "exorbitant demands...... irregularity and carelessness."[91] The sudden shortage of skilled labour led to a rise in wages (Section 6.3.2), which: "increased the demand for self-acting tools, by which the employers might increase the productiveness of their factories without having to resort to the costly and untrustworthy method of meeting the demand by increasing the number of their workmen."[92]

Manufacturers introduced machine tools to speed up repetitive machining of standard parts, such as nut-cutting, and nut and bolt-head shaping, which became widely used in locomotive

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86 Rolt, *op cit* (74), p.125. Also Hamilton, *op cit* (82), p.186.
87 Rolt, *ibid*, p.124.
88 Hills and Patrick, *op cit* (32), p.21.
89 Steeds, *op cit* (83), pp.52/3.
90 Select Committee on Exportation of Machinery, Parliamentary Papers, 1841, Vol.VII, Second Report, p.vii.
91 Smiles, *op cit* (23), pp.199/200.
92 *ibid*, p.307.

factories. These included Nasmyth's 'ambidexter' lathe, which machined two identical pieces simultaneously,[93] and the self-acting milling machine.[94] Other milling machines, including several types by Sharp Stewart & Co., were produced in the 1850s,[95] and by 1860, they were well established in locomotive factories. Their work time was much reduced from that taken by shapers and planers, which were then freed for more suitable work.[96] Wood-working machine tools were also much improved, including precision tools required for pattern-making. The use of self-acting tools was widespread by 1861, when Fairbairn reflected:[97]

> Now everything is done by machine tools, with a degree of accuracy which the unaided hand could never accomplish....... For many of these improvements in 'self-acting' machine tools, the country is indebted to the genius of our townsmen, Mr. Richard Roberts and Mr. Joseph Whitworth.

Table 3 provides a good indication of the machine tools necessary for the production of locomotives and other steam engines and machinery provided by three factory inventories from about 1860.

	E.B. Wilson & Co.	R. & W. Hawthorn	Neilson & Co.
Lathes	66	55	22
Screw-Cutting Lathes	13		2
Planing Machines	32	19	6
Drilling Machines	38	28	?
Boring Mills	5	4	?
Shaping Machines	13	5	6
Slotting Machines	20	?	5
Screwing Machines	8	?	?
Cutting Machines	7	?	?
Nut Milling Machine	None	?	1

Table 3 Examples of Machine Tools In Use c1860[98]

93 Rolt, *op cit* (74), p.112.
94 Ian Bradley, A History of Machine Tools, Hemel Hempstead, 1972, pp.65/6.
95 For example the double-spindle milling machine patented by Sharp Stewart & Co., in Proceedings of the Institution of Mechanical Engineers, 1856.
96 Steeds, *op cit* (83), p.75.
97 William Fairbairn, Presidential Address, 1861, Report of the British Association, 1862, pp.lxiii - lxiv.
98 Analysis of Sale Catalogue of E.B. Wilson & Co., commenced 15th day of August 1859, Hardwicks & Best, Auctioneers, Leeds, Auctioneers' copy in private possession and quoted by permission. Also, for R.&W. Hawthorn, The Artizan, October 1863, quoted in Clarke, *op cit* (5), p.14. Also, for Neilson & Co., John Thomas, The Springburn Story, Dawlish, 1964, pp.88/9, inventory for the firm's move to Springburn in 1861.

At the time of its closure in 1857 (Section 7.5.3), E.B.Wilson was one of the three biggest locomotive manufacturers (possibly the largest), together with Sharp Stewart & Co. and Robert Stephenson & Co. All three, however, were much engaged with other production, and the equipment reflects their overall manufacturing requirements.

In contrast to the extraordinary mechanisation in Britain, the American locomotive industry had advanced slowly, and was under-capitalised by comparison. In 1850 for example, Baldwins still required "the hand skills and muscle power of its workers" aided by basic machine tools.[99] With the rapid expansion of the American machine tool industry from the 1860s, however, Baldwins were thoroughly re-equipped to overcome its shortage of labour. The accent was largely on multiplication of basic equipment rather than on innovative ways of achieving self-acting operations. The tools therefore still required "substantial skill from their operations to achieve acceptable work".[100]

Until the 1860s, the commonly-used 'spear-headed' carbon-steel drills wore out quickly and lost precision. In 1862, the American tool-maker, Brown & Sharpe, developed its 'Universal' milling machine for milling flutes for the production of longer-life twist drills. They were exhibited at the International Paris Exhibition in 1867 where they caused a "sensation", and were soon adopted throughout Britain.[101]

5.5.2 Other Capital Equipment

Labour shortages in other crafts, notably boiler-making, and the requirement for greater precision, also led to significant developments in other forms of capital equipment. During the 1830s, boiler-plate preparation was made easier and more accurate by improvements to shearing, punching and plate-bending machines.[102] One of Sharp Roberts & Co.'s shearing

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[99] Brown, *op cit* (3), pp.167/9.
[100] *ibid.*
[101] Steeds, *op cit* (83), p.102.
[102] For example, R. Buchanan, *op cit* (75), Plates XLVIII, XLIX and L and pp.459-462.

machines could "cut in two, iron plates five inches broad and five-quarters thick, as if they had been as soft as butter."[103]

Boiler plates were first hand-riveted but, in 1838, William Fairbairn patented his steam-riveting machine, allowing boiler-making to be speeded up and more accurately assembled, and with which he claimed a typical boiler barrel could be assembled and riveted in four hours, a fifth of the hand-riveting time.[104] Some companies bought in ready-made rivets, but most rivet iron was supplied in long bars and cut to required lengths.[105] Riveting was further speeded up in 1865, when Ralph Tweddell introduced hydraulic machines, the portable version of which, from 1871, could be moved around boiler shops.[106] The LNWR's Crewe Works were equipped with Tweddell machines in 1875 and later on the larger independent manufacturers, such as Beyer Peacock & Co., were also so equipped.[107]

The early shear-legs lifting equipment generally gave way to pillar cranes, but, when John Bodmer (1786-1864) set up his factory in Manchester in the 1840s, he installed: "small overhead travelling cranes, fitted with pulley blocks, for the purpose of enabling the workmen more economically and conveniently to set the articles to be operated upon in the lathes, and to remove them after being finished."[108] E.B.Wilson & Co. had five overhead cranes by 1857, possibly installed during its major expansion of 1847,[109] and Beyer Peacock & Co. had three or four by 1860.[110] Neilson & Co. appears to have been the first manufacturer to install a traverser, with which to transfer locomotives from one shop to another, when its new factory was opened in 1862.[111]

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103 W.H. Chaloner, 'New Light on Richard Roberts, textile engineer (1789-1864)', Transactions of the Newcomen Society, Vol.XLI, 1968-69, p.43.
104 William Pole (ed), The Life of Sir William Fairbairn, Bart., London, 1877, pp.163/4. Also advertisement, Railway Times, Vol.I, October 13th 1838, p.601.
105 Letter J. Laird (for the Patent Rivet Co.) to Messrs. Jones & Co., Liverpool, Nov.22 1839, Library of the Institution of Mechanical Engineers, Ref. IMS 245/4.
106 Wilfred Lineham, A Text-Book of Mechanical Engineering, London, 1902, pp.313-318.
107 Hills and Patrick, *op cit* (32), p.110.
108 Rolt, *op cit* (74), p.126.
109 E.B. Wilson & Co. Sale Catalogue, *op cit* (98).
110 Hills and Patrick, *op cit* (32), p.23.
111 Moss and Hume, *op cit* (7), p.45.

A significant advance in the safety and economy of volume casting was made with the 'screw safety ladle' in 1838, developed by James Nasmyth, who used the equipment for his early locomotive castings. Other foundries quickly adopted the improvement with warm appreciation to him, and he was awarded a silver medal by the Society of Arts of Scotland.[112] The introduction of steam-hammers, following Nasmyth's patent of 1843, was particularly important for the locomotive industry, as manufacturers were able to undertake their own axle and motion forgings, as well as work for their other markets (Section 5.3.2). Not only had they much work for the hammers, they also used up scrap iron recovered from other components. Several steam-hammers made by Nasmyths Gaskell & Co. were bought by locomotive factories, including Sharp Brothers and E.B.Wilson, before the patent expired in 1856.[113]

Thereafter, locomotive manufacturers, such as Kitson & Co. and Hudswell & Clarke, themselves began to compete in the steam-hammer market.[114] Beyer Peacock & Co. began making small steam-hammers for light forging work, and by 1860, the company was using three for motion forging: "the cost was about £175 exclusive of the anvil."[115] Locomotive crank-shafts were forged from 'faggoted' scrap iron, particularly plate shearings, which Peacock claimed was not only an economic use of scrap, but such axles would last longer than other materials.[116]

Nasmyth first manufactured and sold hydraulic presses for pressing wheels onto axles in 1839, an activity formerly undertaken by manual hammer blows.[117] Other manufacturers, including E.B.Wilson & Co. and Beyer Peacock & Co., were using them by the mid-1850s,[118]

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112 Cantrell, *op cit* (23), pp.123/4.
113 J.A. Cantrell, 'James Nasmyth and the Steam Hammer', Transactions of the Newcomen Society, Vol.56, 1984-85, pp.133/165.
114 Redman, *op cit* (27), pp.24/5.
115 Richard Peacock of Manchester, 'Description of a Steam Hammer for Light Forgings', Proceedings of the Institution of Mechanical Engineers, 1860, pp.284-292.
116 Richard Peacock in discussion following paper by W.L.E.McLean, 'On The Forging Of Crank Shafts', Proceedings of the Institution of Mechanical Engineers, 1879, pp.461-483.
117 Cantrell, *op cit* (23), pp.75/6.
118 Hills and Patrick, *op cit* (32), p.21.

by which date hydraulic power was also used for jacks and cranes.[119] By the late 1870s, hand-flanging of firebox and boiler plates in the larger factories was replaced by hydraulic presses, using cast iron "bending blocks",[120] a 300-ton version being used by Beyer Peacock & Co. by the end of the century.[121] Some presses were made by the manufacturers themselves, including Andrew Barclay Sons & Co. which installed one when equipping its own boiler shop at the end of the century.[122]

An indication of the capital equipment (other than machine tools) necessary for the production of locomotives and other steam engines and machinery in about 1860, is provided by the three factory inventories shown in Table 4:

	E.B. Wilson & Co.	R. & W. Hawthorn	Neilson & Co.
Boiler & Tender Shops			
Punching Machines Shearing Machines	6	7 3	None
Plate-Bending Machines	2	3	None
Rivetting Machines	2	1	None
Wheel Shop			
Hydraulic Presses	1	2	None
Forge			
Steam Hammers	5	2	3
Cranes			
Overhead Travelling	5		
Other Travelling	12	23	?
Pillar Cranes	41		

Table 4 Examples of Other Capital Equipment In Use c1860[123]

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119 Ian McNeil, 'Hydraulic Power Transmission: The First 350 Years', Transactions of the Newcomen Society, Vol.47, 1974-1976, p.153.
120 Neilson & Co. Fittings and Materials Book, Vol.17, 1880, Neilson & Co. Collection, *op cit* (11).
121 Hills and Patrick, *op cit* (32), p.109.
122 Moss and Hume, *op cit* (7), p.56.
123 Analysis of E.B.Wilson & Co. Sale Catalogue, *op cit* (98). Also, for R.&W. Hawthorn, The Artizan, October 1863, quoted in Clarke, *op cit* (5), p.14. Also, for Neilson & Co., Thomas, *op cit* (98), pp.88/9, inventory for the firm's move to Springburn in 1861.

R.&W. Hawthorn was much involved with marine and stationary engine manufacture, as well as locomotives, as reflected by its boiler-making equipment. Neilson & Co. obtained its boilers from its nearby sister company in Glasgow.

5.5.3 Steel Machining and Specialisation

The introduction of steel from the 1860s required the locomotive industry to invest in new equipment, some of it developed by the manufacturers themselves, and to employ men with the requisite skills. Henry Bessemer's Sheffield works produced "high class tool steels", which were, at first, only made available to a few Lancashire machine tool makers, but these included Beyer Peacock & Co., and Sharp Stewart & Co., said to indicate Bessemer's high opinion of them.[124]

In the second half of the century, improvements were made to each type of machine tool, which reduced set-up and operating time, and accommodated more demanding tasks, including steel machining. Specialised machine tools, including larger driving-wheel and crank-shaft lathes,[125] were developed by the manufacturers themselves, particularly Beyer Peacock & Co., Sharp Stewart & Co. and Neilson & Co. The introduction of rolled steel plate for locomotive frames in 1867 (Section 4.4) required a combination drilling, slotting and planing machine, the first example of which was developed by Sharp Stewart & Co., and soon adopted by other manufacturers.[126] Improvements continued and in 1872 Fairbairn, Kennedy & Naylor, machine tool makers of Leeds, developed a slotting machine "to dispose of frames 33 feet long at one setting."[127]

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124 W.M. Lord, 'The Development of the Bessemer Process in Lancashire, 1856-1900', Transactions of the Newcomen Society, Vol.XXV, 1945-1947, p.170.
125 For example Beyer Peacock & Co. installed a 7ft wheel lathe in 1854, Hills and Patrick, *op cit* (32), p.23 & 111; and a Whitworth lathe supplied to Brassey, Peto & Betts could also turn a 7ft wheel, John Millar, William Heap and His Company 1866, Hoylake, 1976, p.46.
126 Engineer, 9th August 1867. Also Steeds, *op cit* (83), p.135.
127 Engineering, Vol.XIII, January 19th 1872, p.49.

Craft manufacturers which had not proceeded with machine tool development, such as Robert Stephenson & Co., were obliged to buy-in the few examples of capital equipment that they did acquire. In 1869, when the company's Head Foreman, George Crow, developed and patented a radial drilling machine with a 'Universal' table, he entered into a 'sole' licensing arrangement for its manufacture and sale with Fairbairn, Kennedy & Naylor.[128] The Stephenson Company also developed an hydraulic locomotive weighing machine in 1886.[129]

In the last three decades of the century, the independent and railway factories developed several specialist machine tools, suitable only for locomotive purposes, and reflecting the more demanding design characteristics initiated by railway companies. Significant advancements were made at Crewe Works and in 1873 Sharp Stewart & Co. exhibited, at the Vienna International Exhibition, an example of Francis Webb's patented 'curvilinear' machine for machining the insides of driving wheel rims.[130] Sharp Stewart & Co., Beyer Peacock & Co. and Neilson Reid & Co. were all prominent in the development, patenting and manufacture of machine tools for larger pieces, that accomplished more complicated machining with greater precision, and minimised manual finishing requirements. They were developed to increase productivity by reducing the need for multiple machining.[131]

By the end of the century, the progressive manufacturers, including Neilson & Co., introduced further machine tools, such as capstan and turret lathes, which were designed to divert further work away from skilled craftsmen, and to increase the proportion of their unskilled labour. Although no details have been ascertained regarding the extent of unskilled machining, the policy did allow Neilsons much more flexibility in employment with which to cope with the fluctuating locomotive demand in the 1890s. Its unskilled labour was hired and discharged according to demand, which served to protect continuity of employment for

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128 Engineering, Vol.VIII, December 17th 1869, pp.402/4.
129 The Railway Engineer, Vol.VII, 1886, p.332.
130 Engineering, Vol.XVII, January 9th 1874, p.30. Also, Brian Reed, Crewe Locomotive Works and its Men, Newton Abbot, 1982, pp.77-79.
131 Engineering, Vol.XVI, October 3rd 1873, p.268 and October 31st 1873, p.351; Engineering, Vol.XIX, June 11th 1875, pp.483/4; Hills and Patrick, *op cit* (32), pp.55-81 *passim*. Also, Steeds, *op cit* (83), pp.91 & 111. Peacock's Patent No.696 of 1887. Steeds, *ibid*, p.155. Engineer, 21st August 1896.

its craftsmen (Section 6.3). The extent of the policy is demonstrated by its workforce total, which from a low of 1500 in 1894, had more than doubled by the end of the century when demand was high (Section 2.8).[132]

In comparison, investment in machine tools by the American manufacturers was much more intense. By re-investing profits, the Baldwin Locomotive Works reordered its production processes with a new generation of machine tools, the value of its fixed capital increasing from $2.8 million in 1880 to $5.7 million in 1890.[133] Between 1882 and 1891, the firm took out fourteen patents related to mechanisation. Learning from the 'American System' of volume production, the radical changes prompted Charles Fitch to say about the American locomotive industry in the mid-1880s: "As the conditions of fire-arms manufacture introduced the interchangeable system and improved machinery into a great range of small manufactures, the conditions of locomotive building are exercising a like influence in the introduction of uniform and labor-saving methods in the manufacture of marine engines and other heavy work."[134]

As part of its mechanisation, Baldwins adopted electric drive motors from 1890, for overhead travelling cranes in its erecting shop.[135] In 1893, it applied electric power to its wheel-shop and, encouraged by 50% savings in power costs, it proceeded "headlong" into electric drive for machine tools and cranes. Brown argues that desperation drove the company into electrification, the increase in productivity allowing it to keep up with the demand in product size and quantity.[136] The larger British locomotive manufacturers also began a programme of workshop electrification at the end of the century. Beyer Peacock &

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132 Reports by Neilson & Co. to the Locomotive Manufacturers Association 1890-1900, LMA Minute Book No.1, National Railway Museum archive.
133 Brown, *op cit* (3), p.187.
134 Charles H. Fitch, 'Report on the Manufactures of Interchangeable Mechanism, in US Department of the Interior, Census Office', Tenth Census of the United States, 1880, Vol.2, Report on the Manufactures of the United States, Washington DC, 1883, pp.58-59; quoted in Brown, *ibid*, p.187.
135 Brown, *ibid*, pp.191/2.
136 Brown, *ibid*, p.196.

Co. made an electrically driven wheel lathe in 1899, and its works were fully electrified by 1904.[137]

It is thus evident that the manufacturers played a pivotal role in the development of machine tools and other capital equipment until the 1850s, and that through their further involvement with machine tool design and construction, the progressive manufacturers continued to demonstrate their ingenuity until the end of the century. The locomotive industry benefited directly from this ingenuity, which significantly reduced component production time and allowed more ambitious tasks to be undertaken by the increasing proportion of un-skilled labour, and which overcame the shortage of craftsmen.

The continuing ingenuity with capital equipment provides evidence of the ways in which the manufacturers fulfilled the proliferation of manufacturing processes that Drummond has drawn attention to in relation to the railway workshops (Section 1.7). There is no evidence of particular manufacturers having 'railway-specific' capital equipment or being favoured by main-line railways for having particular machine tools or skills, when contracts were awarded. The tendering system encouraged multiple tenders from ten or more firms (Section 3.2.1), all of whom would have had the necessary equipment or skills, albeit with varying levels of productivity, reflected in the tender quotation.

Comparison between the progressive manufacturers and the Baldwin Locomotive Works from the 1880s, demonstrates the extent to which economies of scale benefited the latter. It not only had a much larger domestic, and later foreign market, it also pursued a programme of component standardisation which significantly increased the opportunities for larger batch production (Section 5.6). The proliferation of designs, and the consequential lack of standardisation (Section 4.7) denied the British industry this opportunity, and the limitations of the potential market dissuaded the manufacturers from the level of investment embarked on by the Baldwin company.

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137 Hills and Patrick, *op cit* (32), pp.81/105.

5.6 Standardisation

Standardisation of components lay at the heart of the comparison between small batch and mass production, and thus between the heavy manufacturing industry and 'American system' industry. Continuous production of standard components allowed machine tools to remain set up for common machining, increasing output by both machines and machinists, whilst saving time on re-setting for other components. There was, thus, incentive for manufacturers, which sought to specialise in locomotive production, to promote standard components and fittings as far as possible, adopting a range of templates and gauges to ensure interchangeability.

5.6.1 Templates and Gauges

The individuality of early locomotives gave much concern to railways, as incompatible components made maintenance difficult and expensive. Standardisation, which Richard Roberts had begun in the 1820s using his self-acting machine tools for manufacturing textile machines, was later applied to locomotive manufacture.[138] Rolt believed that Roberts was the first to achieve, to a limited extent, standardisation of locomotive components.[139] Smiles referred to Roberts' "system of templates and gauges, by means of which every part of an engine or tender corresponded with that of every other engine or tender of the same class".[140] James Nasmyth also introduced gauges for locomotive manufacture in 1838, confirmed by his order for boiler tubes (Section 5.3.4).

Gauges and templates helped maintain the level of precision necessary for the interchangeability of parts between locomotives of the same class. Tool-settings and components were frequently checked against the gauges, and adjustments for wear made as

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138 H.W. Dickinson, 'Richard Roberts, his Life and Inventions', Transactions of the Newcomen Society, Vol.XXV, 1945-1947, p.127.
139 Rolt, *op cit* (74), p.107.
140 Samuel Smiles, Industrial Biography, 1863, p.271. Also Engineer, 13th February 1863 ascribed the use of standard gauges to Roberts as being employed for all the work on his self-acting mules and locomotives.

necessary. As manufacturers took up their use, each made its own 'standard' and interchangeable components. With their limited manufacturing capacity, however, and the prospects of long delivery times for large orders, railways spread their contracts over several manufacturers (Section 3.6.5). The separate standards of each manufacturer therefore limited component interchangeability, and overall standardisation soon became the railways' major aim.

The first design to be accompanied by working drawings and templates, in pursuit of component interchangeability, was prepared by the Great Western Railway for its *Firefly* class in 1840 (Section 4.7). Daniel Gooch, the railway's Locomotive Superintendent recorded: "when I had completed the drawings I had them lithographed and specifications printed, with iron templates for those parts it was essential should be interchangeable, and these were supplied to the various engine builders with whom contracts were placed."[141]

5.6.2 Standard Threads

Particular inconvenience for all types of machinery, including locomotives, was occasioned by the incompatibility of bolt and nut sizes and their screw threads. Accurate screw-cutting and uniformity of thread had been first undertaken by Maudslay in the 1810s,[142] and Roberts, who improved precision from 1821.[143] However, new manufacturers began making screw-cutting machines with their own threads and bolt sizes, further negating component interchangeability. In 1841, the problem was highlighted by Joseph Whitworth:[144]

> Great inconvenience is found to arise from the variety of threads adopted by different manufacturers. The general provision for repairs is rendered at once expensive and imperfect...... This evil would be completely obviated by

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141 Daniel Gooch diary (1839), quoted in Cdr. John Mosse, 'The *Firefly* Locomotive of 1839', Transactions of the Newcomen Society, Vol.62, 1990-91, p.101.
142 Prof. F.T. Evans, 'The Maudslay Touch: Henry Maudslay, Product of the Past and Maker of the Future', Transactions of the Newcomen Society, Vol.66, 1994-95, pp.157/8. Also Randall C. Brooks, 'Towards the Perfect Screw Thread: the Making of Precision Screws in the 17th-19th Centuries', Transactions of the Newcomen Society, Vol.64, 1992-93, pp.107/8.
143 Dickinson, *op cit* (138), pp.125/6.
144 Joseph Whitworth, 'On an Uniform System of Screw Threads', Proceedings of the Institution of Civil Engineers, 1841, pp.157-160.

> uniformity of system, the thread becoming constant for a given diameter. The same principle would supersede the costly variety of screwing apparatus required in many establishments, and remove the confusion and delay occasioned thereby. It would also prevent the waste of nuts and bolts..... It does not appear that any combined effort has been hitherto made to attain this object. As yet there is no recognized standard.

Although several other Manchester manufacturers, notably Roberts, Nasmyth and Bodmer, had advocated standard threads, it was only through Whitworth's strong advocacy, and the size and success of his own machine tool factory, that his standard 'Whitworth' threads were put into effect. The standards were soon adopted by most railways which specified for their locomotives: "All bolts and studs to be screwed and chased to Whitworth's thread", or similar.[145]

It is surprising that the immediate benefits of standard sizes for bolts, nuts and threads were not equally quickly taken up by American industry. However, it was to be another 20 years, in 1864, before such standards were proposed in Philadelphia. Baldwins lent their weight to the proposal, which went on to become America's national standard.[146]

5.6.3 Interchangeability

Larger manufacturers, such as Sharp Brothers, extended their range of interchangeable components during the 1840s. Following its major factory extension in 1847, E.B.Wilson & Co. standardised its components, and charged a premium for alterations (Section 4.7).[147] However, as Zeitlin has noted in respect of the Nasmyth factory, customers for large capital equipment insisted on designs tailored to their specific requirements.[148] From the 1850s, intra-standardisation of components led the larger railways to provide manufacturing drawings in order that components from their workshops and from the manufacturers were interchangeable. Standards varied between railways, however, as locomotive superintendents pursued their individual design programmes. Although they had a frequent

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145 Specification of Tank Engines for the South Eastern Railway, 9th February 1864, PRO, Rail 635/225.
146 Brown, *op cit* (3), p.183.
147 Redman, *op cit* (27), p.12.
148 Zeitlin, *op cit* (1), p.243.

dialogue at meetings of the Institution of Mechanical Engineers, this largely dealt with design principles, materials, production methods and locomotive performance, whilst standardisation of components was ignored.[149]

Manufacturers pursued standard components for overseas railways as far as they could, within the constraints of designs specified by consulting engineers (Section 4.7). As detailing work and production of working drawings was largely left to the manufacturers' own drawing offices, they could pursue limited standardisation, sometimes providing distinctive component characteristics.[150]

The industrial locomotive market provided good opportunity for interchangeable components. The standard designs developed by manufacturers, such as Hudswell Clarke & Co. and Manning Wardle & Co. (Section 4.5), meant that significant economies of scale could be achieved for many components, even though customers sought a variety of arrangement variations, including gauge. Such components as pistons and connecting rods, were little changed over many years, allowing the manufacturers to produce batches and stock-pile them for subsequent use, or as part of a spares service. At times of slack demand, whole locomotives could be assembled for 'stock' for quick sale, using these standard components (Section 7.5.3).

In marked contrast to these British approaches to standardisation, the Baldwin company in America made a determined effort from 1855 to move wholly towards standard component production.[151] This was largely achieved by 1865, and by the 1870s the company had carried the principle of interchangeable components "to great lengths".[152] It was then able to offer main line and industrial locomotives with many standard components, whilst accommodating the customised arrangement requirements of the railroad master mechanics. Baldwins were

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149 Proceedings of the Institution of Mechanical Engineers, *passim*.

150 Douglas Gordon, 'The Building of a Locomotive', The Railway Magazine, Vol.IX, July-December 1901, p.115.

151 Brown, *op cit* (3), pp.170-183.

152 *ibid*, pp.164 & 174-183.

able to achieve this because the master mechanics largely lacked the large drawing office teams of British railways, and provided general rather than detailed specifications.

Baldwins thus 'leap-frogged' over the British main-line locomotive manufacturers in terms of standardisation, and achieved volume production of many components, emulating the 'American System' of other industries. Production costs of such common components as piston rods, cross-heads and slide-bars, were substantially reduced. Interchangeability meant that railroad maintenance requirements were also significantly aided through supply of replacement components from Baldwins, and which, in turn, became an important additional business for the manufacturer. By the 1890s, there was a large measure of standardised, interchangeable parts, described as being among the most notable feats of 19th century American industry.[153] Although Baldwins maintained its locomotive prices at 'market' levels, its profitability from batch production of components was so good that it allowed it to maintain a high level of re-investment in capital equipment, through the remainder of the century.

5.7 Production Engineering

The reduction in locomotive manufacturing costs, and the evolution of component size and complexity during the century, was achieved as much through improving production engineering procedures as by the advancements in machine tools and standardisation. The manufacturers pursued strategic policies towards improved factory lay-outs and batch production procedures, having to judge the capacity growth they would require to make provision for expanding demand, whilst also accommodating major fluctuations in workload. The fluctuations in their capacity requirements ranged between insufficient work to keep men and machines employed, to periods of high demand when additional capacity was required to

[153] Brown, *op cit* (3), p.172.

supplement the long hours being worked by an enhanced workforce, to minimise the deterioration of delivery times.

The strategic decisions were thus amongst the most crucial taken by the proprietors in terms of risk through over-capitalisation or under-provision of capacity. Because of the uncertainties of the locomotive market, and the different policies relating to diversification between the progressive and craft firms (Section 7.5), these decisions were taken in relation to alternative market opportunities as well as the potential locomotive business.

The beginning of the 'factory system' in the early 19th century brought with it the recognition that matching production facilities to demand, and maximising the employment of capital equipment to provide a satisfactory return, would require improved production control procedures. From 1823, Robert Stephenson & Co.'s factory undertook the manufacture of one stationary or locomotive engine every two months, before undergoing incremental increases in area and equipment to meet increased demand. Occasional downturns in demand left equipment and manpower under-used, and although capacity was doubled by 1829, the company was cautious about further investment to meet the peak locomotive demand for the Liverpool & Manchester and other railways in 1830/1.[154] It therefore concentrated on locomotive manufacture, which, even with detailed variations, benefited from increased output through batch production. Manufacturing time fell to about four months and production increased to two a month, but demand still exceeded capacity, and three locomotives were sub-contracted to Fenton, Murray & Co., for which arrangement drawings were made available by the Stephenson Company.[155]

From 1834/5, locomotive demand grew substantially, coinciding with the rising demand for machine tools and textile machinery, and by 1840 annual output had increased by more than 500% (Fig.1). Manufacturers such as Roberts and Nasmyth, understood that higher output would be achieved with lower costs, if standard components were 'mass' produced in batches

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[154] Bailey, *op cit* (9), pp.93-100 & 265-275.
[155] *ibid*, p.150.

without re-setting the tools, which Nasmyth defined as "the production of standard interchangeable parts by means of power-driven machine tools".[156] Nasmyth's first catalogues in 1838/9, however, contained no less than 126 entries,[157] which, at best, infers 'batch' production rather than 'mass' production, a distinction endorsed by Cantrell in his evaluation of Nasmyth's output.[158] Nasmyth's order for 20 *Firefly* locomotives from the Great Western Railway in 1840, which was accompanied by drawings and templates (Section 5.6.1), lent itself to batch production with which he was experienced. As Fenton, Murray & Jackson also made 20 *Fireflies*, it may similarly have employed batch production techniques, perhaps learned from its long experience with textile machinery.

5.7.1 Factory Layout

The practice of laying out a factory to minimise component handling and time between production processes was also developed in the 1830s. The earliest example of a planned 'work-flow' lay-out was by Nasmyth for the production of machine tools, and applied to locomotive production (Fig.12).[159] Just prior to his factory's construction in 1836, he proposed that the buildings should be "*all in a line*..... In this way we will be able to keep all in good order."[160] On completion, the factory was described in a small booklet:[161]

> With a view to secure the greatest amount of convenience for the removal of heavy machinery from one department to another, the entire establishment has been laid out with this object in view; and in order to attain it, what may be called the straight line system has been adopted, that is, the various workshops are all in a line, and so placed, that the greater part of the work, as it passes from one end of the foundry to the other, receives in succession, each operation which ought to follow the preceding one, so that little carrying backward and forward, or lifting up and down, is required........ By means of a railroad, laid through as well as all round the shops, any casting, however ponderous or massy, may be removed with the greatest care, rapidity, and

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156 A.E. Musson, 'British Origins', in O. Mayr and R.C. Post (eds), Yankee Enterprise:the Rise of the American System of Manufactures, Washington DC, 1982.
157 Cantrell, *op cit* (23), p.67.
158 *ibid*, p.76.
159 *ibid*, pp.64/5.
160 Letter James Nasmyth to Holbrook Gaskell, 11th July 1836, in possession of the Gaskell family, quoted in A.E.Musson, 'James Nasmyth and the Early Growth of Mechanical Engineering', Economic History Review, Vol.X, 1957-58, p.126.
161 Booklet, Manchester As It Is, 1839, quoted by Musson, *ibid*, p.127.

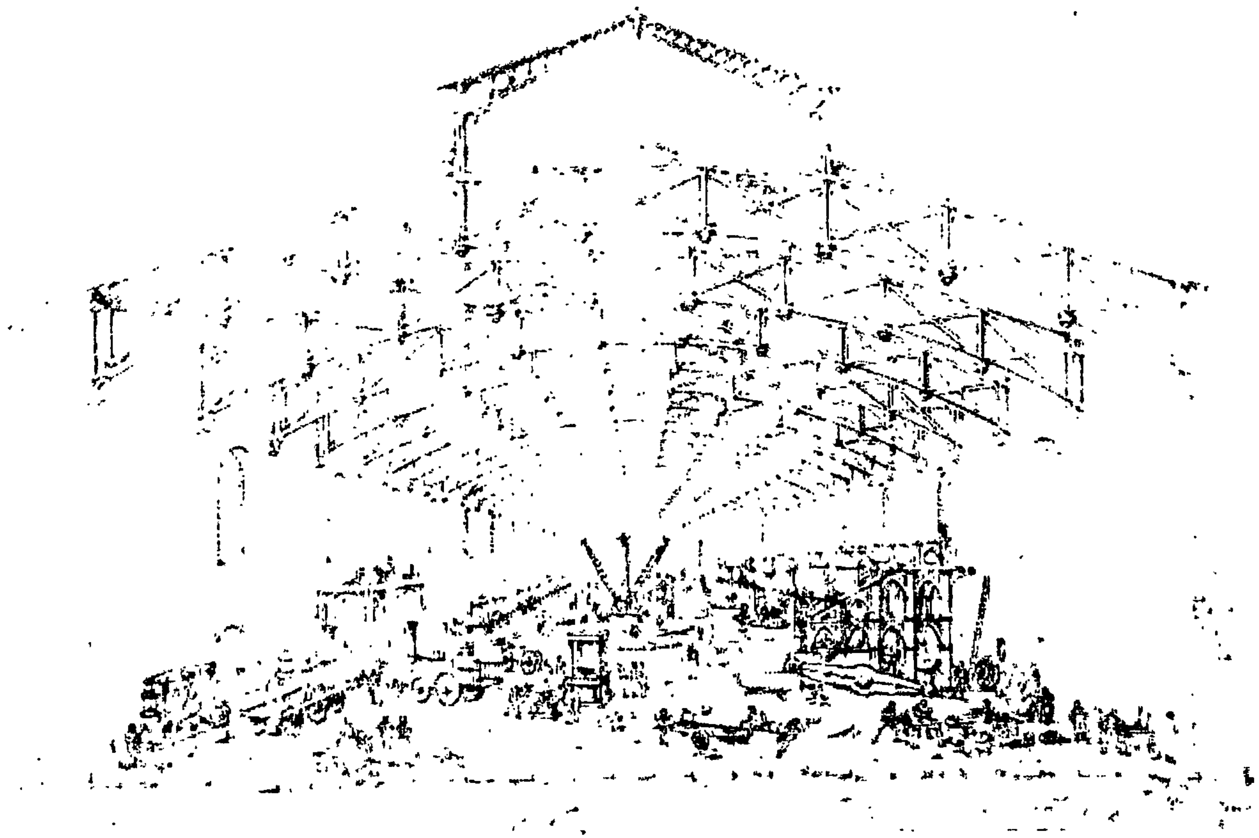

Fig.12 EARLIEST KNOWN ILLUSTRATION OF A LOCOMOTIVE FACTORY
(Bridgewater Foundry, Nasmyths Gaskell & Co., Pencil Drawing by James Nasmyth, December 1840)

(Print Courtesy of the Library of the Institution of Mechanical Engineeers)

> security. The whole of this establishment is divided into departments, over each of which a foreman, or responsible person, is placed, whose duty is not only to see that the men under his superintendence produce good work, but also to endeavour to keep pace with the productive powers of all the other departments. The departments may thus be specified:- The drawing office, where the designs are made out; and the working drawings produced....... Then come the pattern-makers...... next comes the Foundry, and the iron and brass moulders; then the forgers or smiths. The chief part of the produce of the last named pass on to the turners and planers...... Then comes the fitters and filers..... in conjunction with this department is a class of men called erectors, that is, men who put together the framework, and the larger parts of most machines, so that the last two departments..... bring together and give the last touches to the objects produced by all the others.

Although this arrangement was a far-sighted attempt to minimise handling and reduce manufacturing time, it made no provision for expansion, which would have required existing equipment to be moved with additional cost and production loss. Factory layout from the 1840s was generally undertaken on the specialist 'shop' system, which both provided for easy transfer of components between each production process, and allowed for re-arrangement and enlargement with minimal disruption to overall production. Bodmer's factory for building machine tools, textile equipment and locomotives, also employed a work-flow system (Section 5.5.2). It was equipped with an overhead travelling crane, and laid out for sequential machining "according to a carefully-prepared plan"[162]

When Beyer Peacock & Co. established its factory in 1854, it acquired land sufficient for expansion of its manufacturing business. It was laid out both for easy movement of components between shops and for minimal disruption as the site expanded. Its single storey shops were fitted with roof lights to ensure good use of all the working areas, instead of limiting them to side windows as had been the case with earlier factories.[163] The last major new locomotive factory development in the century was the Clyde/Atlas Works in Glasgow, constructed in 1884, which was fully laid out in the shop system (Fig.13).

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162 Rolt, *op cit* (74), p.126.
163 Hills and Patrick, *op cit* (32), pp.15/16.

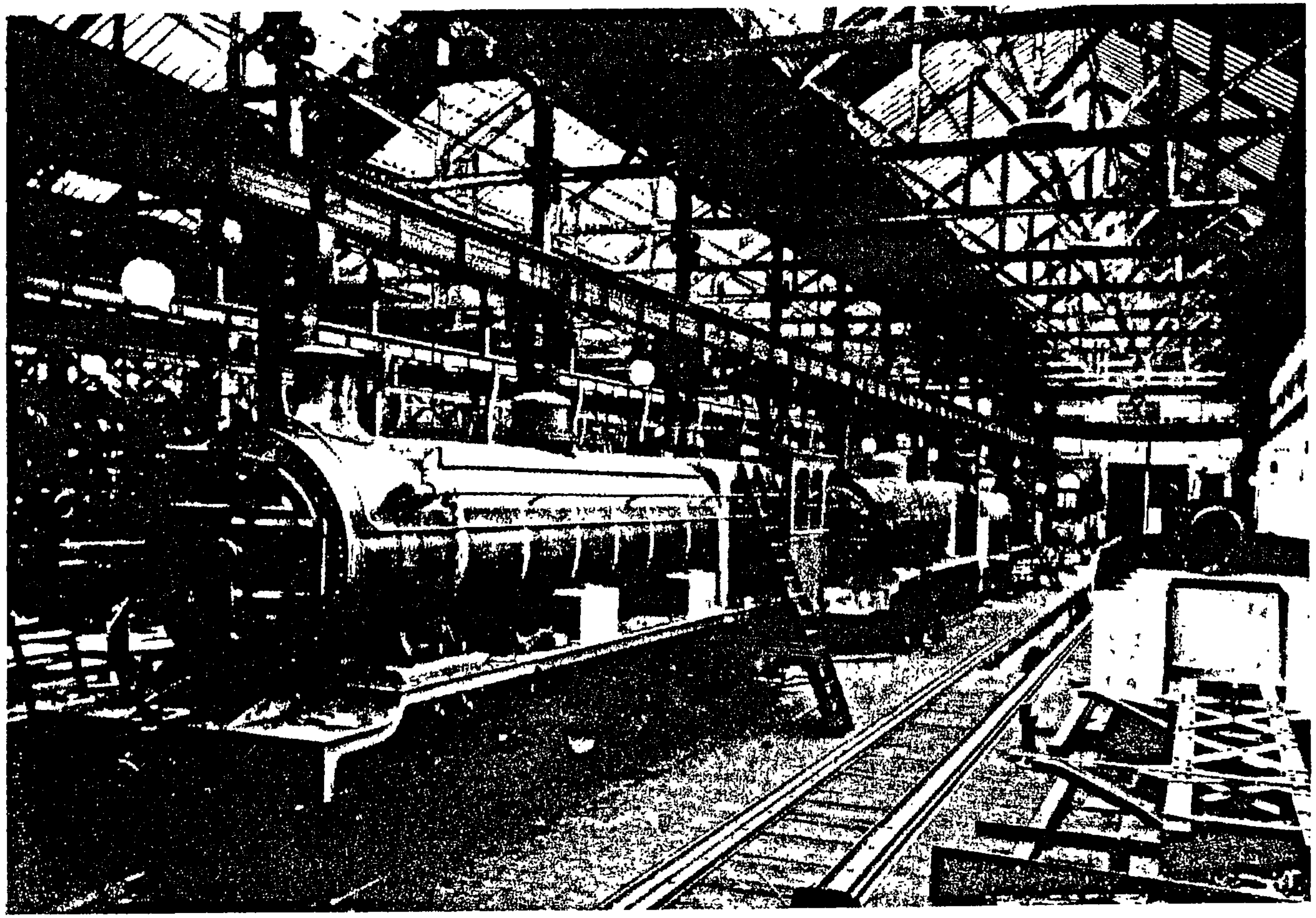

Fig.13 EXAMPLE OF A LOCOMOTIVE ERECTING SHOP AT THE END OF THE 19th CENTURY
(Atlas Works, Glasgow, Sharp Stewart & Co. Ltd.)

(Photograph: Courtesy the Mitchell Library, Glasgow)

5.7.2 Capacity Constraints

Manufacturers faced a critical market when demand rose beyond prevailing capacity, and delivery times lengthened unacceptably. In the extraordinary events of 1844-47 (Section 2.6), delivery times increased to as much as three years. The largest manufacturer, Robert Stephenson & Co., sought to accommodate the demand without risking its longer-term market standing. When it began to experience the surge of orders, it sub-contracted half an order for 30 locomotives for the Marseilles-Avignon Railway to L. Benet of la Ciotat, near Marseilles, which was to supply:[164]

> on the latest and best system for which he had obtained a patent, half of the engines to be built in the works at la Ciotat under his direction and responsibility, and on condition that the engines so built in France may be in all respects equal to those which come from his works at Newcastle.

By November 1844, the Stephenson Company had decided to increase its manufacturing capacity, but, from experience of previous demand surges, it took a seven-year lease on an additional site, half a mile from its main premises. Although this 'West Factory' was equipped with new machine tools requiring additional capital (Section 7.6.2), the lease was not renewed after 1851, due to the much reduced market circumstances of that time. The Stephenson Company was very profitable in the late 1840s and seems fully to have vindicated the decision for the short term lease (Section 7.4.1). There is no evidence that other manufacturers adopted the same strategy, but E.B.Wilson & Co. interpreted the mid-1840s demand as being long-term, and built extensive new erecting shops at its Railway Foundry. The shops were opened with much publicity in December 1847, at the beginning of the sharp decline in orders accompanying the recession (Section 2.6).

In spite of increasing their capacity between 1845 and 1847, the largest manufacturers, particularly Robert Stephenson & Co., were unable to meet the demand without lengthening delivery times. They therefore sub-contracted some orders by forming alliances with other

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164 Rapport à l'Assemblée Générale des Actionnaires de la Cie d'Avignon Marseilles, 29th April 1844, quoted in J.G.H.Warren, A Century of Locomotive Building By Robert Stephenson & Co. 1823-1923, Newcastle upon Tyne, 1923, p.96.

manufacturers, whose reputation was acceptable to the railway customers, but whose longer term interests would not conflict with its own. Nasmyths Gaskell & Co. made 27 patent locomotives, and Jones & Potts also undertook a number of orders, for which the Stephenson Company received its due royalties (Section 4.6).[165] Slaughter & Gruning also sought orders from the Stephenson Company, but was rejected as unsuitable (Section 3.2.1).

At times of slack demand in the 1840s and 1850s, some manufacturers sought continuity of work for their men and equipment by making locomotives for 'stock', in the expectation of finding customers for them at a later date. This was commercially risky because of potential cash-flow problems and the main-line railway practice of specifying precise requirements rather than accepting stock designs (Section 7.5.3).

5.7.3 Batch Production

Improved capital equipment, standardisation of components, and factory lay-out to expedite component production and assembly, were all pursued by the larger manufacturers in the 1840s and 1850s. E.B.Wilson & Co.'s 1847 plant was particularly well equipped and laid out for batch production of standard locomotives at a potential rate of six per month.[166] The new factories built by Peto Brassey & Betts and Beyer Peacock & Co., the first stages of which opened in 1853 and 1854 respectively, were similarly laid out for easy progression of components through specialist shops for their formation and machining processes, sub-assembly and final erection phases.[167]

By the 1860s therefore, there had been a divergence between 'progressive' manufacturers, whose premises were equipped for batch production and ease of work-flow, and 'craft' manufacturers which, although they had partially re-equipped with certain items of capital equipment, still relied on the inherent skills of their workforce, and had limited opportunities

165 Cantrell, *op cit* (23), pp.200/1.
166 Redman, *op cit* (27), p.10.
167 Millar, *op cit* (125), pp.44-46; and Hills and Patrick, *op cit* (32), p.15-24.

for production economies. The latter included the Stephenson and Hawthorn firms, which pursued small batches of marine, factory and colliery engines and other industrial equipment, whilst also pursuing locomotive orders when the market was favourable (Section 7.5.2).

As the 'progressive' manufacturers, such as Neilson & Co. and Dübs & Co., expanded and acquired more specialised machine tools, forging and foundry equipment, the additional expense was further incentive to maximise productive use through the minimisation of tool and work-piece setting up and re-setting time. They were, however, unable to take full advantage of batch production of standard components due to the proliferation of standards of British and overseas railways (Section 5.6.3). With several railways ordering small batches of locomotives, which were not always urgently required, there was little cost advantage for the well equipped firms over the less well equipped. Full benefits of batch production were therefore restricted to the largest locomotive orders, which took advantage of the scale economies of multiple production. Fig.14 illustrates the growth of the largest batches of locomotive orders in the second half of the century:

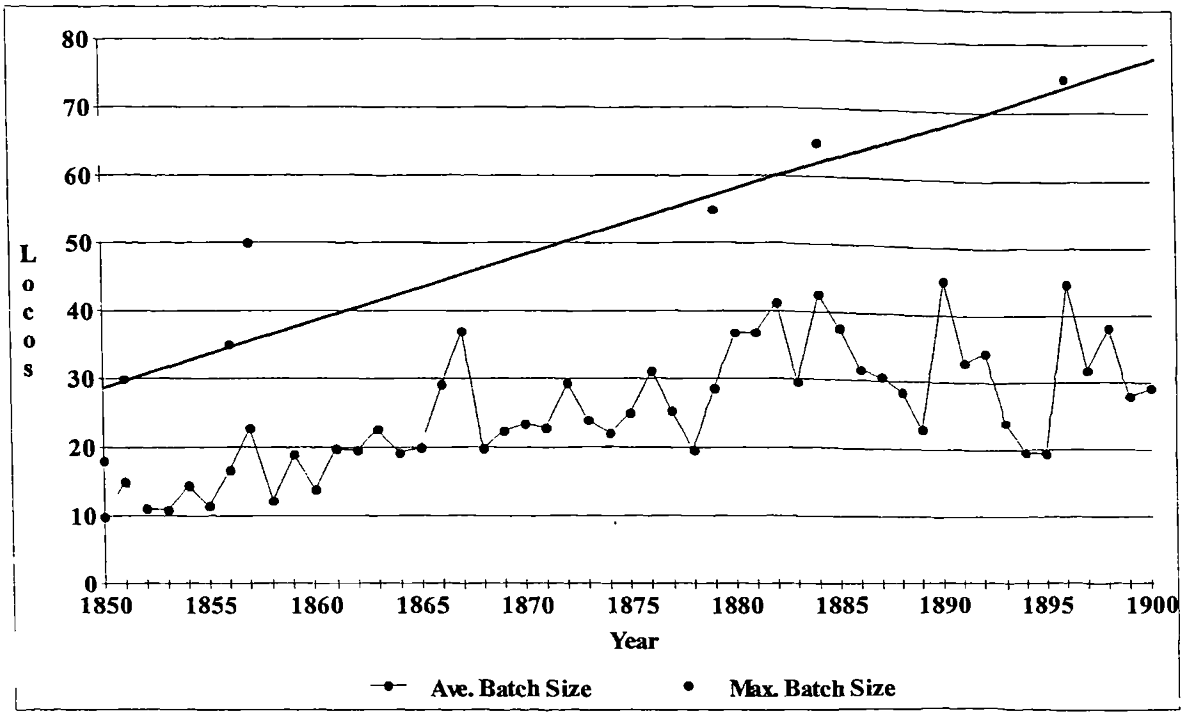

Fig. 14 Growth In Largest Locomotive Batch Size 1850-1900[168]

[168] Analysis of locomotive orders from manufacturers records &c., (Section 2.1).

The average batch for the five largest orders each year grew from 10 in 1850 to 30-40 by the end of the century. The largest orders increased from less than 20 locomotives in 1850 to 75 by the end of the century, which allowed the larger manufacturers to reduce their unit costs. In 1896, for example, Neilson & Co. received an order from the Midland Railway for 75 goods locomotives and tenders at a contract price of £2,200 each. This was won against competing quotations ranging between £2,340 and £2,565.[169]

This slow improvement in productivity was in marked contrast to the American locomotive industry, which capitalised on its manufacture of standard, interchangeable components. By 1865, so soon after the Civil War, it was incorporating "sophisticated adaptations" of New England armoury practice.[170] The drawing office developed 'shop cards' of standard components for use with gauges and templates. Master gauges, kept in a gauge shop, were used each evening to verify working gauges used in production. Each factory shop contained "hundreds of all kinds of standard gauges and templates for boring, turning and planing".[171] By 1881, almost all parts with machined surfaces were "accurately fitted to gauges."[172]

Baldwins' standardisation allowed for good batch production runs with its increasing number of semi-automatic machine tools. Further use was made of this equipment, with increased productivity, when electric lighting was introduced from about 1881, allowing double shifts and round-the-clock operations.[173] Until then, as in the British workshops, all lighting had been by gas, and productivity was poor after dark.[174] British manufacturers did not adopt electric lighting until the introduction of electric power-operated machine tools at the end of

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169 Midland Railway, Minutes of the Locomotive Committee, 3rd January 1896, Minute No.4663, PRO, Rail 491/182. This quotation was, however, subject to the 'cartel' pricing arrangements of the Locomotive Manufacturers Association (Section 3.7), and probably understated the true savings from batch production.
170 Brown, *op cit* (3), p.176.
171 Article, 'The Baldwin Locomotive Works', American Artisan, June 5 1867, pp.482/3, quoted in Brown, *ibid*, p.177.
172 Burnham, Parry, Williams & Co., Illustrated Catalogue of Locomotives, 1881, p.57, quoted in Brown, *ibid*, p.177.
173 Brown, *ibid*, p.189.
174 For example Beyer Peacock & Co. had gas lighting installed in its new factory from 1854. Hills and Patrick, *op cit* (32), p.24.

the century. Although the LNWR's Crewe workshops first used electric powered machine tools in 1890, it did not install a power-house for general electric supply, until 1903.[175] The first independent manufacturer to install, in about the same year, a power-house to supply electric power and lighting, was Beyer Peacock & Co.[176]

5.7.4 Craft Production

In marked contrast to the 'progressive' manufacturers, the 'craft' firms undertook far less re-investment in premises or capital equipment (Section 7.6), and their production costs were higher by comparison with their competitors. Not until the late 1880s did R.&W.Hawthorn Leslie modernise its site. Its Works Manager, William Cross, reported:[177]

> The whole of the erecting shop has been remodelled, the floor lowered, and a proper floor put down, new craneways and powerful power cranes; the roof, which I found in a most dangerous condition, has been almost remade...... The Wheel shop, which was formerly a collection of tumble down sheds, in various stages of dirt and decay has been entirely rebuilt. The boilerpower was formerly so bad, owing chiefly to worn-out boilers, that it was by no means uncommon for the whole place to be laid off for a day or two while they were being timbered up. One new boiler, with one man, now does easily what formerly took five boilers and four men to do with great difficulty..... we now have a (boiler) yard well adapted for the class of work it is intended for, and capable of turning out a very much larger quantity of work than the older one ever could have done.

The 'craft' culture allowed older established firms to continue making locomotives in spite of inadequate equipment. By 1880, Robert Stephenson & Co. was obtaining orders well below its one-time capacity, but, in a buoyant market that year, it obtained an order for 20 locomotives from the Midland Railway. The Railway's inspecting engineer, Robert Weatherburn, later recorded his memories of the Stephenson site in that year:[178]

> .....one of the most striking personalities of the North..... Geordie Crow..... the works manager...... was then a man over sixty years old...... He was at that time, and for years, the most redoubtable mechanic in the north, and such

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175 Drummond, *op cit* (3), p.52.
176 Hills and Patrick, *op cit* (32), p.105.
177 Clarke, *op cit* (5), p.55.
178 Robert Weatherburn, 'Leaves from the Log of a Locomotive Engineer', No.XIX, The Railway Magazine, Vol.34, 1914, pp.294-300.

> men, once met, register an impression that never fades. Responsible, at a time of cutting prices, for the success of works more than half a century old, and destitute of modern machinery, and railway communication, and having to compete with firms equipped with the latest labour-saving tools and machinery, and so planned as to give the most rapid transit incoming and outgoing; yet with this enormous discrepancy...... the firm undertook to build and deliver locomotives to the satisfaction of the Midland Railway Company. Everywhere decrepit old lathes, slotting and drilling machines that no other firm would have harboured, and few would have speculated in except for scrap; yet no finer work ever left a firm than was turned out through the care, aptitude and genius of Geordie Crow...... I always felt as though I was witnessing a last desperate effort against overwhelming odds...... made by one gallant man almost unaided - to regain that which should never have been lost.

In the last 20 years of the 19th century, the 'craft' firms found themselves increasingly uncompetitive in main-line locomotive markets. In the continued absence of major investment, they pursued small-batch manufacture of marine and industrial engines and other machinery, whose complexity benefited from their craft skills (Section 7.5.2), whilst maintaining their locomotive interests through occasional small-batch orders for secondary railway and industrial customers.

5.7.5 The 1890s Demand 'Surge'

With the extraordinary expansion of the British economy in the mid-late 1890s, leading to the unprecedented increase in demand for locomotives, production doubled from a low of 500 main line and industrial locomotives in 1894 to over 1100 in 1899 (Fig.1). The surge in demand was compounded by the 1897/8 seven-month national industrial dispute, which severely disrupted locomotive production (Section 6.5). Although the manufacturers were well used to demand surges, they were quite unable to accommodate the full demand, and delivery times lengthened considerably. With railway workshops at full capacity, large orders were received from the home market to add those from overseas railways. Prices rose and, with the 'progressive' manufacturers working to capacity, orders were obtained by the 'craft' manufacturers, including Robert Stephenson & Co., which won the largest order in 1899, for 40 locomotives for the Midland Railway.[179]

The manufacturers' tactical response to the demand was to use their equipment more intensively, made possible through major recruitment campaigns and multiple shift working. The ten members of the Locomotive Manufacturers Association increased their workforce by two-thirds from 8,250 in 1894 to 13,600 in 1900,[180] but there is no evidence of short-term leasing of additional premises to provide extra manufacturing capacity. The lengthening delivery times caused such frustration amongst some British and overseas railways that some orders were lost to American and German manufacturers (Section 2.5).

5.8 Conclusion

The locomotive firms played a major role in the development of the heavy manufacturing industry in its first 30 years. Together with other 'factory system' industries, they were motivated by a growing and competitive market, and a shortage of skilled craftsmen, to develop new capital equipment and production processes. The investment and technological decisions taken by the manufacturers in those years confirm the benefits of partnership enterprises to use their combined expertise to pursue profitable ventures.

With less than 10 years experience of locomotive manufacture, firms, such as Sharp Roberts & Co. and Nasmyths Gaskell & Co., showed an extraordinary aptitude in developing new capital equipment and production practices which reduced the time and cost of material formation and machining. This aptitude included an understanding of the economic benefits of component standardisation and interchangeability, which they pursued through the introduction of manufacturing drawings, templates and gauges, and took full advantage of

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179 Analysis of locomotive orders from manufacturers records &c., (Section 2.1).
180 Minute Book of the Locomotive Manufacturers Association 1875-1900, Railway Industries Association Collection, National Railway Museum Archive, York.

the introduction of Whitworth's standard screw threads. The industry's requirements for new and larger volumes of raw materials and components, caused major diversification and expansion of the material and component supply industries, especially the iron industries of West Yorkshire and Staffordshire, and the Birmingham copper industry.

From 1860, however, the main-line locomotive industry was constrained from continuing along its evolutionary path from the 'factory system' to the 'American system' of manufacture by means of Chandler's 'second industrial revolution'. To make the transition from a 'heavy' industry, with limited scale and scope opportunities for batch processing, to a 'light' industry, with volume production of common components, would have required very different market opportunities. Design proliferation made such a transition difficult enough, as Brown illustrates in relation to the American industry,[181] but unlike that industry that took the initiative to standardise component production, whilst accommodating design progression from its customers, the British industry was restricted by railway intra-standardisation to small batch sizes with limited scale economies.

As the British main-line locomotive market became fragmented, the manufacturing industry became effectively sub-contractors for the larger railways, whilst retaining only limited detailing discretion for its overseas customers. This fundamental difference between British and American practice was a direct consequence of the growth, both of railway workshops and Britain's consulting engineering profession. Only the slow growth in batch size, particularly from the Indian market, gave any opportunity for the 'progressive' manufacturers to benefit from their investment in improved capital equipment.

Industrial locomotive manufacturers on the other hand, in their very different and more competitive market place, required standard component designs to remain competitive, and came closest to 'American system' manufacture. Firms, such as Hudswell Clarke & Co. and Manning Wardle & Co., had learned the benefits of volume production to produce

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[181] Brown, *op cit* (3), pp.76-85.

competitively priced 'standard' locomotives even allowing for gauge and other specification changes to suit particular requirements.

Differences in interpretation of the long-term growth of the locomotive market, and in strategic investment policies by the manufacturers was a key issue which resulted in the industry's growing divergence between 'progressive' and 'craft' firms (Section 7.6). By the end of the century this had resulted in market diversification and a wide diversity of skills and capital equipment, giving equally wide variations in manufacturing costs and productivity levels. In the 1880s and 1890s, this diversity was partly concealed by the cartel agreements of the ten manufacturers forming the Locomotive Manufacturers Association (Section 3.7). These agreements, which were designed to assist the weaker members of the industry, had the effect of concealing the more costly productions of the craft manufacturers and diluting the benefits of the more productive firms.

In contrast to Drummond's assertion for the railway workshops (Section 1.7), there is no evidence of any policy by the manufacturers to make their capital equipment 'firm-specific' in order to deter free labour movement and suppress wage claims at times of skilled labour shortages. Even following the establishment of the Locomotive Manufacturers Association in the 1870s, there is no evidence of collusion with capital equipment, or in any other way to deter free labour movement. On the contrary, the discussion in the next chapter, on employment and industrial relations, indicates an extraordinary loyalty to their firms by skilled personnel (Section 6.4).

6.0 Management, Employment and Industrial Relations

6.1 Introduction

The growth in the size and scope of the locomotive industry through the century required an evolution in managerial responsibilities to direct employment policies and deal with industrial relations issues. The strategic decisions that were taken by the manufacturers to increase their workforces, against a background of craft shortages and sharply fluctuating demand, and the tactical decisions on employment terms, paternalism and industrial relations, were amongst the most difficult that the manufacturers had to make (Fig.15).

To enable the firms to expand and be competitive, their evolving policies centred around both the growth of their skill-base and the employment of un-skilled labour who could undertake repetitive tasks when demand was high. They also required the flexibility to recruit and dismiss unskilled labour, according to demand, in order to preserve continuity of employment for their skilled personnel. These policies, which varied in their proportion of unskilled labour, were closely related to the progressive and craft firms' strategies on market specialisation and investment for specialised production.

The locomotive industry inherited the proprietorial management practices of the early 19th century heavy manufacturing industry, which it developed to meet its own circumstances. The vertically-integrated structure of the industry meant that it already had experience of administrative co-ordination. Each smithy, foundry, machine and erecting shop had a foreman who was responsible to a 'Head Foreman', who may or may not have been a partner of the firm. Their experience with multi-activity operations led firms to develop their administrative functions, firstly through delegated responsibilities from the partners to experienced workshop foremen and head clerks and, subsequently, through employment of specialist managers.

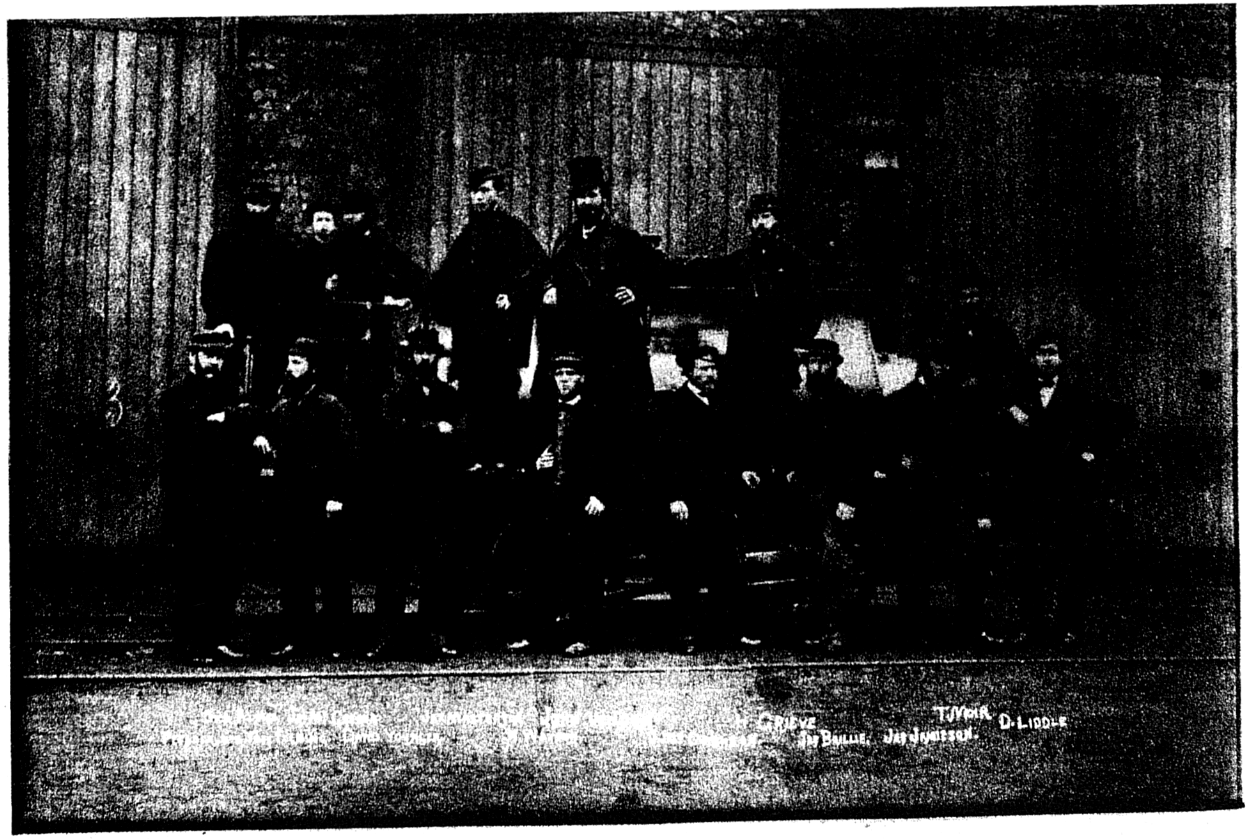

Fig.15 MANAGER AND CRAFTSMEN GROUP PICTURE (Neilson & Co., 1860s)

(Photograph: Courtesy Mitchell Library, Glasgow)

As management and manufacturing technology evolved, so did the division of labour, into 'time-served' skilled craftsmen, semi-skilled artisans, premium and craft apprentices and un-skilled 'labourers'. The changing technologies had both cause and effect on the composition of the workforce and employment policies. The all-embracing skills of the millwrights, foundrymen and boiler-makers were replaced by the hierarchical 'factory' system, which passed their former decision-making discretion to the proprietors, head clerks and head foremen who determined technological progress, designs, material development and manufacturing programmes.

The management and motivation of a mixed labour force, against the background of increasing 'de-skilling' of repetitive production, called for evolving employment policies to administer, encourage and discipline the changing workforce. As Zeitlin has noted, for major firms in the capital goods sector, such as locomotive manufacturers, these policies included further cost-reducing measures, notably productivity-related incentive piece-work and the imposition of overtime when the locomotive market was strong.[1] However, the extent to which differential wage rates and other employment incentives were necessary between manufacturers, to recognise the relative attraction of their different sites and the need to develop paternalism to encourage loyalty and longevity of service, needs to be established.

At the commencement of the railway era, the employment of millwrights and other skilled craftsmen brought an inherent discipline to locomotive manufacturing, born from respect through the apprenticeship system. The commitment of young men to be trained as junior engineers by their experienced elders, or to learn a 'craft' from experienced 'journeymen', and to 'bind' themselves to be trained for a period of between four and seven years, had been established in the 18th century. As Zeitlin has noted, in the nineteenth century craft training remained the central route to skilled employment and manufacturers maintained an ongoing commitment to apprentice training.[2] Although the manufacturers sought to employ unskilled

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[1] Jonathan Zeitlin, 'Between Flexibility and Mass Production: Strategic Ambiguity and Selective Adaptation in the British Engineering Industry, 1830-1914', in Charles F. Sabel and Jonathan Zeitlin (eds), World of Possibilities, Flexibility and Mass Production in Western Industrialization, Cambridge, 1997, p.242.
[2] Zeitlin, *ibid*, p.247.

men for routine machining tasks, their requirement for the craft skills remained high, and the numbers of skilled 'journeymen' exceeded half the country's manufacturing workforce by the end of the century.[3] This draws into question whether firms generally regarded apprenticeship training as an important part of their long-term labour policies, or whether they were seen as a form of inexpensive 'bound' labour.

As experience in locomotive construction developed, the on-going shortages of skilled labour brought the potential for competing claims for manpower between the locomotive firms, and to wage escalation. Drummond has recently emphasised the importance of paternalism in railway workshops, such as Crewe, which was seen as important to prevent workers migrating to other railway towns.[4] Paternalism and patronage not only created the basis for managerial strategy, but it also formed the basis of its system of industrial relations. The employment policies of the independent manufacturers therefore need to be considered to determine whether they were similarly motivated towards paternalism and the extent to which it was felt to be of benefit in avoiding migration.

The improving employment terms mostly arose from industrial disputes, which were as much to do with the retention of craft skills and the preservation of 'closed shops' to minimise the erosion of bargaining power, as they were to do with the basic hours of work or rates of pay. The evolution of these issues from local to national disputes brought about an increased representation by the manufacturers on regional and national employer federations, which does not indicate any particular accommodation with the skilled workers as McKinlay and Zeitlin suggest (Section 1.8).[5] In testing to see the extent of any accommodation, therefore, the part played by the manufacturers, in dealing with both their fellow employers and the trades unions, provides an indication of how influential their role was in the country's overall changing employment scene.

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[3] James B. Jefferys, The Story of the Engineers, Amalgamated Engineering Union, 1945, p.207.
[4] Diane K. Drummond, Crewe: Railway Town, Company and People, Aldershot, 1995, p.63.
[5] Alan McKinlay and Jonathan Zeitlin, 'The Meanings of Managerial Prerogative: Industrial Relations and the Organisation of Work in British Engineering, 1880-1939', Business History, Vol.31, No.2, 1989, pp.33-47.

6.2 Management and Supervision

Strategic decisions relating to employment largely rested with managing partners and, from the 1860s, with General Managers and Managing Directors. Whilst the proprietors of the smaller firms supervised the manufacturing and administrative functions directly, the larger firms delegated the tactical decision-making responsibilities to head foremen and head clerks respectively. At the start of locomotive manufacturing, the vertical integration of the heavy manufacturing industry had already instigated the supervision of employees by shop foremen, and as the firms grew in size and in number of employees, their responsibilities for recruitment, discipline and work programmes grew accordingly. Much reliance was placed by the manufacturers upon policies which sought both to preserve employment for the skilled craftsmen and pursue a growing proportion of un-skilled, but increasingly experienced machinists and other repetitive workers. The head foremen and their respective workshop foremen therefore played key roles in carrying out those recruitment policies in accordance with the prevailing work programmes.

6.2.1 Managing Partners

The salaried responsibilities of managing partners were usually divided between manufacturing and administration. John Jones and Arthur Potts, for example, so divided their activities, Potts spending much time marketing, selling and chasing payments, whilst Jones supervised the manufacturing work at the Viaduct Foundry.[6] The largest manufacturer in the earlier years, Robert Stephenson & Co., was exceptional, as the consulting activities of both George and Robert Stephenson allowed them only occasional appearances at the Newcastle factory. From the 1820s, therefore, although Robert Stephenson, as Managing Partner, made policy decisions through frequent correspondence, the factory was administered by a 'Head Clerk' (Office Manager) and a 'Head Foreman' (Works Manager).

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[6] Letters, Arthur Potts to John Jones, Library of the Institution of Mechanical Engineers, Ref. IMS 248-252.

After Stephenson's death in 1859, his cousin, George Robert Stephenson (1819-1904), became the new Managing Partner and directed the firm's policies from his Westminster consulting office until the end of the century. Although the firm did not obtain limited company status until 1886 (Section 7.6.7), it was the first manufacturer to delegate managerial responsibilities to a salaried General Manager, George K. Douglas, in 1862.[7] No evidence has been found to indicate the motivation for the appointment, but it would seem that, unlike his cousin, Stephenson felt unable to devote sufficient attention to the management of a firm of 1200 men at such a distance.

The conversion of some firms to limited companies from the 1860s (Section 7.6.5), stimulated the appointment of executive Directors to bring in new expertise. The conversion of Charles Tayleur & Co. into the Vulcan Foundry Co. Ltd. in 1864, for example, saw the appointment of William F. Gooch (1825-1892 fl), as Managing Director reporting to the Company's Chairman, Edward Tayleur.[8] Gooch had been the GWR's Swindon Works Manager for seven years before his appointment, and his experience of employment and organisational procedures, as well as production processes brought about the modernisation of the Vulcan Foundry.

In contrast, the conversion of Slaughter Gruning & Co. into the Avonside Engine Co. Ltd. in 1864, saw its Managing Partner, Edward Slaughter, appointed as Managing Director.[9] Although this provided continuity of management, it lacked the injection of new direction into the 28 year old establishment. This was belatedly recognised in 1871, when Slaughter became non-executive Chairman of the company, and engaged Alfred Sacré (1841-1897) as Managing Director.

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[7] J.G.H. Warren, A Century of Locomotive Building By Robert Stephenson & Co. 1823-1923, Newcastle upon Tyne, 1923, p.416.
[8] *Anon*, The Vulcan Locomotive Works 1830-1930, The Locomotive Publishing Co., London, p.8.
[9] C.P. Davis, Locomotive Building in Bristol. The Avonside Ironworks (1837-1882), unpublished BA Dissertation, University of Bristol, 1979, pp.32/3.

Financial incentives were occasionally negotiated to retain the services of competent managers. When Henry Dübs (1816-1876) was appointed Assistant Manager of Beyer Peacock & Co. in 1857, with the expectation of being appointed Manager of its proposed factory in Vienna (Section 7.6.4), he was paid a salary of £500, the same as Beyer and Peacock themselves, and an "additional sum of one half per cent upon the amount of work turned over on trade account or upon a minimum of £100,000 per annum."[10] Although appointed for an initial two years, Dübs was given notice after just six months, the reasons for which were not recorded. He was subsequently taken on by Neilson & Co. and, became a partner, but he also left that company after disagreement, to found his own company (Section 7.6.6).

By the late 1860s, the number of salaried managers (or executive directors) with the largest firms had increased to, typically, six men. The number could be larger, depending upon the breadth of the firm's activities. In 1869, for example, Robert Stephenson & Co. had nine salaried managers, for its workforce of 1200 men:[11] The Vulcan Foundry had five salaried directors by 1891, reporting to William Gooch.[12] R.&W. Hawthorn Leslie & Co., which became a public company in 1886, had a Works Managing Director, William Cross, to represent its engine works, whilst employing a General Manager for its shipyard.[13]

6.2.2 Head Clerks

The employment of head clerks by Robert Stephenson & Co. from 1823, represented an early example of sectional management through delegated responsibility. The practice followed the example of the firm's partner, Michael Longridge, who was, himself, employed as manager of the Bedlington Iron Works (Section 5.4.1). One of the first appointees, Harris Dickinson, was "a very pushing young man",[14] whose actions sometimes caused

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[10] R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982, p.17.
[11] Articles, Newcastle Chronicle, 1st January 1869 and 1st January 1870.
[12] Journal 1864-1900, Vulcan Foundry Collection, National Museums and Galleries on Merseyside, Ref.1970/37/4/2/1.
[13] J.F. Clarke, Power on Land and Sea, Newcastle upon Tyne, nd but 1979, p.14.
[14] Letter, Joseph Locke to Robert Stephenson, Liverpool, Feb:25:1827, Library of the Institution of Mechanical Engineers, Crow Collection.

embarrassment. Robert Stephenson was unhappy that Dickinson had such a prominent position, and disliked the idea of a salaried head clerk, preferring instead the traditional link between risk and reward. When consideration was being given to appointing a new head clerk in 1836, he wrote:[15]

> ......neither do I believe that the management will be much impressed by employing a manager of the description named in your letter - Dickinson was precisely the kind of man you allude to - he was active, intelligent and what is usually termed a man of business - but the Est. would have been ruined by this time had that kind of management not been entirely altered....... if any manager is brought to Forth Street, he ought to have a share - and ought to confine his attention to the financial department, as any interference with the mechanical will I fear throw all wrong -

In 1836, Stephenson recruited Edward Cooke as Head Clerk from his father-in-law's establishment in London, where: "His occupation hitherto has always been confined I believe to accounts"[16] By 1845, Cooke's successor, W.H. Budden, reporting to Stephenson in London, was responsible for external affairs (marketing, sales and purchasing) and the accounting and time offices, and supervised the work of the estimating and purchasing staff, a total of about 40 personnel. In 1849, following four very profitable years for the Stephenson Company (Section 7.4.1), he received a large bonus of £500 as reward for services, dedication and success in achieving profits.[17]

Other manufacturers similarly employed head clerks, and, by the end of the century, it had become normal practice to employ these departmental managers reporting to general managers, managing directors or managing proprietors. Their responsibilities included supervising the preparation of cost and management accounts (Sections 7.2-7.4). Andrew Barclay Sons & Co., which was several times in financial difficulty through poor management practices, was obliged by its creditors to recruit a Financial Manager to place it on a sounder financial footing, after the firm's second sequestration in 1882 (Section 7.6.7).[18]

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[15] Letter, Robert Stephenson to Joseph Pease, Newcastle Upon Tyne, 12 April 1836, Durham County Record Office, Darlington Public Library, Pease-Stephenson Collection, Ref.D/PS/2/54.
[16] Letter, Robert Stephenson to Edward Pease, London, 27 Oct 1836, Pease-Stephenson Collection, *ibid*, D/PS/4/5.
[17] Memorandum, 16 May 1849, in Minute Book, R. Stephenson & Co. Collection, Science Museum, London.
[18] Michael S. Moss and John R. Hume, Workshop of the British Empire, London, 1977, p.73.

6.2.3 Head Foremen/Works Managers

From the opening of their factory in 1823, the Stephensons appointed William Hutchinson as their 'Head Foreman', there being a close harmony between them which allowed him full executive status over manufacturing matters. When, in 1834, Edward Pease proposed that his son, Joseph, might have some executive responsibility, Stephenson wrote with some concern:[19]

> I learnt from Hutchinson that you had spoken to him in reference to the occasional superintendence of your son - To me, he has expressed an apprehension that he might not be allowed in my absence to follow up such arrangements within the walls of the manufactory as he now has the power of doing - This apprehension is quite natural, and I embrace this opportunity of mentioning it, in order that I may express to you, my strongest conviction that Hutchinson is trustworthy - talented & assiduous with the success of the concern at heart - The energies of any man in such a situation as Hutchinson's are I believe maturely influenced by the degree of independence both in thought and action, which he is permitted to experience.......... I feel from a long and thorough acquaintance with him, that the strong interest which he now takes in the economical arrangement in the working department would be lessened by any limitation of his powers -

In 1839, Hutchinson received a £150 bonus from the partners for his services to the firm,[20] and, in 1845, Robert Stephenson recommended to his fellow partners that he should be made a partner. Stephenson's London assistant, J.E. Sanderson wrote:[21]

> Mr. Robert Stephenson has talked the matter over with his father and they think that from Mr. Hutchinson's talent & assiduity he is entitled to have a permanent interest in a concern that he has so ably supported for so many years.

Senior managers were occasionally promoted to become partners after several years with a firm, their equity being built up annually out of profits. By that time, Hutchinson managed 850 employees, and was responsible for all production matters, including design, capital equipment, recruitment and industrial relations.[22] Stephenson's faith in Hutchinson, whom he

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[19] Letter, Robert Stephenson to Edward Pease, Bedlington Iron Works, 25 Dec 1834, Pease-Stephenson Collection, *op cit* (15), D/PS/4/4.
[20] Minute, 26 Feby 1839, R. Stephenson & Co. Minute Book, *op cit* (17).
[21] Letter, J.E. Sanderson to T.Richardson, Westminster, 12 May 1845, Pease-Stephenson Collection, *op cit* (15), D/PS/2/66.
[22] Article, Newcastle Chronicle, September 6th 1845.

referred to as the "oracle",[23] was rewarded by a well-managed factory until his death in 1853. He was succeeded by the equally competent George Crow (Section 5.7.4), who supervised the factory until his death in 1887, and who was, in turn, replaced by his son, W.H. Crow.

Other proprietors were equally aware of the importance of recruiting good works managers as a means of importing both managerial skills and technical capability. In 1839, James Nasmyth gave his opinion on obtaining a suitable candidate, again enforcing the contemporary view of the importance of linking risk and reward:[24]

> If a first [rate] man, a fair salary say £150 a year & a per centage on the work turned out is the only way to secure him for a permanency and if he has a little money of his own get him to put it in the business.

When Nasmyth engaged Robert Willis as his Works Manager in 1852, he paid him a salary of £200 and provided a house, rent free. The following year Willis was also provided with a annual bonus incentive:[25]

> For every £1000 of work ordered ....you shall receive a bonus of £1 per thousand of value up to £50000 and for every £1000 worth of work in excess...... you shall receive a double rate of Bonus namely £2 for every £1000 output.

By 1856, Willis' basic annual salary had been raised to £300, in addition to the bonus incentive.

Works Managers with good reputations were occasionally 'head-hunted' by rival firms. Henry Dübs, who had shown considerable talent in the drawing office of Sharp Roberts & Co., was recruited as Works Manager for Charles Tayleur & Co. in 1842, where he spent 15 years before, in turn, being recruited to Beyer Peacock & Co. (Section 6.2.1).[26] Beyer Peacock's Works Manager from 1860, Francis Holt, was recruited by R.&W. Hawthorn in 1871, and his successor, Robert Burnett, left in 1877 to become Chief Mechanical Engineer

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[23] J.C. Jeaffreson, The Life of Robert Stephenson, F.R.S., London, 2 Vols.,1864, Vol. I, p.13.

[24] Letter J. Nasmyth [for Nasmyths Gaskell & Co.] to J. Dundas, Patricroft, 23 April 1839, Nasmyth Collection, Eccles Public Library, Letter Book 4, p.375.

[25] Letter, J. Nasmyth to R. Willis, 1 June 1853, Bodleian Library, Oxford, quoted in J.A. Cantreli, James Nasmyth and the Bridgewater Foundry, Manchester, 1984, p.237.

[26] R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982, p.17.

of the New South Wales Government Railways.[27] Family connections were occasionally the means to obtain senior positions. William W. Clayton, for example, who was appointed Works Manager of Hudswell, Clark & Rodgers in 1876, was the son of one of the firm's non-executive partners. He was, himself, made a partner on William Hudswell's death in 1882.[28]

6.2.4 Foremen

Works Managers supervised several workshop foremen. In 1839, Nasmyth's works was:[29]

> divided into departments, over each of which a foreman, or a responsible person, is placed, whose duty is not only to see that the men under his superintendence produce good work, but also to endeavour to keep pace with the productive powers of all other departments.

Foremen were, in essence, 'Assistant Works Managers'. Not only did they have responsibility for the output and quality control of each shop, including the motivation and productivity of the work-force, they also had the responsibility of 'hire and fire'. Foremen were best at determining applicants' qualifications, and re-hiring after lay-offs was speeded up by their knowledge of the abilities of many of the applicants, a point which Drummond emphasises in relation to railway-owned workshops, such as the LNWR's Crewe Works.[30] In America, similarly, Baldwins vested the responsibility of recruitment with its foremen.[31]

Reliance upon foremen for efficient operation of their workshops was total. Identifying them as his "vice-regents of practical management", Nasmyth:

> always took care to make my foremen comfortable, and consequently loyal. A great part of a man's success in business consists in his knowledge of character. It is not so much what he himself does, as what he knows his heads of departments can do. He must know them intimately, take cognisance of the leading points of their character, pick and choose from them, and set them to work which they can most satisfactorily

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[27] *ibid*, p.56.
[28] Ronald N. Redman, The Railway Foundry Leeds 1839-1969, Norwich, 1972, p.43.
[29] Booklet, Manchester As It Is, 1839, quoted by A.E. Musson, 'James Nasmyth and the Early Growth of Mechanical Engineering', Economic History Review, Vol.X, 1957-58, p.126.
[30] Drummond, *op cit* (4), p 62.
[31] John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, p.135.

> superintend....... I always endeavoured to make my men and foremen as satisfied as possible with their work, as well as with their remuneration.[32]

By 1869, Robert Stephenson & Co. had twenty foremen reporting to the Head Foreman, George Crow.[33]

Several foremen went out with the first locomotives to be used in a new country or railway, to erect them and train the railway personnel. They were sometimes induced, by the offer of high wages and senior positions, to stay as locomotive superintendents or set up engineering workshops. Being the industry leader in the 1830s, Robert Stephenson & Co. lost several experienced foremen. In 1839, for example, Joseph Hall, who accompanied the first locomotives for the Munich-Augsburg Railway, was induced to remain in Munich by Joseph von Maffei to set up his locomotive factory that became one of the largest in Germany.[34] John Haswell, who accompanied the first locomotives built by William Fairbairn & Sons for the Vienna-Raab Railway in 1840, remained in Vienna to set up the first locomotive works, which became one of the largest in Austria.[35]

There is no evidence that the manufacturers introduced 'piecemastering'. This was the practice of engaging sub-contracted workshop personnel under the management of a foremen or 'piecemaster', who was wholly responsible for the profitable execution of work in each workshop. As Drummond has discussed, it was adopted by some railway-owned workshops in the 1840s, notably 'railway towns', such as Swindon, Wolverton and Derby, although strangely not in Crewe which maintained a policy of direct labour employment.[36]

Although there is no conclusive evidence to explain fully the benefits of the piecemastering system, Drummond believes that it was a means of overcoming the shortage of skilled men at relatively isolated locations.[37] The piecemasters used social, religious and family associations

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[32] Samuel Smiles (ed), James Nasmyth Engineer, An Autobiography, London, 1883, pp.311-312.
[33] Articles, Newcastle Chronicle, *op cit* (11).
[34] Article, The Engineer, Vol.84, 1897, pp.31/2.
[35] J. N. Westwood, Locomotive Designers in the Age of Steam, London, p.218.
[36] Drummond, *op cit* (4), p.69.
[37] *ibid*, pp.72/3.

in their recruitment drives, which were seen to provide family loyalties and a well-managed workforce, although there could often be a dislike of the piecemaster. As workforces became more stable, piecemastering in railway workshops was replaced by directly employed, piecework labour. Swindon works, for example, switched to direct labour in 1865, although Derby and Wolverton workshops maintained the practice through to the 1890s.

The Baldwin Works in the USA introduced an 'inside-contracting' system in 1872, to counter a strike threat.[38] It was seen to offer the advantages of group piecework, for which the contractor would bid by the piece or job, whilst assisting supervision in a workforce of over 2,500 men. An American railroad executive noted in 1903 that "The contractor is a piece-worker on a larger scale. As he is paid by the job, he has the incentive to turn out his work as quickly as possible and to get as much as possible out of the men under him."[39]

It is possible that piecemastering was introduced by the larger independent firms, such as Neilson & Co. or Dübs & Co., or by sites such as the Vulcan Foundry, whose remoteness led to recruitment difficulties. The lack of evidence, however, regarding either perceived advantages or any discontent, suggests that the system was not practised. It is likely that, with the firms mainly based in Manchester, Leeds, Newcastle, Glasgow and other major manufacturing centres, workmen were easier to recruit than for the railway workshops, and there was no need to sub-contract the work. The manufacturers' workforce was generally more secure in the knowledge that their skills could be switched to other products, such as marine and stationary engines, at times of low demand for locomotives. *In extremis*, they also knew that, if they had to be laid off, or if their employer failed completely, they had the opportunity of recruitment by other firms in their town.

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[38] Brown, *op cit* (31), pp.153-157.
[39] John W. Converse, 'Some Factors of the Labor System and Management at the Baldwin Locomotive Works', Annals of the American Academy of Political and Social Science, Issue 21, Jan. 1903, p.6, quoted in Brown, *ibid*, p.156.

6.3 Employment

Manufacturers developed employment strategies which recognised the importance of the skilled crafts, whilst avoiding dependence upon them. Their strategic decisions on levels of employment for each of the several craft skills that they employed were, as far as possible, related to a continuing level of work, to maintain their availability and loyalty in a competitive labour market. The shortage resulted from the lengthy apprenticeship system and the limitations placed upon recruitment of apprentices by the 'journeymen' craftsmen, which served to secure their employment at potentially higher wage levels.

It was, however, the very dependence upon the craftsmen, in the 1830s and 1840s, which threatened to restrict the growth of the industry and which prompted the manufacturers to pursue, vigorously, the development of capital equipment to allow routine tasks to be performed by men who were not 'time-served' journeymen (Section 5.5). The employment of this unskilled labour for much of the repetitive machining, which was contentious throughout the century (Section 6.5), not only overcame the shortage of skilled craftsmen when locomotive demand was high, it also reduced the wage bills.

Employment policies were, however, constantly being conditioned by the uncertainties and fluctuations of the locomotive market (Section 2.6). As they evolved after the 1850s, therefore, these policies contributed to the divergence of the industry, between the progressive manufacturers, which pursued largely specialised locomotive production, and craft manufacturers, which pursued a broader market of customised heavy machinery, including small locomotive batches. The larger investment in capital equipment, particularly machine tools, by the larger companies increased their proportion of unskilled labour by comparison with the craft manufacturers.

The extraordinary fluctuations in the locomotive market led to tactical decisions by the manufacturers, which largely saw continued employment for skilled men, whilst unskilled labour was laid off and recruited according to demand. As Rowe has noted, when demand was slack, manufacturers would endeavour to retain their craftsmen in order to be well-placed when orders built up again.[40] When labouring staff were laid off, craftsmen diversified, where possible, into alternative product manufacture, or were put on short-time working. James Nasmyth thought it unwise "to let your men scatter all over the country" during depressed periods, but rather "to wait for the good times to come."[41] In this way, there could be said to have been an accommodation between the employers and their skilled labour, but this mutually beneficial arrangement was limited to a ready supply of skills and continuity of employment, which engendered a tradition of staying with one firm, rather than any accommodation on the terms of employment.

In planning the locations of their factories, the manufacturers had to anticipate the limitations and availability of labour in their respective areas, which resulted in significant variations in labour rates and other terms of employment. Not only had wage levels to be higher in more remote areas, but housing and other benefits had to be provided. The larger manufacturers were anxious to improve levels of productivity following their increased levels of investment in capital equipment in the latter part of the century. Several firms introduced incentive piecework payments, but success usually depended upon the system and its often contentious implementation.

The apprenticeship procedures lay at the heart of the skilled labour market, and were vigorously protected by the craftsmen who saw the system as the means to preserve their job security and terms of employment. The manufacturers were equivocal in their approach to the training, particularly premium apprenticeships, which were not always beneficial to their long-term labour requirements, but represented a compromise in the confrontations over un-skilled labour.

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[40] D.J.Rowe, 'Trade Unions and Strike Action in the North-East', in E.Allen, J.F.Clarke, M.McCord and D.J.Rowe (eds), The Strikes of the North-East Engineers in 1871: The Nine Hours League, Newcastle, 1971, p.79.

[41] Royal Commission on Trades Unions, Tenth Report, Parliamentary Papers, 1868, Vol.39, Q.19,155, quoted in Cantrell, *op cit* (25), p.242.

6.3.1 Levels of Employment

Skilled labour was scarce before the locomotive industry began. Jenkins has noted that millwrights in the main textile manufacturing areas were in short supply in the 1820s,[42] and in 1824, William Fairbairn found some difficulty in employing a sufficient number of millwrights at his Manchester works because such "hands are very scarce at present."[43] Millwrights, whose skills and experience were wide-ranging and who were generally independent craftsmen, limited their own numbers in order to safeguard their negotiating strength in terms of wage levels and hours of work. Their numbers were restricted through the apprenticeship system partly because the millwrights with a "rude independence.... would repudiate the idea of working.... with another unless he was born and bred a millwright."[44]

There was no alternative to employing millwrights for locomotive manufacture, as they had the necessary skills on which the emerging industry depended. Fairbairn, himself a former millwright, later wrote that:[45]

> The millwright....... was to a great extent the sole representative of mechanical art, and was looked upon as the authority on all the applications of wind and water....... as a motive power for the purposes of manufacture. He was the engineer of the district in which he lived, a kind of Jack-of-all-trades, who could with equal facility work at the lathe, the anvil, or the carpenters bench...... Generally, he was a fair arithmetician, knew something of geometry, levelling, and mensuration, and in some cases possessed a very competent knowledge of practical mathematics. He could calculate the velocities, strength and power of machines; could draw in plan and section and could construct buildings, conduits, or watercourses, in all the forms and under all the conditions required in his professional practice.

The shortage of millwrights threatened to curtail locomotive development, particularly as demand grew rapidly in 1835/6 (Section 2.6). Manufacturers were concerned that the shortage would lead to a general rise in wages which would make them less competitive, whilst not allowing for any significant reduction in manufacturing time. The shortage thus

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[42] D.T. Jenkins, The Wool Textile Industry 1770-1835, Edington, 1975, pp.109/110.
[43] Fifth Report from Select Committee Respecting Artisans &c., Parliamentary Papers, 1824, Vol.5, pp.566-569.
[44] *ibid.*
[45] William Pole (ed), The Life of Sir William Fairbairn, Bart, London, 1877, pp.26/7.

prompted the introduction of self-acting machine tools (Section 5.5.1), which not only reduced machining time substantially, but were operated by un-skilled machinists, trained relatively quickly to operate them. The several new types of artisans thus caused the millwrights' activities to be subsumed into the residual work of fitters and erectors, where their skill and experience of tolerances and fitting remained essential. Fairbairn later described this evolution into the 'factory system' of manufacturing:[46]

> In these manufactories the designing and direction of the work passed away from the hands of the workman into those of the master and his office assistants. This led also to a division of labour; men of general knowledge were only exceptionally required as foremen or outdoor superintendents: and the artificers became, in process of time, little more than attendants on the machines.

By the time Nasmyth set up his Bridgewater Foundry in 1836, he recruited unskilled men to train as machinists, and took on men who lived near the Patricroft site:[47]

> It was for the most part the most steady, respectable, and well-conducted classes of mechanics who sought my employment...... In the course of a few years the locality became a thriving colony of skilled mechanics..... The village of Worsley...... supplied us with a valuable set of workmen. They were, in the first place, labourers: but, like all Lancashire men, they were naturally possessed of a quick aptitude for mechanical occupations connected with machinery.....

Boiler-making was another skilled craft in short supply as the early locomotive market expanded, and the manufacturers had to look further afield to recruit sufficient men. In 1830, the Stephenson Company's Head Clerk, reported that: "The Liverpool men have arrived and got to work, and seem tolerably contented; but we have not had sufficient experience to form as yet much opinion of their abilities."[48] The boiler-makers 'bretheren' or unions maintained a tight 'closed shop' that, again, kept recruitment low and wages high. Edward Pease wrote in 1835 that: ".... we sent here and there, & gave great wages for the

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46 *ibid*, p.47.
47 Smiles, *op cit* (32), pp.216/7.
48 Letter, Harris Dickinson to Edward Pease, Newcastle Upon Tyne, 10 Mo.21.1830, Pease-Stephenson Collection, *op cit* (15), D/PS/2/52.

most experienced boiler makers...."[49] Boiler-making remained a skilled craft throughout the century, although routine tasks were speeded up by new equipment, especially riveting machines and hydraulic presses (Section 5.5.2).

The introduction of the steam-hammer from the mid-1840s saw the manufacturers broaden their skill-base by re-training some of their smiths, and recruit experienced forgemen from iron-works. Forging, particularly by wheel-smiths, remained a skilled craft throughout the century, as was the work of the pattern-makers and foundrymen, whose skills were enhanced as more complex casting was pursued.

The extraordinary demands for locomotives during the mid-1840s, led to a severe shortage of machine-shop craftsmen, prompting further advances to capital equipment in an endeavour to reduce manning requirements (Section 5.5.1). As volume production of certain components became feasible with new milling and other improved machine tools, the repetitive nature of some of this turners' work was also passed to un-skilled machinists. Their output was passed to the turners, fitters and erectors who continued to exercise skill and judgement in the finishing work. As improved machine tools were introduced during the remainder of the century, yet further skills were removed from the turners' craft and placed with un-skilled machinists.

The shortage of craftsmen was sometimes compounded by the absence of suitable housing. Whilst most locomotive factories were located in urban areas and recruited their workforce locally, some manufacturers were obliged to provide housing and other amenities. So poor was the available housing in Patricroft, that Nasmyth "Expended several of pounds in erecting cottages for our own workmen, because those in the district were so defective."[50] By 1850, he had built 89 dwellings, for each of which the men paid a 3/- weekly rent.[51]

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[49] Letter, Edward Pease to Thomas Richardson, Darlington, 7 Mo 4 1835, Hodgkin Collection, Durham County Record Office, Darlington Public Library, Ref.D/HO/C/63/18.
[50] Board of Health Report, Barton-Upon-Irwell, 1852, p.22, quoted in Cantrell, *op cit* (25), p.230.
[51] Nasmyths Gaskell & Co. Day Book, 8th February 1850, quoted in Cantrell, *ibid*, p.230.

The two factories established at Newton-le-Willows were too far from both Liverpool and Manchester to recruit their workforce. Charles Tayleur & Co. built the 'Vulcan Village' on the south side of the Vulcan Foundry to accommodate many of its employees.[52] The village had its own school, inn and general stores, but was small compared to railway workshop towns, such as Swindon and Crewe. Jones & Potts' Viaduct Foundry at Newton had similarly been provided with 33 workers' cottages by its closure in 1851.[53] Beyer Peacock & Co. provided some housing in order to recruit a sufficient workforce to its relatively isolated Gorton Foundry, east of Manchester. Charles Beyer also paid for the building of a church and a day school close to the factory, and the re-building of the parish church.[54]

Although Vamplew has pointed out that Neilsons & Co.'s growth was constrained by lack of skilled men,[55] it is likely that this was due to the somewhat extreme Scottish patriotism of its proprietor, Walter Neilson, reflected in his avowed intention not "to employ a single Englishman", when he started up in the 1840s. He experienced a shortage of craftsmen, however, when he embarked on locomotive work in Glasgow, and it was necessary for him to recruit some English workmen.[56]

Habakkuk has noted that wages rose in the early 1850s, because the demand for labour exceeded the expansion of the labour force.[57] It is more likely, however, even with the greater use of self-acting tools, that the shortage of craftsmen was due to the effects of the national 'lock-out' of 1852 (Section 6.5). Nasmyth wrote at this time:[58]

> It will be well mean time that you be looking out for some first rate handy fellows who you know to be such and who will knock out the work in first rate style and with all speed........ I allude more particularly to [locomotive] Erectors among whom should be one or two men suitable to go out with the

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[52] The Vulcan Locomotive Works, *op cit* (8), p.14.
[53] Brian Reed, Crewe Locomotive Works and Its Men, Newton Abbot, 1982, p.26.
[54] Hills and Patrick, *op cit* (26), p.54.
[55] Wray Vamplew, 'Scottish Railways and the Development of Scottish Locomotive Building in the Nineteenth Century', Business History Review, Vol.46, 1972, No.3, p.328.
[56] Mark O'Neill, 'Walter Montgomerie Neilson and the Origins of Locomotive Building in Glasgow', in Murdoch Nicolson and Mark O'Neill (eds), Glasgow Locomotive Builder to the World, Glasgow, 1987, p.5.
[57] H.J. Habakkuk, American and British Technology in the Nineteenth Century, Cambridge, 1962, p.195.
[58] Letter J. Nasmyth to R.Willis, 29th April 1852, Bodleian Library, Oxford, quoted in Cantrell, *op cit* (25), p.236.

> Engines when they are ready and see them delivered in a most satisfactory manner to the company....... Mean time if you happen to know of a few first rate turners you will oblige us by sending them this way as we are more in want of hands in that department than any other.

Habakkuk further argued that because, in the peak of the 1868-1873 cycle, there was a rapid rise in wages, that it was the first boom actually to be constrained by labour shortage. It is, again, equally likely that the effects of the 1871 'nine-hours' labour dispute caused the increase in wage costs. The disputes and the resulting wage increases are evidence of the lack of accommodation between the employers and their skilled labour over terms of employment (Section 6.5).

When the locomotive market was depressed, manufacturers laid off un-skilled labour. In 1842, R.B. Longridge & Co. was obliged to release its men, the local press reporting: "It is no uncommon circumstance to see groups of men, sitting about unfrequented parts of the town [Bedlington], playing cards."[59] Fig. 16 provides an example of the effect on the Vulcan Foundry Ltd., of the relationship between the number of locomotives manufactured and the annual wages bill.[60] Although a direct comparison is not possible because of the several other engines and machinery also manufactured by the firm, it is clear that there was a close relationship between employment and locomotive orders.

The rise and fall of the wages bill reflects the recruitment and lay-offs of labourers (and craftsmen in severe recessions such as 1868) and by overtime payments or short-time working. The proportion of labourers to skilled personnel was between 15 and 25 per cent and their dismissal was the easiest way of reducing the workforce and the wage bill, even though craftsmen then had to undertake some of the residual repetitive tasks.[61] Commitments to apprentices meant retaining them until the conclusion of their 'time'.

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[59] Evan Martin, Bedlington Iron & Engine Works 1736-1867, Newcastle upon Tyne, 1974, pp.16/7.
[60] Data obtained from Vulcan Foundry Ltd. Ledger 1864-1889, Ref.1970/37/4/1, and Journal 1864-1900, Ref.1970/37/4/2/1, Vulcan Foundry Collection, *op cit* (12).
[61] The proportion of labourers to skilled artisans was 20-25% at Crewe Works. Drummond, *op cit* (5), p.49.

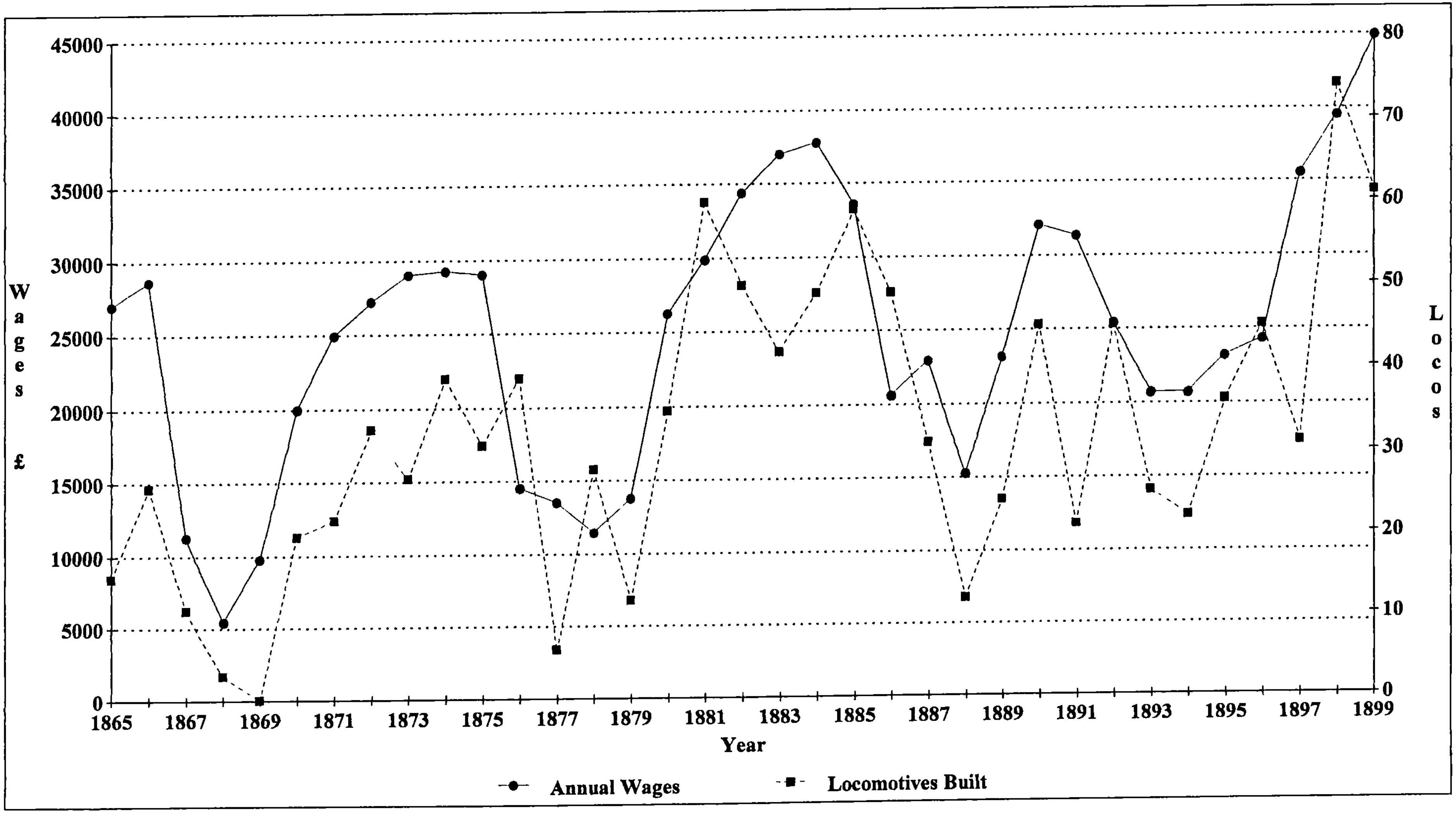

Fig. 16 Vulcan Foundry Ltd Comparison Between Annual Wages and Numbers of Locomotives Manufactured 1865 - 1899

(Source: Vulcan Foundry Ledger and Journal 1864-1900)

6.3.2 Terms of Employment

Craftsmen usually supplied their own 'tools of the trade'. In 1846, when R.&W. Hawthorn's Forth Banks Works burnt down, there was "a considerable loss.....[including] the tools of about 200 workmen."[62] The Stephenson Company's draughtsmen were each required to "provide himself with all necessary Drawing Instruments."[63] R.B. Longridge & Co., however, provided tools for its employees, each man being responsible for the tools supplied, the value of any losses being deducted from his wages.[64]

In the early years of the century, the millwrights' 'societies' had laid down a 6am to 6pm workday (daylight hours in winter), a net 10½ hour day after meal breaks.[65] R.B. Longridge & Co. adopted this working day although, following the 1836 dispute (Section 6.5), this was reduced to 10 hours, with higher rate overtime.[66] By the mid-1840s, whilst most manufacturers were working 60 hour weeks, some voluntarily reduced this figure accepting that too long hours could actually reduce productivity. In 1846, Robert Stephenson & Co.'s draughtsmen worked from 7am to 6pm, (4pm on Saturdays), a net 55 hours.[67] Some Lancashire manufacturers introduced the 'English Week' (early finish on Saturdays), resulting in 57½ or 58½ hour weeks, whilst the normal Saturday finish in the north-east became 4pm.[68] By 1861, the average working week remained at 58.8, although the normal working week in the north-east was 60-61 hours.[69] In spite of the 1852 dispute largely against the expectation of systematic overtime (Section 6.5), manufacturers required regular overtime to be worked at times of high demand.

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62 Article, Newcastle Chronicle, 3rd Feb 1846, quoted in Clarke, *op cit* (13), pp.9/10.
63 "Regulations for the Drawing Office of R. Stephenson & Co.", quoted in Warren, *op cit* (7), p.100.
64 Martin, *op cit* (59), p.45.
65 Rowe, *op cit* (40), p.41.
66 Martin, *op cit* (59), p.45.
67 Warren, *op cit* (7), p.100.
68 Rowe, *op cit* (40), p.45.
69 J.B. and M. Jeffrys, 'The Wages, Hours and Trade Customs of the Skilled Engineer in 1861', Economic History Review, Vol.XVII, 1947, p.32.

The passing of the 1867 Factory Acts Extension Act brought the manufacturing industry into the same legislative framework as textile and other factories, which had been progressively subject to employment restrictions under the Factory Acts of 1831-1864. Although it was the first legislation to affect the locomotive manufacturers, it had little direct effect as their hours were generally below those required by the Act.[70]

At the beginning of the railway era, wages in the main manufacturing centres averaged about 20/- per week. Foreman millwrights could earn up to 42/- per week, including allowances for installing engines on customers' premises. R.&W. Hawthorn employed smiths and fitters for about 18/-, an experienced machinist received 22/-, whilst long-serving men and foremen could earn 25/- to 28/- weekly. Labourers were paid, typically, 12/- per week.[71] By the early 1870s, the company's wage scales had increased generally to an average of 28/- weekly.[72]

Higher wage rates were necessary in relatively remote areas to attract sufficient labour. In 1855, Beyer Peacock & Co. paid higher wages to attract a workforce from other manufacturers to its factory in the Gorton area of Manchester. Its average weekly wage was about 34/-, with all craftsmen receiving more than 30/-, and foremen receiving £5 a week.[73] Beyer Peacock's wage rates remained higher than their competitors in the main industrial centres, such as Leeds. In 1866, the Hunslet Engine Co. paid an average wage of about 30/-, with fitter/erectors being paid 26/- to 32/-, boiler makers up to 34/-, machinists 16/- to 26/-, and labourers 16/-. Overtime figures showed that wages could be increased for working up to a 72 hour week.[74]

At the conclusion of the 'lock-out' dispute of 1898 (Section 6.5), minimum weekly wage rates had been agreed with the ASE Union for skilled men working a 53 hour standard week.

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70 Rowe, *op cit* (40), p.52.
71 Clarke, *op cit* (13), p.4.
72 *ibid*, p.29.
73 Hills and Patrick, *op cit* (26), pp.19/20/285.
74 L.T.C. Rolt, A Hunslet Hundred, Dawlish, 1964, p.34.

The wage-scales ranged between foundrymen and pattern-makers at 36/-, to machinists at 26/- per week.[75]

Incentive piecework payments were introduced by several locomotive manufacturers in the latter part of the century as they pursued larger batch production (Section 5.7.3). Piecework was largely confined to volume industries where there was incentive and opportunity for productivity improvements. Surprisingly, the earliest reference to piecework in a locomotive factory was in the 'Rules and Regulations' of R.B. Longridge & Co. on its start-up in 1837, which required "Every workman on piecework" to give an "accurate account of time at the office when leaving work".[76]

With greater batch production opportunities, piecework was introduced into railway-owned locomotive factories early on. By 1861, half of Swindon's union-based workforce was so employed, with smaller proportions at Brighton, Crewe, Wolverton, Doncaster and Darlington.[77] Baldwins in America had fully implemented piecework payments by 1857, as it pursued interchangeable component batch production (Section 5.7.3), and demonstrated that increased productivity not only lowered unit production costs, but also unit overhead charges.[78] During boom markets, piece rates were left unchanged, the workforce took home more pay by increasing output and enhanced the company profits. This gave the workforce a larger than average portion of the margin between production costs and selling prices.

By the 1880s/1890s, several independent manufacturers had implemented piecework schemes, as they sought to reduce costs in the face of increased competition. Piecework offered opportunity for higher wages through faster production, particularly for un-skilled machinists who operated several machines simultaneously, with lower supervision. Kitsons' Works Manager, E.K.Clark, introduced a form of 'Payment by Results' in the 1880s, but serious anomalies arose in the distribution of awards by the "autocratic and ingenious

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[75] Michael R. Lane, The Story of the Steam Plough Works, London, 1980, p.166.
[76] Martin, *op cit* (59), Appendix, p.45.
[77] Drummond, *op cit* (4), p.70.
[78] Brown, *op cit* (31), pp.149/150.

Leading Hand", which led to several disputes.[79] As estimating experience was gained by the 'Price Settler', piecetimes were reduced and stifled incentive. In replacing this system, Clark himself allocated a price to each 'piece' and machine process, by his own "observation, and estimate, by trial and error". Employees were made individually accountable for their time, a move which still met with dissatisfaction, and which Clark later determined was a failure.

Habakkuk has argued that, in England, it was more difficult to reduce piece rates, justified by increases in labour productivity, due to the introduction of labour-saving machines, which made them less attractive to manufacturers.[80] Unlike the Baldwin practice, as piecework experience was gained, manufacturers reduced standard production times, making them more difficult to improve upon. Piece-work rates, introduced by Hudswell Clarke & Co. by the end of the century, were described as 'low', the bonus for early completion being usually time and one eighth, but long hours of overtime were worked, sometimes through the night.[81] If piece times were regularly bettered, the price was re-assessed for future work, with a consequent reduction in earnings. This practice by several manufacturers led to growing discontent, building to outright opposition by the 1898 'lock-out' (Section 6.5).

Not all locomotive works successfully introduced a piece-work system. At R.&W. Hawthorn Leslie's factory in 1889, William Cross complained of the lack of accurate cost records:[82]

> .... piecework is simply guess-work on the part of the foreman aided by such imperfect costs as he has been enabled to obtain for himself. At present and for some time past, we have been working no piecework in the machine and erecting shops, owing to want of sufficient data to settle prices......

Pecket & Sons went as far as to state that: "No piece work is allowed, as the proprietors are determined to avoid scamping, and to ensure first-class workmanship......"[83] Manning Wardle also continued to pay its workforce an hourly wage rather than by piece work.[84]

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79 Edwin Kitson Clark, Kitsons of Leeds, nd but 1937, pp.154/5.
80 Habakkuk, *op cit* (57), p.156.
81 Redman, *op cit* (28), p.59.
82 Clarke, *op cit* (13), pp.55/6.
83 Article, The Railway Engineer, Vol.VIII, No.10, October 1887, pp.304-309.
84 Redman, *op cit* (28), p.21.

6.3.3 Premium Apprenticeships

Some manufacturers engaged educated young men from families of 'reasonable means', and gave them five to seven year apprenticeships, for which their fathers paid a premium to the firm's partner as well as meeting their sons' living expenses. Such men, some related to the firm's proprietors, could expect to become engineers in due course, and their apprenticeships involved several aspects of 'civil engineering' beyond workshop craft skills. Thomas Gooch was apprenticed to George Stephenson for six years in 1823, the first two of which were "in the occupation or business of practical engineer and in making building and fitting up Steam engines and the various branches of Machinery."[85] In 1827, Stephenson wrote to another parent, William Salvin:[86]

> I will engage to take your son to give him instruction in my profession, for the term of five, six or seven years - My fee is 200 guineas at the signing of the indentures: his board and lodging to be paid by his friends, until I can receive such a sum for his labor, as will pay it.

The Stephensons attracted several applications from families in the 1830s, which prompted them to increase the premium, up to £300 and even to £500. Robert Stephenson wrote:[87]

> We have at present as many, indeed more, young men than we can sufficiently employ. If we increase the number (which we have frequent opportunities of doing) we should only be doing the young men injustice, because they would not have proper and sufficient experience to learn the profession....... Taking young men, although it may be a profitable part of our business is one that incurs great responsibility......

In 1839, William Lawford was apprenticed to Stephenson for five years for a premium of £525, about 18 months of which was spent at the Stephenson factory.[88] Other engineers also received many applications for premium apprenticeships. James Nasmyth agreed to take George Grundy's son in 1838 for £300, even though he could not be accepted for three or

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[85] Articles of Apprenticeship, Sixth day of October 1823, Library of the Institution of Mechanical Engineers, Phillimore Collection.
[86] Letter, George Stephenson to William Salvin, Liverpool, 25th June 1827, Durham County Record Office, Ref.D/Sa/C/139.2.
[87] Letter, Robert Stephenson to Thomas Richardson, Dieppe, July 11th 1833, quoted in Jeaffreson, *op cit* (23), p.182.
[88] Article, Biographer and Review, Vol.III, No.40, September 1900, Copy in the Northumberland County Record Office, Ref.NRO765.

four months.[89] At that time, Nasmyth set down the distinction between premium and craft apprenticeships:[90]

> It is only our premium apprentices whom we engage to instruct 'in every branch' of the art or business of machine makers & engineers - the others are continued at one employment such as fitting or turning or removed from it to another occupation to suit our convenience.

The jump in demand for locomotives in the mid-1830s and the consequential increase in the Stephenson Company's workforce was accompanied by an increase in the number of apprentices. This was not welcomed by Robert Stephenson, as reflected in a letter to Joseph Pease:[91]

> If it be the particular wish of your father to place the youth (mentioned in your letter) at Forth Street, I shall of course not object, although I had given instructions that no more apprentices should be taken - they are an everlasting source of mischief - we were always in hot water with them, and I regret having made any arrangements for allowing some of them to come into the office, to become acquainted in every detail with our plans &c - They have no sooner done so, than they leave and carry away what has cost us a great deal of money and more thought -

Nasmyth went further in his dislike of the apprenticeship system, which he considered to be "the fag end of the feudal system" and advocated its abolition "in every branch of business".[92] He also felt "they caused a great deal of annoyance and disturbance. They were irregular in their attendance, consequently they could not be depended upon for the regular operations of the [Bridgewater] foundry. They were careless in their work, and set a bad example to the unbound."[93]

The premium apprentice system had the benefit of revealing promising talent at an early stage, and allowing that talent to be developed accordingly. Edward Snowball was apprenticed to Stephenson in 1846 at the age of 16, and such was his intuitive design talent

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[89] Nasmyths Gaskell & Co. to G. Grundy, 10th November 1838, Nasmyth Collection, *op cit* (24), Letter Book 3, p.240.
[90] Letter, Nasmyths Gaskell & Co. to S.Wardle, 28 June 1838, *ibid*, Letter Book 2, p.253.
[91] Letter Robert Stephenson to Joseph Pease, Weedon, 7 Sept:1836, Pease-Stephenson Collection, *op cit* (15), Ref.D/PS/2/55.
[92] Royal Commission on Trades Unions, Tenth Report, Parliamentary Papers, 1868, Vol.39, Q.19,201, quoted in Cantrell, *op cit* (25), p.239.
[93] Smiles, *op cit* (32), p.227.

that, before he had completed his five year term, Stephenson installed him as his Chief Draughtsman.[94]

Although there were limited openings for premium apprenticeships in the second half of the century, the demand largely favoured railway-owned workshops,[95] although some firms, such as R.&W. Hawthorn, did engage 'operative and scientific' apprentices, for which parents paid a premium of £400.[96] Proprietors' sons often undertook apprenticeships in their fathers' firms. In 1863, for example, J. Hawthorn Kitson started his apprenticeship at the Kitsons' Airedale Foundry.[97] Later in the century, Edwin Kitson Clark was apprenticed there, after leaving Cambridge University with a first class classics tripos in 1887. He later became a foreman, Works Manager, Partner, Director and finally Chairman of Kitsons.[98]

6.3.4 Craft Apprenticeships

Each manufacturer took on craft apprentices in accordance with its anticipated long term requirements. Young men were given five to seven year apprenticeships in a specific craft, as set down on their 'indentures', which was signed by a partner or director, the apprentice's father and the youth himself. The standard and legally-binding indentures set out the nature and period of the training, together with the annual wage rates, which depended upon the nature of the training and a proportion of the craftsmen wage rates. The apprentice was 'bound' to the principal who was, in turn, obliged to see the youth through to the completion of his 'time'.

The crafts were jealously guarded within families, it being the normal practice for the eldest son of a 'journeyman' to be offered a preferential apprenticeship, which Southall refers to as a

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[94] John Thomas, The Springburn Story, Dawlish, 1964, p.103.
[95] Drummond, *op cit* (4), p.42.
[96] Clarke, *op cit* (13), p.29.
[97] Clark, *op cit* (79), p.175.
[98] *ibid*, Chapters 8, 9 and 10.

self-perpetuating permanent upper class within the working classes.[99] As Taksa has noted in relation to the Eveleigh Workshops,[100] the practice of sons following in their fathers' crafts was widespread and served to reinforce the claim for 'closed shop' status adopted throughout the century, and to maintain which there were several disputes, particularly towards the end of the century (Section 6.5). With the expansion of the industry in the 1830s, the supply of eldest sons was insufficient, and second and third sons, and sons of fathers out of the trade, were encouraged to take up an apprenticeship.[101]

Apprenticeship periods and wages varied according to the craft. Three apprentices engaged by Robert Stephenson & Co. at the beginning of the railway era were, respectively, taken on for seven years as an 'Iron Founder' (wages 4/- rising to 12/-), a five year term as an 'Engine Builder' (wages 6/- to 14/-), and a four year term as a 'Boiler Builder' (8/- to 12/-).[102] The apprentices were reliant at first on families or friends for accommodation and subsistence. Robert Millward, who was 'bound' to Nasmyths Gaskell & Co., was reliant upon his father to "provide for the said Robert Millward meat drink washing and lodging and wearing apparel and necessary Instruments and Tools of all kinds......"[103]

Nasmyth was much against the apprenticeship system and soon abandoned it in favour of employing unbound "intelligent well-conducted young lads" who were given responsibility according to aptitude:[104]

> They took charge of the smaller machine tools, by which the minor details of the machines in progress were brought into exact form without having recourse to the untrustworthy and costly process of chipping and filing........ We were always most prompt to recognise their skill in a substantial manner.

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99 A. Charlesworth, D. Gilbert, A. Randall, H. Southall and C. Wrigley (eds), An Atlas of Industrial Protest in Britain 1750-1990, Basingstoke, 1996, Section B 1850-1900, p.61.
100 Lucy Taksa, 'Political and Industrial Mobilization, Workplace Culture and Citizenship at the New South Wales Railways and Tramways Department Workshops 1880-1932', Colin Divall (compiler), Workshops, Identity and Labour, Working Papers in Railway Studies, Number Three, Institute of Railway Studies, York, 1998, p.7.
101 Jefferys, *op cit* (4), p.58.
102 Indentures for John Simpson, December 8th 1827, Crow Collection, *op cit* (14); for Michael Hobson, May 15th 1830, McDowell Collection of the Stephenson Locomotive Society, Ref.P.14; and for Edward Bates, October 25th 1830, Crow Collection.
103 Indenture, Robert Millward, 15 March 1839, Science Museum Library, London.
104 Smiles, *op cit* (32), pp.227/8.

> there was the most perfect freedom between employer and employed. Every one of these lads was at liberty to leave at the end of each day's work. This arrangement acted as an ever-present check upon master and apprentice. The only bond of union between us was mutual interest.

Apprentices would occasionally be used as less expensive 'labourers', particularly when major disputes were looming. In advance of the nine-hours dispute of 1871 (Section 6.5), for example, R.&W. Hawthorn recruited 101 apprentices and, by August 1872, just over 20% of its 1000 employees were apprentices.[105]

Although long apprenticeships were seen both as a way of developing future skills and as a justifiable form of 'bound' servitude to provide a ready means of inexpensive labour, they continued to limit the availability of skilled labour during the century. The pressure from the journeymen, in their protracted dispute with the employers over the use of non-apprenticed labour (Section 6.5), meant that a high proportion of labour was being apprenticed unnecessarily. By the end of the century, the training requirements of manufacturing industry generally were considered to be backward by comparison with normal American practice. Orcutt stressed this backwardness in a paper in 1902:[106]

> It is wasteful and foolish that a man must serve from four to five years before he can become a proficient turner, when we know that in a few weeks a laborer can learn to operate two grinding machines and produce cylindrical surfaces that it is impossible for the most skillful turner to duplicate, either in regard to quality or to cheapness. This is not saying that it is unnecessary to train men to become good turners; it is, however, unnecessary to train them to perform many operations which are superseded by new methods of working...

and concluded that training should be confined to "men who are necessary for supervising and keeping plant in a high state of efficiency."

The British practice was pursued by the locomotive industry through to the twentieth century, in contrast to the Baldwin locomotive works in America which discontinued craft apprenticeships after 1868. Although providing no evidence to explain this move, Brown

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105 Clarke, *op cit* (13), p.29.
106 H.F.L. Orcutt, 'Machine Shop Management in Europe and America', paper to the Institution of Mechanical Engineers, Engineering Magazine, January-March 1902, pp.551-554 & 703-710.

suggests that, as the firm moved so comprehensively towards component standardisation and batch production (Section 5.7.3), the necessity for lengthy training became irrelevant.[107]

The manufacturers' employment policies were thus dominated by the relationship between skilled and unskilled labour. The craft culture, which had been so dominant at the beginning of the railway era, continued to dictate employment decisions in the locomotive factories, in spite of the manufacturers' moves to decrease dependence on craft skills. The motivation for employing un-skilled labour, made possible through the introduction of self-acting and automatic machine tools, was three-fold. Not only were the costs of repetitive production reduced, and the shortage of skilled labour minimised, but un-skilled men provided an employment cushion, which allowed their level of employment to rise and fall in accordance with the fluctuating market. This general policy resolved one of the manufacturers' major tactical problems, whilst allowing them to preserve their requisite levels of craft skills through favourable employment terms and paternalistic incentives.

6.4 Paternalism

With the continuing shortage of skilled craftsmen during the century, paternalistic as well remuneration incentives were important aspects of the manufacturers' employment policies. This was as much to stimulate loyalty and continuity of service in manufacturing areas where the men had alternative employment opportunities, as it was to attract men to the more remote locations.

Drummond has noted that paternalism was introduced from the start-up of the railway workshops in the 1840s,[108] but its origins lay much earlier, with some manufacturing proprietors, such as Michael Longridge.[109] From 1810, the men of the remote Bedlington

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[107] Brown, *op cit* (31), pp.136-143.
[108] Drummond, *op cit* (4), p.63.
[109] Daniel Liddell, The Practicability of Improving The Condition of the Working Classes, printed pamphlet for circulation, Newcastle, 1836.

Iron Works could send their children to 'schools', the boys receiving instruction "in the usual branches of education", whilst the girls were "instructed in needle-work &c". The workmen were provided with a library and regular newspapers, and with "surgical advice and medicine", towards which married men paid 2d a week, and single men 1d per week. A benefit society was formed into which members paid 3d per week, and to which was added the value of any fines imposed on the workmen. Any contributor unable to work through sickness received 8/- weekly from the Society, which by 1836, had 80 members. A savings bank was also set up, into which over £1,000 had been deposited by 1836.

It is not recorded if Longridge introduced similar benefits at the Stephenson factory during his tenures as managing partner, but they were introduced for the R.B. Longridge & Co. men from 1837.[110] It was a condition of service that "every person who enters service shall pay to the medical fund." A pension scheme was also introduced, its terms being:

> Any agent, clerk or man in the works service, shall after ten years (not including term of apprenticeship) becoming incapable of work through old age or accident in the company's service or receiving any disease not occasioned by intemperance, receive a pension of £5 per annum for life, or after twenty years, £10 per annum, and after one year, £1 for each year.

In 1839, a Bedlington news sheet wrote: "Few establishments can boast a better regulated set of workmen. No means have been left unemployed to make them comfortable."[111] The provision for the well-being of the Bedlington workmen was, however, two or three generations ahead of such provision generally in the country. Not until 1880 did the Employers' Liability Act require employers to set up insurance schemes for their employees,[112] whilst only in 1897 did the Workmen's Compensation Act introduce the responsibility on employers to provide for the welfare of their employees.[113] One of this Act's provisions allowed claims for compensation to be made against employers for injuries due to an "accident arising out of and in the cause of his employment."

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110 Martin, *op cit* (59), p.45.
111 The Blyth and Bedlington Literary Supplement, 1839, quoted in Martin, *ibid*, p.38.
112 Drummond, *op cit* (4), p.64.
113 Lane, *op cit* (75), p.166.

Welfare and educational opportunities were provided by some other employers. In 1853, for example, when the Canada Works at Birkenhead was opened by Peto, Brassey & Betts, a canteen was provided, whilst the three proprietors donated £75 for the construction and filling of a 600-volume library. A concert and dance in Birkenhead was put on for five hundred of the men and their wives, which raised a further £12 for the library, which was stocked with copies of local and national newspapers. The men paid a penny a week towards the reading room which was run by the workmen themselves.[114]

Prior to the confrontational industrial relations of 1871 and later years (Section 6.5), looser forms of paternalism, such as works dinners and other collective activities, were usually perceived to engender loyalty and longevity of service. On New Year's Eve, 1839, Robert Stephenson provided a dinner in the Newcastle factory, which was well received by the workmen.[115] A more ambitious dinner was provided by Stephenson in 1845 for his 850 workmen, who processed from the factory to the centre of Newcastle to celebrate the passing of the Newcastle & Berwick Railway Act, for which he was Chief Engineer. They then "were provided with a Dinner at the expense of their employers, and others interested in Railways." This was seen to be "proof of the kindly feeling that exists between the employers and their workmen."[116]

At the beginning of each year, from 1856, Beyer Peacock & Co. provided a "Programme of Amusements" for its workforce "to celebrate the [anniversary of] the opening of Gorton Foundry."[117] The venue was Manchester's Belle Vue Gardens and a procession by the workmen was followed by a programme of sporting events, and concluded at five o'clock when the men were "allowed to introduce Ladies for Dancing."

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114 John Millar, William Heap and His Company 1866, Hoylake, 1976, p.48.
115 Report of speech by R. Brown at New Years' Eve dinner for the boiler-makers of R.Stephenson & Co. at the Garrick's Head, Newcastle on Tyne, Newcastle Courant, January 1st 1870.
116 Report, Newcastle Chronicle, September 6th 1845.
117 Hills and Patrick, *op cit* (26), p.20.

In c1864, five years after becoming Managing Partner of the Stephenson Company (Section 6.2.1), George Robert Stephenson instituted an annual New Year's Eve dinner for the c1,250 men. Over 20 taverns in Newcastle were needed to accommodate everyone.[118] As Taksa has noted in relation to the Eveleigh Workshops,[119] the reports of the dinners reflected the strong 'collectivism' by each craft group, who dined separately. They were addressed by their foremen, who were the "Chairmen" for the evening, and whose speeches reflected a good relationship between management and workforce. It is likely, however, that the dinners were discontinued after 1870 as the workforce became embroiled in the nine-hour dispute (Section 6.5), and went short of money through their contributions to the movement's strike fund.

Paternalism was rewarded by loyalty and longevity of service. An 1888 article about Robert Stephenson & Co., noted that two employees had continuous service since the late 1830s, one of whom was still employed at the age of 72.[120] Neilson & Co. had one employee who began his apprenticeship in 1859 and retired in 1901,[121] but the longest service seems to have been that of Beyer Peacock's first employee, Thomas Molyneaux, who was recruited from Sharp Stewart & Co., where he had been engaged since 1831, and who retired in 1903 after 49 years service (and a total working life of 72 years).[122] Such longevity has similarly been noted by Drummond in relation to railway-owned workshops.[123]

Loyalty and longevity of service for senior personnel could be rewarded by *ex-gratia* payments. In 1860, George Crow, the Stephenson Company's Head Foreman, received from George Robert Stephenson, £100 "as a token in expression of this feeling [the deep interest you have always taken in performing the duties of your department] on my part and of my

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118 Reports, Newcastle Chronicle, 1st January 1869 and 1870.
119 Taksa, *op cit* (100).
120 Article, 'Workers in Steel and Iron, 1', Messrs. R. Stephenson & Co. Ltd., Newcastle Upon Tyne, The Shipping World, March 1 1888, pp.338/9.
121 Thomas, *op cit* (94), p.84.
122 Hills and Patrick, *op cit* (26), p.19.
123 Di. Drummond, 'Specifically Designed'? Employers' Labour Strategies and Worker Responses in British Railway Workshops. 1838-1914', Business History, Vol.31, 1989, p.12.

sincere regard for you."[124] In 1856, three senior employees of the Stephenson Company, George Crow, L. Kirkup and Edward Snowball, were considered to be "deserving of distinction" by the International Jury for the 1855 Paris Universal Exhibition.[125]

Loyalty to employers and to each other was a notable characteristic of paternalistic employment. The workmen themselves would occasionally contribute to persons or groups in distress. In 1836, for example, when a John Dixon and family lost their Newcastle home by fire, the workmen from several factories donated sums of money into a relief fund for him.[126] The death of a proprietor or senior manager saw collective mourning by the workmen. The funeral of William Hutchinson, one of the Stephenson Company's partners (Section 6.2.3), in 1853, saw a procession of over 800 workmen, "the whole proceedings were conducted in a solemn and creditable manner."[127] On the death of Robert Stephenson six years later, "a great number of gentlemen from Newcastle attended the funeral [in London] - the North Eastern Railway Co. gave them return tickets." In Newcastle itself, the memorial service in St. Nicholas Church was attended by 1,000 workmen "from the different factories."[128]

Paternalism was thus recognised by the manufacturing proprietors as an important policy with which to maintain their requisite levels of craftsmen in a competitive labour market. The loyalty and longevity of service demonstrably confirmed the benefits of this policy. After 1871, however, reports about paternalistic endeavours are noticeably absent. The inference is that the 'nine hour' dispute of that year, marked the beginning of an era of confrontational relationships in which paternalism could no longer play such a significant part in the manufacturers' employment policies.

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124 Letter G.R. Stephenson to George Crow, Newcastle upon Tyne, July 13th 1860, Northumberland County Record Office, Ref.NRO793/5.
125 Letter, G.F. Duncombe, for the Board of Trade, to Messrs. R. Stephenson & Co., London, 5th April 1856, Northumberland County Record Office, Ref.NRO793/4.
126 Article, Newcastle Courant, 20th February 1836.
127 Article, Newcastle Courant, 19th August 1853.
128 Francis Mewburn, The Larchfield Diary, Darlington, 1876; also Report, The Times, October 21st 1859.

6.5 Industrial Relations

"The Employers explain too little; the Employees exclaim too much"[129] Clark's exhortation summed up the industrial disputes which, in separate eras through the 19th century, severely disrupted the heavy manufacturing industry, including the production of locomotives. The proprietors and their senior managers were central to these disputes which were as much concerned with the displacement of skilled by un-skilled men, as they were on wage and reduced hour claims. As the trades unions became more unified in their preparations for the disputes, the manufacturers' independent tactics employed in the early disputes were replaced by joint responses by employers' federations. There was, however, a lack of cohesion between them, which prolonged some disputes and failed to resolve the central issue of skilled employment by the end of the century.

The foundations of collective representation were laid at the beginning of the locomotive industry. In 1825, a "Millwrights Benevolent Benefit Society.... For the Relief Of Each Other When In Distress And For Other Good Purposes...." was formed in Newcastle. Its founding committee, including at least one employee of Robert Stephenson & Co.,[130] restricted its membership such "that no one shall be admitted a member who is not working as a journeyman Millwright or Engine Builder." There was an "admission-money of ten shillings and sixpence" and a monthly shilling subscription, which allowed the Society to build up sick benefit funds.

This and other societies, such as the Friendly Society of Mechanics formed in Manchester in 1826, were used to establish 'closed shops' by the millwrights. William Fairbairn complained that the millwrights had a "rude independence.... [and] would repudiate the idea of working.... with another unless he was born and bred a millwright."[131] The resulting

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[129] Edwin Kitson Clark, quoted in Clark, *op cit* (79), p.170.
[130] Printed notice, "Articles, Rules & Regulations of the Millwrights' Benevolent Benefit Society, instituted at Newcastle Upon Tyne, February 19th 1825...... To be held at the House of Mr. Heron, The Sign of the Cock Inn, Head of the Side, Newcastle Upon Tyne".
[131] Fifth Report from Select Committee Respecting Artisans etc., Parliamentary Papers, 1824, Vol.5, pp.566-569.

shortage of millwrights was already evident in 1825 when the Stephenson Company was manufacturing its first locomotives. Michael Longridge wrote:[132]

> As the Darlington Rail Way Engines must be finished in three months we have no choice at present but to comply with the demands of the Men - which however will be attended with bad consequences. there have been two Meetings of the Master Millwrights - & there is to be another on Monday - but it is of no use whatever.

Rowe noted that were several industrial disputes in 1836, as the new trades unions sought to take advantage of the healthy economic climate to increase wages and reduce working hours.[133] Employers saw the co-ordinated action of the unions as a particular threat to be denounced and turned some of the disputes into issues of union membership and closed shop practices. Boiler-makers' 'Friendly Societies', including the Manchester-based Society of Friendly Boiler Makers, effected a closed shop. Nine Liverpool firms, including the locomotive manufacturers, Edward Bury & Co. and George Forrester & Co., jointly sought to get around this by laying off boiler-makers who had struck for higher wages, and refused to re-instate them unless they "quit the 'union'." Several thousand men were laid off during the dispute, which the managements sought to end by recruiting men "who will pledge themselves to remain unconnected with the present or any future boiler-makers club" from other parts of the country.[134] The strike succeeded in winning a 10-hour day for the employees of several Lancashire firms.

A strike at James Nasmyth's new Bridgewater Foundry in 1836, had a profound effect on his attitude to industrial relations. The issue was the first confrontation over the skills issue, with the Engineer Mechanics Trade Union seeking employment only for 'time-served' union members.[135] Pickets prevented most willing employees from getting to work during the three months strike, and to avoid a humiliating defeat Nasmyth travelled to his native

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[132] Letter, Michael Longridge to George Stephenson, Bedlington Iron Works, 5 Mar 1825, Crow Collection, *op cit* (14).
[133] Rowe, *op cit* (40), p.41.
[134] Newcastle Courant, 24th September and October 1st 1836.
[135] Copy letter, Nasmyths Gaskell & Co. to Braithwaite Milner & Co., 2nd November 1838, Nasmyth Collection, *op cit* (24), Letter Book 3, p.262.

Scotland to recruit "64 first-rate men, who had been wheelwrights and carpenters, smiths and stonemasons." The strike effectively collapsed on their arrival, and, when regular working proceeded, the majority of Nasmyth's men were Scottish.[136] Following the conflict, he would neither tolerate trade unionism nor employ only time-served journeymen.

Against this background of closed-shop dispute and resulting shortage of craftsmen, Nasmyth, Fairbairn, Roberts and others introduced their new equipment and processes that could be taken up by un-skilled workmen. With each successive demand-peak for locomotives and other capital goods, particularly in the mid-1840s, the consequential requirement for routine machining was met by further machine tool innovation (Section 5.5). Nasmyth, who was not alone in refusing to employ trade union members, arranged a separate employment contract with each employee, determining that relations between employer and workman should be based on "the principles of free trade, without the intervention of third parties."[137]

Demonstrations in favour of political aims were not unusual in the 1830s, and Longridge's reputation of being a good but firm manager (Section 6.4), was tested in 1839 when the 'Chartist' movement turned on the Bedlington Iron Works and the adjacent locomotive Works of R.B. Longridge & Co. Over several days, there was a 'riotous assembly' which some of the Bedlington men were intimidated to join, about which Longridge wrote: "I felt utterly ashamed that any of my men should thus far sully the fair name of the Bedlington Iron Company's workmen by mixing with such a rabble."[138] Longridge's long oration to the mob, which he printed and circulated, demonstrated his firm opposition to Chartism and likened its advocates as being novices trying to repair an engine: "We might possibly have skill enough to take the engine to pieces, but I am sure that we could never put it together again...." The

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136 Royal Commission on Trade Unions, Tenth Report, Parliamentary Papers, 1868, Vol.39, Q.19,112, quoted in Cantrell, *op cit* (25), p.241.

137 Royal Commission, Q.19,234, *ibid*, p.237.

138 Printed pamphlet: 'An Address Delivered to the Workmen Employed at the Bedlington Iron Works, Upon the 21st June 1839', Michael Longridge, Newcastle, 1839, Newcastle Public Library, Ref. L042, Local Tracts D34, Political No.7.

cessation of the conflict was a vindication of Longridge's tough stand, which earned the respect of the workmen: "... I am very popular with all the Workmen."[139]

The 'Plug Riot' strike in the summer of 1842, which Mather describes as the first general strike in Britain, spread out from the north west of England.[140] Although the country's recession had led to wage reductions, the multi-origin discontent gave fuel to the embers of the Chartist and anti-Corn Law movements. The strike and attendant rioting affected most industries, including the north-west locomotive manufacturers. A deputation of Sharp Roberts & Co.'s men organised the Manchester trades regarding Corn Law repeal, and one of their smiths, described as a "ringleader" and an "Owenite Socialist", was arrested during the disturbances.[141] There is no surviving record of Sharp Roberts' response, or that of any other locomotive firms, but the strike collapsed through lack of internal cohesion and the determined actions of the Magistrates.[142]

The 1842/43 recession reduced the shortage of craftsmen, but, with the rapid growth in the locomotive market from 1844 (Section 2.6) the shortage returned. The manufacturers employed further unskilled personnel who could be quickly trained to operate the new self-acting machine tools (Section 5.5.1). There was strong resistance from the trades unions, such as the Journeymen Steam Engine and Machine Makers' Society (JSEM) and the Friendly Society of Ironfounders. The employment of 'adult' apprentices and 'illegal' men by Jones & Potts in 1846 led to a direct conflict with the JSEM, the resulting four month strike at their Viaduct Foundry becoming a test case on the closed-shop issue.[143] Several strikers were arrested, including the General Secretary of the Union, which undertook nation-wide fund-raising towards the men's defence. After trial and conviction of the strikers at the

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139 Letter, Michael Longridge to William Longridge, Bedlington, July 14th 1839, in private possession of Mr. R. Longridge, and quoted with permission.
140 F.C. Mather, 'The General Strike of 1842', in R. Quinault and J. Stevenson (eds), Popular Protest and Public Order, London, 1974, pp.115-140; Also M.Jenkins, The General Strike of 1842, London, 1980, *passim*.
141 Charlesworth &c, *op cit* (99), Chapter 7, The General Strike of 1842, pp.51-58.
142 Mather, *op cit* (140), pp.133-135.
143 Jefferys, *op cit* (3), pp.26/7; Also K.Burgess, The Origins of British Industrial Relations, 1975, pp.11 & 16.

Liverpool Assizes in 1847, the union raised further funds for their appeal which was successful in reversing their conviction.

The economic upturn from 1851 coincided with a re-organised and enlarged union organisation in the manufacturing sector, the JSEM having become, through amalgamation, the Amalgamated Society of Engineers (ASE). So soon after the euphoria of the Great Exhibition, the ASE sent demands to employers on three main employment issues, namely the employment of un-skilled men, the removal of piecework and automatic overtime working. 34 Manchester employers, including Sharp Brothers, Fairbairn & Sons and Nasmyths Gaskell, formed a 'Central Association', and invited major London employers to join their resistance.[144] They advised the ASE that its demands were "totally inconsistent with the rights of employers of labour" and that if a strike occurred at any of the 34 firms they "have unanimously determined to close our establishments."[145] The employers duly closed their works and 'locked out' 3,500 union members, 1,500 other artisans and 10,000 labourers in Lancashire and London.

Sharp Brothers laid off over 600 men, and Fairbairns 2,500 men in their Manchester and London factories. Thomas Fairbairn took an active part in trying to resolve the dispute, and wrote letters on the subject to the 'Times'.[146] Nasmyth 'locked out' 300 union members from the Bridgewater Foundry, but employed all his other men, and used the opportunity to increase his quota of 'unbound' apprentices.[147] He later wrote:[148]

> I placed myself in an almost impregnable position, and showed that I could conduct my business with full activity and increasing prosperity, and at the same time maintain good feeling between employed and employer.

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144 Charlesworth &c, *op cit* (99), Chapter 9, Lock-Outs and National Bargaining in the Engineering Industry 1852, pp.72/3.

145 The Times, 20th December 1851.

146 The Times, for example letter, 14th January 1852, quoted in R.A. Hayward, Fairbairns of Manchester, unpublished MSc thesis, UMIST, 1971, p.2.14.

147 Royal Commission, 1868, Q.19,134, quoted by Cantrell, *op cit* (25), p.243.

148 Smiles, *op cit* (32), p.311.

The lock-out lasted for nearly three months, by which time the ASE funds were nearly exhausted, and its survival threatened. Although the ending of the dispute heralded a long period of industrial peace, the ASE had learned lessons, and resolved that any future dispute would be regional rather than national, to make better use of its financial resources.[149]

Labour relations were generally harmonious for the twenty years between 1851 and 1871, in which year the issue of the basic working week erupted. The economic recovery in 1870 was the opportunity for the men of the Tyneside shipyards and factories, including the Stephenson and Hawthorn sites, to seek weekly instead of fortnightly pay, calculated to be worth 2/- a week from the resulting credit saving.[150] The request was promptly accepted by most employers, with the exception of R.&W. Hawthorn, whose 1200 men walked out. It was the first general stoppage at the site, and the Hawthorn management hurriedly implemented weekly payment.[151]

Even after the provisions of the 1867 Factories Act Extension Act (Section 6.3.2), the 1871 'Nine Hours Movement' on Tyneside pursued a shorter working week, without any political issues or fratricidal conflicts. McCord noted that less than a quarter of the skilled engineering workers were members of trades unions in the build up to the dispute.[152] Although the leaders of the 'Nine Hours League' held trade union office, their influence and authority derived primarily from individual qualities of leadership, rather than from trade union organisation.

The nine hour demand was first rejected by Wearside manufacturers, prompting a strike which sent Tyneside employers into immediate conference to agree a response when the demands would also be made on them. Sir William Armstrong, whose works were by far the largest, and who was emphatically opposed to a reduction in hours, took charge of the

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149 Charlesworth &c, *op cit* (99).
150 Rowe, *op cit* (40), p.91. Also, Article, Local Industrial Sketches, Northern Echo, January 3rd 1873.
151 Engineering, Vol.XI, March 10 1871, p.172; Also, Clarke, *op cit* (13), pp.21/2.
152 N. McCord, '1871 Strike - Prelimineries', in Allen, Clark, McCord and Rowe (eds), *op cit* (40), pp.100-168, *passim*.

employers' strategy, and dominated its proceedings. Armstrong needed the support of other large firms, particularly R.&W. Hawthorn and Robert Stephenson & Co., both with c1,200 men, (and Black Hawthorn & Co. with 500 men), whose conduct was central to the dispute. R.&W.Hawthorn was a new private limited company, whose inexperienced directors, faced with the conflicting demands of the nine hour claim and the strength of Armstrong's advocacy to reject, felt obliged to prove themselves as strong proprietors and joined Armstrong's intransigent stand.

The same dilemma was faced by George Robert Stephenson, resident in London and dependent upon his General Manager, George Douglas, for the detail and mood of the dispute. Stephenson was a sagacious and generous employer (Section 6.4), who was not prepared to throw away years of equitable industrial relationships to suit Armstrong's unequivocal approach. He wrote a long letter to his men from London declining their request for a nine hour day, agreeing to discuss the issue without coercion, and stating explicitly that he would not join the other Tyneside employers. The men remained at work throughout the dispute, but contributed substantial sums of money to the strike fund, which placated any antipathy there may otherwise have been.[153]

The crippling strike lasted from May to October 1871, when the nine hours day was conceded by the manufacturers to commence from the beginning of 1872. Stephenson also promptly conceded the nine hour day but, characteristically sending a message of independence to the other employers, brought forward its implementation to November. There was a rapid implementation of the reduced hours in factories around the country. In December 1871, for example, when the men of the Avonside Engine Co. requested the nine hour day, the Chairman, Edward Slaughter, replied that: "the hour was given by the Directors ungrudgingly, and it was resolved upon by the Board even before the men applied for it."[154]

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153 Presidential Address of George Robert Stephenson, Proceedings of the Institution of Civil Engineers, Session 1875-76, Vol.44, Part II, January 11 1876, pp.14-15.
154 Article, Engineering, Vol.XII, December 29th 1871, p.424.

The events of 1871 had demonstrated the successful outcome of a regional dispute, and, with further industrial disputes breaking out, the manufacturers' representatives formed the Iron Trades Employers' Association (ITEA). The Glasgow and north-east employers declined to join, the latter group admitting they "were still disunited as a district".[155] Further disputes flared up on Tyneside in 1874/5 as a representative committee of the workforce, requested all "The Employers of Engineering Labour in the Newcastle District" to provide a general increase in wage rate. After negotiations beset with communication difficulties, the employers, including Robert Stephenson & Co., agreed to two phased 5% increases, to be followed by a third 5% "later". "Later" was open to interpretation, as Armstrongs and Stephensons first paid it, but then withdrew in the face of the recession later in the year, and Hawthorns withdrew from it completely.[156]

In devoting part of his Presidential Address to the Institution of Civil Engineers in 1876, George Robert Stephenson stressed the importance of employment terms being commensurate with business opportunities, and accepted that employers were far from always being correct.[157] In an obvious reference to Armstrong's stand in the 1871 dispute he stated: "It cannot be denied that 'temper' has been a very potent element in causing and prolonging some of the larger strikes with which the country has been afflicted." He appealed for understanding and reconciliation and observed that:

> The men themselves have the cure in their own hands, and it can only be effected by their strong determination to stamp out the cause of so much unhappiness..... I do not speak bitterly, but in sorrowful earnest, and I know that there are a large number of good men to whom these remarks will not apply. Let me say, therefore, that it behoves us, who have had superior opportunities, better culture, more immediate means of surrounding ourselves with refining influences, to prove that we are, at least, learning to overcome prejudices, and patiently to take every reasonable method of proving to the men whom we have to employ that we entertain no animosity against them.

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155 Eric Wigham, The Power to Manage: A History of the Engineering Employers' Federation, London, 1973,p.12.
156 Clarke, *op cit* (13), pp.29/30.
157 Stephenson Presidential Address, *op cit* (153).

Industrial disputes became more widespread in the late 1870s and 1880s, however, as the workmen pursued further reductions in hours and wage increases. The survival of the Avonside Engine Co. was threatened by a bitter dispute over the directors' imposition of a 12½ % wage reduction from 1878.[158] Other locomotive manufacturers enjoyed better industrial relations, not least because of loyalty after many years service. E.K.Clark, later wrote that "Among the [Kitsons'] men as a whole there was a continuous rumble of complaint as to the rates of wages, but partly because of the permanence of employment in the past, and confidence in the future, there was little active discontent."[159] Drummond has also noted a similar feeling that was prevalent in Crewe and Derby workshops in the 1880s.[160]

There were several strikes in the early 1890s, for a shorter working week and higher wages, and, in 1896, the ITEA, which helped employers financially, supplying strike-breakers and black-listing strikers, was enlarged into the national Engineering Employers' Federation (EEF).[161] McKinlay and Zeitlin argue that the central constitutive element in the formation of the EEF was the diversity and deep ambiguity which underlay the employers' insistence on managerial prerogative.[162] Although the employers, including the locomotive manufacturers, were responding to cost pressures by further capital investment and employment of un-skilled labour (Section 6.3), their sectoral diversity, overlaid by regional specialisation was to produce internal dissension in the confrontations of 1897/8.

Although the employment of non-union men led to the first round of inconclusive negotiations between the ASE and the EEF, the spark which led to the 1897 dispute was a further call for an eight-hour day, about which the employers had been in two minds, prompted by the recession of 1893 and the consequential availability of labour. Francis Marshall, of R.&W. Hawthorn Leslie, had suggested in that year that "all should lead to an

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158 Davis, *op cit* (9), p.44.
159 Clark, *op cit* (79), pp.146/7.
160 Drummond, *op cit* (123), p.13.
161 Charlesworth &c, *op cit* (99), pp.76/7.
162 McKinlay and Zeitlin, *op cit* (5), pp.33-47.

immediate reduction and I would support an 8-hour day - omitting breakfast time - this should be done now...." There was no response from his Chairman, Benjamin Browne, however, who was a leading member of the EEF, which had no such policy, and he probably suppressed the idea.[163]

In July 1897, before a selective strike could take hold, the EEF 'locked-out' 25,000 workers from 250 firms. By mid-September, with the core of the dispute reverting to working practices, the lock-out affected 34,000 workers, largely in the north of England, and including several locomotive manufacturers, which had far-reaching effects on the industry (Sections 2.8 and 5.7.5). In Glasgow, Sharp Stewart & Co. locked-out its men, although Neilson Reid & Co. avoided action, Hugh Reid stating there was no point in joining the EEF "to fight for a freedom which we already possess."[164] There was a shut-down by Fowlers in Leeds[165], whilst John Kitson, Kitsons' Chairman, took an active part in the dispute, as a member of the EEF's Emergency Committee.[166] Sir Benjamin Browne, R.&W. Hawthorn Leslie's Chairman, played a central role, and in October 1897, wrote to a fellow Hawthorn-Leslie Director:

> I *must* ask the Board to acknowledge that all Union or strike questions be left to me. I am practically the Head of the Peace Party on the Executive of the Engineering Employers and my position is a *very* delicate one.....

Browne helped bring about the end to the dispute, after seven months, in January 1898. The EEF held fast to the employers' right to introduce into all workshops any condition which had previously been accepted by the union somewhere in the country, and the eight hour day was rejected.[167] The ASE's right to collective bargaining over wages was re-affirmed, in return for an acknowledgement of the employers' right to hire non-union personnel, demand up to 40 hours overtime per month, employ as many apprentices as they chose, place any suitable worker on any machine at a mutually agreed rate, and institute piecework systems at

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163 Clarke, *op cit* (13), pp.58/9.
164 Thomas, *op cit* (94), p.155.
165 Lane, *op cit* (75), p.165.
166 Clark, *op cit* (79), p.177.
167 Charlesworth &c, *op cit* (99), p.77.

prices agreed with individual workers.[168] Clark describes one of the "essential agreements" as being the provision for all piecework payments to be paid directly to the employees, and not determined and distributed by leading hands (Section 6.3.2).[169] Southall describes the lock-out as a turning point in industrial relations, following which unions gave less emphasis to craft exclusivity and more to political action.[170]

The cost of the dispute had been dear, having occurred during a buoyant economy, and the effects were serious for the locomotive manufacturers. Edwin Kitson Clark, for example, later wrote, with some understatement, that: "in the guerrilla skirmishes before 1896, in the direct campaign that followed, the firm and personnel of Kitson & Co. have played a part sometimes wisely, sometimes unwisely....."[171] The back-log of locomotive orders was extreme and the industry as a whole was forced to quote the longest delivery times to their customers since the mid-1840s (Section 2.8).

The proprietors and their senior managers were equivocal in their handling of industrial disputes. Nasmyth's strong stance on freedom to employ un-skilled labour was too early for other proprietors, who may have felt vulnerable to the loss of scarce skilled men, and preferred a more measured transfer of repetitive tasks to un-skilled personnel. The equivocation was due both to concern over losing craftsmen and to the personal characteristics of the proprietors themselves. This ranged between the confrontational approach of James Nasmyth and John Jones, and the more conciliatory approach of those other proprietors, such as Michael Longridge and the Stephensons, whose firm but fair employment maintained the men's respect and loyalty.

The effective accommodation between the manufacturers and their workforce in the twenty years before 1871, left them unprepared to face the concerted approach of the trades unions. The new generation of proprietors and senior managers retained divergent views on the

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168 McKinlay and Zeitlin, *op cit* (5), p.36.
169 Clark, *op cit* (79), pp.155/6.
170 Charlesworth &c, *op cit* (99), p.62.
171 Clark, *op cit* (79), p.168.

major issues, especially the employment of un-skilled men. The regional federations, and the later national representative bodies, which were formed as defensive responses to the disputes, were dominated by strong personalities and were not wholly representative of employers' views. This weakened their resolve to deal conclusively with the issue of un-skilled employment, which was thus carried forward into the 20th century.

6.6 Conclusion

Manufacturers were generally successful in developing managerial practices to meet the substantial growth in their activities and the size of their workforce. For more than 30 years the industry was reliant upon its managing partners, who had complete executive control over the strategic and tactical affairs of their firms. From the 1860s, as the early proprietors were ageing, and faced with growing businesses and more demanding strategic decision-making, some introduced salaried general managers and managing directors, whilst others promoted specialist managers to become managing partners. The evident choice of suitable personnel confirms Pollard's thesis that management in the 19th century had progressed from nepotistic to merit selection (Section 1.1).

Some firms converted to limited companies following the 1862 Companies Act, and passed the responsibility for strategic planning to boards of directors attended by managing directors, whilst others remained as partnerships (Section 7.6). By the last decade of the century, the breadth of responsibilities varied widely, between full control by executive partners, such as Neilson Reid & Co. and Dübs & Co., executive directorships of private limited companies, such as Beyer Peacock & Co. Ltd., executive directorships of public limited companies, such as R.&W. Hawthorn Leslie & Co. Ltd. and the Vulcan Foundry Ltd., and General Managers of limited companies, such as Robert Stephenson & Co. Although some limited companies were amongst the leading firms in the country in the development of the new administrative order, the Neilson and Dübs partnerships were the most 'progressive' in terms of manufacturing and employment strategy (Section 7.6).

The long tradition of vertical integration in the manufacturing industry brought significant workshop management experience to locomotive manufacture. This experience was developed from the 1820s into responsible workshop management by Robert Stephenson & Co., thus allowing the Stephensons to pursue their consulting careers. The employment of a salaried 'head foreman' and 'head clerk' was soon emulated by other firms, placing the locomotive industry in the forefront of the emerging multi-activity managerial practice. The stimulus to the recruitment of specialist managers from outside the locomotive firms was the Companies Act of 1862. These managers brought with them particular knowledge of capital equipment, production processes, organisational and employment procedures, as well as the administrative skills of cost and financial accounting (Sections 7.2-7.4).

The delegation of departmental responsibilities to workshop foremen from the 1830s, provided an effective management and organisational system that was a precursor to Chandler's "multi-unit enterprises".[172] Unlike his 'Modern Business hierarchy', however, the workshop foremen, reporting to the proprietors or 'head' foremen, had the authority of 'lower' or even 'middle' management and were not, as became the practice in the 20th century, supervisory grade personnel reporting to junior management. The firms' organisational 'pyramids' were thus low and unlike the multi-level hierarchy of main-line railways although, as Drummond has demonstrated, they were similar to their workshop organisations.[173] The foremen thus took over the decision-making discretion of the former millwrights, foundrymen and boiler-makers, their departmental responsibilities including hiring and firing of personnel, and supervision of work. The lack of any evidence of piece-mastering suggests that they always acted directly for their employers, rather than as sub-contracted 'gang leaders'.

The shortage of skilled craftsmen during the century led to extraordinary measures, both by the employers, to increase productivity, and the men themselves, to retain their craft dominance. The introduction and development of self-acting machine tools, and the

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[172] Alfred D. Chandler Jr., The Visible Hand: The Managerial Revolution, Harvard, 1977, pp.1-6.
[173] For example the LNWR, Drummond, *op cit* (4), pp.58-65.

conversion from a fully craft-based to a 'factory'-based workforce, retaining essential craft skills, allowed the manufacturers to expand their production and largely cope with succeeding demand peaks. The introduction of self-acting machines and the employment of un-skilled personnel became an essential feature of the industry, not just to increase productivity, but to accommodate demand fluctuations. The engagement and dismissal of 'labourers', according to the state of the locomotive market, provided an essential employment cushion with which firms could protect themselves by providing continuity of work for their craftsmen. They kept employment levels in line with cyclical demand swings, as demonstrated by the close co-relation between earnings and turn-over.

The shortage of craftsmen served to maintain favourable terms of employment, which were always superior to volume industries. Wage scales and hours of work were in advance of the minimum provisions of the 1867 Factory Acts Extension Act, and the paternalistic employment provisions generally succeeded in providing for a stable and loyal workforce. The significant variation in wage levels, however, reflected the relative recruitment difficulties between the sites, the more remote of which, such as the Vulcan and Viaduct Foundries, required the further incentives of housing and other community provision. The firms were equivocal in their application of productivity incentives, the application of piece-work being widely, but not wholly adopted. Compulsory overtime was more widely applied as a further measure to meet demand peaks.

With the exception of the Bedlington works, paternalism in the locomotive industry was limited to works' events rather than a deeper community involvement. It is likely that the urban location of most of the locomotive factories meant that migration of craftsmen was not the significant issue it was for railway workshops, such as Drummond describes for Crewe.[174] Even so, the level of paternalism served its purpose of maintaining satisfactory relations between the proprietors and their workforce up to the early 1870s. Michael Longridge, on the other hand, was particularly pioneering in his introduction of welfare and

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174 Drummond, *op cit* (4).

other community benefits, the motivation for which was, almost certainly, the remoteness of the Bedlington works. From the 1870s, however, paternalism reduced as accommodation between the industry and its men suffered from the several industrial relations disputes.

The lack of evidence regarding the adoption of 'piece-mastering' as a means of maintaining a satisfactory level of employment and productivity in the locomotive industry, is in marked contrast to the Baldwin Company in the USA, which saw 'inside-contracting' as an important means of raising productivity in the last three decades of the century. The different approach on such an important issue is most likely to have been the diverging production systems. The comprehensive adoption of interchangeable components and their volume production by Baldwins required a 'mass-production' employment policy, with a greater emphasis on routine production by an un-skilled workforce. The much smaller batch production opportunities of the British industry, and their retention of a higher proportion of craftsmen called for a continuation of direct employment.

Employment policies between the British and American industries similarly diverged over the question of apprenticeship training. Baldwins' cessation of its apprenticeship schemes in favour of machine-related training, was again in marked contrast to the perpetuation of apprenticeships by the British manufacturers. Premium apprenticeships were peculiar to Britain and reflected the practical characteristics of British engineering training, in contrast to the theoretical technical school courses of their European counterparts. The maintenance of a high proportion of craft jobs in the industry justified the continuation of craft apprenticeships, but the evidence strongly suggests that the extent of their engagement was to provide inexpensive 'bound' labour, particularly during times of dispute.

In contrast to McKinlay and Zeitlin's view (Section 1.8), the main failure that may be ascribed to the manufacturing industry generally and the locomotive firms in particular, was their inability to find an accommodation with the trades unions over the employment of un-skilled men. The issue was a running sore throughout the century, re-surfacing with each claim for improved hours and wages. The issue was the driving force behind the expansion of the 'Friendly Societies' into national trades unions, which brought about, in response, the development of the Engineering Employers' Federation. In spite of the loyalty generated by generally good terms of employment and paternalistic benefits, the confrontations were largely driven by the perceived dilution of the standing of skilled craftsmen.

The century ended with the crippling effects of the 1897 dispute, which revealed divisions of opinion within the Employers' Federation, representatives of the locomotive firms being directly involved in the dispute's conduct and resolution. The issue of the erosion of craft skills remained unresolved after the dispute, and, as McKinlay and Zeitlin have determined, in spite of their overwhelming victory the employers' internal divisions failed to make significant progress in reshaping work organisation. They carried into the next century their continued dependence on skilled labour leaving them vulnerable to future craft disputes.[175]

The divergent employment policies thus highlighted the individualism of the manufacturing proprietors. Their strategic and tactical decisions on employment represented differing views on the levels of un-skilled employment and the rate of their introduction, employment terms, paternalism and the maintenance of industrial harmony. Employers such as Michael Longridge and the Stephensons had shown extraordinary vision in attracting core workforces that remained loyal even in adversity. In contrast, Nasmyth's confrontational approach, for all his pioneering advancements in machine tool technology, had resulted in continuing problems that eventually led to his premature retirement.

There was no distinction in industrial relations between the 'progressive' firms with a high proportion of un-skilled labour, and the 'craft' firms more dependent upon their skilled workforce. Amongst the most harmonious firms were Neilson & Co. and Robert Stephenson & Co., respectively the largest and most successful firm, and the least successful which failed at the end of the century (Section 7.6.7). Employment decisions, and acceptance of those decisions were a combination of business acumen and respect.

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175 McKinlay and Zeitlin, *op cit* (5).

7.0 Corporate Decision Making

7.1 Introduction

The growth of the manufacturing firms engaged in the locomotive industry through the nineteenth century introduced new kinds of decision making, both for the profitable execution of their day-to-day business and the development of strategies for their long-term direction. The proprietors' decisions revealed both their motivations in running their businesses, and their competence in managing the complex requirements of large, integrated operations. The entrepreneurial/behavioural inter-relationship of the proprietors governed their strategies on expansion, investment, diversification, incorporation, amalgamations and even survival. Their managing competence required leadership attributes and delegation of authority, as well as sufficient information on which to base their decisions.

The entrepreneurial motivation and combined expertise of the early proprietors was replaced in the following generation by a more cautious interpretation of the locomotive market's development, derived from experience of its uncertain evolution, combined with a growing sense of loyalty towards their longer-serving workforce of managers, craftsmen and clerks. The confidence and ability of the early proprietors to raise sufficient capital to commence locomotive production was followed in the next generation with further capital requirements for replacement, upgrading and expansion. These wider capital commitments depended upon continuing entrepreneurial flair or acceptance of the need for incorporation and the transfer of strategic decision making to a wider directorate.

The size, diversification and integrated structure of the firms called for the development of management information and accounts, which the proprietors and their senior managers could use to monitor profitability and guide them in their tactical policies. The development of management and financial accounts and information systems made extraordinary progress through the century, particularly in serving the integrated requirements of the heavy manufacturing industry. They provided the potential for firms to make good use of assets, minimise costs of raw materials and finished components, deal with receipts and payment pressures, and contain their working capital requirements. The introduction of allowances for overhead costs and other general charges, and of 'cost-centre' monitoring, provided the potential for sounder decisions on workshop profitability and wider production costing.

Edwards and Newell have demonstrated that the foundations of cost accounting had been well established since the 18th century by large companies such as Boulton & Watt and Josiah Wedgewood.[1] This countered earlier conclusions by Pollard, Solomons and Garner that 'total' cost accounting did not become an established management tool until the last quarter of the 19th century.[2] Solomons had concluded that lack of progress in cost accounting had been due to the absence of keen competition, allowing prices which produced generous profit margins. Edwards and Newell's investigations of the metal producing industries from the 18th century did, however, conclude that secrecy hampered the diffusion of ideas and techniques.[3]

Cost accounting methods and management information systems were therefore developed in accordance with the perceived requirements of individual firms. Yet Boyns and Edwards have identified several examples of similar cost-accounting practices in the coal, iron and steel industries, suggesting a measure of skill transfer through recruitment of experienced cost-accounting clerks.[4] These practices provided management information systems, evolving in tandem with financial accounting. Industry in the 19th century was thus well versed in integrating cost with financial accounting, but not until the 1870s was it recognised in Britain as a text-book subject that would lead to a more consistent approach. This

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[1] John Richard Edwards and Edmund Newell, 'The Development of Industrial Cost and Management Accounting Before 1850: A Survey of the Evidence', Business History, Vol.33, No.1, 1991, pp.35-57, quoting from E. Roll, An Early Experiment in Industrial Organisation: Being a History of the Firm of Boulton & Watt, 1775-1805, 1930, pp.244-252, and N. McKendrick, 'Josiah Wedgewood and Cost Accounting in the Industrial Revolution', Economic History Review, 2nd Series, Vol.XXIII, 1970.
[2] S. Pollard, The Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain, 1965; D. Solomons, 'The Historical Development of Costing', in D. Solomons (ed), Studies in Cost Analysis, 2nd Ed., 1968; S.P. Garner, Evolution of Cost Accounting, Alabama, 1954, Chapter 2.
[3] Solomons, *ibid.* Also Edwards and Newell, *op cit* (1), p.53.
[4] Trevor Boyns and John Richard Edwards, 'The Construction of Cost Accounting Systems in Britain to 1900: The Case of the Coal, Iron and Steel Industries', Business History, Vol.39, 1997, pp.1-29.

compares badly with France, where Boyns, Edwards and Nikitin have noted that the discipline had become well developed, both in text and in practice, from the 1820s.[5] There is yet to be a satisfactory explanation for the delay, but it could well reflect a more general antipathy towards formal learning in Britain.

Financial accounting and depreciation policies, both through balance sheet and profit and loss statements, developed slowly through the century, with diverse definitions and practices. Following the Joint Stock Companies Act of 1856, and until the Companies Act of 1900, there was no compulsory financial reporting or auditing for firms with limited liability, and thus no formalisation of financial accounts.[6] Cottrell considered that England had the "most permissive commercial law in the whole of Europe" as far as general manufacturing companies were concerned.[7] Whilst it was in their own best interests for firms to prepare accounts in sufficient detail, and with sufficient discipline, to reflect their true financial position, there would have been a particular requirement to demonstrate competence, and stimulate confidence, when seeking investment capital from their backers.

Against the background of an unpredictable market, manufacturers' re-investment decisions related to expansion and modernisation of manufacturing capacity and capital equipment, diversification into second factories, at home and abroad, and backwards integration through supplier acquisition. The different interpretations of the market, and the varied entrepreneurial inclinations of the proprietors, caused a divergence in strategic policies, which ranged between major investment for the 'progressive' specialised locomotive factories and the maintenance of 'craft'-based general manufacturing sites, whose output included locomotives (Section 5.7). The raising of sufficient capital for expansion received a

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[5] T. Boyns, J.R. Edwards and M. Nikitin, 'Comptabilité et Revolution Industrielle: Une Comparaison Grand Bretagne/France', in Comptabilité Contrôle Audit, La Revue de l'Association Française de Comptabilité, tome 2, Vol.1, 1996, pp.15-20.
[6] T.A. Lee, 'Company Financial Statements, An Essay in Business History 1830-1950', in Sheila Marriner (ed), Business and Businessmen, Studies in Business, Economic and Accounting History, Liverpool, 1978, pp.235-261; also, A.J. Arnold, 'Should Historians Trust Late Nineteenth-Century Company Financial Statements?', Business History, Vol.38, No.2, 1996, pp.40-54.
[7] P.L. Cottrell, Industrial Finance 1830-1914: The Finance and Organisation of English Manufacturing Industry, London, 1980, p.41.

significant boost with the formation of some limited companies from the 1860s. With the move towards incorporation tempered by the proprietors' desire to retain control of their firms, however, the industry's conversion to private and public companies was spread throughout the remainder of the century.

To accommodate the severe market fluctuations (Fig.1), the manufacturers were faced with difficult medium-term strategic decisions to optimise their production capacity and maintain satisfactory levels of employment for their men and capital equipment. Whilst much of the capacity variation was absorbed through the recruitment and lay-off of un-skilled machinists (Section 6.3), each demand peak raised consideration of investment for further capacity. Options with each downturn in the market, however, ranged between complete withdrawal from locomotive manufacture, and partial withdrawal through diversification into alternative markets. The correct interpretation of the locomotive and other heavy engineering markets allowed manufacturers to sustain their production capacity through diversification. Consideration of the causes of company failures and the absence of company amalgamations, provides further insight into the reasons for the continued proliferation of locomotive firms at the end of the century.

7.2 Cost and Management Accounting

The locomotive sector, as part of the heavy manufacturing industry, was in the forefront of the development of cost accounting in Britain. The accounts, including prevailing raw material and bought-in component charges, were essential management information on which were based not only tender quotations (Section 3.6.3), but the monitoring of locomotive production costs. The early development of cost-centre accounting allowed an increased understanding of the cost-effectiveness of each production process, but there was a wide diversity in its use and interpretation which was reflected in company profitability.

The first locomotive manufacturers inherited the accounting practices of manufacturing industry. Robert Stephenson & Co.'s first accounts were overseen by its partner, Michael Longridge, with practices transferred from the Bedlington Iron Works (Section 6.2.2). The Stephenson Company's first ledger reveals that cost and financial accounts were fully integrated.[8] The ledger is a compendium of folio entries in the company's materials purchase book, wages book, Goods (sales) account, Trade (maintenance and manufacturing overheads) account, Stock (capital goods) account, and Cash Received (income) account.

Raw materials and sub-contracted components for each order were recorded by weight and unit price. The men's time may also have been set down against each order in the wages book, as off-site wage rates and hours allocated (installing stationary engines for example) were separately recorded in the ledger. The detail allowed the company to predict the likely production, delivery and installation costs for each quotation. Multiple items, such as trackwork and wagon components were quoted by weight, including machining and finishing costs. Multiple component machines, such as locomotives, were quoted a single ex-factory or delivered price (Section 3.6.3).

Separate accounts were kept for the firm's foundry and stable, including purchase, goods and trade books, with each credit matched as a debit in the main works accounts. This early cost-centre accounting allowed the proprietors to identify the foundry's losses, which prompted their decision to close it in 1832 (Section 5.3.1). This example precedes by three decades the example of the Consett Iron Company, for which Boyns and Edwards have reported cost-centre accounting being practised.[9]

Whilst the ledger does not confirm that overhead costs were analysed to form a percentage on-cost for quotations, the allocation of overheads is confirmed in a surviving Cost and

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[8] Ledger, 1823-1831, R. Stephenson & Co. Collection, National Railway Museum, York. Michael R. Bailey, Robert Stephenson & Company 1823-1836, unpublished MA thesis, University of Newcastle-upon-Tyne, 1984, p.19.

[9] Boyns & Edwards, *op cit* (4), p.36.

Profit Account Book for 1834/5.[10] This shows that the Stephenson Company was making full use of the cost information at its disposal. Costs were separately recorded for each locomotive, the entry for the *Rapid*, delivered to the Newcastle & Carlisle Railway in 1835, being an example shown in Table 5:

	Cwt	qr	lb	R[ate]	£	s	d
Boiler with Copper Firebox & Tubes	57	0	9	95/-	271	2	8
Iron Castings	28	3	3		22	1	6
Brass Do	5	3	15		24	4	10
Forged Work & Material	47	1	9		114	4	4
Cut Nuts, Springs &c fm Store					59	18	11
Brass & Copper Pipes					35	11	7
Timber Painting & Carriage					20	10	1
Wages					125	5	4
Machinery					62	9	8
Patterns					3	8	2
					738	17	1
	Trade Exps			15 pr Ct	110	14	0
					849	11	1
				25 pr Ct	212	5	0
					1061	16	1
Charged	916	10	0				
Cost	849	11	1				
	66	18	11				
Contract price £940							

Table 5 Example of Locomotive Costings 1835
(R. Stephenson & Co. for the *Rapid* Locomotive)

(Source: Cost & Profit Account Book, Bidder Papers, Science Museum Library, Ref. Arch:Bidd27/8)

The example includes the apportionment of overhead costs through the 15% on-charge. The further 25% charge may have been for comparative purposes, perhaps reflecting a target profit margin that was being considered as the market began to expand (Section 3.6.3). The 2.5% difference between the charged and contract prices may have been a working capital allowance due to bills of exchange credit delays.

[10] R. Stephenson & Co., Cost & Profit Account Book, Bidder Papers, Science Museum Library, Arch:Bidd 27/8.

Cost accounts were made available by the manufacturers to customers requiring to check the accuracy of locomotive charges. Daniel Gooch, Locomotive Superintendent of the Great Western Railway, reported to I.K.Brunel, the railway's engineer in 1839: "I have gone carefully through the whole of Hawthorn's accounts, and find everything charged very moderately......"[11] The engineer, T.E. Harrison, similarly reported that Hawthorns had "placed the whole of the Books at my command" and "I must say [amounts] are down in a most clear and satisfactory manner."[12]

By 1839, Kitson Laird & Co. had adopted job numbers in its wages book to allow ready abstraction of cost data for each job, as well as for making up the wages.[13] Time, to the nearest quarter-hour, was related to each man's wage rate to determine the costs for each job. Piece-work was introduced in 1839 (Section 6.3.2), and the wages book recorded additional wages paid for productivity improvements, in addition to component weights and machinery and fitting times. Charles Tayleur & Co. employed an 'Abstract Book' from 1844, in which the material and wages costs of each locomotive batch were recorded, and which reflected the value of bulk purchasing of raw materials in reducing locomotive costs.[14] The grouping of wage costs for each activity similarly reflected an understanding of the benefits of batch production (Section 5.7.3). Beyer Peacock & Co. set up similar detailed cost analyses in a 'Cost of Work' book from 1855, showing profits or losses on each locomotive after deduction of commission.[15]

That cost accounting in manufacturing companies had developed and been fully integrated with financial accounting by about 1860, was demonstrated by the recollections of a

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[11] Letter, Daniel Gooch to I.K. Brunel, August 1839, quoted in J.F. Clarke, Power on Land and Sea, Newcastle-upon-Tyne, nd but 1979, p.8.

[12] Report, by T.E. Harrison, August 1839, quoted in Clarke, *ibid*, p.8.

[13] Kitson Laird & Co., Wages Book, May 18th 1839 to March 7th 1840, in private possession of Mr. E.F. Clark, and quoted with permission.

[14] C. Tayleur & Co., Abstract Book 1844-1870, Vulcan Foundry Collection, National Museums & Galleries on Merseyside, Ref 1970/37/6/1, p.3.

[15] Cost of Work Book, Beyer Peacock Collection, Museum of Science & Industry in Manchester, and quoted in R.L. Hills and D. Patrick, Beyer Peacock Locomotive Builders to the World, Glossop, 1982, p.38.

chartered accountant, Thomas Plumpton. He had been instructed in cost accounting in the early 1860s by a professional accountant:[16]

> "I had the advantage of a thorough training in a large engineering concern, manufacturing locomotive and marine engines, boilers, and every kind of machinery, where the Cost Accounts were so interwoven with the Commercial Accounts as to form an integral part of the whole on the system known as the Italian System [double-entry accounting], which until recent years was so universally adopted......."

An expanded form of cost-centre accounting was being practised by R.&W. Hawthorn during the 1860s.[17] Its profit and loss management summary included separate accounts for its forge, brass foundry and machine shop, with internal debits being traced through from those shops to the erecting shop and included in its profitability assessment. That assessment was further divided between locomotives and marine engines as shown in Table 6:

	1864	1865	1866	1867	1868
	£	£	£	£	£
Locomotive Engines & Tenders	3680	4443	9949	-1284	-1572
Marine & Stationary Engines	9737	3154	1726	2035	676
[other] Orders	3568	2949	2915	2388	3965
Brass Foundry	400	408	1506	1162	757
Forge	-247	1272	1049	337	110
Tools	1648	2321	1902	163	-556
Discounts & Charges	-2591	-1369	604	-1455	-2734
Total (Profit)	16196	13180	19654	3349	645

Table 6 Example of Cost Centre Profit and Loss Accounting

(R.&W. Hawthorn (Engine Works) 1864-1868)

(Source: J.F. Clarke, Power on Land and Sea, Newcastle-upon-Tyne, nd but 1979, p.16)

Management accounting was generally well established by the 1870s. For example, regular cost analyses became a feature of the Vulcan Foundry's management control systems.[18] Wage comparisons, between similar locomotives made for different railways, were used to

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[16] T. Plumpton, 'Manufacturing Costs', Accountant, Vol.20, 1894, p.990, quoted by Boyns and Edwards, *op cit* (4), p.11.
[17] Clarke, *op cit* (11), p.16.
[18] Vulcan Foundry Cost Book, 1870-1939, Vulcan Foundry Collection, *op cit* (14), Ref.1970/37/6/3, *passim*.

identify high cost examples, allowing corrective action to be taken, and batch production costs to be monitored. Its quarterly analyses of workshop expenses were more frequent than the half-yearly analyses that Boyns and Edwards determined had generally been undertaken in the coal, iron and steel industries in the second half of the 19th century.[19] During the last third of the century, six year summaries were compiled to provide longer-term trend analyses.

Close monitoring of raw material charges and other costs allowed manufacturers to respond better to the external factors affecting their profitability. The Vulcan Foundry's 'Abstract Book' recorded price variations for raw materials and sub-contracted components, used both in submitting quotations and in determining the profitability of each locomotive batch.[20] It reveals, for example, that between 1871 and 1873 there was a 50% increase in coal prices with a consequential affect on iron prices, arising from the economic effects of the Franco-Prussian War (Section 2.8), and compounded by the affects of the 1871 'nine-hour' dispute (Section 6.5). The Hawthorn Company's Chairman, Benjamin Browne, noted that "we had therefore to work off a very heavy order book, taken at low prices, at greatly increased costs and heavy loss."[21] Weekly meetings of the partners delivered the tactical decisions necessary to minimise the firm's losses.

Not all firms maintained good management accounts, and some failed to identify loss-making areas and take decisions to rectify problems. The failure of Andrew Barclay & Son in 1874 (Section 7.6.7) was attributable to poor management and lack of financial control.[22] Its reconstitution with new backers the following year was dependent upon new financial controls being introduced. Day books were started up, setting out details of each job undertaken and its cost.

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[19] Boyns and Edwards, *op cit* (4), p.12.
[20] Tayleur Abstract Book, Vulcan Foundry collection, *op cit* (14), p.87
[21] Quoted in Clarke, *op cit* (11), p.23.
[22] Michael S. Moss and John R. Hume, Workshop of the British Empire, London, 1977, p.72.

The level of cost detail also varied considerably between manufacturers. By the late 1880s, Neilson & Co.'s' cost accounting records were detailed, with materials and wages booked to each batch of components.[23] In 1889, however, the Hawthorn Leslie Company was only recording broad estimates of costs because of the lack of clerical staff. William Cross, the Company's Managing Director, complained about the lack of accurate records which prevented the successful continuation of piece-work (Section 6.3.2) and suggested that "one, if not two, clerks employed in such work [keeping accurate cost sheets] would repay their cost over and over again......"[24]

By 1886, Robert Stephenson & Co.'s detailed cost analyses used a printed ledger with headed columns.[25] Data was transferred from workshop folios, summarising material costs, wages, trade expenses, other expenses and commission payments (where applicable). Cost totals were matched with invoice figures to determine profits or losses. Larger engines and components had separate analyses, whilst the many smaller items were grouped into half-yearly summaries by customers. Half-yearly reports were prepared for its three businesses, 'Engine Works', 'Boiler Shop' and 'Shipyard', which were separately accounted for, work done for one being charged by another, for example a marine engine charged to the shipyard.

The detail to which most British companies recorded their manufacturing costs was followed, to a limited extent, by the Globe Locomotive Works in Boston, USA, which by 1851 assembled unit cost data, including labour, materials and some overhead charges.[26] This was, however, in marked contrast to the Baldwin Locomotive Works, which kept no cost accounting records until the mid-1870s recession forced upon it the necessity of knowing and controlling costs. Until then Baldwins merely charged what the market would bear for locomotives and, so long as the company was in profit, considered cost accounting a drag on its business.[27] After 1878, however, the trend away from standard locomotive

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[23] Cost and Weight Books, Neilson Reid & Co. Collection, University of Glasgow Archives and Business Records Centre, Ref.UGD 10/4.
[24] Clarke, *op cit* (11), pp.55/6.
[25] Cost Analysis Ledger, 1886-1901, R. Stephenson & Co. Collection, *op cit* (8).
[26] John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, p.121.
[27] *ibid.*

designs (Section 4.7) in America increased the importance of cost accounting, and Baldwin's cost controls grew increasingly sophisticated and detailed.

Although the locomotive industry was generally advanced in its use of cost and management accounts, the wide divergence in their interpretation, and in the decisions based upon them, seems to confirm Edwards and Newell's view that secrecy hampered the diffusion of accounting techniques, and Boyns and Edwards' view that accounting knowledge depended upon recruitment of experienced cost-accounting clerks (Section 7.1). Although proprietors were used to receiving cost-centre based information, they would not necessarily use the data to improve their capacity to make managerial decisions and take appropriate action to remedy cost over-runs. In spite of good accounting procedures, for example, the Stephenson company did not act to stem its major losses in the 1880s which eventually led to its failure (Section 7.6.7).

7.3 Receipts, Payments and Working Capital

The necessity to be alert to cash-flow problems and the adequacy of working capital was constantly addressed by the proprietors and their senior managers. Tactical judgement was required with the timing of both payments and receipts. When markets were buoyant advanced payments with orders were sought, but at times when credit was limited considerable ingenuity was necessary to prevent cash short-falls. The larger, progressive manufacturers undoubtedly benefited from more frequent receipt of payments, and their greater purchasing power allowed them to delay raw material payments. The 'craft' manufacturers, however, were less well placed because of longer periods between payments for their small-batch products, and their propensity to deal with 'doubtful debt' customers.

Until the 1860s, payments were in the form of bills, the credit for which was redeemable after a specified time and which sometimes incurred interest. Manufacturers' working capital therefore made provision for the redeemable periods, both for supplier payments and customer receipts. Cash flow projections were occasionally undertaken, particularly when trading conditions were tight and problems anticipated. Robert Stephenson & Co.'s head clerk, for example, prepared statements for the partners to assist their tactical decision making. A statement prepared for early 1830, when the company was embarking on its first multiple locomotive orders, showed expected liabilities for loan interest, bills payable, tradesmen, wages, salaries and a £500 dividend. To meet these liabilities, the credit entries showed bills and cash, "Capital from Partners" (loan capital), and book debts. A shortfall of £2246 was shown to be "wanted".[28]

Insufficient working capital frequently led to cash flow problems, particularly with large locomotive orders. As early as 1832, R.&W. Hawthorn, when manufacturing six locomotives for the Stockton & Darlington Railway, had to write to its customer that "our pecuniary source.... is rather low" and asked for "a remittance either in Cash or Bills on London for One Thousand on account.... "[29] The Stephenson Company also withstood long periods of cash shortage, which were met by borrowings from its partners, repayable with interest. In July 1833, the company faced up to an accumulation of bad debts, and wrote off nearly £1,000 from the balance sheet.[30]

With the buoyant market of 1835-38, however, the Stephenson company sought advance payments when orders were placed (Section 3.6.4). Its head clerk wrote in 1837:[31]

> We have been very well off for some time past in money matters and at present have a Balance in hand in cash & Bills of nearly £5000. We are moreover looking for large remittances..... and may 'ere long look for the confirmation of a contract upon which we are to receive an advance of £4000.... Now all this will not only make us quite easy, but I anticipate will enable us to pay off our borrowed Capital which will of course be very desirable as we shall thereby save the Interest. Upon these advances we pay no Interest.

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[28] 'Finance Statement' for R. Stephenson & Co. to 30 Jun 1830, Pease-Stephenson Collection, Durham County Record Office, Darlington Public Library, D/PS/2.
[29] Clarke, *op cit* (11), p.7.
[30] Partners Minute Book, R. Stephenson & Co. Collection, Science Museum, London, p.37, 7 Mo 3 1833.
[31] Letter, Edw. J. Cook (for R. Stephenson & Co.) to Edward Pease, Newcastle, 22 Decr 1837, Pease-Stephenson Collection, *op cit* (28), D/PS/2/38.

Towards the end of the 1843 recession, during which advance payments had ceased, the Stephenson Co.'s cash position had reduced, the head clerk reporting that: "We have paid off all the money we had upon the advance account & therefore are as it were entirely dependent upon our resources."[32] The situation was soon reversed with the extraordinary demand for locomotives from 1844, and advanced payments were again sought (Section 3.6.4). By June 1846, the Company had £10,000 in hand through advanced payments.[33]

Smaller manufacturers, such as Jones & Potts, were particularly aware of money markets and the relative merits of cash and bill payments. Even during the boom year of 1846, Arthur Potts wrote to his partner about a customer payment by "bank bill for £500 and you may draw upon them at 2 months for the remainder adding Intt [interest], 2 months only, I should do this if I was you at once.... The money market is in an awful state. Would it not be better to have cash for the whole...."[34]

The 1847-50 recession caused severe liquidity problems for the manufacturers due to the poor financial position of their railway customers, leading to the failure of some companies (Section 7.6.7). Potts' correspondence reveals some of the extraordinary payment problems that arose, and as early as August 1847 he wrote that "money is indeed very tight here [London]."[35] In the following month he wrote:[36]

> .... I thought I had better get this money matter settled at once - London is in a fearful state people do not know who to trust...... Mr. Rankine [customer] informed me that he had sent to the works a 6 months promisory note for the amount of our account. Should he have done so please return it as any Bill at 6 months however well Backed is worth in London no more than waste paper.

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32 Letter, Edw. J. Cook, for R. Stephenson & Co., to Edward Pease, Newcastle, 11 Decr.1843, Pease-Stephenson Collection, *ibid*, D/PS/2/44.

33 Estimate of Finance Statement for R. Stephenson & Co. for 3 months ending June 12 1846, Pease-Stephenson Collection, *ibid*, D/PS/2.

34 Letter, Arthur Potts to John Jones, Chester, March 28th 1846, Jones & Potts Collection, Institution of Mechanical Engineers Library, Ref.IMS 248/1.

35 Letter A. Potts to J. Jones, London, August 16th 1847, Jones & Potts Collection, *ibid*, IMS249/1.

36 Letter A. Potts to J. Jones, London, Sepr. 18th 1847, Jones & Potts Collection, *ibid*, IMS249/3.

By the summer of 1848, the company's cash flow was very poor, and Potts was obliged to press for payment from several railways, including the Caledonian, whose Edinburgh headquarters he visited several times. After a frustrating day he wrote that he had:[37]

> ..... waited upon the Caledonian Board to day for fully 2 hours and we have not succeeded in procuring an interview we have been put off until tomorrow If we are not seen tomorrow D---n em we will pitch into them I'm in a d---l of a rage at them.

By 1849, some railways were unable to pay their creditors. The Scottish Central Railway had "no money or Bonds" and could only pay Jones & Potts by "selling 5 engines to the Aberdeen Railway and on receipt of this money they will pay us our debt - "[38] Even the London & North Western Railway found difficulty meeting its payments, and having extracted a promise to pay, Potts reflected "....there is so many slips between the cup & the lips that I shall not believe I shall get it until I have got it."[39]

Negotiations over discount arrangements for bills of exchange could provide welcome additional revenue. When the London & Blackwall Railway paid £3,000 for its locomotives with a 3 month bill, Jones & Potts sought to find the best exchange terms from the discount banks. Potts wrote to Jones:[40]

> I wish you to..... ask them [Messrs. Parr & Co.] what they will discount the Blackwall Cos. Bill...... Curries have offered to discount it at £5 per cent - without commission Dont mention this to Parr as if they charge the ¼ per cent and £5 besides I shall get Curries to discount it -

A favourite form of extending credit for railways with cash problems was to make payment in their own debenture bonds which could be subsequently exchanged, albeit being discounted each time. A payment dispute with the Eastern Counties Railway saw Jones & Potts offered payment in this form, the railway's Secretary, Roney, suggesting to Potts that he should make a proposition to the Directors:[41]

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[37] Letter A. Potts to J. Jones, Edinburgh, July 3rd 1848, Jones & Potts Collection, *ibid*, IMS250/3.
[38] Letter A. Potts to J. Jones, Perth, Augt 7th 1849, Jones & Potts Collection, *ibid*, IMS252/4.
[39] Letter A. Potts to J. Jones, London, nd, but postmark SP (September) 26.1848, Jones & Potts Collection, *ibid*, IMS250/5.
[40] Letter A. Potts to J. Jones, London, Jany 2 1849, Jones & Potts Collection, *ibid*, IMS251/1.
[41] Letter A. Potts to J. Jones, London, Jany 2 1849, Jones & Potts Collection, *ibid*, IMS251/2.

> That provided the Company pays us the Int[erest] we will take the Debenture Bonds - (which Roney promises to dispose of for us at £98 for each £100 -) this interest will more than cover the Loss - by the Bonds being at a discount of £2 per £100...... Should they accept my offer of taking their Bonds, (provided they allow us this Intt.) we shall be a gainer of £100 or more and we shall get the money within one week -

If the shares and bonds could not be immediately exchanged, they were divided out as a dividend between the partners, and were shown as a double entry in the manufacturers' balance sheets. Beyer Peacock & Co., for example, occasionally received preference share payments both for home and London-based overseas railways from the 1850s, which were shown in its balance sheets.[42]

Following the failure of the Overend Gurney Discount Bank in 1866, the British banking system was radically changed. Credit was sought from, and approved by, commercial banks, and direct payments were made by cheques rather than bills. The manufacturers were as much to benefit from the new arrangements as their customers. Some came under considerable financial strain following the 1871 strike (Section 6.5) and the sharp increase in commodity prices in the early 1870s (Section 7.2). R.&W. Hawthorn was obliged to borrow heavily from its bankers to maintain sufficient working capital, and, by 1876, its overdrafts had risen to nearly £44,000.[43]

Whilst the larger main line railways were usually credit-worthy, other main line and industrial customers were not always so, and there was often concern regarding their ability to pay on time, or at all. Delays were costly for the manufacturers but, in a tight market, there was a reluctance to drive away customers. Awaiting an outstanding payment from the Alexandra Dock Co. in 1890, the Hawthorn Leslie company feared that "[if we] bully them they won't come to us for any more locos...."[44] Part exchange with old locomotives was occasionally accepted, usually requiring an independent valuation, if only to establish a scrap value. Hawthorn Leslie, for example, sold a small tank locomotive in 1896 for £700 plus an old

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42 Hills and Patrick, *op cit* (15), p.35.
43 Clarke, *op cit* (11), p.23
44 Clarke, *ibid*, p.56.

locomotive valued at £200.[45] In 1897, Benjamin Browne warned that a quarter of Hawthorn Leslie's "doubtful locomotive customers" would in the end have to be written off as bad debts.

Some manufacturers went into liquidation in the worst recessions and down-turns in the locomotive market during the century (Section 7.6.7). Lack of evidence makes it impossible to confirm that poor judgement by their proprietors was the primary cause. Conversely, the majority of manufacturers survived the worst recessions, which is indicative not only of the effectiveness of their diversification policies (Section 7.5), but also of close attention to payment timing and adequacy of working capital.

7.4 Financial Accounting

Although there was no compulsory preparation of financial accounts during the century, manufacturers prepared them, both for their own internal knowledge and as the means to satisfy their backers of a continuing return on capital investments. Decisions taken on investments, and the awarding of dividends, depended on accurate balance sheets and profit and loss statements, the preparation for which required supporting ledgers and periodic valuations. Manufacturers were equivocal in applying depreciation policies, which had become more widely practised after 1800, particularly in the textile industries.[46] After 1830, significant developments in the treatment of depreciation occurred in the railway industry, and some, at least, of the manufacturers introduced it from that time. Their treatment of depreciation indicates how they developed their capital investment programmes, whilst accommodating fluctuating incomes from the cyclical trading patterns.

There were model Articles of Association shown in the 1856 Act, re-iterated in the 1862 Companies Act, which may have encouraged companies to prepare comparable accounts, but

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[45] *ibid.*
[46] Edwards and Newell, *op cit* (1), p.52.

there was no requirement to adopt a depreciation policy. Marriner believes that the biggest variant in accounting practice during the century was asset depreciation,[47] and has developed Lee's thesis that 'secret reserve' accounting was prevalent before 1900.[48] Secret reserve accounting was an expedient used by firms to depreciate quickly, or by under-valuing assets during prosperous trading years, and making little or no allowance during less prosperous years. It was a common practice to reverse depreciation by altering asset values to cover up trading losses. Exaggeration of liabilities through undisclosed transfers not entered on balance sheets, was a further method of creating secret reserves as a hedge against poor trading years.[49] There was no debate on the subject of undisclosed reserves until 1895,[50] and in 1899 the 'Accountant' was reporting the belief among Manchester accountants that secret reserve accounting was widespread among manufacturing companies.

7.4.1 Balance Sheets

The best set of surviving financial accounts for a locomotive manufacturer is a discontinuous set for Robert Stephenson & Co. between 1824 and 1855.[51] As with its cost accounts (Section 7.2), its balance sheet and profit and loss accounts were initiated under the experienced supervision of Michael Longridge. The balance sheets provided the partners with a generally good presentation of assets and liabilities at the end of each calendar year. When working capital was insufficient, loan capital, mostly provided by the partners themselves, was shown as a liability, usually at 5% interest. Asset valuation was maintained in a 'stock account' which, by inference, appears to have been an inventory of assets with current values as marked down by depreciation, to which new items were added when acquired, and removed if sold or scrapped. As asset value increased with new buildings and equipment, the partners' capital was increased correspondingly in the balance sheet.

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47 S. Marriner, 'Company Financial Statements as Source Material for Business Historians', Business History, Vol.XXII, 1980, pp.219.
48 G.A. Lee, 'The Concept of Profit in British Accounting 1760-1900', Business History Review, Vol.XLIX, 1975, p.33.
49 Arnold, *op cit* (6), Section VI, pp.45-49.
50 Accountant, 1895, pp.75-6, quoted by Arnold, *ibid*, p.47.
51 Pease-Stephenson Collection, *op cit* (28), D/PS/2.

The accounts confirm that depreciation, separately recorded for 'Buildings & Fixed Machinery' and 'Utensils', was undertaken in those years. Fig. 17 shows the relationship between the depreciation of the 'Stock Account' (where provided in the Balance Sheet) and the declared annual surplus (loss where not shown).

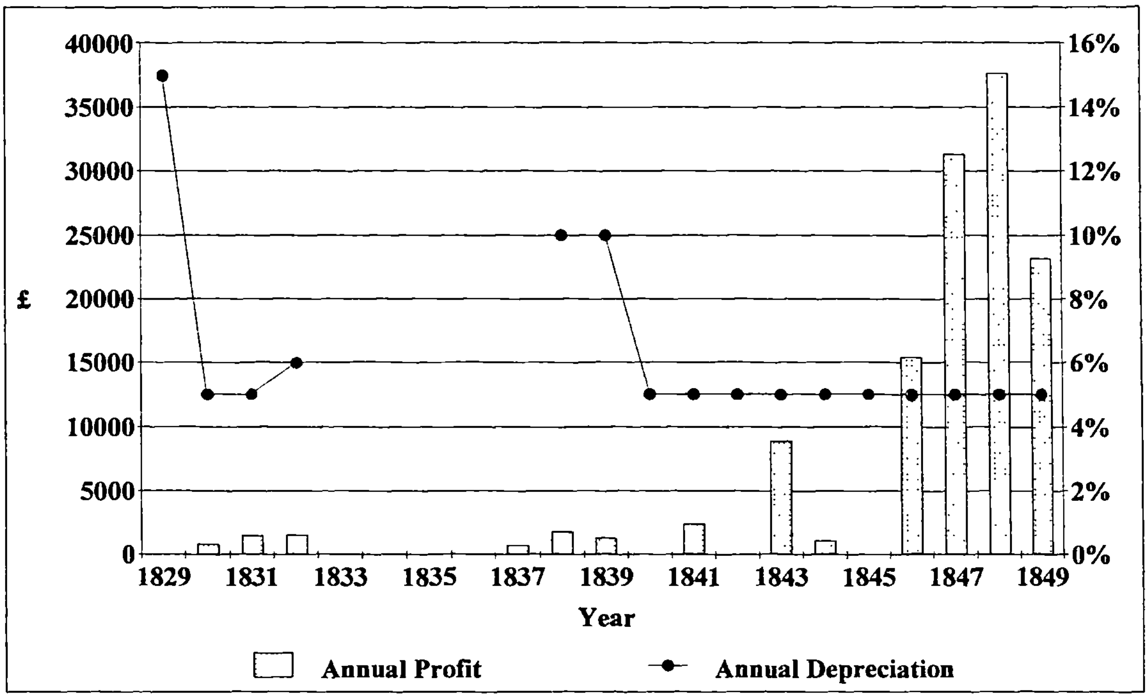

Fig. 17 Comparison of Depreciation and Profitability

(R. Stephenson & Co. 1829-1849)

(Source: Pease-Stephenson Collection, Durham County Record Office, Darlington Public Library, D/PS/2)

In 1829, a 15% (by calculation) depreciation was shown, being a 'catching up' figure to represent reduction in asset value, "diminished value if sold", over the firm's first six years of operation. A 5% figure was put in for 1830, whilst the 1831 figure was "about 5 p.cent" for buildings and fixed machinery and "near 2½ p.cent" for utensils. Nothing was shown during the loss-making years, 1833-36, suggesting that secret reserve accounting was being practised, with the 10% depreciation in 1838/39 representing a measure of 'catching up'. However, from 1840 an annual 5% depreciation was adopted, regardless of profit or loss levels, and thus without recourse to reserve accounting.

The Company's Head Clerk explained the depreciation entry in the 1845 balance sheet:[52]

> "I may state that the amount shewn as the value of Buildings Fixed Machinery &c is the net amount after deducting 5 per cent from the former years stock for depreciation - This deduction is regularly made every year - The amount of "Utensils" viz Smiths' Fire-places, vices, moveable tools such as Files, Chisels &c &c appears heavier than last year partly in consequence of additions to the stock & partly because the Inventory has been very carefully made out so as to include everything on the premises without the least omission, which has not been done for a year or two past. The valuation is according to Mr. Hutchinson's Estimate of the selling price of the various materials."

In the absence of further balance sheets, with the exception of 1855 which makes no reference to depreciation, it is not possible to confirm the continuation of this policy.

In contrast, Beyer Peacock & Co. made no allowance for depreciation until as late as the 1870s, after 20 years or so of operation.[53] The firm's accountants tried to introduce depreciation in 1869 and again in 1872, but for unexplained reasons, the partners would not adopt the practice. Capital assets remained on the balance sheet at their full purchase value, or scrap price, credited to the books. From 1878, however, after the death of Charles Beyer, an annual 5% depreciation was introduced, with 10% for the shorter-life shop boilers. Even then, the half-yearly returns still included the original equipment value up to 1888, when Henry Robertson died, after which annual depreciation figures were reported.

7.4.2 Profit and Loss Accounts

The few surviving profit and loss accounts for Robert Stephenson & Co. in the 1830s/1840s show them to be adjuncts to balance sheets rather than trading records, with summaries of financial movements over 12 month periods.[54] Entries related to liabilities, such as increases in capital holdings, dividend payments, asset depreciation and interest on loan capital and borrowings, which were balanced by credit movements. Commencing with the balance from

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[52] Letter W.H. Budden to Edward Pease, Newcastle-upon-Tyne, March 12th 1846, Pease-Stephenson Collection, *ibid*, D/PS/2/47.

[53] Hills and Patrick, *op cit* (15), p.70.

[54] R. Stephenson & Co. profit & loss accounts, Pease-Stephenson Collection, *op cit* (28), D/PS/2.

the previous account, entries were made for the net profit from the "Goods Account" (manufacturing profit) and "undivided profits" (net profits after dividend payments). The true summaries of operating profits were encompassed in the "Goods Accounts" and other 'profit centre' accounts, few of which have survived. For the year ending April 1834, debit entries represented opening stock value, total amounts paid for materials and wages and a derived surplus for the year-end. The two credit entries show the value of "sales" and the closing valuation of the stock.

R.&W. Hawthorn's surviving profit and loss accounts for 1864-68 show them to be more comprehensive and, being an annual statement rather than a ledger, were more akin to latter-day profit and loss statements.[55] Net profit (loss) entries were provided for locomotives and tenders, marine and stationary engines, and other orders (duplicates and a wide variety of general manufactured items), with separate profit or loss entries for the brass foundry, forge and "tools" (machine shop), as well as entries for discounts and charges.

Although manufacturers developed their financial accounts in the absence of any accounting conventions, the surviving examples demonstrate an impressive level of detail. From these it is clear that from the outset, they maintained a good understanding of their financial position and could demonstrate to their backers the current state of their business and the returns that were being made. Although there is no evidence of business plans or any form of projections being made based on these fundamental statements, it is likely that they provided financial 'comfort' for raising capital and loans for investment and expansion and, from the 1860s, for negotiations leading to incorporation.

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[55] Clarke, *op cit* (11), p.16.

7.5 Diversification

Throughout the century, proprietors were faced with uncertain business prospects arising from the unpredictable nature of the manufacturing markets, and the locomotive market in particular. All manufacturers, to a greater or lesser degree, hedged against market fluctuations through diversification. In the earlier, craft-based, manufacturing years, this policy worked well and allowed most companies to remain in business. In later years, and based on this early experience, proprietors sought to predict the long-term trend in locomotive demand, whilst re-investing to meet a sustainable and competitive proportion of that market.

Their judgement included divergent expectations of medium-term economic recessions, and their strategic decision-making therefore included a wide range of diversification strategies to accommodate the periodic decline in locomotive orders. In this way they sought to maintain sufficient work to retain their skilled craftsmen (Section 6.3), and maintain sufficient income to meet their loan and other short-term financial commitments. The choices, which largely fell on the ingenuity of the craft manufacturers to pursue were:

- to withdraw from the locomotive market temporarily, or on a permanent basis, and revert to, or diversify into, alternative markets,
- to continue to pursue locomotive orders, whilst seeking to use up excess capacity through alternative markets,
- to manufacture locomotives for 'stock' and later sale, in order to pursue batch production and sales benefits when the demand returned,
- to manufacture locomotive components, such as replacement boilers and wheelsets, for locomotive refurbishments, or undertake locomotive refurbishment programmes themselves.

7.5.1 Withdrawal from Locomotive Manufacture

Whilst many firms halted locomotive production during recessions, 39 factories withdrew permanently from locomotive work during the course of the 19th century, and concentrated on alternative markets.[56] There is no evidence to indicate how withdrawal decisions were made, but an analysis of their timing provides some indications of the reasoning.

Eleven firms withdrew in the 1839-1843 period when the first serious downturn in orders was experienced (Section 2.6). They ranged from Summers Groves & Day, which built just six locomotives before concentrating on marine engineering,[57] to Kirtley & Co., which had promoted itself widely with published drawings of its locomotive designs, but then opted to revert to colliery work.[58] It would seem that the uncertainty of the locomotive market in the early 1840s caused these companies to abandon locomotive manufacture and revert to the markets that they knew better.

A further ten firms withdrew in the post-1847 depression, ranging from Hick Hargreaves & Co., which switched production fully to the textile and colliery industries, to W.J. & J.Garforth, a general manufacturer which had been sub-contracted to make locomotives at the height of the 'mania' order boom. The 'feast or famine' nature of the locomotive market, and the failure of one of the largest manufacturers, Bury Curtis & Kennedy (Section 7.6.7), may well have influenced several firms, including Hick Hargreaves.

The remaining withdrawals, in the second half of the century, cannot be related to poor or uncertain market conditions, suggesting that the proprietors rejected the investment requirements for competitive locomotive production in favour of their alternative markets. Both the Canada Works and the Teesside Engine Works, for example, concentrated largely

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56 Analysis of Appendix.
57 W.H.Wright and S.H.P. Higgins, 'Summers Groves and Day', Journal of the Stephenson Locomotive Society, October 1952, pp.263-264.
58 W.Templeton, The Locomotive Engine Popularly Explained &c, London, 1841, pp.1-41.

on bridge-building as their main activity, allowing them to preserve their craft manufacturing base, and avoiding investment in capital equipment for competitive locomotive production.[59]

7.5.2 Diversification into Alternative Markets

The recession of 1848-1851 prompted Robert Stephenson & Co. to re-deploy part of its capacity to the manufacture of **marine engines**, as well as revert to **industrial engine** manufacture, although evidence towards the policy decision is lacking.[60] Although the locomotive market recovered in the 1850s, the suspicion about the effects of a further recession maintained the perception of the need for a broad market. The Stephenson Company further diversified into the manufacture of **steam-plough machinery** for John Fowler of Leeds, until his own works began production in 1862.[61]

Ingenuity was required by some manufacturers to maintain work for their workshops. For R.&W. Hawthorn, 1857 was "a time of very great industrial depression.... all kinds of orders had to be picked up.... a machine for cutting tobacco, some flour grinding machinery and even cooling apparatus for Allsopp's Brewery...."[62]

Industrial locomotive manufacture was usually closely allied to **mining or iron-works machinery**, its prosperity often rising and falling according to the health of those industries. John Fowler & Co. decided in 1875 to switch its production from main-line to industrial locomotives, for which the characteristics of standard designs with interchangeable components were more closely allied to its main **agricultural equipment** market.[63]

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[59] John Millar, William Heap and His Company, Hoylake, 1976, p.78; also James Lowe, British Steam Locomotive Builders, Cambridge, 1975, p.192.
[60] For example the Starbuck papers, Tyne & Wear Record Office, File 131; also Pease-Stephenson Collection, *op cit* (28), D/PS/2/72.
[61] Fowler's illustrated catalogue for 1858, Michael R. Lane, The Story of the Steam Plough Works, London, 1980, p.22.
[62] Note by Wigham Richardson, quote in Clarke, *op cit* (11), p.9.
[63] Lane, *op cit* (61), p.146.

Beyer Peacock established its factory at Gorton in the 1850s, chiefly for "The manufacture of locomotive engines" but, together with several other manufacturers, it also made a range of **machine tools**, to supplement its business, particularly at times of low locomotive demand.[64] In its early years, Beyer Peacock supplied machine tools for maintenance workshops for railways in Sweden, Austria and Spain.

Beyer Peacock & Co., Kitson & Co., Henry Hughes & Co. and several other smaller locomotive manufacturers diversified into the extensive urban **steam tram market** from the 1870s, which helped to offset the downturn in locomotive demand in both the late 1870s and the late 1880s.

The need for diversification to offset the irregularity of orders was also experienced by overseas manufacturers. The French Fives-Lille Company, for example, diversified into hydraulic lifting and handling equipment and eventually into armaments.[65] American manufacturers were similarly obliged to diversify, alternative markets including steam fire-engines, marine engines and bridge-building.[66] The Baldwin locomotive works, however, limited its diversification to other forms of motive power, notably in the industrial and 'street-car' sectors, in order to maximise the use of 'standard' components.[67]

7.5.3 Stock Production

During recessions, a few firms took the risk of making main-line locomotives, of their 'standard' designs, for 'stock' and subsequent sale, whilst others avoided this policy, aware of the dangers of excessive working capital requirements risking their viability. Nasmyths Gaskell & Co., for example, made three locomotives for stock in 1840 but, in a poor market, were obliged to sell them for much below their expected price.[68] From the 1850s, stock

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[64] Beyer Peacock Memorandum of Partnership, quoted in Hills and Patrick, *op cit* (15), p.39.
[65] François Crouzet, 'When the Railways Were Built', in Marriner *op cit* (47), p.114.
[66] Brown, *op cit* (26), p.48.
[67] *ibid*, pp.83-85.
[68] Nasmyths Gaskell & Co., Letter Book 3, p.54, and Sales Book A, pp.158/182, Nasmyth collection, Eccles Central Area Library.

locomotives became less acceptable to the larger railways, who increasingly favoured their own specifications (Section 4.5). Some had to be sold at lower prices, in order for the manufacturers to 'cut their losses'.

E.B.Wilson's policy of standardised locomotive production in the 1850s, pursuing the cost benefits of batch production (Section 5.7.3), encouraged excessive stock production which placed severe financial strains on the company. In the last three years of its trading, 1855-57, the firm built 79 locomotives for which it had no immediate customers.[69] Wilson fell out with his non-executive partners, Pollard and Turner, almost certainly over this policy, the resulting litigation forcing the winding up of the company.

Although the larger industrial locomotive manufacturers, such as the Hunslet Engine Co., Hudswell Clarke and Manning Wardle, could better anticipate subsequent orders for their standard designs to risk making locomotives for stock, main-line manufacturers generally resisted such a move, perhaps in the knowledge of what happened to E.B.Wilson. Between 1886 and 1898, however, Hawthorn Leslie maintained production at the Forth Banks works by making industrial locomotives for stock, 88 out of their total of 227 being built without orders. This policy put financial strains on its whole operation, and differing opinions within the Board of Directors were evident when, in 1890, the Chairman, Benjamin Browne, retorted: "No doubt it is the least disgusting part of the locomotive trade but it is not <u>much</u> good."[70]

Although William Cross, the Works Managing Director, feared the Board would consider "a proposition...... as to the desirability of altogether closing the works," it decided instead to modernise them to reduce production costs (Section 5.7.4).[71] The Company returned to manufacturing for stock in the early 1890s recession, however, a policy which again forced it to consider closing the Forth Banks works and writing off its investment. In 1897, Browne

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69 Ronald Redman, <u>The Railway Foundry Leeds</u>, Norwich, 1972, pp.17-19.
70 Clarke, *op cit* (11), pp.54.
71 *ibid*, p.55.

saw the loss as being "so heavy a drag on the Company" and argued that "the value of the Company's property would be materially increased if the locomotive business was abandoned."[72] The works were rescued from closure by the extraordinary demand for locomotives from 1898 (Section 2.8).

7.5.4 Refurbishment

There was a substantial locomotive refurbishment market, particularly during economic recessions, which provided a cheaper alternative to new locomotive orders for both railways and industrial customers. Because of the small order sizes and sporadic timing, it was more attractive to the 'craft' than the 'progressive' manufacturers. There is no record, for example, of the large batch-production companies, such as Neilson & Co. and Dübs & Co., undertaking this work, whereas Robert Stephenson & Co. and R.&W. Hawthorn Leslie frequently competed for it.

The Stephenson Company's refurbishment market replaced its profitable 'duplicates' market (Section 3.6.2), which declined from the 1850s as component reliability improved. The increase in the Company's refurbishment work, compared with its reducing locomotive market after 1880, is illustrated in Fig.18.[73] Whilst the refurbishment work was largely for the smaller British railway and industrial companies, replacement boilers were also made for overseas customers.

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[72] *ibid*, p.57.
[73] Analysis of Engines Delivered Books, R. Stephenson & Co. Collection, *op cit* (8).

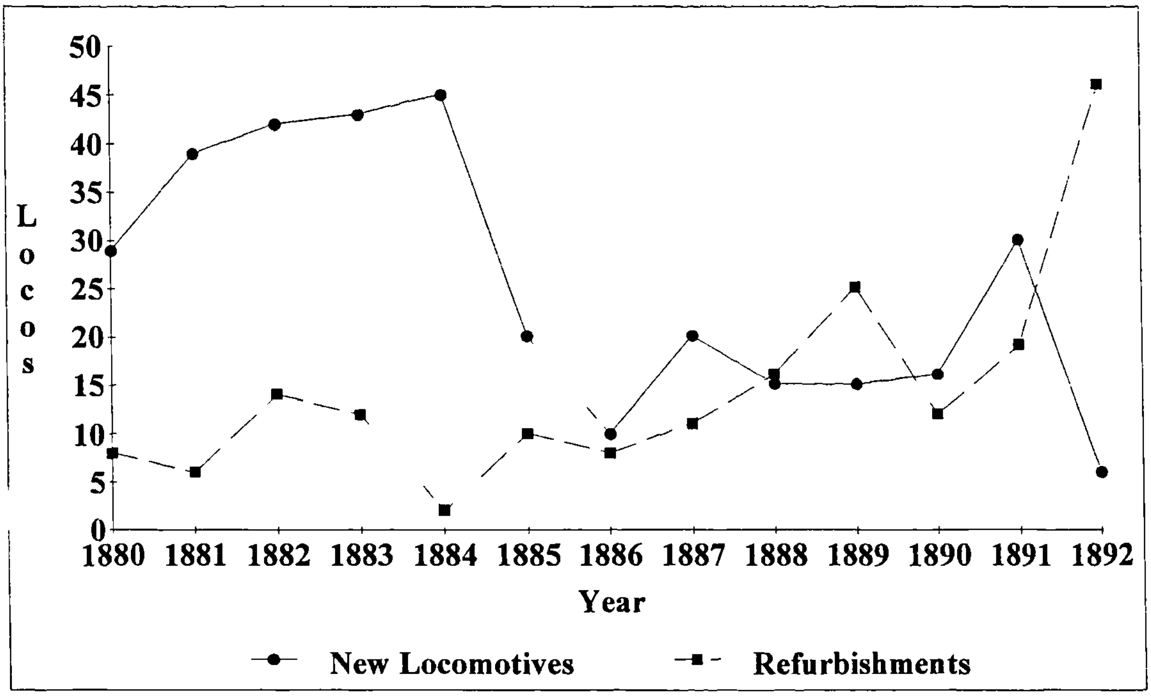

Fig. 18 Comparison of New Locomotive Manufacture to Refurbishment

(R. Stephenson & Co. 1880 - 1892)

(Source: Analysis of Engines Delivered Books, R. Stephenson & Co. Collection, National Railway Museum)

Hawthorn Leslie made modest profits on its locomotive refurbishment business (as well as its general manufacturing business and marine work) which off-set its continuing locomotive manufacturing losses.[74]

7.6 Investment and Company Status

Partnership enterprises benefited from the combined expertise of both executive and non-executive partners. Their ability to interpret the potential of the locomotive market was built on their previous manufacturing experience, and their entrepreneurial flair had a capacity to persuade potential backers that attractive returns on investment could be made from locomotive factories. The ability of the early proprietors to take the decisions necessary for the development of their manufacturing businesses is demonstrated by the fact that there are

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[74] Clarke, *op cit* (11), pp.24/5.

no recorded examples of consultants being brought in, as was necessary, for example, for the iron industry.[75] Proprietors could easily demonstrate their capacity to supervise the preparation of cost and financial accounts and to monitor the profitability of their enterprises, as well as take the tactical decisions necessary to maintain that profitability (Sections 7.3 and 7.4).

The growth of the locomotive industry from the 1840s brought with it the potential for expansion, on existing or second sites, the further capital requirements for which benefited from the potential for incorporation from the 1860s. The decisions made by the proprietors in pursuing this potential were diverse, and reflected a wide degree of willingness to share their enterprises with non-executive directors. The diversity was regardless of the size of firms or their depth of involvement in locomotive work; early incorporation of some small firms contrasted to the status of other, larger firms, which remained as partnerships throughout the century. There was a growing divergence within the industry from the 1860s, through the decisions of the second generation of proprietors, between the 'progressive' manufacturers, which had the confidence to pursue increased locomotive production, and the more cautious approach of the 'craft' manufacturers, which maintained a broad market base (Section 1.3).

The will to remain independent, let alone to survive, was very strong. The reluctance of some proprietors' to incorporate, caused by their desire to remain in absolute control of their firms, applied equally to the potential for amalgamations. There were no amalgamations until the creation of the North British Locomotive Company in 1903, even though there would have been economies of scale benefits. Yet, in all too many cases, the will to survive was insufficient on its own to prevent company failures.

[75] Boyns and Edwards, *op cit* (4), p.35, refer to three consultants for the Consett Iron Co. in the 1860s.

7.6.1 Partnerships

Although partners usually approached their ventures with entrepreneurial as well as technical flair, partnerships frequently changed according to personal circumstances, and the partners' ability to attract loan capital and sustain and increase their financial holding. The Airedale Foundry in Leeds is an example, where, in 1863, Kitson & Co. became the fifth partnership to own the works in 28 years (Appendix). Other firms, however, were much more stable. Charles Beyer and Richard Peacock, of Beyer Peacock & Co., for example, retained their involvement and shareholding until they died, and then passed on their interests to other members of their family.[76]

The raising of investment capital today requires rigorous assessment through business plans, requiring considered predictions of expenditure, income and cash-flow. Although in setting up and expanding their sites, and renewing capital equipment, the proprietors usually required to attract equity or loan capital, there is no evidence of even basic business plans being prepared to demonstrate what sort of returns they expected. The capital appears to have been attracted largely through the technical capabilities of the proprietors, their powers of persuasion and, where they were already in business, their 'track record'.

No consistent pattern of capital funding can be discerned. The Manchester-based Birley family business, for example, provided the Nasmyth brothers and Gaskell with loan capital to build and equip the Bridgewater Foundry in 1836.[77] Cantrell believes that the most obvious reason for this investment was their own perception that the future looked healthy for the manufacturing industry in the 1830s, and that James Nasmyth had shown business acumen with his first small workshop in Manchester. Nasmyth who, together with his fellow partners, was under 30 years of age, was described as having "excellent sense and experience", possessing "genius in a variety of ways", and uniting "force of character" with

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[76] Hills and Patrick, *op cit* (15), pp.53/73.

[77] J.A. Cantrell, James Nasmyth and the Bridgewater Foundry, Manchester, 1984, p.20.

"sharp hard cleverness".[78] Although the factory's early years were profitable, for unknown reasons the Birleys withdrew their investment after just two years, but, again, Nasmyth had no difficulty in attracting replacement capital. It is most likely that other early manufacturers also relied heavily on personal reputations to raise their requisite capital.

The risks associated with workshop investment were brought home to investors in 1847, when E.B. Wilson & Co. built perhaps the largest and best equipped workshops thus far provided for locomotive manufacture. Wilson announced that "no expense has been spared to obtain the newest machinery of the day" when he 'opened' them with a major dinner in December 1847 (Section 5.7.2), but it was just as the country's recession was commencing and locomotive orders had dropped substantially.[79]

Provision of additional capital for expansion of manufacturing capacity and new equipment, was addressed in different ways by the proprietors. Whilst some firms sought loan capital, others acquired additional equity, such as Sharp Brothers who in 1852 brought in Charles Stewart to provide additional capital as well as expertise. Other firms, such as Beyer Peacock & Co., brought in non-executive partners. When it was formed in 1854, both Beyer and Peacock held £10,000 in shares, funded from their own resources, including loans.[80] The third, non-executive, partner, Henry Robertson, also invested £10,000 having been convinced of the credentials of Beyer and Peacock by the contractor, Thomas Brassey. The Partnership Memorandum determined that further investment up to £90,000 would be met out of profits, thus delaying the first dividends, but avoiding any dependency on external investment or loans.

Partnerships could raise significant sums of capital for major expansion programmes. The establishment of purpose-designed locomotive factories by E.B.Wilson and Beyer Peacock,

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[78] K.M. Kyell (ed), Memoirs of Leonard Horner, 1890, Vol.1, p.356, & Vol.2, pp.3/106; and M.J. Shaen, (ed), Memorials of Two Sisters, Susanna & Catherine Winkworth, 1908, p.133; quoted in Cantrell, *ibid*, p.21.
[79] Speech by E.B. Wilson at the opening of the Railway Foundry extension, December 1847, quoted in Redman, *op cit* (69), p.10.
[80] Hills and Patrick, *op cit* (15), pp.13/14.

encouraged other 'progressive' firms to follow suit. Walter Neilson and James Reid, and Henry Dübs, respectively of Neilson & Co. and Dübs & Co., commanded particular respect in Glasgow banking circles that enabled them to raise sufficient capital to fund their several expansion programmes. In America, similarly, the Baldwin Locomotive Works had fourteen different partnerships before becoming an incorporated company in 1909, each able to encourage sufficient capital for the factory's several expansion programmes.[81] However, as the size of factories and the capital value of their equipment increased from the 1860s, it became increasingly difficult to stimulate sufficient partnership equity, and other firms became limited companies in order to raise the requisite capital (Section 7.6.5).

Other firms, which remained as largely craft-based manufacturing organisations, found it increasingly difficult to raise capital. In 1870, the new proprietors of R.&W. Hawthorn acquired the firm's Newcastle premises and goodwill for £60,000, but achieved this only through substantial loans from family and business contacts, and a £25,000 mortgage from William Hawthorn.[82] Again, there is no evidence of a business plan, but the Chairman, Benjamin Browne, observed that "the Company was strengthened" by the "extraordinary ability" of the Company Secretary, J.H. Ridley, "to make accurate forecasts."[83]

Some proprietorial firms maintained their family status, but the succession from one generation to the next was not always accomplished. Pioneering attributes were not necessarily passed on or, if they were, they proved unequal to the changing business environment. Some proprietors put more emphasis on their sons acquiring engineering and production experience than they did on business matters, which was largely to be gained when they were promoted to senior positions. John Hawthorn Kitson, for example, served an apprenticeship at Kitsons' Airedale Foundry, and was promoted through several departments before becoming a partner.[84] In the next generation, Edwin Kitson Clark, was

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[81] Brown, *op cit* (26), pp.96/7.
[82] Clarke, *op cit* (11), pp.15-21.
[83] *ibid.*
[84] Edwin Kitson Clark, Kitsons of Leeds, nd but 1937, p.177.

also apprenticed at the Airedale Foundry and was promoted through several senior posts, before his partnership appointment in the twentieth century.[85]

7.6.2 Second Site Investment

Several companies considered establishing a second manufacturing site. As early as 1830, the threat from the Lancashire manufacturers of textile, mining and marine equipment, notably Edward Bury & Co. (Section 3.2), to diversify into locomotive manufacture following the opening of the Liverpool & Manchester Railway, prompted Robert Stephenson to consider establishing a second factory in Liverpool.[86] Without a business plan, but stressing the geographical disadvantage of the Newcastle factory, he discussed the proposal with his fellow partners of Robert Stephenson & Co. They were opposed to his proposal so soon after the difficult financial years of the 1820s, when closure of the Newcastle factory had been considered. Their views were summed up by Michael Longridge:[87]

> The establishment you contemplate at Liverpool appears to me fraught with injury to Forth Street: the chief employment of which will be transferred to your new establishment. How then are you ever to pay the Dividends and recover the Capital?

By March 1831, Longridge was sufficiently convinced about the competition to concede: "It is certain the demand for Engines will be much greater than we can supply at Newcastle, and if we can keep that place fully employed, we shall in a few years receive back our Money at any rate."[88] The partners compromised by allowing Robert Stephenson to enter another partnership in order to establish the new factory, but he was obliged to pledge that:[89]

> Should I become connected with another Manufactory for building Engines in Lancashire or elsewhere I have no objections to bind myself to devote an equal share of my time and attention to the existing establishment at

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[85] *ibid*, Chapter VIII, pp.139-170.
[86] Bailey, thesis, *op cit* (8), Section 10.2, pp.150-159.
[87] Letter, M. Longridge to R. Stephenson, B[edlington] I[ron] W[orks], 13 Dec.1830, Pease-Stephenson Collection, *op cit* (28), D/PS/2/34.
[88] Letter, M. Longridge to Thos. Richardson, Bedlington Iron Works, 24 Mar 1831, Pease-Stephenson Collection, *ibid*, D/PS/2/62.
[89] Letter R. Stephenson to fellow partners of R. Stephenson & Co., Newcastle, 7 March 1831, R. Stephenson & Co. Collection, *op cit* (8).

> Newcastle. I will also pledge myself not to hold a larger interest in any other factory, than I have in Forth Street and to divide the Locomotive Engine orders equally.

George and Robert Stephenson formed a partnership with Charles Tayleur, a Liverpool businessman and Director of the Liverpool & Manchester and Grand Junction Railways, and his son, also Charles Tayleur. The Stephenson company partners agreed "That the firm at Liverpool shall be Charles Tayleur, Junr. & Co. or any other Firm not embracing the name of 'Stephenson' so as to distinguish it entirely from the Newcastle House."[90] Locomotive orders were equally divided between Newcastle and the Tayleur Company's Vulcan Foundry, which began production in 1834,[91] but by the end of 1835, the agreement ended and the Stephensons withdrew from the partnership.[92] The cause of their withdrawal cannot be confirmed, but it probably arose from the disagreements over early locomotive specifications (Section 3.2), from which the Tayleurs concluded that their investment would be better protected without the Stephensons.[93]

In the peak market conditions from 1844, the Stephenson Company found itself with a severe capacity constraint and lengthening delivery times (Section 5.7.2). With the experience of previous demand cycles, it opted to take a short (seven-year) lease on a site half a mile from its main premises. The 'West' factory required significant new capital as observed by the firm's partner, Edward Pease:[94]

> the increased number of Engines you are laying yourselves out for completing next year, will no doubt keep your capital near its tension yet as you have some small advance from purchasers I cannot think our capital will cause account below respectable - If a small number of the contemplated RWays only be sanctioned by the ensuing Parliament, what a number of Loco factorys [sic] may be expected to spring up & many a sorry engine be made!

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90 R. Stephenson & Co. Minute Book, entry for 27: day of June 1831, *op cit* (30).
91 D. Gooch, Memoirs and Diary, Transcribed and Edited by R.B. Wilson, Newton Abbot, 1972, p.18.
92 Bailey, thesis, *op cit* (8), p.157.
93 Minutes of the Grand Junction Railway Board, 4th November 1835, PRO Rail 220/1.
94 Letter E. Pease to E.J. Cooke (for R. Stephenson & Co.), Darlington, 11 Mo 29. 44, Library of the Institution of Mechanical Engineers, Crow Collection.

R.&W. Hawthorn was similarly inundated with orders, and relieved the problem by acquiring and adapting a works at Leith as a locomotive erecting shop, to which components made at its Newcastle works could be shipped and erected for delivery to its several Scottish customers.[95] By 1850, the downturn in locomotive demand made the plant superfluous, and the Hawthorn family sold two thirds of its holding to local land and marine engineering interests.[96] A new company, Hawthorns & Co., enlarged the site into a locomotive factory which, for 22 years manufactured industrial locomotives. Shortly after the sale of his Newcastle factory, William Hawthorn also sold his interests in the Leith Works, after which it concentrated on its main marine engineering work.[97]

7.6.3 Backward Integration

Some manufacturers believed there would be financial advantages through acquiring their main suppliers of iron, although there is no evidence to indicate whether those advantages were realised. In 1854, the Kitson family acquired Whetham's Forge in Holbeck (Leeds), which they enlarged and renamed the Monk Bridge Iron Works.[98] The ironworks supplied Kitsons' Airedale Foundry with iron plate, bars and sections, as well as forgings. The Monk Bridge Company became a large supplier of iron, principally for 'railway material', and diversified into steel production from the 1860s. At around the same time, Neilson & Co. acquired the Summerlee Ironworks in Coatbridge, although it is not clear for how long. It was unlikely to have acquired it prior to its move to Springburn in 1862, and its first attempt to sell the site in 1873 suggests that its involvement was of short duration.[99] It is possible that the switch to steel would have required substantial investment, which Neilsons were, perhaps, unwilling to make; a limited liability company hoping to acquire the site in 1873 was seeking a capital of £400,000. In 1872, Andrew Barclay Sons & Co. set up the North British

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[95] Clarke, *op cit* (11), p.10.
[96] Wray Vamplew, 'Scottish Railways and the Development of Scottish Locomotive Building in the Nineteenth Century', Business History Review, Vol.46, No.3, 1972, p.327.
[97] *ibid*, p.332.
[98] Clark, *op cit* (84), pp.70/176.
[99] Engineering, Vol.XVI, October 24th 1873.

Iron Hematite Co., but this was a financial disaster which brought both firms into sequestration within two years (Section 7.6.7).[100]

7.6.4 Overseas Ventures

As the overseas locomotive market expanded, some manufacturers considered setting up subordinate factories in other countries. The earliest was by the Fairbairn family, who "issued prospectuses of an establishment" at Malines in Belgium in 1839: "Mr. William Fairbairn is to superintend the heavy department for engines, locomotives, &c, and Mr. Peter Fairbain that for spinning machinery."[101] Malines was the centre of the new Belgian State railway system, suggesting that locomotives were to have formed a large part of the business. The factory would have competed with Cockerill's large works near Liège, but there is no further record of the Fairbairn proposal.

Also in 1839, Robert Stephenson was said to have agreed with the French engineer, Paulin Talabot, to set up a locomotive factory "somewhere in France".[102] There is no evidence that Stephenson proceeded with this idea, indeed, the division of the 1844 locomotive order for the Marseilles-Avignon Railway between the Newcastle factory and the Benet Company (Section 5.7.2) would seem to confirm this. Following its acquisition of the Leith Works to accommodate the large locomotive demand in the mid-1840s, further erecting facilities were found by R.&W. Hawthorn through association with the German firm of Lindheim, whose factory was at Ullesdorf in Silesia.[103] Although components for three locomotives for Silesia were sent to Ullesdorf, there is no evidence of a lasting association.

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100 Moss and Hume, *op cit* (22), p.72.
101 Report quoted by S. Pollard and C. Holmes, Documents of European Economic History, London, Vol.1, 1968, p.321, quoted by R.A.Hayward, Fairbairn's of Manchester, unpublished MSc thesis, UMIST, 1971, p.28.
102 Letter M. Longridge to W.S. Longridge, Brussels, 19 Sept 1839, in private possession of Mr. R. Longridge and quoted with permission.
103 Clarke, *op cit* (11), p.10.

Two overseas factories were built with British capital, neither being associated with a British-based works. In 1842, the Sotteville Works in Rouen were built and operated by William Buddicom, to supply locomotives for the Paris-Rouen and later French railways.[104] The second was established in Montreal in 1853, to make locomotives for the Grand Trunk Railway, by the two Kinmond brothers who had withdrawn from the Kinmond Hutton & Steel partnership at a time of low locomotive demand in 1850. Despite a promising start, the venture failed in 1857.[105]

Immediately after establishing the Gorton Foundry in 1855, Beyer Peacock & Co. considered a design, build and management contract for an engineering works in Vienna, probably responding to an approach from Austrian interests.[106] The company proposed to supply all designs and drawings for the works for a charge of 5% of its outlay, and to supervise its construction for 2½%, as well as supply and install all capital equipment. Beyer Peacock recruited Henry Dübs to manage the Vienna Works for five years, for which it was to receive an unspecified percentage of turnover (Section 6.2.1). Beyer Peacock was to invest £10,000 in the venture, a substantial sum so soon after establishing the Gorton Foundry, and nominate a director to the Vienna Board, but there is no evidence that they proceeded, and Dübs only remained at Gorton for six months, before taking up his position with Neilson & Co.[107]

When the contracting partnership, Peto Brassey & Betts, won the contract to build and equip the Canadian Grand Trunk Railway, including the Victoria Bridge near Montreal, the three proprietors established their own works. Although they had the option of setting up a factory in Canada, they established the Canada Works in Birkenhead, alongside a deep-sea berth.[108] With an urgent requirement, their decision was probably influenced by Brassey's familiarity with Birkenhead, and his ability to build the works, recruit the craftsmen and have

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104 Jacques Payen, La Machine Locomotive en France, Lyon, 1986, pp.123-130.
105 Vamplew, *op cit* (96), pp.324-327.
106 Draft Agreement, Manchester, Decr.19th 1856, Beyer Peacock collection, *op cit* (15), MS0001/255.
107 Letter, C. Beyer to H. Roberston, Gorton Foundry, March 5th 1857, Beyer Peacock collection, *ibid*, MS0001/256.
108 Millar, *op cit* (59), pp.44-46.

it up and running within six months. The works were also available for the manufacture of locomotives for other world markets.

The majority of locomotives built for Canadian railroads were made by American manufacturers. In the 30 years from 1860, only 200 were exported to Canada, the worst market in the Empire for the British manufacturers (Fig.9).[109] Against this background, Dübs & Co. established, in the mid-1880s, at Kingston, Ontario, the only example of a British locomotive manufacturer opening a subordinate overseas factory.[110] Production lasted until 1900, but it has not been possible to determine the arguments for its establishment or the reasons for its termination after the short period.

The lack of diversification into overseas plants is difficult to explain because of lack of evidence. It is likely that, with the exception of Canada, the need was perceived not to be required because of the dominance of London in the locomotive market (Section 3.4). Also, most manufacturers had experienced the cyclical locomotive market changes from the 1830s onwards, which persuaded them to maintain interests in non-locomotive markets. As these were often of a local or regional nature, for example mining equipment for a local coalfield, the British-based manufacturers may have felt less secure in an overseas market with which they were less familiar.

7.6.5 Incorporation

From the 1860s, the expansion of locomotive works and re-investment in new machinery began to exceed the ability of some proprietors to raise sufficient capital; for others, the raising of such sums was perceived to be too great a risk. Following the passing of the 1856 Joint Stock Companies Act, and the consolidating Company Act of 1862, 'private' or 'public'

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[109] Robert F. Legget, Railways of Canada, Newton Abbot, 1973, p.50.
[110] S.B. Saul, 'The Engineering Industry', in D.H. Aldcroft (ed), The Development of British Industry and Foreign Competition 1875-1914, p.201, quoting O.S.A.Lavallee and R.R.Brown, 'Locomotives of the Canadian Pacific Railroad Company', Railway and Locomotive Historical Society Bulletin, Vol.LXXXIII, 1951, p.9, and R.R.Brown, 'British and Foreign Locomotives in Canada and Newfoundland', Railway and Locomotive Historical Society Bulletin, Vol.XLIII, 1937, pp.6-23.

limited liability status opened the way for the introduction of new capital. The Vulcan Foundry Co. was incorporated as a private company in 1864, whilst Sharp Stewart & Co. and the Avonside Engine Co. were the first manufacturers to be floated as public companies, also in 1864. The Yorkshire Engine Co. was started up with public company status in 1865.

Similar limited liability opportunities opened up in Europe, to provide for a significant expansion of locomotive manufacturing capacity. In France, the Parent, Schaken Caillet et Cie. partnership was incorporated as the Compagnie de Fives-Lille in 1865, allowing it to increase its capital. Three years later, it became the first of three public locomotive manufacturing 'Société Anonymes', the further injection of capital providing for an increase in production to one locomotive per week.[111] In Germany, similarly, several locomotive manufacturers were incorporated as 'Aktien-Gesellschafts' after 1870, and the increase in capital provided for the major expansion of the country's locomotive industry.[112]

No British firms were incorporated in the depression years of the 1870s, but as confidence returned in the 1880s/1890s, eleven manufacturers became limited companies.[113] These included 'progressive' companies, such as Beyer Peacock & Co., 'craft' companies, such as Hawthorn Leslie, which became a public company in 1886 after only a year as a private company, and industrial locomotive manufacturers, such as Fletcher Jennings and Dick Kerr & Co. Hawthorns' new status, and its acquisition of the Andrew Leslie shipyard, clearly prompted the Stephenson Company to acquire its own shipyard the following year, prior to which it also became a private limited company.

In practice, public company status was not always pursued vigorously, and the sharing of strategic decision-making responsibilities with a Board that included non-executive directors caused discontent amongst the longer-serving executive directors. Only a quarter of the Hawthorn Leslie shares were taken up at first, for example, the remainder being retained by

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[111] François Crouzet, 'When the Railways Were Built', in Marriner *op cit* (47), p.106.
[112] Analysis of data contained in J.O. Slezak, Die Lokomotivfabriken Europas, Internationales Archiv Für Lokomotivgeschichte, Wien, 1962.
[113] Analysis of Appendix.

the original Board members. The Company Secretary felt that quotation on the London Stock Exchange was not possible because "our Company is to all intents and purposes a Private one as our Directors hold more than 5/6ths of the Capital and it is not our wish to give the concern a public character for some years to come."[114] Shortly afterwards, the Company's chairman, Benjamin Browne, criticised his fellow directors when writing about the responsibilities of public companies:[115]

> The principle that nothing should be left permanently to one director is, to my mind, a vital point in any Public Company....... Being a Director of a Public Company involves some extra trouble, but this is inevitable and should have been thought of before...... No man likes to be told he must not act independently but it is inevitable not only that he be told so but that he should accept the fact and act accordingly.......

The extraordinary market events of 1897-1900 (Section 2.8) also stimulated further incorporations, the largest of which were Kitson & Co. and, after 33 years as a private company, the Vulcan Foundry Co.

7.6.6 Amalgamation

No amalgamations took place between any of the locomotive manufacturers during the 19th century, even though pooling of capital and goodwill would have had clear advantages, and public company amalgamations had been well understood since the first railway mergers in the 1830s. Firms such as Robert Stephenson & Co. and R.&W. Hawthorn, on adjacent sites in Newcastle, and the Hunslet Engine Co., Hudswell Clarke, and Manning Wardle on adjacent sites in Leeds, could have amalgamated with economies of scale. Hawthorn's merger with the Andrew Leslie shipbuilding company in 1885 confirmed the principle of amalgamation in the manufacturing industry, albeit towards horizontal integration of related activities, rather than production economy within one of them.

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114 Statement by Thomas Ridley, Newcastle Journal, quoted in Clarke, *op cit* (11), p.49.
115 *ibid.*

The lack of interest in amalgamation is difficult to explain in the absence of firm evidence, but it seems to have been due to the tenacious desire of the partners themselves to remain in control of their firms. Even after incorporation, companies were usually dominated by the senior directors, for whom amalgamation would have represented loss of influence or control. Mistrust could also rule out any moves in this direction. There had been a long-standing antagonism between the Stephenson and Hawthorn families, for example, which kept their firms in competition. The row over patent infringement in 1844 (Section 4.6) deepened the mistrust, which continued after the demise of the original protagonists. The Stephenson Company, which had been remarkably profitable,[116] could have acquired the Hawthorn Company in 1870, when it had been available "for some time" and "the place might probably be bought cheap."[117] It had an excellent opportunity to combine the two sites and, albeit with major investment, create a progressive locomotive manufacturing site. The subsequent purchase of the Hawthorn site by other interests, and its integration with the Leslie shipyard, may have caused the Stephenson Company proprietors to regret the lost opportunity.

A proprietor, such as Andrew Barclay, was tenacious in his desire to remain independent, even though it was clear that he was unable to maintain financial independence and attract sufficient funds for investment at the Caledonia Works (Section 7.6.7). Such tenacity could even have far-reaching effects for the progressive manufacturers, and occasional disagreements amongst partners could threaten the survival of a company, such as occurred with E.B.Wilson & Co. Far from considering amalgamations, Walter Neilson, the charismatic proprietor of the Glasgow firm that bore his name, had major disagreements, firstly with Henry Dübs and latterly with James Reid, both leading to the establishment of large competitors in the same city. Neilson later claimed that "Dübs made himself so excessively disagreeable and having offered to give up his partnership and leave the works upon my paying him a certain sum of money...... he left."[118] Neilson chose to retire in 1884 and

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116 M.W.Kirby, Men of Business and Politics &c, London, 1984, p.43.
117 Communication, Thomas Hodgkin to Benjamin Browne, quoted in Clarke, *op cit* (11), p.19.
118 Walter Neilson, autobiographical notes, Neilson Reid & Co. Collection, *op cit* (23), UGD10.5/1.

invited his fellow partner, James Reid, to buy out his share, but there was a deep disagreement over the valuation, "I considered I was being robbed by Mr. Reid of a sum equal to £20,000".[119]

As if to prove a point to James Reid, Neilson convinced Glasgow's banking community, by virtue of his experience and strength of character, to provide loan capital to establish a new factory, the Clyde Locomotive Works. His claim that his personal reputation would retain a sizeable portfolio of customers proved to be exaggerated, and Neilson's career ended in 1888 when his firm ceased trading through lack of orders. The works were acquired for about a third of their cost by Sharp Stewart & Co., which, as a public company, raised additional capital to move from its cramped central Manchester site and re-locate to the failed Clyde Locomotive Works.

The American and European locomotive industries also resisted amalgamations. Serious consideration was given to it in America after 1892, but the prolonged recession in the decade saw a serious downturn in its domestic locomotive market. In such an unsettled situation, the proprietors could not agree on terms for any mergers, but agreed instead to face the recession by co-operating under a freshly constituted American Locomotive Manufacturers Association.[120] This collusion was seen as a successful response to narrowing profit margins and mounting capital costs.

Only as the locomotive market regained strength from 1898, and through the initiative of a financier and industrialist, Joseph Hoadley, was there confidence for a major amalgamation, in 1901, of the ten smaller manufacturers to form the American Locomotive Company (ALCO).[121] This extraordinary move, to achieve rough parity with Baldwin's productive capacity, recognised both the economies of scale of large batch production, and the negotiating strength of large suppliers in pursuing the standardisation of components to

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119 *ibid.*
120 Brown, *op cit* (26), p.53.
121 *ibid.*

achieve large batch orders. The lesson was quickly learned by the three main Glasgow firms (Neilson Reid & Co., Dübs & Co. and Sharp Stewart & Co. Ltd.), already Britain's most progressive main-line locomotive firms, which amalgamated in 1903 to form the North British Locomotive Company.[122]

7.6.7 Failures

There were 33 failures of locomotive manufacturing companies during the course of the 19th century, including two sites which failed on two occasions.[123] 22 of the failures, such as that of the Worcester Engine Co. in 1872, saw the ending of locomotive production altogether.

In the absence of company papers, the circumstances of most failures are unknown, although their timing goes some way towards explaining them. Some occurred during recessions and times of low locomotive demand, such as Mather Dixon in 1843; whilst the liquidation of Bury Curtis & Kennedy in 1851 was the largest of all the 19th century failures. The majority occurred at other times, however, suggesting that proprietors failed to take the strategic decisions necessary to maintain their competitiveness, or the tactical decisions necessary to deal with raw material price movements and working capital requirements.

Tenacity alone was insufficient in keeping a business solvent, as demonstrated by Andrew Barclay, the largest employer in Kilmarnock in 1871. He faced a liquidity crisis after a re-investment programme at the Caledonia Works coincided with a downturn in demand and prices for mining machinery. Fearing a collapse of his business, he set up his five sons in a separate business, Barclays & Co., at the Riverbank Works in the town, to which most locomotive orders were then directed.[124] In spite of many endeavours, Barclay could not recover financial independence and profitability. His business was sequestrated in 1874, re-

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122 A History of the North British Locomotive Co Ltd, 50th Anniversary publication, Glasgow, 1953, pp.44/5.
123 Analysis of Appendix.
124 Moss and Hume, *op cit* (22), pp.70-75.

instated the following year through new securities, but sequestrated again in 1882. Its re-instatement in 1886 was through the control of the firm's creditors, under whom it continued trading before incorporation as a limited company in 1892. That Barclay's autocratic style of direction was partly at fault for the firm's difficulties was born out with the firm's move into profit after 1894, in which year he had stood down as Managing Director, after 47 years in charge of the Caledonia Works.

The failure of Robert Stephenson & Co.Ltd. in 1899, at a time of extraordinary demand for locomotives, and when prices were high, was the outcome of its long policy of inadequate investment. As early as 1883, Sir Joseph Pease, who had inherited his partnership shares from his father, observed that "the management seems all asleep and wants waking up."[125] Following the Company's incorporation in 1886, it appointed a new General Manager, G.H. Garrett. In spite of his rigorous cost analysis (Section 7.2), showing that some activities were unprofitable, including locomotive manufacture, Garrett, who died in 1889, appears to have taken insufficient action to stem the losses.

Garrett's replacement from 1891, John Walker, similarly took insufficient action to rectify the losses on locomotive production.[126] Between 1886 and 1900, most locomotives were made at a loss, including the 40 tank locomotives for the Midland Railway in 1899 (Section 5.7.5), when the locomotive market was high and the prevailing prices should have earned a good profit. The Newcastle site could no longer sustain multiple locomotive manufacture down to the costs of other manufacturers, and its output was no longer acceptable to any but a handful of loyal customers. Between 1876 and its failure in 1899, the site accumulated losses of £580,000.[127] A new public company was formed that year to acquire the Stephenson Company's assets and goodwill, and to provide the capital for the building of a new factory in Darlington, which allowed the Stephenson Company name to be carried forward into the 20th century.

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125 Kirby, *op cit* (116), p.79.
126 J.G.H.Warren, A Century of Locomotive Building By Robert Stephenson & Co. 1823/1923, Newcastle-on-Tyne, 1923, pp.416/7.
127 Kirby, *op cit* (116), p.79.

The success of many of the first proprietors in diversifying and expanding their manufacturing businesses into locomotive production confirmed the strengths of the combined expertise of partnership enterprises. They established reputations for profitable operations, which were confirmed by the returns on investment achieved until the late 1840s. However, the uncertainties of the locomotive market, particularly with the reducing proportion of domestic main-line orders (Section 2.3), and in the wake of the recession in the early 1850s, resulted in different interpretations of the industry's progress thereafter.

The anticipation of the market's growth, albeit with unpredictable demand fluctuations, particularly for overseas, encouraged the 'progressive' manufacturers and their backers to expand their factories and provide further capital equipment towards specialised locomotive production. The 'craft' firms chose not to put themselves at the risk of the uncertain market, and fell back on their broad manufacturing base or diversified further into other markets with a reduced capital requirement. For almost all manufacturers, the uncertainties of the market were too risky for second-site investments.

The manufacturers equivocated about the opportunities for raising further capital through incorporation from the 1860s. Whether they were large progressive firms or smaller craft firms, their caution reflected the reluctance to lose the decision-making control over their affairs. The success of some early incorporated firms, however, encouraged several other firms to expand their capital requirement through incorporation later in the century.

7.7 Conclusion

The proprietors in the first 30 years of the railway era showed extraordinary entrepreneurial flair in committing equity and loan capital to develop manufacturing concerns which employed advanced capital equipment and production control procedures. In spite of the limited evidence to suggest how proprietors made their strategic decisions, it is evident that, at the end of the 19th century, the locomotive industry as a whole remained dominated by individualism, and lacked the capability for making strategic business plans for long-term growth and profitability. With the exception of the progressive manufacturers, the tenacious desire to survive was not matched by an understanding of the developing economics of heavy manufacturing. There were still too many craft firms offering non-standard, small-batch, high-cost products manufactured as part of wider heavy manufacturing activities.

This is best illustrated by comparing the number of British and overseas firms involved in locomotive manufacture. In the USA, the 40 manufacturers making locomotives in 1854 had dropped to 16 by 1877.[128] Five large concerns and eleven smaller firms provided not only for the whole North American market, but for a growing export market as well. In Britain, even with the loss of much of the domestic market to the railway workshops, there were 27 large and medium size companies (and 16 smaller companies) making locomotives in 1877, all with varying degrees of involvement in other manufacturing activities (Appendix).

In the last quarter of the century, the number of American firms remained at about 16, with the five largest companies investing heavily to meet the extensive growth in both the domestic and foreign locomotive markets.[129] In Germany by the end of the century, there were eight '*Aktien-Gesellschafts*' and 12 other large manufacturers making locomotives for the whole domestic market, and a growing foreign market.[130] The French locomotive industry had three 'Société Anonyme' and six other manufacturers, also with large domestic and foreign markets.[131] Britain, however, still retained 26 large and medium manufacturers (and 7 smaller ones) by the end of the century, 13 being private limited companies, 8 public limited companies and 12 partnerships. The production capacity of 230 locomotives a year of the largest British manufacturer, Neilson & Co., was much less than Baldwins' production of 1100 a year.[132]

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128 John H. White Jr., A History of the American Locomotive Its Development: 1830-1880, Baltimore, 1968, p.19.
129 Brown, *op cit* (26), p.31.
130 Slezak, *op cit* (112), pp.6-9.
131 *ibid*, pp.10-12.
132 Brown, *op cit* (26), p.195.

It is apparent that throughout the century most proprietors were well served with management information and accounts, and had good knowledge of wages, component and material costs, as well as overhead cost assessments from which their direct cost manufacturing base was determined. The use made of this information in making tactical decisions was, however, somewhat uneven. Some proprietors responded well in making tactical decisions, including negotiations to minimise cash flow problems arising from sudden rises in raw material costs and bad debts. Equally, they took advantage of increasing demand through advance payments to provide periods of healthy cash flow to reduce their loan capital. Other firms did not keep adequate cost accounts and allowed costs to escalate.

The proprietors were also generally well served with financial accounts and knowledge about their company performances and profitability, with depreciation allowance well developed from the industry's earliest years. In spite of this information, the proprietors were generally poor at taking strategic decisions towards the long-term future of their companies. This conclusion reflects Pollard's view that "accountancy in its wider sense was used only minimally to guide businessmen in their decisions, and where it was so used the guidance was often unreliable."[133] Decisions relating to site expansion, development of new sites at home and abroad, re-investment in capital equipment and diversification into and out of locomotive manufacture, were based on caution born from the uncertain market trends, and without the discipline of business plans.

The lack of consideration of business mergers, which would have provided larger capital concentrations and economies of scale, suggests that survival and proprietorial pride was always more important than profit. It can only be speculated that if Walter Neilson had applied as much energy in pursuing the growth of his Glasgow factory to three times its end-of-century size as he did in spreading the potential market between three factories by falling out with his partners, Britain might have had at least one factory better able to compete with the growing American and German competition.

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[133] S. Pollard, Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain, London, 1965, p.245.

Even though the three leading progressive firms, Neilson & Co. Dübs & Co. and Sharp Stewart & Co. Ltd., had clearly demonstrated that investment for higher production brought down unit costs, the risk of further capital commitment was too great for some firms, even with limited liability protection. That ten manufacturers protected themselves through the cartel pooling arrangement of the Locomotive Manufacturers Association (Section 3.7), suggests that this was a further disincentive to amalgamations, even though maintenance of high production costs was threatening the export market by the end of the century.

It is thus apparent that, as Simon has proposed, the proprietors' decisions were more dependent upon their behavioural characteristics and personal persuasions than on clear business objectives.[134] When the Hawthorn Company was acquired by new partners in 1870, it was fully their intention:[135]

> to confine ourselves to marine engines, but the North Eastern Railway Co. were buying new locomotives very freely and encouraged us to go on with the trade, and, what with the old reputation of the firm and orders being so easy to get, we yielded to temptation and decided to go on with this business also.

The Stephenson Company was similarly motivated during the loss-making years prior to its failure in 1899. The lack of decisive action revealed an extraordinary inertia born of the contemporary opinion that 1873 to 1896 represented a period of 'Great Depression' in trade and industry, and that by taking a long-term view, the company would return to profitability. It clearly took the major market upturn from 1897, and the Stephenson Company's inability even to make a profit on the large order it did receive, to convince the proprietors to wind up the business, and make a fresh start on a new site.

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[134] H.A.Simon, Models of Bounded Rationality, 2 Vols., Cambridge, USA, 1982, quoted by Boyns and Edwards, *op cit* (4), p.29.
[135] Clarke, *op cit* (11), p.21.

8.0 Conclusions

It is difficult to see how Chandler's basic criticisms, about British industry's reluctance to embrace the economies of both scale and scope of mass production and the re-organisation of firms towards 'managerial' enterprises, can be applied to the heavy manufacturing industry (Section 1.0).[1] These firms were dominated by strongly demand-led markets for small batch machinery, requiring vertically-integrated production facilities. It follows that only those sectors which controlled, or could have controlled their markets can reasonably be criticised if they failed to embrace the structural changes advocated by Chandler. In considering the decision-making capabilities of the locomotive industry's proprietors, therefore, this thesis has considered the question of whether the industry could have sustained a supply-led market through the 19th century in order to benefit from larger batch production. An increase in standardisation of components would have permitted economies of scale, but to achieve production economies of the levels of the American and German locomotive industries by the end of the century, the British industry would have required fewer factories, each producing more units of fewer designs.

The industry's failure to achieve these production levels was due to its inability to control the locomotive market. In the progressive early years until the 1850s, the industry had moved strongly towards standardised designs and batch production of components. Thereafter, however, it became increasingly dominated by its market which it then served largely as a contract manufacturing industry with only the growing industrial locomotive sector able to sustain a production-led market. The factors that led to this regression to contract manufacturing were three-fold, namely the determination of each firm to survive, the introduction and expansion of British railway company workshops, and the isolating effects of the London-based overseas market.

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[1] Alfred D. Chandler, Jr., Scale and Scope The Dynamics of Industrial Capitalism, Harvard, 1990, Part III, 'Great Britain: Personal Capitalism', pp.235-294.

8.1 Survival

The culture in heavy manufacturing firms, of preserving a broad market base to provide continuity of work for skilled personnel and capital equipment, had been present since the pre-railway era. To overcome market fluctuations these firms sought continuity of work through diversification, not just of product, but of market, a welcome new form of which was the manufacture of locomotives. The culture was continued as manufacturers experienced the sharply fluctuating locomotive demand during the 19th century, which was closely related to cyclical movements in the domestic British economy and capital export market, as well as to overseas economic and political events. The ability of manufacturers to survive the low-points in these cycles through diversification explains the continued existence of so many firms in the locomotive market. This became more significant later in the century as the very characteristics enabling their survival, a broad market base using a high proportion of skilled labour, increasingly constrained firms' ability to compete with more progressive companies that specialised in locomotive production.

The rate of survival among British locomotive manufacturers contrasts with the American industry, which developed to exploit the rapid growth of its domestic locomotive market. This it achieved largely through specialisation in locomotive production but, without a broad manufacturing base, the industry was more vulnerable to market fluctuations, and several firms failed, particularly in the 1850s. With their greater vulnerability to market trends, and faced with a greater shortage of skilled labour, the sixteen or so surviving American manufacturers at the end of the century accommodated the fluctuations through layoffs and recruitment of un-skilled labour. They also increasingly developed overseas markets during the worst recessions in the American domestic market. The four or five largest manufacturers, plus the dozen smaller firms, which fulfilled the requirements of the large domestic American market, provided the opportunities for production economies denied to the British industry, and gave it the strength to sustain a production-led market.

8.2 Railway Workshops

The British locomotive manufacturers adapted well to the introduction and development of the tendering and contracting practice required by the 'transparency' of competition for public railways. Their marketing became solely representational, as each sought inclusion and retention on railway tender lists from which obtaining orders was determined by price quotation and delivery times. Their inability to expand quickly enough to meet the extraordinary demand of the domestic railways in the mid-1840s, however, produced delivery dates which were quite unacceptable, and prompted the railways to diversify into locomotive manufacture.

The start up and development of the British railway workshops from the 1840s was the greatest influence on the evolution of the independent locomotive industry from that time. The increasing loss of much of the domestic main-line market was compounded by the conversion of the remainder from a supplier-led to a customer-led, contract market. The initiative for technological innovation passed to the railway development teams, and the opportunity for design innovation was increasingly restricted to smaller railways which did not have a design capability.

The proliferation of railway workshops led to a proliferation of design teams, in turn leading to a proliferation of designs. The absence of any co-operative dialogue on designs, and, as Kirby has written, the 'Empire-building propensities' of the locomotive superintendents (Section 1.6),[2] saw the standardisation of components within, but not between, railway companies. These multiple standards were of more consequence to the independent manufacturers than the proliferation of designs, as the resulting small batch orders offered few production economies unlike the systemisation of production pursued by the American manufacturers.

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[2] M.W. Kirby, 'Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineer's Paradise?, Business History, Vol.30, No.3, 1988, pp.287-305.

The proliferation of domestic railway companies, encouraged by Parliament from the 1870s through its suppression of mergers, helped to maintain the large number of railway-owned locomotive workshops (Section 1.6). The independent manufacturers were called upon to supplement the main-line locomotive stock with relatively small batches only when demand was beyond the capacity of these workshops. There was an acceptance by the railway companies that prices for these small batches would be higher than would have been the case if the independent industry alone had provided all their fleet requirements. This was acceptable to the railways because greater use was made of their workshops, which were primarily maintenance factories.

8.3 London Overseas Market

Until the 1850s, the manufacturers' foreign markets, particularly in Europe, were mostly conducted through commission agents, who, as Chapman states, were of much importance in dealing with the large risks then associated with exporting (Section 1.5).[3] The agents negotiated prices, payment terms, delivery and proving arrangements, as well as providing expertise in credit transactions and shipping. They were also well experienced in providing intelligence about market opportunities and the activities of their British and foreign competitors. From the 1850s, however, their use diminished as the locomotive market in the major European economic centres moved in favour of the developing continental capital markets.

The change in emphasis of British capital exports for railways, from portfolio to foreign direct investments, including government 'guarantee' lines, in the developing countries of Europe, the Empire and South America, opened up the locomotive market to many new opportunities. This is confirmed by Cottrell and Edelstein's findings that over 40% of Britain's overseas investments between 1865 and 1914 were for railway projects (Section

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[3] S.D. Chapman, Merchant Enterprise in Britain: From the Industrial Revolution to World War I, Cambridge, 1992, pp.129-166.

1.4).[4] However, despite Jenks' conclusion to the contrary, there was a close relationship between British foreign direct investment and the locomotive industry.[5] This illustrates the close liaison between the manufacturers, on the one hand, and the railway companies and government agencies on the other, focused on London.

Overseas railways funded through foreign direct investment, and colonial government railways mostly had offices or representation in the City, providing the manufacturers with a much easier way to sell locomotives than their former reliance on commission agents. Market intelligence was maintained by firms' London managers, or their representative agents, in the close confines of the London business houses, and the market became the exclusive preserve of the British industry. Manufacturers' marketing efforts were focused on obtaining and retaining places on the tender lists of the railways and their consulting engineers.

The growth of the commercial, guaranteed and government railways was accompanied by the growth of the London-based consulting engineering firms representing those railways (Section 1.6).[6] Their role in specifying their principals' locomotive requirements increasingly developed into overall locomotive design work, thus further removing the manufacturers' discretion to innovate. The locomotive industry became less able to influence even the principles of some designs, even though it was aware of the unsuitability of British-style 'rigid' designs for railways in undeveloped countries, for which American-type 'flexible' designs would have been more suitable.

The manufacturers were mostly restricted to the detailing design work prior to manufacture, and, as with domestic railway designs, there was no agreed standardisation for components

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[4] P.L. Cottrell, British Overseas Investment in the Nineteenth Century, Studies in Economic and Social History, London, 1975, Fig.1, p.14; Also, Michael Edelstein, Overseas Investment in the Age of High Imperialism, The United Kingdom 1850-1914, New York, 1982, p.37.
[5] L.H. Jenks, The Migration of British Capital to 1875, London, 1927, re-published 1963, p.175.
[6] S.B. Saul, 'The Market and the Development of the Mechanical Engineering Industries in Britain, 1860-1914', in S.B. Saul (ed), Technological Change: The United States and Britain in the Nineteenth Century, London, 1970, pp.146-150.

between overseas railways. Each manufacturer was free to adapt as many of its templates and gauges as the design would allow. This practice, which was closest to that of the American domestic railroad market, did allow a measure of standardisation for each manufacturer. However, the general lack of standardisation between manufacturers was the cause of considerable concern, particularly in larger economic regions such as India, whose railways acquired locomotives from several British firms.

The convenience of the London market saw the manufacturers largely withdraw from other foreign markets, in which they faced competition from American and continental industries which benefited from tariff impositions on imported locomotives. Without the spur of competition from those industries, however, a growing diversity developed, both technical and commercial, between the London-based market and the rest of the world. The convenience and lack of competition from non-British manufacturers led to a collective market assurance in which wider marketing through international exhibitions was largely felt to be unnecessary and, as with the domestic market, the sole emphasis was on maintaining the right to inclusion on tender lists.

As the world market opened up from the 1880s, in geographical areas outside the dominance of the British, German and American industries, the British firms were faced with direct competition from their counterparts. This revealed both the extent of the diversity in the market and the inability of the British firms to compete. The British industry, used to the substantial 'rigid' designs perpetuated by the consulting engineers, was less able to provide locomotives of the more 'flexible' American type, and price comparisons frequently favoured the standardised products of the American and German industries.

Subsequent organisational reforms did nothing to alleviate these problems. The Locomotive Manufacturers Association, born out of the perceived threat to the industry's existence from British railway workshops, became the vehicle for protective cartel arrangements from the 1880s. This served to accommodate the inefficiencies of the smaller, craft-based firms, the consequent raising of prices being indicative of an industry that had got out of touch with wider railway developments after years of dependency on the London market.

8.4 Strategic Decision-Making

The British locomotive industry had to develop strategies for growth and re-investment in accordance with the reducing proportion of the domestic main-line market and the uncertain and fluctuating overseas market. The marked divergence in the manufacturers' strategies resulted from these uncertainties, and was also affected by the degree of confidence felt by proprietors when it came to re-investment and expansion, and by their strong will to survive. 'Progressive' firms were prepared to risk investments to develop their businesses as specialist locomotive manufacturers whose increasing emphasis on batch production would require expanding capital equipment programmes and employment of unskilled labour. The more cautious approach by the 'craft' firms saw them risk less capital for investment as they relied on a broad market base of small batch orders requiring a higher proportion of skilled labour.

Until the 1850s, the industry controlled the locomotive market and evolved new decision-making practice as it developed policies in marketing, selling, technology, design, manufacturing, employment and administration. It had begun with an "intensive burst" of technological development, between 1828 and 1830 (Section 1.6)[7], that had made possible the rapid expansion of railway networks. The locomotive then developed incrementally, in terms of thermodynamics and material technology as well as design, to fulfil the railways' requirements for improving economy, power and speed. Firms, such as Nasmyths Gaskell & Co., Sharp Stewart & Co. and E.B.Wilson & Co., emulated the earlier progressive role of Robert Stephenson & Co. in pursuing standard design strategies, and demonstrated extraordinary progress in manufacturing development. The industry pioneered new capital

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[7] M.W. Kirby, 'Technological Innovation and Structural Division in the UK Locomotive Building Industry, 1850-1914', in Colin Holmes and Alan Booth (eds), Economy and Society: European Industrialization and Its Social Consequences, Leicester, 1991, pp.25-42.

equipment and production processes which reduced manufacturing time and cost for increasingly standardised and interchangeable components, as well as reducing the requirement for craft labour.

However, as the industry's influence over its market declined from the 1850s, it largely lost discretion for technology and design improvements with the transformation in both domestic and overseas sectors from supplier-led to customer-led markets. This rôle was taken on by railway workshops and consulting engineers, and, by the 1890s, as empirical advancement gave way to scientific progress, much initiative had passed to foreign railways, manufacturers and technical institutions. The changing markets, with limited scope for standardisation and the resulting proliferation of designs, reduced considerably the opportunity for manufacturing procedures to evolve towards the 'American system' of manufacture.

The main-line locomotive manufacturers were too small and diverse to counter the rise of the large railway workshops, and too dependent upon the consulting engineers to counter the fragmented development of the London overseas market. They had no option but to accept the largely contract manufacturing rôle, which would continue to be subject to the market fluctuations. As Saul has noted (Section 1.7),[8] the progressive manufacturers accommodated the new market requirement by pursuing specialised locomotive production. They introduced, as Scranton puts it, "Systematized, but not standardized" batch control procedures, as far as the market would allow, which did much to reduce production time and cost (Section 1.7).[9] The 'craft' manufacturers opted to retain their traditional methods of manufacture, through their broad, heavy manufacturing market base, to accommodate market fluctuations. By the end of the century, therefore, there was a wide diversity of skills, capital equipment and production procedures, although the true costs of manufacture were partly concealed by the cartel pricing agreements of the ten firms forming the Locomotive Manufacturers Association.

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[8] S.B. Saul, 'The Engineering Industry', in Derek H. Aldcroft (ed), The Development of British Industry and Foreign Competition 1875-1914, London, 1968, Table 1, p.192.
[9] Philip Scranton, Endless Novelty, Princeton, 1997, p.99.

The loss of market control, which resulted in this diversity, therefore prevented the industry from continuing its progress towards greater standardisation and batch production and, ultimately, an 'American system' of production. Chandler's criticism of failure to pursue greater economies of scale and scope therefore has some relevance in regard to the locomotive industry, in which too many firms continued in business chasing small batch orders (Section 1.7).[10] Had the industry not been subjected to these market changes, it is likely that it would have evolved in a similar manner to the locomotive industry in the United States. More firms would have had a sufficiently large market base to encourage further investment and specialisation in locomotive production, although the survival rate may have been lower, with some firms unable to protect themselves from market recessions. These companies would, in turn, have been of sufficient size to have played a more influential role in the overseas market by offering a higher degree of standardisation and design in the manner successfully pursued by the German locomotive industry.

The plausibility of this argument is strengthened by reference to the industrial locomotive sector which had quite different characteristics from the main-line sector, and in which manufacturers retained discretion for specification and design. Although there was no scope for technological development, industrial locomotives followed main-line practice with new materials and increasing performance specifications, to provide more power without an increase in weight or dimensions. Manufacturers of industrial locomotives, both specialist firms and the larger firms also engaged in main-line production, took full advantage of their discretionary strength to maintain and develop fleets of standard designs. Their vigorous marketing and selling adopted the practices of the light manufacturing sector, using catalogues, trade fairs and selling agents. Production, similarly, used mostly standardised components, whilst accommodating the variations of track and profile gauge required by the customers.

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[10] Chandler, *op cit* (1).

8.5 Tactical Decision-Making

The locomotive industry was generally successful in its tactical decision-making, although the failure of several firms confirms that adequate provision was not always made for sufficient working capital or to deal with market changes. Confirming the views of Wilson and Pollard (Section 1.1),[11] from its outset the locomotive industry was run by, and was dependent upon, managing partners assisted by specialist managers. The latter were largely selected on merit rather than nepotism, and usually invested in the firms that employed them. The employment of specialist and general managers was increasingly adopted by all firms in the sector, particularly from the 1860s as the early proprietors were ageing, and faced with expanding businesses and more demanding decision-making. A form of functional line management evolved. Head foremen and head clerks were delegated responsibilities for employment, production, procurement, sales and marketing, cost and financial accounting. Workshop foremen were delegated full responsibility for hiring and firing, discipline and production control, which they achieved without the necessity for sub-contracted 'piece-mastering'.

The quality of business information available to manufacturing proprietors and senior managers was generally good during the century. Most proprietors were well versed in credit arrangements, debt recovery and, within the limits of small batch production, in raw material cost limitation. Although cost and management accounting procedures were well developed, however, the use of this information in making tactical decisions was somewhat variable. Several firms used the information effectively, with separate management information for each of their main workshops, making them effectively 'cost-centres'. They thus conformed to good business practice as defined by Chandler's first 'proposition' (Section 1.1).[12] Other firms paid less attention to this detail and were less aware of cost escalation.

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[11] John F. Wilson, British Business History, 1720-1994, Manchester, 1995, p.27; Sidney Pollard, The Genesis of Modern Management, Cambridge, Mass., pp.174/185.
[12] Alfred D. Chandler Jr., The Visible Hand: The Managerial Revolution, Harvard, 1977, pp.253/4.

The early locomotive firms achieved a major adaptation of their skill-base, transforming a 'craft culture' to a 'factory culture' among their workers. Discretionary responsibilities for design, selection of materials and work administration was passed to the specialist managers and foremen. The shortage of craftsmen during the century, accentuated at times of high locomotive demand, was alleviated by the introduction of self-acting machine tools and the employment of un-skilled labour. The majority of tasks, however, continued to require the presence of 'time-served' journeymen boiler-makers, forgemen, foundrymen, fitters and erectors.

The dependence on these craft skills, and the ongoing shortage of craftsmen, meant that manufacturers were obliged to maintain skilled workers in employment as far as possible. There is, however, no evidence of a policy to make machine tools 'firm-specific' in order to deter free labour movement and suppress wage claims, as Drummond suggests was the case with the railway companies in their workshops (Section 1.7).[13] Rather, fluctuations in overall labour requirements were absorbed through the engagement and dismissal of un-skilled men to carry out routine machining tasks. This provided an essential employment cushion allowing firms to provide continuity of work for their craftsmen. The higher proportion of un-skilled men employed by the progressive manufacturers, following their programmes of investment into more types of advanced machine tools, gave them greater facility to reduce their total work-force when demand was low. The 'craft' manufacturers, however, were less able to reduce their work-force at such times, and were obliged to retain a higher proportion of craftsmen in order to maintain their breadth of production.

Joyce's view that factory employers secured both ideological and cultural hegemony over their workforce, largely related to volume industries and did not apply to the locomotive industry (Section 1.8).[14] With most locomotive factories being located in urban areas,

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[13] Diane K. Drummond, 'Technology and the Labour Process: A Preliminary Comparison of British Railway Companies' Approaches to Locomotive Construction Before 1914', Perspectives on Railway History, Working Papers in Railway Studies Number One, Institute of Railway Studies, York, 1997, pp.32/3, Note 22.

[14] P. Joyce, Work, Society and Politics: The Culture of the Factory Town in Late Victorian England, 1980, p.92.

paternalism was generally limited to works' events rather than fulfilling a deeper community involvement. However, even this modest action was seen by the proprietors as an important means of fostering a 'factory culture' which helped to maintain craft employment levels. Although paternalism was not as pervasive as in the railway workshop towns, such as Crewe,[15] the depth and early date of the paternalistic endeavours at Bedlington mark them out as being the progenitor for the independent industry.

The manufacturers were obliged to confront major industrial relations issues, and were in the forefront of some of the major industrial disputes during the century. This confirms Southall's point that the urban manufacturing craftsmen held real bargaining power (Section 1.8).[16] In contrast to the views of McKinlay and Zeitlin,[17] however, there was no accommodation between the trades unions and the manufacturers over the erosion of craft skills and the employment of un-skilled labour. The issue was a running sore throughout the century, re-surfacing with each claim for improved hours and wages. Even after the long-running 1897 dispute, the divisions within the Employers' Federation left the issue un-resolved to be carried into the next century.

8.6 Corporate Decision-Making

The development of the locomotive industry was largely dictated by the nature of its market rather than any limitations in enterprise of manufacturers. This runs counter to Chandler's theme that British industry did not pursue 'managerial capitalism' quickly enough (Section 1.0).[18] The success of some of the larger partnerships which relied upon specialist managers demonstrated that many of the benefits of separating ownership from management could be

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[15] Diane K. Drummond, Crewe Railway Town, Company and People 1840-1914, Aldershot, 1995, pp.186-208.
[16] Humphrey Southall, 'Industrial Protest: 1850-1900', in Andrew Charlesworth *et al*, An Atlas of Industrial Protest in Britain 1750-1990, Basingstoke, 1996, p.61.
[17] Alan McKinlay and Jonathan Zeitlin, 'The Meanings of Managerial Prerogative: Industrial Relations and the Organisation of Work in British Engineering, 1880-1939', Business History, Vol.31, No.2, 1989, p.34.
[18] Chandler, *op cit* (1).

achieved without the wholesale separation inherent in managerial capitalism. 'Partnership capitalism' served the locomotive industries of Britain, America and Germany well throughout the 19th century, proving to be a system that could accommodate generational transition through external recruitment and internal promotion, whilst attracting increasing managerial specialisation. Indeed, the effectiveness of partnership capitalism seems to have contributed to the slow introduction of managerial capitalism.

Partnership capitalism was not a cause of the industry's failure to maintain control of the locomotive market from the 1850s. Progressive companies, such as the Vulcan Foundry Co. Ltd.. and the Yorkshire Engine Co. Ltd., which were themselves early examples of managerial enterprises, were just as influential in the conduct of the market as the partnership enterprises, but just as vulnerable to its limitations. The presence of general and specialist managers could not alter the dominance of main-line railways and the London-based overseas market, which resulted in locomotive design remaining in the hands of railway locomotive superintendents and consulting engineers. Only a significant increase in the size of the manufacturing firms, through substantial investment or through amalgamations, would have provided economies of scale sufficient to have encouraged a return of some market control to the industry, emulating the influence of the Baldwin works in America.

There were examples of hereditary partnerships amongst the locomotive firms, some of which succeeded and some of which failed. However, it cannot be said that they generally contributed to Britain's relative economic decline as Chandler suggests, and there were only a few examples of 'gentrification' (Section 1.0)[19], the most notable being Robert Stephenson & Co.[20] The criticism that partners tried to maintain an assured income at the expense of investment for long-term growth is also difficult to sustain. Failure to invest there certainly was in some firms, but this reflected the divergent interpretations of market growth between

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[19] As discussed by M.J. Wiener, English Culture and the Decline of the Industrial Spirit, 1850-1980, Cambridge, 1981; with a counter view by W.D. Rubinstein, Capitalism, Culture and Decline in Britain, 1750-1990, London, 1993, pp.25-44.

[20] Roper, Robert S., The Other Stephensons: The Story of the Family of George and Robert Stephenson, nd but 1992, Rochdale, *passim*. Also, M.W. Kirby, Men of Business and Politics &c. London, 1984, p.79.

the progressive and craft firms, the latter being more cautious in investing for batch production. This was more a reflection of poor strategic decision-making than a deliberate policy of financial benefit to the partners, a number of whom lost substantial sums through the poor performance of their firms in the last quarter of the century.

From the commencement of the railway era there were many non-executive partners who oversaw the financial well-being of their firms, and who directed the managing partners towards corporate strategies in much the same way that would have been achieved by latter-day managerial enterprises. The perceived success of this form of enterprise gave no cause for change, nor perception of resistance to managerial capitalism as Lazonick suggests (Section 1.0).[21] The incorporation of public locomotive companies was not undertaken as a means of hiring in specialist managers, but to gain access to new capital sources for investment.

The incorporations in the locomotive industry did not constitute full 'managerial capitalism' in the Chandlerian definition (Section 1.0).[22] Indeed, as Payne suggests, the private limited companies were a means to attract additional capital without the partners having to give up full control of their companies.[23] The take-up of public limited company status was rather higher for the locomotive industry than Cottrell suggested;[24] there being eight such firms by the end of the century who used the status to raise capital for significant investment programmes. Although limited companies were amongst the most progressive locomotive firms, employing career managers with ever-greater experience and expertise, the largest and most profitable British firms, Neilson Reid & Co. and Dübs & Co., both remained partnerships throughout the 19th century. Only when they amalgamated in 1903 with Sharp Stewart & Co. Ltd. (by then a public company of long-standing) to form the North British Locomotive Co. Ltd. did the combined enterprise become a public company.

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[21] W. Lazonick, Business Organisation and the Myth of the Market Economy, Cambridge, 1991, pp.25-27, 45-49.
[22] Chandler, *op cit* (1), p.240.
[23] P.L.Payne, 'The Emergence of the Large-Scale Company in Great Britain', Economic History Review, Vol.20, 1967, p.520.
[24] P.L. Cottrell, Industrial Finance, London, 1980, pp.39-45.

Similarly in America, successful companies remained as partnership enterprises until such time that their re-capitalisation requirements made incorporation desirable. Notably, the most progressive locomotive manufacturer, the Baldwin Locomotive Works, remained a partnership enterprise through to 1909, and did not convert to a public corporation until 1911.[25] The Baldwin and North British incorporations were to provide substantial capital for investment. This was perceived to be necessary as a defensive response to the major amalgamation and incorporation in 1901 of the American Locomotive Company (ALCo), the motivation for which was to pursue greater economies of scale in production (Section 7.6.6).

On the other hand, non-executive partnerships employing general and specialist managers were not necessarily going to provide a level of expertise that would guarantee a firm's long-term prosperity, or even survival. For example, the first locomotive company to employ a General Manager, Robert Stephenson & Co., continued as a 'craft' enterprise after his appointment in 1862, but the firm declined and failed at the end of the century (Section 7.6.7). These comparisons between successful and failed companies illustrate the importance of combining the talents of individuals with experience, capability, vision and entrepreneurial drive, whether they be partners or directors, to ensure the long-term prosperity of enterprises.

It is most likely that the 'will to survive' in some partnerships was so strong that it actively discouraged mergers that could have consolidated markets and produced economies of 'scale and scope'. This will to survive was perhaps a form of cultural restraint that Elbaum and Lazonick believe was one of the principle 'institutional rigidities' of the British economy (Section 1.0).[26] There was, however, an equally strong desire for American manufacturers to remain independent, and mergers in that country did not occur either until the formation of ALCo in 1901. Undoubtedly, more could have been done in this direction by the British

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[25] John K. Brown, The Baldwin Locomotive Works 1831-1915, Baltimore, 1995, pp.216/220.
[26] B. Elbaum and W. Lazonick, 'An Institutional Perspective on British Decline', in B. Elbaum and W. Lazonick (eds), The Decline of the British Economy, Oxford, 1986, pp.1-15.

industry, which lost an opportunity to consolidate through the medium of the Locomotive Manufacturers Association. The Association lacked strength of purpose in its early years and the very formula agreed by the ten member firms, by which the progressive manufacturers diluted the value of their production economies to support the craft firms, would, in another era, have led to mergers.

In spite of being well-served with cost and financial accounts and other management information, proprietors were generally poor at taking strategic decisions upon which the long-term future of their companies depended. Decisions relating to site expansion, development of new sites at home and abroad, re-investment in capital equipment and diversification into and out of locomotive manufacture, were based on caution, born from uncertain market trends, and without the discipline of business plans. Such caution could lead to conservatism with damaging long-term consequences. In particular, several firms did not respond to the general reduction in prices in the 'Great Depression' from 1873, believing that it was to be temporary and that strategic decisions could wait until prices returned to their former levels.

Long-term profit was perceived by some locomotive manufacturers to be less important than short-term survival and loyalty to their workforce. This conclusion supports the current writings by Boyns and Edwards (Section 1.0).[27] Indeed, it is also apparent that the strategic decisions of some proprietors were more dependent upon their personal persuasions than on clear business objectives.[28] The Pease family, for example, non-executive proprietors of the Stephenson company throughout the 19th century, allowed it to continue trading in spite of its accumulating losses, partly for 'non-entrepreneurial' reasons.[29]

Resistance to change, perhaps the primary non-entrepreneurial influence on proprietors, can best be summed up as being sentiment for their firms and loyalty to their long-serving

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[27] Trevor Boyns and John Richard Edwards, 'Accounting Systems and Decision-Making in the mid-Victorian Period: The Case of the Consett Iron Company', Business History, Vol.37, July 1995, pp.30/31.
[28] H.A. Simon, 'Rationality in Psychology and Economics', Journal of Business, Vol.59, 1986, p.S223.
[29] Kirby, *op cit* (20), p.115.

craftsmen. This resistance has been shown in the American context by Marx and Churella to reflect proprietors' social status and pecuniary awards, as well as their unthinking continuation of operational routines embedded in old corporate cultures (Section 1.3).[30] Some proprietors perceived sentiment to be of greater importance than the more radical alternative strategies of closure or merger, which the more productive use of capital might otherwise have suggested. Perhaps the best reflection of the feelings that determined the survivability of some companies, in spite of uncertain profitability, was expressed by Benjamin Browne, the Chairman of Hawthorn Leslie & Co. Ltd.:[31]

> ...when the North Eastern Railway ceased to order locomotives regularly there were strong grounds for saying that it would have paid us to give up the locomotive trade altogether as far as mere money is concerned, but there was a widespread feeling of unwillingness to abandon an old and celebrated business: we also had a body of particularly high-class and loyal workmen whom we did not want to turn adrift; and, of course, we always hoped that something would turn up sooner or later.

Browne's views confirm how, even when all the management information may have strongly suggested a contrary action, decision-making was influenced by considerations other than those of profit maximisation (Section 1.0).[32] Personal agendas, such as the individualism pursued by Walter Neilson (Section 7.6.6), and the sentiment and loyalty, pursued by Benjamin Browne, could override the search for a return on capital investment that may otherwise have dictated expansion or closure. These agendas serve to emphasise that the industry's development was determined not just by business judgement but also by personal persuasions. This inter-relationship is therefore important to the central theoretical questions of why firms exist and grow. Business historians considering the new institutional theory of the firm therefore need to accommodate these persuasions in their deliberations. It is hoped that the evidence put forward in this thesis will assist such historians who, through,

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[30] Thomas G. Marx, 'Technological Change and the Theory of the Firm: The American Locomotive Industry, 1920-1955', Business History Review, Vol.L, No.1, 1976, p.19. Albert Churella, 'Corporate Culture and Marketing in the American Railway Locomotive Industry: American Locomotive and Electro-Motive Despond to Dieselization', Business History Review, Vol.69, 1995, p.196.
[31] J.F. Clarke, Power on Land and Sea, Newcastle upon Tyne, nd but 1979, p.25.
[32] Boyns and Edwards, *op cit* (27). Simon, *op cit* (28).

transaction cost economics, may seek to use the example of the locomotive industry to further their understanding of the growth of firms.

There is scope to carry forward the conclusions reached in this thesis, through more detailed business studies into individual progressive and craft locomotive companies. This will provide further evidence to confirm the motivations and varying levels of vision and entrepreneurship that were present in the industry. There is also considerable scope to follow through the conclusions of this thesis to determine how the locomotive industry evolved in the 20th century to face the growing challenges of foreign competition, with its greater emphasis on increased output, standardisation and economies of scale and scope. It would need to focus on the industry's corporate development to highlight the weaknesses of the continued proliferation of firms, and to ascertain how quickly it responded to its challenges through a conscious movement towards managerial enterprise. Such enquiry would include the extent to which the industry's lack of experience in technological and design development became a contributory cause in Britain's growing reliance on overseas motive power technology.

In concluding this thesis, therefore, it is emphasised that the locomotive industry was central to Britain's extraordinary contribution to technology and business development in the early years of the 'industrial revolution'. Partnership enterprise made possible the co-ordination of technical and business talent, and entrepreneurial drive, which developed this sector of the heavy manufacturing industry from small craft-based activities to large vertically-integrated factories. The industry would undoubtedly have continued its progress towards fewer specialist manufacturers producing larger numbers of standardised locomotives, with greater economies of scale, but for the radical changes to its markets. The industry failed to prevent these changes and, in accommodating the resulting proliferation of orders and designs, diversified between 'progressive' firms, which pursued greater production economy, and 'craft' firms, which retained a broad manufacturing base.

The industry, which had benefited substantially from Britain's large foreign direct investments, became insular through its monopoly of the London-based overseas locomotive market. At the end of the century, as it became subjected to increasing competition from foreign manufacturers, the industry was shown to have too many firms, manufacturing locomotives of too many designs with less economy than their competitors. The progressive firms, however, with their advanced managerial organisations, carried into the 20th century the entrepreneurship that had been present across the very complex industry, and that had played such an important part in the 19th century British economy.

APPENDIX

LIST OF PRINCIPAL INDEPENDENT LOCOMOTIVE WORKSHOPS AND FIRMS

(Manufacturing Locomotives for Sale to Main Line and Industrial Railways)

(Where no further reference is shown information has been obtained from: Lowe, James W., British Steam Locomotive Builders, Cambridge, 1975)

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Airdrie Engine Works	Airdrie	1790	1864-1890	Dick, Stevenson & Dick	Part'shp	F
Airedale Foundry (1)	Leeds	1835	1838-1838	Todd Kitson & Laird	Part'shp	C
			1838-1842	Kitson Laird & Co	"	C
			1842-1858	Kitson Thompson & Hewitson	"	C
			1858-1863	Kitson & Hewitson	"	C
			1863-1899	Kitson & Co	"	I
			1899-20thC	Kitson & Co Ltd	Priv. Ltd	-
Globe Works	Manchester	1828	1833-1843	Sharp Roberts & Co	Part'shp	A
(Caledonian Fdry.)	Manchester	1790	1831-1839	Galloway, Bowman & Glasgow	Part'shp	F
Atlas Works			1843-1852	Sharp Brothers	"	C
			1852-1863	Sharp Stewart & Co	"	P
			1864-1888	Sharp Stewart & Co Ltd	Pub. Ltd	M
	Glasgow		1835-1851	J.M. Rowan & Co.	Part'shp	D
(Clyde Loco Works)		1884	1884-1888	Clyde Locomotive Co Ltd	Priv. Ltd	F
Atlas Works (2)			1888-20thC	Sharp Stewart & Co. Ltd	Pub. Ltd	-
Atlas Engine Works (3)	Bristol		1864-1879	Fox Walker & Co	Part'shp	F
			1880-20thC	Peckett & Sons	"	-
Aveling & Porter Wks	Rochester		1864-20thC	Aveling & Porter Ltd.	Priv. Ltd	-
Avonside Ironworks (4)	Bristol	1837	1840-1841	H. Stothert & Co	Part'shp	C
			1841-1856	Stothert Slaughter & Co	"	C
			1856-1864	Slaughter Gruning & Co	"	P
			1864-1879	Avonside Engine Co Ltd	Pub. Ltd	F
			1879-1881	Avonside Engine Co Ltd	"	F
			1881-20thC	Avonside Engine Co Ltd	Priv. Ltd	-
Banks' Works	Manchester	c1833	1835-1840	T. Banks & Co.	Part'shp	D
Barr & McNab Works	Paisley		1840	Barr & McNab	Part'shp	D
Bath Street Foundry	Liverpool	1826	1833-1843	J.P. Mather Dixon & Co	Part'shp	F

(1) Clark, Edwin Kitson, Kitsons of Leeds, London, nd but 1937.
(2) Nicolson, Murdoch and O'Neill, Mark, Glasgow, Locomotive Builder to the World, Glasgow, 1987, pp.4 - 9.
(3) Jux, Frank, Peckett & Sons, Industrial Locomotive Society, Richmond, 1987, pp.3 - 4.
(4) Davis, C.P., Locomotive Building in Bristol, The Avonside Ironworks (1837-1882), unpublished BA Dissertation, University of Bristol, 1979.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Bedlington Locomotive Works (5)	Bedlington	1837	1837-1853	R.B. Longridge & Co	Part'shp	F
Boyne Engine Works	Leeds	1858	1859-20thC	Manning Wardle & Co	Part'shp	-
Bridgewater Foundry (6)	Manchester	1836	1839-1850	Nasmyths Gaskell & Co	Part'shp	C
			1850-1857	J. Nasmyth & Co	"	C
			1857-1867	Patricroft Iron Works	"	C
			1867-1882	Nasmyth Wilson & Co	"	I
			1882-20thC	Nasmyth Wilson & Co Ltd	Priv. Ltd	-
Britannia Works (7)	Kilmarnock	1873	1873-1879	Allan Andrews & Co	Part'shp	C
			1879-1881	Andrews, Barr & Co	"	F
			1881-1884	Barr, Morrison & Co	"	F
			1884-1890	Dick, Kerr & Co	"	I
			1890-1899	Dick, Kerr & Co Ltd	Priv. Ltd	P
			1899-20thC	Dick, Kerr & Co Ltd	Pub. Ltd	-
Broad Oak Works	Chesterfield		1888-1889	Oliver & Co Ltd	Priv. Ltd	S
			1889-20thC	Markham & Co Ltd	"	-
Butterley Ironworks	Ripley	1790	1839-20thC	Butterley Co.	Part'shp	-
Caird Works	Greenock	1809	1838-1841	Caird & Co.	Part'shp	D
Caledonia Works (8)	Kilmarnock	1847	1859-1874	A. Barclay	Part'shp	C
			1874-1874	A. Barclay & Son	"	F
			1874-1875	Trustees, A.Barclay & Son	"	C
			1875-1882	A. Barclay & Son	"	F
			1882-1886	Trustees, A.Barclay & Son	"	C
			1886-1892	A. Barclay, Son & Co	"	I
			1892-20thC	A. Barclay, Sons & Co Ltd	Priv. Ltd	-
California Works (9)	Stoke-on-Trent	1877	1891-1893	Hartley Arnoux & Fanning	Part'shp	S
			1893-20thC	Kerr Stuart & Co Ltd	Priv. Ltd	-
Canada Works (10)	Birkenhead	1853	1854-1875	Peto Brassey & Betts	Part'shp	D
Canal Street Works (11)	Manchester	1817	1839-1859	W. Fairbairn & Sons	Part'shp	C
			1859-1863	Fairbairn & Co	"	D
Castle Eden Foundry	Hartlepool	1838	1840-1845	Richardson Brothers	Part'shp	C
			1845-1857	T. Richardson & Sons	"	D
Castle Engine Works (12)	Stafford	1875	1876-1887	W.G. Bagnall	Part'shp	I
			1887-20thC	W.G. Bagnall Ltd	Priv. Ltd	-

(5) Martin, Evan, Bedlington Iron & Engine Works 1736-1867, Newcastle upon Tyne, 1974.
(6) Cantrell, J.A., James Nasmyth and the Bridgewater Foundry, Manchester, 1984.
(7) & (8) Wear, Russell, 'The Locomotive Builders of Kilmarnock', Industrial Railway Record, No.69, January 1977, pp.325-408.
(9) Rolt, L.T.C., A Hunslet Hundred, Dawlish, 1964.
(10) Millar, John, William Heap and His Company 1866, Hoylake, 1976, pp.44 - 73.
(11) Hayward, R.A., Fairbairns of Manchester, unpublished MSc dissertation, UMIST, Manchester, 1971.
(12) Civil, Allen and Baker, Allan C., Bagnalls of Stafford, Oakwood Press, 1974.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Clarence Foundry	Liverpool	c1825	1830-1842 1842-1851	E. Bury & Co Bury Curtis & Kennedy	Part'shp "	C F
Cranstonhill Eng. Wk	Glasgow		1860-1888	A. Chaplin & Co	Part'shp	D
Dallam Foundry	Warrington		1837-1841	Kirtley & Co	Part'shp	D
Dens Iron Works	Arbroath	1840	1872-1877	A. Shanks & Son	Part'shp	D
Donnington Wd. Wks	Oakengates	1764	1862-1888	Lilleshall Co	Part'shp	D
Drogheda Iron Works	Drogheda	1835	1844-1868	T. Grendon & Co	Part'shp	D
East/Victoria Found's.	Dundee	1790	1834-1843 1843-1850	J. Stirling & Co Gourlay Mudie & Co	Part'shp "	S D
Fairfield Works	London	1843	1843-1850	W.B. Adams	Part'shp	F
Falcon Works (13)	Lough-borough	1865	1865-1883 1883-1889 1889-20thC	H. Hughes & Co Falcon Engine & Car Works Ltd Brush Electrical Engineering Co Ltd	Part'shp Priv. Ltd Pub. Ltd	F S -
Forth Banks Works (14)	Newcastle-on-Tyne	1817	1830-1870 1870-1885 1885-1886 1886-20thC	R. & W. Hawthorn R. & W. Hawthorn R. & W. Hawthorn Leslie & Co Ltd R. & W. Hawthorn Leslie & Co Ltd	Part'shp " Priv. Ltd Pub. Ltd	S I P -
Forth Banks West Works	Newcastle-on-Tyne	1846	1846-1851 1867-1894	R. Stephenson & Co. J. & G. Joicey & Co.	Part'shp Part'shp	A D
Forth Street Works (15)	Newcastle-on-Tyne	1823	1825-1886 1886-1899 1899-20thC	R. Stephenson & Co. R. Stephenson & Co Ltd R. Stephenson & Co Ltd	Part'shp Priv. Ltd Pub. Ltd	I F -
Fossick & Hackworth's Works	Stockton-on-Tees	1839	1839-1865 1865-1866	Fossick & Hackworth Fossick & Blair	Part'shp "	C D
Garforth Works	Manchester		1847-1850	W.J. & J. Garforth	Part'shp	D
Glasgow Loco. Works (16)	Glasgow	1864	1864-20thC	Dübs & Co	Part'shp	-

(13) Brush Traction 1865 - 1965 Brush Traction, Loughborough, 1965, pp.3 - 5.

(14) Clarke, J.F., Power on Land and Sea, Newcastle upon Tyne, nd but 1979.

(15) Warren, J.G.H., A Century of Locomotive Building By Robert Stephenson & Co. 1823/1923, Newcastle on Tyne, 1923.

(16) Nicolson, Murdoch and O'Neill, Mark, Glasgow, Locomotive Builder to the World, Glasgow, 1987, pp.4 - 9.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Gorton Foundry (17)	Manchester	1854	1855-1883 1883-20thC	Beyer Peacock & Co Beyer Peacock & Co Ltd	Part'shp Priv. Ltd	I -
Haigh Foundry	Wigan	1810	1835-1856	Haigh Foundry Co	Part'shp	A
Hatcham Ironworks	London	1839	1849-1869 1869-1872	G. England & Co Fairlie Engine & Steam Carriage Co	Part'shp "	S F
Hayes Fdry/Tyndell St	Cardiff		1862-1881	Parfitt & Jenkins	Part'shp	D
Helen St. Works	Govan	1891	1891-1895 1895-20thC	D. Drummond & Son Glasgow Railway Eng. Co. Ltd.	Part'shp Priv. Ltd	I -
Hill Street Foundry	Glasgow		1831-1841	Murdoch Aitken & Co	Part'shp	D
Holland Street Works	London	1833	1838-1843	G. & J. Rennie	Part'shp	D
Holmes Engine Works	Rotherham	c1842	1849-1867	Dodds & Son	Part'shp	F
Hope Foundry	Bolton		1840-1841	Thompson & Cole	Part'shp	D
Hope Town Foundry	Darlington	1790	1835-1862 1862-1885	W. & A. Kitching C. I'Anson & Co.	Part'shp Part'shp	S A
Hope Town Works	Darlington		1838-1841	W. Lister	Part'shp	D
Hunslet Engine Works (18)	Leeds	1864	1865-20thC	Hunslet Engine Co	Part'shp	-
Hyde Park Street Wks	Glasgow	1837	1843-1855 1855-1862	Neilson & Mitchell Neilson & Co	Part'shp "	C M
Hyde Park Works (19)	Glasgow	1862	1862-1898 1898-20thC	Neilson & Co Neilson Reid & Co	Part'shp "	C -
Leith Engine Works	Leith	1846	1846-1850 1850-1872	R. & W. Hawthorn Hawthorns & Co.	Part'shp Part'shp	S D
Lowca Works	Whitehaven	1763	1840-1857 1857-1884 1884-20thC	Tulk & Ley Fletcher Jennings Lowca Engineering Co Ltd	Part'shp " Priv. Ltd	S I -
Meadowhall Works	Sheffield	1865	1865-20thC	Yorkshire Engine Co Ltd	Pub. Ltd	-
Millbrook Foundry	Southamptn	1834	1837-1839	Summers Groves & Day	Part'shp	D
Neath Abbey Ironwks	Neath	1792	1829-1871	Neath Abbey Iron Co	Part'shp	D
New Road Works	London	1818	1829-1836 1836-1841	Braithwaite & Ericsson Braithwaite Milner & Co	Part'shp "	C F

(17) Hills, R.L., and Patrick, D., Beyer Peacock Locomotive Builders to the World, Glossop, 1982.

(18) Rolt, L.T.C., A Hunslet Hundred, Dawlish, 1964.

(19) Nicolson, Murdoch and O'Neill, Mark, Glasgow, Locomotive Builder to the World, Glasgow, 1987, pp.4 - 9.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Newton Moor Ironwks	Manchester	1842	1866-1896	D. Adamson & Co.	Part'shp	D
Northfleet Ironworks	Northfleet		1848	A. Horlock & Co.	Part'shp	D
Ouseburn Engine Wks	Newcastle-on-Tyne		1855-1856	R. Morrison & Co.	Part'shp	F
Pagefield Ironworks	Wigan	1872	1872-1880	J.S. Walker & Brothers	Part'shp	I
			1880-1888	Walker Bros. (Wigan) Ltd	Priv. Ltd	D
Penrhyn Works	Falmouth	1857	1860s	Sara & Burgess	Part'shp	D
Providence Works	St. Helens	1865	1872-20thC	E. Borrows & Sons	Part'shp	-
Quarry Field Iron Wks (20)	Gateshead	1840	1840-1853	J. Coulthard & Son	Part'shp	C
			1853-1865	R. Coulthard & Co	"	S
			1865-1892	Black Hawthorn & Co	"	I
			1892-1896	Black Hawthorn & Co Ltd	Priv. Ltd	F
			1896-20thC	Chapman & Furneaux	Part'shp	-
Railway Foundry (21)	Leeds	1838	1839-1844	Shepherd & Todd	Part'shp	C
			1844-1846	Shepherd & Wilson	"	C
			1846-1847	Fenton Craven & Co	"	C
			1847-1858	E.B. Wilson & Co	"	L
			1860-1870	Hudswell & Clarke	"	C
			1870-1880	Hudswell Cl'rke & Rodgers	"	C
			1880-1899	Hudswell Clarke & Co	"	I
			1899-20thC	Hudswell Clarke & Co Ltd	Priv. Ltd	-
Railway Works	Chippenham	1842	1857-1867	R. Brotherhood	Part'shp	F
Riverbank Works (22)	Kilmarnock	1871	1872-1886	Barclays & Co	Part'shp	F
Round Foundry	Leeds	1795	1812-1826	Fenton Murray & Wood	Part'shp	C
			1826-1843	Fenton Murray & Jackson	"	F
Rowan Works	Glasgow		1839-1851	J.M. Rowan & Co	Part'shp	D
Scotswood Works	Newcastle-on-Tyne		1847-1864	W.G. Armstrong & Co.	Part'shp	D
Scott Sinclair Works	Greenock	c1832	1847-1849	Scott Sinclair & Co	Part'shp	D
Sheaf Iron Works	Lincoln	1857	1866-1899	Ruston Proctor & Co	Part'shp	I
			1899-20thC	Ruston Proctor & Co Ltd	Priv. Ltd	-
Soho Ironworks	Bolton	1833	1833-1842	B. Hick	Part'shp	C
			1842-1850	Hick Hargreaves & Co	"	D
Soho Works	Shildon	1833	1833-1840	Hackworth & Downing	Part'shp	C
			1840-1850	T. Hackworth	"	F

(20) Baker, Allan C., Black Hawthorn & Co., Industrial Locomotive Society, Richmond, 1988.

(21) Redman, Ronald, The Railway Foundry Leeds: 1839-1969, Norwich, 1972.

(22) Moss, Michael S., and Hume, John R., Workshop of the British Empire, London, 1977.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Standard Works	Airdrie		1869-20thC	The Airdrie Iron Co.	Part'shp	-
St. Rollox Foundry	Glasgow		1835-1840	St. Rollox Foundry Co.	Part'shp	D
Stark & Fulton Works	Glasgow		1839-1849	Stark & Fulton	Part'shp	D
Steam Plough Works (23)	Leeds	1862	1866-1886	John Fowler & Co	Part'shp	P
			1886-20thC	John Fowler & Co (Leeds) Ltd	Pub. Ltd	-
Sutton Engine Works	St. Helens	1864	1864-1869	J. Cross & Co	Part'shp	F
Teesdale Ironworks	Stockton-on-Tees		1866-1876	Head Wrightson & Co.	Part'shp	D
Teesside Engine Wks	Middles-brough	1843	1847-1865	Gilkes Wilson & Co	Part'shp	I
			1865-1874	Hopkins Gilkes & Co Ltd	Priv. Ltd	P
			1874-1875	Tees-Side Iron & Engine Works Co Ltd	Pub. Ltd	D
Thames Bank Ironwks	London		1848-1849	Christie Adams & Hill	Part'shp	D
Thornewill & Warham's Works	Burton-on-Trent	1840s	1861-1890	Thornewill & Warham Ltd	Priv. Ltd	A
Townholme Eng. Wks	Kilmarnock	1876	1879-20thC	Grant Ritchie & Co	Part'shp	-
Union Foundry	Bolton	1830	1830-1832	Rothwell Hick & Rothwell	Part'shp	C
			1832-1864	Rothwell & Co	"	F
Union Works	Caernarvon	1840s	1869-20thC	De Winton	Part'shp	-
Vauxhall Foundry	Liverpool	1827	1834-1847	G. Forrester & Co.	Part'shp	F
Viaduct Foundry	Newton-le Willows	1834	1834-1844	Jones Turner & Evans	Part'shp	C
			1844-1852	Jones & Potts	"	F
Village Foundry	Covan		1860-1874	J. Smith	Part'shp	A
Victoria Engine Work	Airdrie	1866	1894-20thC	Gibb & Hogg	Part'shp	-
Vulcan Foundry (24)	Newton-le-Willows	1832	1834-1847	C. Tayleur & Co	Part'shp	C
			1847-1864	The Vulcan Foundry Co	"	I
			1864-1897	Vulcan Foundry Co Ltd	Priv. Ltd	P
			1897-20thC	The Vulcan Foundry Ltd	Pub. Ltd	-
Vulcan Works	Kilmarnock	1847	1876-1889	Thos. McCulloch & Sons	Part'shp	I
			1889-1894	McCulloch, Sons & Kennedy Ltd	Priv. Ltd	F
Walker Works	Bury		1838-1854	R. Walker & Brother	Part'shp	D

(23) Lane, Michael R., The Story of the Steam Plough Works, London, 1980.

(24) Anon, The Vulcan Locomotive Works 1830 - 1930, Locomotive Publishing Co., 1930.

Locomotive Works	Location	Year Works Began	Period of Locomotive Manufact.	Name of Firm	Type of Firm	Reason for Change
Walker Works	Bury		1838-1854	R. Walker & Brother	Part'shp	D
Wallace Foundry	Dundee		1838-1850 1850-c1857	Kinmond Hutton & Steel J. Steel	Part'shp "	C F
William Street Works	Liverpool	1853	1853-1863	J. Jones & Son	Part'shp	F
Worcester Eng. Wks	Worcester	1865	1865-1872	Worcester Engine Co	Part'shp	F
Wylam Colliery	Wylam		1839-1841	Thompson Brothers	Part'shp	D
York Place Ironworks	Aberdeen		1845-1852	Simpson & Co.	Part'shp	F

Reason for Change:-

A Site sold/leased for alternative use
C Change of partnership
D Diversification to other manufacturing markets
F Partnership/ Company failure
I Incorporation of Private Limited Company
L Sale of assets from litigation
M Move of factory premises
P Incorporation of Public Limited Company
S Sale of assets as a going locomotive concern

Note:

The locomotive outputs from each factory have been set down on computer-based data spreadsheets which have been deposited in the library of the National Railway Museum and are available for consultation. The spreadsheets include the reference sources and market category analyses.
See Chapter 2, page 51, note 1.

BIBLIOGRAPHY

Ahrons, E.L., The British Steam Railway Locomotive 1825-1925, London, 1927.

Aldcroft, Derek H., (ed), The Development of British Industry and Foreign Competition 1875-1914, London, 1968.

Alford, B.W.E., 'Entrepreneurship, Business Performance and Industrial Development', Business History, Vol.XIX, No.2, 1977, pp.116-133.

Arnold, A.J., 'Should Historians Trust Late Nineteenth-Century Company Financial Statements?', Business History, Vol.38, No.2, 1996, pp.40-54.

Bailey, Michael R., 'Robert Stephenson & Co. 1823-1829', Transactions of the Newcomen Society, Vol.50, 1978-1979, pp.109-138.

Bailey, Michael R., 'George Stephenson - Locomotive Advocate: The Background to the Rainhill Trials', Transactions of the Newcomen Society, Vol.52, 1980-1981, pp.171-179.

Bailey, Michael R., Robert Stephenson & Co. 1823-1836, unpublished MA thesis, University of Newcastle on Tyne, 1984.

Bailey, Michael R., 'Learning Through Replication: The *Planet* Locomotive Project', Transactions of the Newcomen Society, Vol.68, 1996/7, pp.109-136.

Boyns, Trevor, and Edwards, John Richard, 'Accounting Systems and Decision-Making in the mid-Victorian Period: The Case of the Consett Iron Company', Business History, Vol.37, July 1995, pp.28-51.

Boyns, Trevor, and Edwards, John Richard, 'The Construction of Cost Accounting Systems in Britain to 1900: The Case of the Coal, Iron and Steel Industries', Business History, Vol.39, 1997, pp.1-29.

Boyns, T., Edwards, J.R., and Nikitin, M., 'Comptabilité et Revolution Industrielle: Une Comparaison Grand Bretagne/France', in Comptabilité Contrôle Audit, La Revue de l'Association Française de Comptabilité, tome 2, Vol.1, 1996, pp.15-20.

Bradley, Ian, A History of Machine Tools, Hemel Hempstead, 1972.

Braverman, H., Labor and Monopoly Capitalism, New York, 1974.

Broadberry, S.N., The Productivity Race: British Manufacturing in International Perspective, 1850-1990, Cambridge, 1997.

Brooks, Randall C., 'Towards the Perfect Screw Thread: the Making of Precision Screws in the 17th-19th Centuries', Transactions of the Newcomen Society, Vol.64, 1992-93, pp.101-119.

Brown, J., and Rose, M.B., Entrepreneurship, Networks and Modern Business, Manchester, 1993.

Brown, John K., The Baldwin Locomotive Works, 1831-1915, Baltimore, 1995.

Burawoy, M., The Politics of Production, London, 1985.

Burgess, K., The Origins of British Industrial Relations, 1975.

Burton, Anthony, The Railway Empire, London, 1994.

Cantrell, J.A., James Nasmyth and the Bridgewater Foundry, Manchester, 1984.

Cantrell, J.A., 'James Nasmyth and the Steam Hammer', Transactions of the Newcomen Society, Vol.56, 1984-85, pp.133-138.

Casson, Mark, 'Institutional Economics and Business History: A Way Forward?', Business History, Vol.39, No.4, October 1997, pp.151-154.

Chaloner, W.H., 'New Light on Richard Roberts, textile engineer (1789-1864)', Transactions of the Newcomen Society, Vol.XLI, 1968-69, pp.27-44.

Chandler, Alfred D. Jr., The Visible Hand: The Managerial Revolution, Harvard, 1977.

Chandler, Alfred D. Jr., and Daems, Herman, Managerial Hierarchies, Harvard, 1980.

Chandler, Alfred D. Jr., Scale and Scope The Dynamics of Industrial Capitalism, Harvard, 1990.

Channon, Geoffrey, 'A.D. Chandler's 'visible hand' in Transport History - A Review Article', The Journal of Transport History, 1981, pp.53-64.

Chapman, S.D., Merchant Enterprise in Britain: From the Industrial Revolution to World War I, Cambridge, 1992.

Charlesworth, A., Gilbert, D., Randall, A., Southall, H., and Wrigley, C., (eds), An Atlas of Industrial Protest in Britain 1750-1990, Basingstoke, 1996.

Church, Roy, 'The Family Firm in Industrial Capitalism: International Perspectives on Hypotheses and History', Business History, Vol.35, No.4, 1993, pp.17-43.

Churella, Albert, 'Corporate Culture and Marketing in the American Railway Locomotive Industry: American Locomotive and Electro-Motive Despond to Dieselization', Business History Review, Vol.69, 1995, pp.191-229.

Clark, Edwin Kitson, Kitsons of Leeds, London, nd but 1937.

Clarke, J.F., Power on Land and Sea, Newcastle upon Tyne, nd but 1979.

Coase, R.H., 'The Nature of the Firm', Economica, Vol.IV, 1937, pp.386-405.

Colburn, Zerah, Locomotive Engineering and the Mechanism of Railways, 2 Vols., London, 1871.

Collins, Michael, 'English Bank Lending and the Financial Crisis of the 1870s', Business History, Vol.32, No.1, 1990, pp.198-224.

Cookson, Gillian, 'Family Firms and Business Networks: Textile Engineering in Yorkshire, 1780-1830', Business History, Vol.39., No.1, 1997, pp.1-20.

Corley, T.A.B., 'Britain's Overseas Investments in 1914 Revisited', Business History, Vol.36, No.1, 1994, pp.71-88.

Cottrell, P.L., British Overseas Investment in the Nineteenth Century, Studies in Economic and Social History, London, 1975.

Cottrell, P.L., 'Railway Finance and the Crisis of 1866: Contractors' Bills of Exchange, and the Finance Companies', The Journal of Transport History, Vol.III, New Series, No.1, 1975, pp.20-38.

Cottrell, P.L., Industrial Finance 1830-1914: The Finance and Organisation of English Manufacturing Industry, London, 1980.

Crouzet, François, 'Essor, Déclin et Renaissance de l'Industrie Française des Locomotives, 1838-1914', Revue d'Histoire Economique et Sociale, Vol.55, 1977, pp.112-209.

Däbritz, Walther, and Metzeltin, E.H. Erich, Hundert Jahre Hanomag, Düsseldorf, 1935.

Davis, C.P., Locomotive Building in Bristol, The Avonside Ironworks (1837-1882), unpublished BA Dissertation, University of Bristol, 1979.

Devine, P.J., 'The Firm' and 'Corporate Growth', in Devine, P.J., Jones, R.M., Lee, N., and Tyson W.J., (eds), An Introduction to Industrial Economics, London, 1976.

Dickinson, H.W., 'Richard Roberts, his Life and Inventions', Transactions of the Newcomen Society, Vol.XXV, 1945-1947, pp.123-137.

Dodsworth, Charles, 'The Low Moor Ironworks Bradford', Industrial Archaeology, 1965, pp.122-164.

Drummond, Di, 'Specifically Designed'? Employers' Labour Strategies and Worker Responses in British Railway Workshops, 1838-1914', Business History, Vol.31, No.2, 1989, pp.8-31.

Drummond, Diane K., Crewe Railway Town, Company and People 1840-1914, Aldershot, 1995.

Drummond, Di, 'Technology and the Labour Process: A Preliminary Comparison of British Railway Companies' Approaches to Locomotive Construction Before 1914', Perspectives on Railway History, Working Papers in Railway Studies Number One, Institute of Railway Studies, York, 1997, pp.22-34.

Edelstein, Michael, Overseas Investment in the Age of High Imperialism, The United Kingdom 1850-1914, New York, 1982.

Edwards, John Richard, and Newell, Edmund, 'The Development of Industrial Cost and Management Accounting Before 1850: A Survey of the Evidence', Business History, Vol.33, No.1, 1991, pp.35-57.

Elbaum, B., and Lazonick, W., 'An Institutional Perspective on British Decline', in Elbaum, B., and Lazonick, W., (eds), The Decline of the British Economy, Oxford, 1986.

Ericson, Steven J., The Sound of the Whistle, Railroads and the State in Meiji Japan, Council on East Asian Studies, Harvard, 1996.

Evans, C., 'Manufacturing Iron in the North-East During the Eighteenth Century: The Case of Bedlington', Northern History, Vol.28, 1992, pp.178-196.

Evans, F.T., 'The Maudslay Touch: Henry Maudslay, Product of the Past and Maker of the Future', Transactions of the Newcomen Society, Vol.66, 1994-95, pp.153-174.

Ewald, Kurt, 125 Jahre Henschel, Kassel, 1935.

Farnie, D.A., 'The Textile Machine-Making Industry and the World Market, 1870-1960', Business History, Vol.32, No.4, 1990, p.150-165.

Friedman, A., Industry and Labour, London, 1977.

Gale, W.K.V., The Black Country Iron Industry, London, 1966.

Garner, S.P., Evolution of Cost Accounting, Alabama, 1954.

George, K.D., Joll, C., and Lynk, E.L., Industrial Organisation, Competition, Growth and Structural Change, London, 1991.

Gilbert, K.R., The Portsmouth Block-Making Machinery, London, 1965.

Gilbert, K.R., 'The Control of Machine Tools - A Historical Survey', Transactions of the Newcomen Society, Vol.XLIV, 1971-72, pp.119-127.

Gordon, D., Edwards, R., and Reich, M., Segmented Work, Divided Workers, Cambridge, 1982.

Greenhalgh, Paul, Ephemeral Vistas, The Expositions Universelles, Great Exhibitions and World's Fairs, 1851-1939, Studies in Imperialism, Manchester, 1988.

Habakkuk, H.J., American and British Technology in the Nineteenth Century, Cambridge, 1962.

Hamilton, S.B., 'Sixty Glorious Years: The Impact of Engineering on Society in the Reign of Queen Victoria', Transactions of the Newcomen Society, Vol.XXXI, 1957-59, pp.184-187.

Hannah, L., 'Mergers in British Manufacturing Industry, 1880-1918', Oxford Economic Papers, Vol.XXVI, 1974, pp.1-20.

Hannah, L., The Rise of the Corporate Economy, 2nd Edition, London, 1983.

Hayward, R.A., Fairbairns of Manchester, unpublished MSc dissertation, UMIST, Manchester, 1971.

Hills, R.L., and Patrick, D., Beyer Peacock Locomotive Builders to the World, Glossop, 1982.

Jeaffreson, J.C., The Life of Robert Stephenson, F.R.S., 2 Vols., London, 1864.

Jefferys, James B., The Story of the Engineers, Amalgamated Engineering Union, London, 1945.

Jenkins, D.T., and Ponting, K.G., The British Wool Textile Industry 1770-1914, Pasold Research Fund, 1975.

Jenks, L.H., The Migration of British Capital to 1875, London, 1927, re-published 1963.

Jenkins, M., The General Strike of 1842, London, 1980.

Jones, Charles, 'Institutional Forms of British Foreign Direct Investment in South America', Business History, Vol.39, No.2, 1997, p.21-41.

Jones, Geoffrey, and Rose, Mary B., 'Family Capitalism', Business History, Vol.35, No.4, 1993, pp.1-16.

Jones, S.R.H., 'Transaction Costs and the Theory of the Firm: The Scope and limitations of the New Institutional Approach', Business History, Vol.39, No.4, 1997, pp.10-25.

Joyce, P., Work, Society and Politics: The Culture of the Factory Town in Late Victorian England, London, 1980.

Kirby, M.W., Men of Business and Politics, The Rise and Fall of the Quaker Pease Dynasty of North-East England,1700-1943, London, 1984.

Kirby, M.W., 'Product Proliferation in the British Locomotive Building Industry, 1850-1914: An Engineer's Paradise?', Business History, Vol.30, No.3, 1988, pp.287-305.

Kirby, M.W., 'Technological Innovation and Structural Division in the UK Locomotive Building Industry, 1850-1914', in Holmes, Colin, and Booth, Alan, (eds), Economy and Society: European Industrialisation and Its Social Consequences, Leicester, 1991.

Lane, Michael R., The Story of the Steam Plough Works, London, 1980.

Larkin, Edgar J., and Larkin, John G., The Railway Workshops of Britain 1823-1986, Basingstoke, 1988.

Lazonick, W., Business Organisation and the Myth of the Market Economy, Cambridge, 1991.

Lee, G.A., 'The Concept of Profit in British Accounting 1760-1900', Business History Review, Vol.XLIX, 1975, pp.19-33.

Lee, T.A., 'Company Financial Statements, An Essay in Business History 1830-1950', in Marriner, Sheila, (ed), Business and Businessmen, Studies in Business, Economic and Accounting History, Liverpool, 1978.

Legget, Robert F., Railways of Canada, Newton Abbot, 1973.

Lewin, H.G., Early British Railways, &c., 1801-1844, London, n.d. but 1925.

Lewin, Henry Grote, The Railway Mania and Its Aftermath: 1845-1852, London, 1936.

Lindner, Helmut, and Schmalfuß, Jörg, 150 Jahre Borsig Berlin-Tegel, Berlin, 1987.

Lineham, Wilfred, A Text-Book of Mechanical Engineering, London, 1902, pp.313-318.

Lloyd-Jones, R., and LeRoux, A.A., 'Marshall and the Birth and Death of Firms: The Growth and Size Distribution of Firms in the Early Nineteenth-Century Cotton Industry', Business History, Vol.XXIV, 1982, No.2, pp.141-155.

Lord, W.M., 'The Development of the Bessemer Process in Lancashire, 1856-1900', Transactions of the Newcomen Society, Vol.XXV, 1945-1947, pp.163-180.

Lowe, James W., British Steam Locomotive Builders, Cambridge, 1975.

MacLeod, Christine, 'Concepts of Invention and the Patent Controversy in Victorian Britain', in Fox, Robert, (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996, pp.140/1.

Marriner, S., 'Company Financial Statements as Source Material for Business Historians', Business History, Vol.XXII, 1980, pp.203-235.

Martin, Evan, Bedlington Iron & Engine Works 1736-1867, Newcastle upon Tyne, 1974.

Marx, Thomas G., 'Technological Change and the Theory of the Firm: The American Locomotive Industry, 1920-1955', Business History Review, Vol.L, No.1, 1976, pp.1-24.

Mather, F.C., 'The General Strike of 1842', in Quinault, R., and Stevenson, J., (eds), Popular Protest and Public Order, London, 1974.

McCord, N., '1871 Strike - Prelimineries', in Allen, E., Clarke, J.F., McCord, N., and Rowe, D.J., (eds), The Strikes of the North-East Engineers in 1871: The Nine Hours League, Newcastle, 1971.

McKendrick, N., 'Josiah Wedgewood and Cost Accounting in the Industrial Revolution', Economic History Review, 2nd Series, Vol.XXIII, 1970.

McKinlay, Alan, and Zeitlin, Jonathan, 'The Meanings of Managerial Prerogative: Industrial Relations and the Organisation of Work in British Engineering, 1880-1939', Business History, Vol.31, No.2, 1989, pp.32-47.

McNeil, Ian, 'Hydraulic Power Transmission: The First 350 Years', Transactions of the Newcomen Society, Vol.47, 1974-1976, pp.149-159.

Millar, John, William Heap and His Company 1866, Hoylake, 1976.

Milward, Alan S., and Saul, S.B., The Development of the Economies of Continental Europe 1850-1914, London, 1977.

Mokyr, Joel, 'Evolution and Technological Change: A New Metaphor for Economic History?', in Fox, Robert, (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996.

More, C., Skill and the English Working Class, 1870-1914, London, 1980.

Morton, John, Thomas Bolton & Sons Ltd. 1783-1983, Ashbourne, 1983.

Moss, Michael S., and Hume, John R., Workshop of the British Empire, London, 1977.

Mott, R.A., 'Dry and Wet Puddling', Transactions of the Newcomen Society, Vol.49, 1977-78, pp.153-8.

Musson, A.E. 'James Nasmyth and the Early Growth of Mechanical Engineering', Economic History Review, 2nd Series, Vol.10, No.1, 1957-58.

Musson, A.E., 'The 'Great Depression' in Britain, 1873-1896: A Reappraisal', Economic History Review, Vol.12, 1959-60, pp.199-228.

Musson, A.E., 'Joseph Whitworth and the Growth of Mass-Production Engineering', Business History, Vol.XVII, No.2, 1975, pp.109-149.

Musson, A.E., 'British Origins', in Mayr, O., and Post, R.C., (eds), Yankee Enterprise:the Rise of the American System of Manufactures, Washington DC, 1982.

Nicolson, Murdoch, and O'Neill, Mark, (eds), Glasgow Locomotive Builder to the World, Glasgow, 1987.

O'Brien, P., (ed), Railways and the Economic Development of Western Europe 1830-1914, Oxford, 1983.

O'Brien, Patrick, Griffiths, Trevor, and Hunt, Philip, 'Technological Change During the First Industrial Revolution: The Paradigm Case of Textiles, 1688-1851', in Fox, Robert, (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996.

Payen, Jacques, La Machine Locomotive en France, Lyon, 1986.

Payne, P.L., 'The Emergence of the Large-Scale Company in Great Britain', Economic History Review, Vol.20, 1967.

Payne, P.L., 'Industrial Entrepreneurship and Management in Great Britain', in Mathias, P., and Postan, M.M., (eds), The Cambridge Economic History of Europe VII, Part I, 1978.

Payne, P.L., British Entrepreneurship in the Nineteenth Century, London, 1988.

Picon, Antoine, 'Towards a History of Technological Thought', in Fox, Robert, (ed), Technological Change: Methods and Themes in the History of Technology, Studies in the History of Science, Technology and Medicine, Harwood Academic, 1996.

Pole, William, (ed), The Life of Sir William Fairbairn, Bart., London, 1877.

Pollard, Sidney, 'Factory Discipline in the Industrial Revolution', Economic History Review, 2nd Series, Vol.16, 1963-64, pp.254-271.

Pollard, Sidney, The Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain, Cambridge, Mass, 1965.

Pollard, S., 'Fixed Capital in the Industrial Revolution in Britain', in Creuzet, F., Capital Formation in the Industrial Revolution, London, 1972.

Prais, S.J., The Evolution of Giant Firms in Britain, Cambridge, 1976.

Prior, Ann, and Kirby, Maurice, 'The Society of Friends and the Family Firm, 1700-1830', Business History, Vol.35, 1993, pp.66-85.

Redman, Ronald N., The Railway Foundry Leeds: 1839-1969, Norwich, 1972.

Reed, Brian, 'Norris Locomotives', Locomotives In Profile, Windsor, 1971, Vol.1, No.11.

Reed, Brian, 150 Years of British Steam Locomotives, Newton Abbot, 1975.

Reed, Brian, Crewe Locomotive Works and its Men, Newton Abbot, 1982.

Revill, George, 'Railway Paternalism and Corporate Culture, 'Railway Derby' and the Formation of the ASRS', in Divall, Colin, (compiler), Workshops, Identity and Labour, Working Papers in Railway Studies, Number three, Institute of Railway Studies, York, 1998.

Riden, Philip, The Butterley Company 1790-1830, Chesterfield, 1973.

Rippy, J. Fred., British Investments in Latin America, 1822-1949, Minneapolis, 1959.

Roll, E., An Early Experiment in Industrial Organisation: Being a History of the Firm of Boulton & Watt, 1775-1805, London, 1930.

Rolt, L.T.C., A Hunslet Hundred, Dawlish, 1964.

Rolt, L.T.C., Tools For The Job, Dawlish, 1965.

Rosenberg, N., 'Economic Development and the Transfer of Technology: Some Historical Perspectives', Technology and Culture, Vol.11, 1970.

Rowe, D.J., 'Trade Unions and Strike Action in the North-East', in Allen, E., Clarke, J.F., McCord, N., and Rowe, D.J., (eds), The Strikes of the North-East Engineers in 1871: The Nine Hours League, Newcastle, 1971.

W.D. Rubinstein, Capitalism, Culture and Decline in Britain, 1750-1990, London, 1993.

Saul, S.B., Studies in British Overseas Trade 1870-1914, Liverpool, 1960.

Saul, S.B., 'The Engineering Industry', in Derek H Aldcroft (ed), The Development of British Industry and Foreign Competition 1875-1914, London, 1968.

Saul, S.B., 'The Market and the Development of the Mechanical Engineering Industries in Britain, 1860-1914', in Saul, S.B., (ed), Technological Change: The United States and Britain in the Nineteenth Century, London, 1970.

Scranton, Philip, and Licht, Walter, Work Sights: Industrial Philadelphia, 1890-1950, Philadelphia, 1986.

Scranton, Philip, Endless Novelty, Princeton, 1997.

Simon, H.A., Models of Bounded Rationality, 2 Vols., Cambridge, USA, 1982.

Simon, H.A., 'Rationality in Psychology and Economics', Journal of Business, Vol.59, 1986.

Slezak, J.O., Die Lokomotivfabriken Europas, Internationales Archiv Für Lokomotivgeschichte, Wien, 1962.

Smiles, Samuel, The Life of George Stephenson, London, 1857.

Smiles, Samuel, Industrial Biography, 1863.

Smiles, Samuel, (ed), James Nasmyth Engineer An Autobiography, London, 1883.

Smith, R.T., 'John Gray and His Expansion Valve Gear', Transactions of the Newcomen Society, Vol. 50, 1979/80, pp.139-154.

Solomons, D., 'The Historical Development of Costing', in Solomons, D., (ed), Studies in Cost Analysis, 2nd Ed., 1968.

Southall, Humphrey, 'Industrial Protest: 1850-1900', in Charlesworth, Andrew, *et al*, An Atlas of Industrial Protest in Britain 1750-1990, Basingstoke, 1996.

Steeds, W., A History of Machine Tools 1700-1910, Oxford, 1969.

Sullivan, Richard J., 'The Revolution of Ideas: Widespread Patenting and Invention During the English Industrial Revolution', Journal of Economic History, Vol. L., No.2, June 1990, pp.349-361.

Supple, B., Essays in British Business History, Oxford, 1977.

Taksa, Lucy, 'Political and Industrial Mobilization, Workplace Culture and Citizenship at the New South Wales Railways and Tramways Department Workshops 1880-1932', in Divall, Colin, (compiler), Workshops, Identity and Labour, Working Papers in Railway Studies, Number Three, Institute of Railway Studies, York, 1998, pp.1-24.

Tann, Jennifer, 'Marketing Methods in the International Steam Engine Market: The Case of Boulton and Watt', Journal of Economic History, Vol.38, 1978, pp.363-391.

Thomas, John, The Springburn Story, Dawlish, 1964.

Thomas, R.H.G., The Liverpool & Manchester Railway, London, 1980.

Usselman, Steven Walter, 'Air Brakes for Freight Trains: Technological Innovation in the American Railroad Industry, 1869-1900', Business History Review, Vol.58, Spring 1984, pp.30-50.

Usselman, Steven Walter, Running The Machine: The Management of Technological Innovation on American Railroads, 1860-1910, unpublished PhD. thesis, University of Delaware, 1985.

Vamplew, Wray, 'Scottish Railways and the Development of Scottish Locomotive Building in the Nineteenth Century', Business History Review, Vol.46, No.3, 1972, pp.320-338.

van-Helten, J.J., and Cassis, Y., (eds), Capitalism in a Mature Economy: Financial Institutions, Capital Exports and British Industry 1870-1939, London, 1990.

van Riemsdijk, J.T., 'The Compound Locomotive, Part I 1876-1901', Transactions of the Newcomen Society, Vol. XLIII, 1970-71, pp.1-17.

van Riemsdijk, J.T., Compound Locomotives, Penryn, 1994.

Walker, Charles, Thomas Brassey Railway Builder, London, 1969.

Wardley, P., 'The Anatomy of Big Business: Aspects of Corporate Development in the Twentieth Century', Business History, Vol.33, No.2, 1991.

Warren, J.G.H., A Century of Locomotive Building By Robert Stephenson & Co 1823/1923, Newcastle on Tyne, 1923.

Wear, Russell, 'The Locomotive Builders of Kilmarnock', Industrial Railway Record, No. 69, January 1977, pp.325-408.

Westwood, J.N., Locomotive Designers in the Age of Steam, London, 1977.

White, John H. Jr., A History of the American Locomotive, 2nd Edition, New York, 1979.

White, John H. Jr., A Short History of American Locomotive Builders in the Steam Era, Washington D.C., 1982.

Wiener, M.J., English Culture and the Decline of the Industrial Spirit, 1850-1980, Cambridge, 1981.

Wigham, Eric, The Power to Manage: A History of the Engineering Employers' Federation, London, 1973.

Wilkins, M., 'The Free-Standing Company, 1870-1914: An Important Type of British Foreign Direct Investment', Economic History Review, 2nd Series, Vol.41, 1988, pp.259-282.

Williamson, O.E., The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting, New York, 1985.

Williamson, O.E., Economic Organisation: Firms, Markets and Policy Control, London, 1986.

Wilson, John F., British Business History, 1720-1994, Manchester, 1995.

Wilson, R.B., (ed), D. Gooch Memoirs and Diary, Newton Abbott, 1972.

Zeitlin, Jonathan, 'Between Flexibility and Mass Production: Strategic Ambiguity and Selective Adaptation in the British Engineering Industry, 1830-1914', in Sabel, Charles F., and Zeitlin Jonathan, (eds), World of Possibilities, Flexibility and Mass Production in Western Industrialization, Cambridge, 1997.