Innovation, diffusion and technology change.

A study of the Yorkshire worsted industry (1890-1939)

Eugene Joseph Nykolyszyn

Submitted in accordance with the requirements of the degree of Doctor of Philosophy

The University of Leeds

School of Design

Leeds

August 2022

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Acknowledgements

The completion of any thesis is always a sustained and collaborative effort. Without the help and expertise of many talented and knowledgeable people the completion of this thesis would not have been possible. It is, therefore, incumbent on me to extend my sincere thanks to all the persons who have helped me, over the years, to complete this thesis.

I would like to begin by thanking Professor Michael Hann for suggesting, encouraging and guiding me to undertake this research degree. My thanks also go to Dr. Briony Thomas and Dr. Jamie Marsden for their help. Special mention and heartfelt thanks must go to Dr. Ken Jackson for giving up his time, sharing his immeasurable textile knowledge, providing advice, feedback and above all friendship.

A vote of thanks goes to the late Mr. Graham Waddington, Messrs., John and Andrew Lambert from British Wools, Dr. and Mrs. Heycock, the late Dr. Philip Townhill for his past support, the late Dr. Ian Holme for his past encouragement, the late Mark Keighley for the many years of providing me with all manner of information on the local, regional and national textile industry and Dr. Alice Humphrey who has always been available to provide assistance when needed.

Other people who deserve acknowledgements for their help in granting me access to holdings and archives as well as helping me in facilitating my research are the staff members from many learned establishments such as the West Yorkshire Archive (Bradford), Bradford Central Library, Colour Experience (Bradford), British Library, ULITA - An Archive of International Textiles, University of Bradford School of Management, J. B. Priestley Library (Bradford), Bradford Industrial Museum, Keighley Library (Archive/Special Studies), Leeds Libraries and the University of Leeds Library.

This completion of this thesis would not have been possible without the sterling assistance, good nature, unfailing support and friendship of Dr. Bruce Carnie who helped me to develop a greater clarity of thought and precision of expression.

Finally, and most important of all, I am deeply grateful to my mother and father who will never see the culmination of this thesis and my brother Robert for his love, sterling support, patience, encouragement and belief in me throughout this very long journey. Moreover, thank you for all your advice, reviews, editing and putting up with me over the years.

Eugene Nykolyszyn

August 2022

Abstract

The principal aim of this thesis is to investigate the central role played by Messrs., Hattersley and Sons Limited., Keighley (hereafter cited as Hattersley or Hattersley's) in the design and manufacture of different looms between 1890 and 1939.

Hattersley, a long-established firm, founded at the onset of the French Revolution and during the so-called period known as the 'Industrial Revolution', continued to market the claim that they were the '*world's oldest loom makers'*. This thesis seeks to validate this assertion by establishing whether this statement is correct and if so, how the role of innovation, not least in Hattersley's technical developments, secured its pivotal position in the textile industry. It also examines the demonstrable contribution that the firm's innovations made in the wider context during this period.

A critical review of the types of qualitative research methodologies used in similar academic studies was undertaken in order to determine which approach to utilise in the collection and collation of key material in this thesis. The chosen methodology was the case study and a *PEST* (Political, Economic, Social and Technological) analysis framework with the addition of a Geographical component which highlighted the influence and importance of the 'industrial district'.

A detailed scrutiny of 'sources' drawn from a wider and more varied range of primary and secondary sources than had been used in previous studies, were critically assessed and evaluated. These findings contribute substantively to a broader understanding of how *one* loom manufacturer based in Keighley, Yorkshire continued to play a leading role in the innovative design and manufacture of successive looms, gain commercial successes in important local, regional, national and international trade exhibitions (see Appendix 1), whilst at the same time confronting and overcoming the many challenging economic, social and technological issues during the period 1890 to 1939.

Finally, the thesis sets out to redress the under-representation of Hattersley as a subject of academic scholarship, allowing researchers the opportunity not only to re-evaluate the fortunes of the firm's competitors and allied industries in a similar historical context, but also to better understand how Hattersley's innovative designs and enterprising business acumen at the peak of their success could be assimilated into the business models of today.

Table of Contents

Declaration p. 2

Acknowledgments p. 3

Abstract p. 4

Introduction p. 15

Chapter 1 p. 22

1 Introduction p. 22

1.1 The importance of innovation, diffusion and technological change p. 22

1.2 The ongoing debate and its influences on the so-called 'Industrial Revolution' p. 23

1.3 Important determinants which underpin the foundations of the worsted textile machine industry: First principles p. 23

1.4 A brief review of some notable technological advances in textile machinery during the 'Second Industrial Revolution' [c1870-1914] p. 25

1.5 The rise and developments of the worsted industry in Bradford and textile machine-making in Yorkshire - a brief overview p. 26

1.6 Worsted industry and machine manufacture in Keighley p. 28

1.7 The origins and history of Messrs., George Hattersley and Sons Limited p. 28

1.8 The importance of 'industrial clusters' p. 30

1.9 Summary p. 34

Chapter 2: Methodology undertaken to investigate the company of Messrs., George Hattersley and Sons Limited., loom machinery manufacturers of Keighley (1890-1939). p. 36

2 Introduction p. 36

2.1 The research paradigm and definitions p. 37

2.2 The definition of research p. 38

2.3 Investigation and review of different research of methodologies p. 38

2.4 Rationale for selecting and developing a 'single case study' p. 41

2.4.1 The 'single case' study: an assessment p. 42

2.5 The issues of reliability, viability and rigour in a 'single case' study p. 43

2.6 Selecting and developing the case study data p. 45

2.7 Collect, analyse and evaluate the case study data incorporating the *PEST* analysis framework tool p. 46

Political (P) p. 47

Economic (E) p. 47

Social (S) p. 47

Technological (T) p. 47

2.7.1 Advantages of using a *PEST* analysis framework tool p. 49

2.7.2 Limitations of the *PEST* analysis framework p. 50

2.8 Limitations of the 'case study' approach p. 51

2.9 Summary p. 52

Chapter 3. Technological change: An overview of key determinants which support and progress economic change. p. 53

3 Introduction p. 53

3.1 Characteristics of technological change p. 54

3.2 The study of innovations p. 56

3.3 Schumpeter's viewpoint of technological innovation p. 56

3.4 Definitions of technological innovation - radical innovation - incremental innovation - disruptive innovation p. 60

3.4.1 The importance of Radical Innovations p. 61

3.4.2 The importance of Incremental Innovations p. 63

3.4.3 The importance of Disruptive Innovations p. 64

3.5 The definitions of innovation and imitation p. 65

3.6 The dual interaction of imitation and invention on innovation p. 66

3.7 Technological Diffusion p. 69

3.8 Summary p. 71

Chapter 4: The dynamic interdependencies of invention, innovation, technological change and diffusion in the Yorkshire worsted industry (1890-1939): A brief overview. p. 73

4 Introduction p. 73

4.1 The importance of invention, innovation and diffusion p. 73

4.2 The role of invention in the innovation of the Raper autoleveller and the Northrop Loom p. 75

4.3 An historical overview of Yorkshire worsted industry p. 76

4.4 Messrs., Prince-Smith and Son Limited., in the 1930s p. 80

4.5 Messrs., Prince-Smith and Stells Limited., and spinning frames p. 81

4.6 Messrs., George Hattersley and Sons Limited., - inventors p. 83

4.7 Investigation 1: The Raper autoleveller p. 84

4.8 Investigation 2: From hand-loom to automatic weaving p. 88

4.9 Summary p. 96

Chapter 5: Invention, innovation, technological change and diffusion: A case study of the Yorkshire worsted manufacturing industry (1800-1939) p. 99

5 Introduction p. 99

5.1 The importance of the 'Industrial Revolution' to worsted processing p. 100

5.1.1 Technology p. 102

5.1.2 Bradford: the development of the Yorkshire worsted manufacturing industry

pre-1800-1850 p. 103
5.1.3 Social development and the entrepreneurial generation p. 105
5.1.4 The contributory factor of iron-works and production to the development of Bradford as an industrial centre p. 106
5.1.5 The impact of coal-rich reserves on Bradford and its environs p. 107
5.1.6 The impact of a network of inland waterways on Bradford's economic growth p. 108
5.1.7 The socio-economic impact of an emergent road and railway infrastructure on the Bradford's worsted industry p. 108
5.2 Bradford: 'Worstedopolis' - The rise and development of the worsted industry post-1800 p. 110
5.3 Power transmission in the industrial worsted landscape p. 112
5.3.1 Combing innovations p. 113
5.3.2 Jacquard weaving p. 115
5.3.3 Patents and textile exhibitions p. 116
5.3.4 Trade shows and Exhibitions p. 119
5.4 Summary p. 119
5.5 An analysis of the Yorkshire worsted manufacturing industry (1800-1939 utilising the *PEST (&G)* analysis framework p. 121
5.5.1 Political p. 121
5.5.2 Economic p. 123
5.5.3 Social p. 125
5.5.4 Technological p. 127
5.5.5. Geographical p. 130
5.6 Findings of the *PEST(&G)* analysis; a summary p. 132
Chapter 6: Messrs., George Hattersley and Sons Limited., loom production 1890-1939 p. 137
6 Introduction p. 137
6.1 Weaving p. 137
6.2 Weaving motions p. 137
6.3.1 Primary weaving motions p. 137
6.3.2 Secondary weaving motions p. 139
6.3.3 Tertiary or auxiliary weaving motions p. 139
6.4 Shedding mechanisms p. 140
6.4.1 Tappet looms p. 140
6.4.2 Dobby looms p. 140
6.4.3 Jacquard looms p. 141
6.5 Inventions and inventors p. 141
6.5.1 Hattersley key inventors p. 142

6.5.2 Importance of patents and fees p. 145
6.5.3 Patent infringements and litigation p. 145
6.6 Hattersley key loom inventions p. 148
6.6.1 Hattersley weft-replenishments mechanism p. 148
6.6.2 Hattersley and the smallware loom (or narrow fabric) p. 152
6.6.3 Hattersley 'Standard Model' loom p. 153
6.7 Hattersley loom production during the decade 1900-1910 p. 156
6.7.1 Hattersley loom production during the decade 1911-1920 p. 158
6.7.2 Hattersley loom production during the decade 1921-1930 p. 159
6.7.3 Hattersley loom production during the decade 1931-1939 p. 161
6.8 Summary p. 163
6.9 *PEST* (Political, Economic, Social, Technological) p. 165
6.9.1 Political p. 165
6.9.2 Economy p. 168
6.9.3 Social p. 169
6.9.4 Technology p. 171
6.9.5 Findings of the *PEST* analysis; a summary p. 172
Chapter 7: An analytical case study examining the expansion and challenges affecting Messrs., George Hattersley and Sons Limited., loom machinery production (1890-1939) p. 176
7. Introduction p. 176
7.1 Messrs., George Hattersley and Sons Limited., and the importance of the 'industrial cluster' p. 176
7. 2 Messrs., George Hattersley and Sons Limited., production data p. 180
7.3 Inter-generational employment and workforce retention and continuity p. 181
7.4 Messrs., George Hattersley and Sons Limited., loom production during the decade 1900-1910 p. 182
7.5 Messrs., George Hattersley and Sons Limited., loom production during the decade 1911-1920 p. 187
7.6 Messrs., George Hattersley and Sons Limited., loom production during the decade 1921-1930 p. 193
7.7 Messrs., George Hattersley and Sons Limited., loom production during the decade 1931-1939 p. 197
7. 8 Summary p. 202
7.9 *PEST* (& *G)* (Political. Economic, Social, Technological and Geographical) p. 204
7.9.1 Political (P) p. 204
7.9.2 Economic (E) p. 205
7.9.3 Social (S) p. 206
7.9.4 Technological (T) p. 209

7.9.5 Geographical (G) p. 212

7.9.6 Findings of the *PEST(&G)* analysis; a summary p. 215

Chapter 8 p. 219

8 Conclusion p. 219

8.1 The Legacy of Messrs., Hattersley and Sons Limited., Keighley: A New Appraisal p. 219

8.2 Limitations and further work p. 237

8.2.1 Limitations of the thesis p. 237

8.2.2 Some suggested recommendations for future research p. 238

References p. 241

Appendix 1 Exhibition Gold Medals and Awards given to Hattersley 1862-1911 p. 278

Appendix 2 Promotional Image of Standard Model Hattersley Loom p. 279

Appendix 3A Flow chart showing woollen processing from raw wool to spun yarn p. 280

Appendix 3B Flow chart showing worsted processing from raw wool to spun yarn p. 281

Appendix 3C Flow chart showing spun yarn processing to finished cloth p. 282

Appendix 3D Flow chart showing woollen finishing to inspection p. 283

Appendix 3E Flow chart showing worsted processing from finishing to inspection p. 284

Appendix 3F Flow chart showing woollen processing from wool to yarn winding p. 285

Appendix 3G Flow chart showing woollen processing from wool to winding yarn p. 286

Appendix 3H Flow chart showing woollen processing wool to spun winding yarn p. 287

Appendix 4 Selection of Hattersley loom specifications p. 288

Appendix 5 6 and 6 Revolving Box, ‘Dress Goods’ Model p. 289

Appendix 5 Automatic Border Motion Non-Positive Dobby Model No. 4 p. 289

Appendix 6 Automatic Self-Shuttling Coating Loom 1913 Model p. 290

Appendix 6 Automatic Coating Loom for Weft Mixing 1913 Model p. 290

Appendix 7 Automatic Self-Shuttling Loom 1913 Model p. 291

Appendix 7 Double Lift Jacquard Engine p. 291

Appendix 8 Chenille Setting Loom p. 292

Appendix 8 Coating Weft Mixing Model p. 292

Appendix 9 Heavy Woollen loom p. 293

Appendix 9 Ingrain or Scotch Loom p. 293

Appendix 10 Light Coating Gabardine Model p. 294

Appendix 10 Medium Light Coating Model p. 294

Appendix 11 Non Positive Dobby Model No. 4l p. 295

Appendix 11 Non Positive Dobby Model No. 246 p. 295

Appendix 12 Non Positive Dobby Model No. 254 p. 296

Appendix 12 Non Positive Dobby Model No. 282 p. 296

Appendix 13 Non Positive Dobby Model No. 8 p. 297

Appendix 13 Overpick Rising Box, ‘Dress Goods’ Model Loom p. 297

Appendix 14 Overpick Tapestry Loom p. 298
Appendix 14 Piano Jacquard-card Stamping Machine p. 298
Appendix 15 Revolving Box, ‘Dress Goods’ Model p. 299
Appendix 15 Single Shuttle Tappet Coating Loom p. 299
Appendix 16 Revolving Box Loom for Light and Medium Coatings p. 300
Appendix 16 Single Shuttle Dress Goods Loom p. 300
Appendix 17 Underpick Centre Shed Dobby Woollen Loom p. 301
Appendix 17 Weft Feeler Motion p. 301
Appendix 18 Hattersley Cigarette Stripping Machine No. 1/212. Model p. 302
Appendix 18 Hand Cigarette Machine No. 3/212 Goods Model p. 302
Appendix 19 Hattersley Circular Knife Grinding Machine No. 2/212. Model p. 303
Appendix 19 Hattersley Domestic Loom No. 65. Model p. 303
Appendix 20 Hattersley Patent Domestic Loom No. 113. Model p. 304
Appendix 20 Hattersley Single Shuttle Loom No. 33 Model p. 304
Appendix 21 Hattersley Smallware Loom 1909 No. 200 Model p. 305
Appendix 21 Hattersley Smallware Loom No. 18 Model p. 305
Appendix 22 Hattersley Automatic 1912 Loom No. 50 Model p. 306

List of Tables

Table 1. Growth of technical educational establishments in Great Britain 1891 - 1939 p. 24

Table 2. Selected perspectives of 'industrial cluster' by key theorists p. 31

Table 3. Quantitative versus Qualitative Methodology p. 40

Table 4. Different attributes underpinning rigour in research p. 44

Table 5. Amended *PEST* analysis framework table. p. 48

Table 6. Guiding principles when undertaking research in a case study p. 51

Table 7. Different definitions of innovation recorded between 1934 - 2007 p. 58

Table 8. Definitions of radical innovations p. 61

Table 9. Selected definitions of innovation recorded between 1934-2000 p. 71

Table 10. Table showing the difference between the Open and Continental drawing used when drafting wool sliver. p. 79

Table 11. A typical set of worsted drawing machines used in the Anglo-Continental system p. 79

Table 12. Type of wool used on different combs p. 81

Table 13. Raper autolevellers purchased and used in Europe and outside Europe. p. 87

Table 14. Duties placed by United States of America and European Competitors on goods from 1875 to 1913. p. 122

Table 15. Comparison of Power Loom workers versus Hand Loom workers 1780-1838 p. 126

Table 16. Comparison of Power Loom workers versus Hand Loom workers 1855-1901 p. 126

Table 17. Types of dobbies found in general mill use p. 141

Table 18. Registration of patents by Hattersley 1886-1917 p. 148

Table 19. Patent developments of the weft replenishment mechanisms p. 149

Table 20. Selection of firms favouring Hattersley 'Standard Model' loom p, 156

Table 21. Reduction of looms between 3rd Sept, 1936 and 3rd Sept, 1939 p. 163

Table 22. Percentages of tariffs imposed during 1875-1904 p. 166

Table 23. Different percentage of World Trade 1883-1913 p. 167

Table 24. Selection of British export values between 1880-1900 (in thousands) p. 169

Table 25. Messrs., George Hattersley & Sons Limited., looms in 1893 p. 210

List of Figures

Figure 1. Location of textile processing in the West Yorkshire area p. 13

Figure 2 Development of railway network 1834-1884 p. 13

Figure 3 Location of Coal Measures in the West Yorkshire area p. 14

Figure 4. Porter's 'Diamond' Model p. 33

Figure 5. *PEST* analysis framework p. 47

Figure 6. Rothwell's technology 'push model' linear progression seen in development of the Raper autoleveller. p. 74

Figure 7. Rothwell's 'Interactive model' linear progression seen in the development of the Raper autoleveller. p. 74

Figure 8. Side elevation of the Raper autoleveller. p. 85

Figure 9. Schematic representation of the component parts found on the Raper autoleveller. p. 86

Figure 10. Graph showing the sales of Northrop looms in the American Northern and Southern States. p. 91

Figure 11. Illustration showing the future developments of the weaving loom after 1939. p. 96

Figure 12. Component found in Porter's cluster p. 132

Figure 13. Shedding in weaving p. 138

Figure 14. Picking or weft insertion in weaving p. 138

Figure 15. Beating-up in weaving p. 139

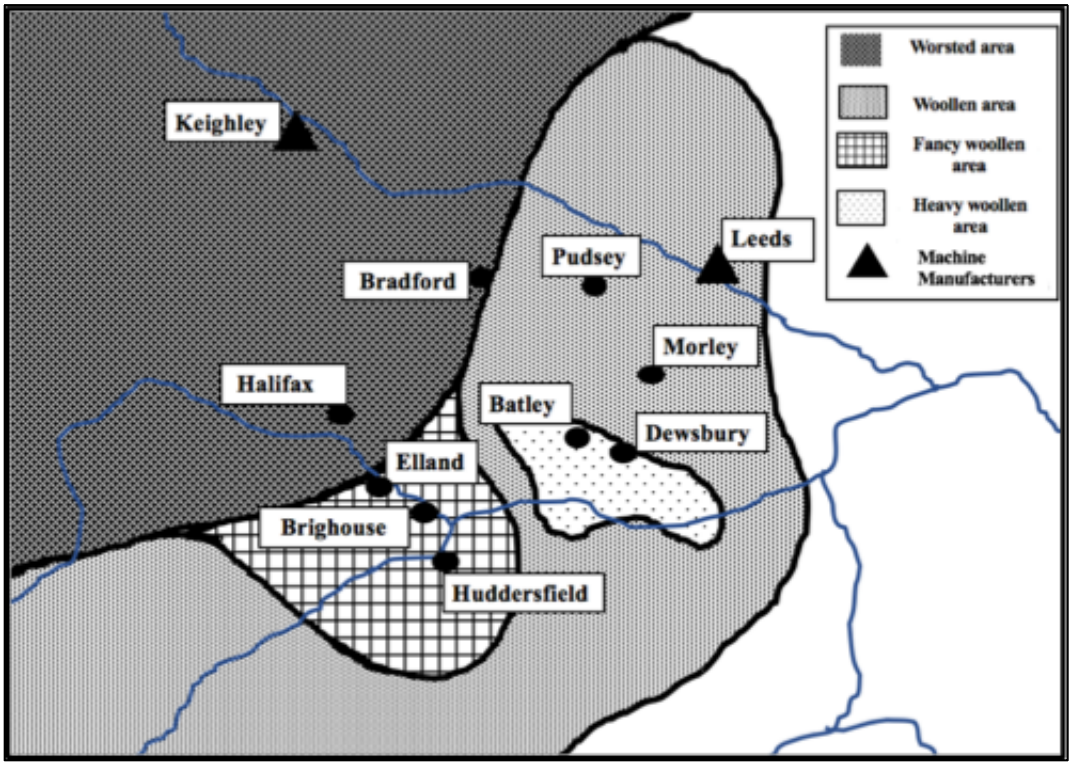
Figure 16. Looms produced during the period 1900-1910 p. 156

Figure 17. Looms produced during the period 1911-1920 p. 158

Figure 18. Looms produced during the period 1921-1930 p. 159

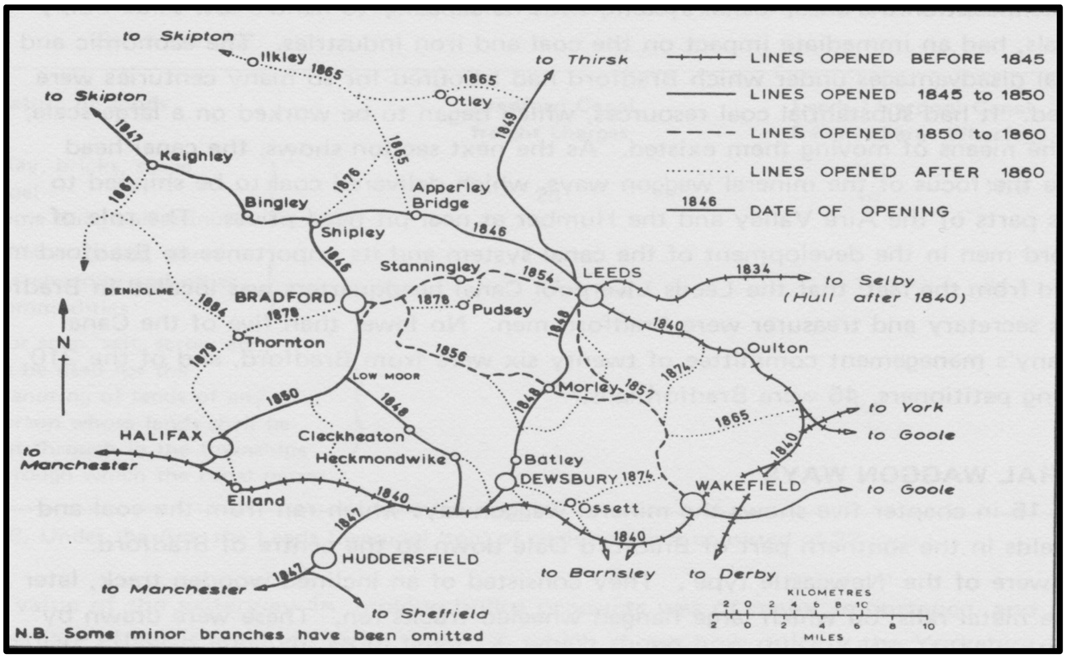
Figure 19. Looms produced during the period 1931-1939 p. 161

Figure 20. *PEST* Framework analysis p. 165



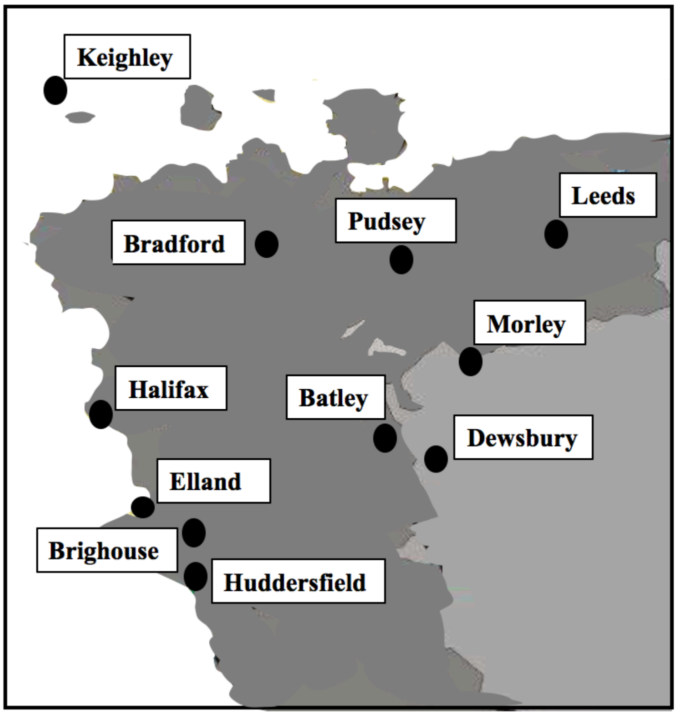
Source: Clarke, 1994

Figure 1. Location of textile processing in the West Yorkshire area



Source: Richardson, 1977, p. 56

Figure 2. Development of railway network 1834-1884



Source:www.nmrs.org.uk/mines-map/coal-mining-in-the-britishisles/yorkshirecoalfield/

Figure 3. Location of coal measures in the West Yorkshire area

Introduction

Lipson claimed that in the study of British economic history, the woollen industry had been the "most widespread of all English industries" in addition claiming that "there was not a town, village or hamlet throughout the length and breadth of the country which was not connected at some time or other with the manufacture of cloth" (Lipson, 1921, p. 6).

Accordingly, the processing of wool textiles and the manufacture of textile machinery became very important as the economic and technological determinants of Yorkshire and Great Britain. Moreover, the geographical location, distribution of wool textile processing (see Figure 1) and subsequent impact of the manufacture of machinery also played a significant role in the specialisation of the various processing industries located in Yorkshire.

Interest in the history of the firm of Hattersley began during my tenure as Education Officer then progressing to Senior Keeper of Technology at the Bradford Industrial Museum. One of the many duties of a Senior Keeper of Technology was to collect, research and publicise histories of past textile companies, based in the Bradford/Keighley Metropolitan areas, which had contributed to Bradford becoming the '*Worstedopolis*' of the world.

Whilst at the museum, I was responsible for the submission of the museum's worsted collection to the Arts Council Designation Scheme and securing their award for one of the 'best collections held in museums, libraries and archives across England' (at the time one of only 154 designated collections in the country). This award was given as a recognition of the uniqueness of the collection as well as raising the profile of the collection nationally and internationally. The granting of this award has also allowed the opening up many streams of funding to enhance the museum's collection.

The main purpose of this thesis was to draw attention to, evaluate and supplement existing knowledge gleaned from the review of key theories and past scholarly studies in the area of loom innovation, diffusion and technological change. All these factors converged and ultimately established the Yorkshire worsted textile industry (see flow charts Appendix 3A-3H to explain the processing of wool into finished worsted cloth). At the heart of this research is a critical appraisal and evaluation of the impact made by *one* particular firm, Hattersley who were based in Keighley, Yorkshire. This long-standing firm was founded in 1789 and was reputed to be the world's oldest textile loom makers. as well as assembling a pool of outstanding inventors, innovators and traders of textile weaving looms from 1890 to 1939.

As part of this research, the thesis also highlighted and investigated the many adverse factors which the firm of Hattersley had to face and subsequently overcome throughout their extensive loom manufacturing and trading history (1890-1939). Research material was drawn from a number of primary sources such as order books, contemporaneously-published pamphlets, documents and secondary sources such as books, patents, journals, trade journals (such as the Textile Manufacturer, Wool Record, Textile Institute Proceeding and Abstracts, Journal of the Bradford Textile Society, The Journal of Economic History), official Government Reports, theses, local/regional newspapers and business records including supplementary material held in Universities, Libraries, Record Offices and Archives. These documents delivered rich insights into how the Yorkshire textile processing and loom manufacturing trade fared during the '*boom and bust*' years as well as their reactions to peacetime and wartime work (1890-1939). This thesis also examined and challenged the various determinants which are underpinned by a series of aims. These aims are as follows:

a. How did Hattersley's become one of the foremost innovative worsted loom manufacturers in Great Britain and one of the world's premier loom manufacturers and what were the key contributory factors?
b. Did Hattersley's loom-making manufacture contribute significantly to the development of the worsted industry in neighbouring Bradford and if so, how was this achieved against the background of industrialisation?
c. How did Hattersley's embrace socio-political and economic changes at successive periods in its history and to what extent did his technological innovations replace and develop new skills in the workplace?
d. How important were trade exhibitions to Hattersley's status at home and abroad and to what extent did these venues strengthen his resolve to continue exhibiting the firm's patented innovations throughout the period 1890 to 1939?

As part of the methodology used in this thesis, the selection of a 'single case study' was adopted. This research approach, widely used by researchers (Hyett, *et al.,* 2014), was selected because of its value in examining a series of disparate events synthesised from a succession of historical events. Creswell (2013, p. 97) has defined the case study as a:

> "real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information ... and reports a case description and case themes."

Furthermore, using a case study methodology proved to be a very useful method in gaining a greater understanding and appreciation in the subject area as well as providing an in-depth investigation. This case study will draw attention to the origin of the firm which has the distinction of beginning its development during the First Industrial Revolution [c.1760-1840] although officially it was established during the French Revolution [1789-1799]. Similarly, Hattersley's is acknowledged to have made the first power loom for the worsted trade which was destroyed by a mob of rampaging, disgruntled handloom weavers (The Textile Weekly, 1951). The unexpected destruction of the first power loom proved to be a temporary set-back and not an encumbrance. In spite of this, the firm went on to patent and develop many important inventions for the worsted trade and other textile industries.

The selection of Hattersley's as a 'single-case' study follows the accepted view that the researcher should examine the findings at a "micro level" (Zainal, 2007, p. 5). Case studies are an extremely useful tool for research as they provide the scholar with the "examination of a simple example" (Abercrombie *et al*, 1984, p. 34). According to Stake (2000, p. 437) there are three types which may be considered for in-depth investigation.

i) Intrinsic case study used to obtain a deeper awareness of the subject

ii) Instrumental case study is ideal when examining a selected item or issue. The micro information will prove useful when comparing it to macro events or data.

iii) A collective case study tends to be adopted if there are several factors under investigation

Care and attention must always be exercised in the selection of one of these approaches to ensure that any findings or summaries are not influenced by the researcher's bias (Yin, 1984, p. 21). According to Stake (1995, p. 1), the fundamental reasons for any researcher to adopt a case study is to:

> "enter the scene with a sincere interest in learning how [actors] function in ordinary pursuits and milieus and with a willingness to put aside many presumptions while we learn."

The conclusions of a case study approach have the potential to generate new ideas, in-sights and evaluations. In his thesis Halton, echoing the viewpoint of Soy, has argued that the use of a case study can:

> "clarify a situation, offer possible reasons for its manifestation, and thereby reinforce, or cast doubt on, extant general theories" (Halton, 2010, p. 11)

To further enhance and strengthen the findings of this research, the *PEST* analysis framework is the diagnostic tool which will be used to examine the firm of Hattersley's. A close study of the Political, Economic, Social and Technological (*PEST*) factors will provide an invaluable insight into the important, external determinants which have influenced or impacted on the fortunes of the firm.

The conclusions of this thesis will provide three important additions to the history and growing knowledge of Hattersley's. First, it will challenge the assertions put forward by certain scholars that:

> "those at the centre of industrial and economic growth… [were instrumental in creating] more failures than successes in Great Britain" (Chandler Jnr, 1990, p. 274).

Second, the research in this thesis will demonstrate the importance of geographical industrial cluster locations. The close geographical proximity to Bradford, the '*Worstedopolis*' or '*epicentre'* of the worsted industry, was an important strategic factor and important trading corridor for Hattersley's which supplied the local textile industry with worsted weaving looms thus enabling them to progress from a small, local loom manufacturing business into an international, innovative, industrial power house.

Third, this thesis will bring to light new, significant contributions and findings to counter the disparities and the gaps found in the current literature on Hattersley's. It is also important that the limitations or omissions of this research thesis are critically assessed.

The timeframe of this thesis does not chart the company's business fortunes after 1939. The research into the firm during the years 1890-1939 has been impeded by the absence of minute books. Despite this unforeseen challenge, an holistic approach has been taken in the research of this subject which draws parallels to the work by Merriam who affirms that:

> "Documents of all types can help the researcher uncover meaning, develop understanding and discover insights relevant to the research problem" (Merriam, 1998, p. 118).

The narrow focus of this thesis did not allow an in-depth investigation into social conditions and local labour politics. Subsequent attention was given over to the availability and relative accessibility to recorded data of the manufactured technological output by the firm. This provided an invaluable source of materials in the subsequent research. The company produced a variety of textile machinery which was not restricted solely to worsted production. Consequently, in an attempt to frame this study within a definite temporal and geographical context, only the occasional brief mention is made to the substantial quantity of non-worsted producing machinery.

While the main aim of this thesis is to undertake a close investigation of technological innovations and diffusion in textile loom production, the key focus of this study is the period 1890-1939 rather than a detailed examination machines produced prior to this period. Consequently, production data was taken from selected years within this designated period.

Even within the chosen timeframe of this study, it is unfortunate that the first economic Census of Production of 1907 (having been instigated by the 1906 Production Act) did not cover woollen or worsted machinery production. Consequently, this omission proved difficult to ascertain what type of worsted machinery manufacture and technological developments, if any, had been officially recorded.

In Chapter one, the thesis presents an overview of the importance of innovation, diffusion and technological change, factors which were particularly important during the so-called 'Industrial Revolution'. The timeframe of this widely used historical term has long been contentious and continues to generate lively debates amongst scholars whose own interpretations of this period are, paradoxically wide and varied. Whilst it is not in the scope of this thesis to examine the exact timeframe of the so-called 'Industrial Revolution,' as such, this study sets out to outline the fundamental determinants of any 'industrial revolution' (which are key to an understanding of this period). Typically, these will include location, a labour force, a market mechanism, capital, natural and mineral resources. In this respect, the origin, location and subsequent importance of loom manufacture by Hattersley is investigated and Bradford's rise as the '*epicentre'* of the worsted trade is discussed. The geographical proximity and importance of these two industrial centres is vital to the concept of an 'industrial cluster'.

Chapter two looks at and examines the types of methodology suitable for this type of research investigation. The choice of research into areas of interest must, in the first instance, clearly define the subject in question and outline an agreed method of investigation such as a survey, an experiment, a case study, archival research etc., (Saunders *et al.,* 2009). Gould maintained that the guiding principle in the selection of methodology relies on the choice, interests and beliefs of the investigator (Goulding, 2002). Even so, when selecting a mode of research, the choice of adopting a methodology will always governed by the availability of reliable data, access to existing knowledge and the constraints of time (Saunders *et al.,* 2009). This study will need to adopt a flexible approach in order to address the challenges within this research area and will be underpinned by the central tenets of Creswell's thesis, who argued that there is no correct or incorrect methodology. Instead, the research questions are pertinent when determining the choice or strengths of the methodology (Cresswell, 2003).

In the discussion on the methodology, the concepts of Quantitative and Qualitative method are explored and differentiated. The case study method was ultimately selected to investigate the firm of Hattersley as this form of analysis was considered to be more flexible and applicable to the understanding the origin and development of the firm. Furthermore, the choice of case study and any research-based evidence allows the investigator to apply a rigorous approach in a reliable and viable model.

Chapter three sets out to examine the key determinants involved in technological change. All such changes involve certain characteristics which are important to economic growth. As well as invention, the other main contributing factor is innovation. This study also seeks to understand and validate the assertions made in Schumpeter's research work in which he places great emphasis on the integral role that innovation plays in commerce and industry.

The phenomenon of innovation continues to attract the interest of many theorists whose interpretations of this concept continue to create further dialogue and academic research. Although the importance of innovation is key to a firm's success, the areas of invention, imitation and subsequent diffusion cannot be overlooked and will need to be assessed. This study will investigate the inter-play between all these factors in the rise and development of Hattersley as a business producing innovative looms.

Chapter four examines the historical development of the Yorkshire textile loom industry together with its many influences, machine inventions and innovations. It also considers how these technological changes were diffused in to the emerging textile markets. Despite these developments during the rise of this industry, some wool processors continued to be hesitant and reluctant to purchase new machinery with their innovative mechanisms. The two key Keighley machine manufacturers [spinning and weaving] are discussed. This chapter will also show the crucial role that inventors played in the development of technology in the textile trade not least in the firm of Hattersley where innovative looms and loom mechanisms were being manufactured. Included in this chapter is an investigation into the Raper autoleveller and automatic weaving [Northrop loom], both machines devised by Yorkshire inventors. The chapter looks at the fierce competition between the British Hattersley automatic loom and the American Northrop automatic loom which, from the early part of the twentieth century, began to saturate the American, British and European markets.

Successive generations always build on the foundations of their forefathers. Although the main focus of this study is the period 1890 to 1939, Chapter five looks at the foundations of the worsted manufacturing industry in Yorkshire prior to 1890. The contributory role played by different determinants such as patents, trade shows, trade exhibitions and improved textile machines are explored and discussed in the context of understanding the pivotal importance of worsted textile innovations in Yorkshire and the rise of machine usage across the county.

Chapter six investigates the production of different Hattersley looms and explores the innovative mechanisms invented during the period 1890-1939. Loom development was not possible without the contribution of skilled inventors who understood the intricate workings of different aspects of textile machine designs. In order to protect their inventions, it was imperative to patent or safeguard their original ideas against any infringements from their competitors which could result in expensive court cases, appearances and repercussions. During 1890-1939, in an effort to protect the intellectual property rights of their designs, Hattersley's were involved in a number of high-profile and complex litigation cases, the details of which will be examined in this chapter.

In Chapter seven, the *five* key factors which made a significant impact on the fortunes of Hattersley and their loom production over the course of four specific time spans (1900-1910; 1911-1920; 1921-1930 and 1931-1939) are highlighted and discussed. The *five* key factors closely examined are the political, economic, social and technological and geographical influences (*PEST) (&G)* on the firm during this period. This chapter discusses the key external factors, such as competition and the arrival of new looms into the British market, and how these new challenges influenced the development of Hattersley and the firm's role within the 'industrial cluster.'

Chapter eight sums up all the findings in this thesis. During the course of this research, it became evident that whilst there were various extant primary sources related to Hattersley's, the absence of any of the firm's minute books made it difficult to ascertain with any degree of certainty the managerial decisions that the firm's directors may have discussed and decided during 1890 to 1939. This is a common problem which Floud came across in his research. He concluded that:

> "… securing the necessary information becomes progressively more difficult as the enquiry is pushed backed to the nineteenth century" (Floud, 1976).

Despite Floud's valid point, the past continues to be a rich seam of untapped material from which to draw hitherto dormant information, indispensable to gaining a better knowledge and understanding of past successes and failures of industry and crucial to ensuring that the same mistakes are avoided.

Investigations into this area of research will not only enable future scholars to think critically and interpret different kinds of information creatively as they consider researching other local, regional or national textile manufacturers, but also on a wider level, to see and understand how the successes and failures of the innovators of the machine age can still provide valuable lessons for future decision-makers in the digital age.

Chapter 1

1 Introduction

The underlying themes in this chapter and thesis will highlight and introduce the emergence of Hattersley's as an important worsted machinery manufacturer. Following the company's foundation in 1789, Hattersley's not only evolved from being the 'oldest firm of loom makers in the world,' but also one of the most versatile British worsted loom manufacturer (Messrs., Hattersley and Sons Limited., 1908). During their long, creative and business history, Hattersley's was directly responsible for manufacturing different types of textile looms for all manner of natural and man-made fibre as well as creating new markets for their products.

1.1 The importance of innovation, diffusion and technological change

Hattersley's meteoric rise as a successful weaving loom manufacturer may best be understood against a backdrop of the importance of innovation, diffusion and technological change in Yorkshire's wool and loom manufacturing industry, an area of academic study which has, over the years, stimulated great interest and debate.

This criteria-based approach has reached the status of an important area of analysis framework which has drawn the interest to research scholars from a wide range of subjects. According to Heaton, next to agriculture, the processing and trading of wool had been one of the oldest and most important industries found in Great Britain (Heaton, 1965). In fact, by the twentieth century, all three areas of consideration - innovation, diffusion and technological change - were viewed as crucial stimuli for economic growth at local, regional, national and international levels (Habakkuk, 1962).

Consequently, subject areas such as technological innovation, 'invention and commerce' have continued to remain the powerhouse of economic growth and structural change (Berg, 2002). Some scholars, have chosen to focus on and discuss their interpretation of the determinants which underlined technological change in a restricted or narrow manner. Terms such as "invention" have been defined as the creation of something new whilst "innovation" is seen as a product or process which was successfully introduced into the commercial market place (Jamison, 1989, p. 505). These terms have become the bedrock to understanding the technological development of worsted textile machinery, not least in the Bradford and Keighley area.

1.2 The on-going debate and its influences on the so-called 'Industrial Revolution'

On examination of the research literature on this subject, many scholars have subscribed to the notion that the beginnings of technological and mechanised change had originated from the period of history known as the so-called 'Industrial Revolution' [c1760 - 1840]. There are many historical examples which reveal and demonstrate the *continual* development of technological innovations. This change was soon recognised by many individuals such as Samuel Johnson [1709-1784] who remarked to Sir William Scott [1745-1836] that "the age is running mad after innovation; and all the business of the world is to be done in a new way" (Powell, 1971, p. 118).

It was the economic historian and social reformer, Arnold Toynbee [1852-1883], who has been credited with introducing the widely-used term of 'Industrial Revolution' (Mantoux, 1983). This phrase was first seen in his influential booklet 'Lectures on the Industrial Revolution' which was posthumously published in 1884. Perhaps, Toynbee was unaware that the phrase '*Grande Révolution Industrielle'* had already been used and recorded fifty-seven years earlier in an article taken from the *Le Moniteur Universel* [1789-1829]. The original article together with the phrase had appeared in *Le Journal des Artistes* (*Le Moniteur Universel*, 17th August 1827).

During the unprecedented social and economic upheaval, Great Britain's status evolved from a farming and rural sector into an industrial, manufacturing society (Williamson, 1984). According to Toynbee (1884), this dislocation from an agrarian to an industrial economy was due to the introduction of both radical inventions and innovative technology. By the end of the so-called 'Industrial Revolution' period [c1760-1840], political reform, technological developments, socio-economic changes, transportation, population growth, urbanisation, labour changes, demographic changes, developments in commerce and cultural changes had radically impacted on Great Britain making it arguably the world's first leading urban, industrialised country.

Commentators, such as Jamison, have argued that the so-called 'Industrial Revolution' could be traced back to the European Medieval Period or Middle Ages [5th–15th century] or even further back into antiquity (Jamison, 1989). Researchers such as Gimpel, on the other hand, have gone further still and argued that the European Medieval Period or Middle Ages [5th–15th century] should be recognised as the *first* industrial revolution (Gimpel, 1979).

1.3 Important determinants which underpin the foundations of the worsted textile machine industry: First principles

According to Kuznets (1965, pp. 85-87)., innovative technology was only made possible by the addition of "useful knowledge." It was Moykr who described the term "useful knowledge" as the:

> “observation, classification, measurement, and cataloguing of natural phenomena. The other was the establishment of regularities, principles, and natural laws” (Moykr,1999, p. 3).

Some researchers have chosen to pursue and expand this viewpoint. Rostow (1960) focused on the integral contribution that science and scientific knowledge have played in a society’s economic progress. The idea of science or the probing strategies of science would certainly be justified when applied to technological innovations which occurred after 1870 but not necessarily before this date (Mokyr, 1999). Although this thesis will examine textile technological innovations which occurred during and after the ‘Second Industrial Revolution’ [c1870-1914] it will not be possible to investigate all the determinants, but this study will note the contributions of both “internal processes of development but also their internationalisation” (Paliokaite, 2019) made throughout the ‘First Industrial Revolution’ [c1760-1840]. This chapter looks at the origin of the key worsted textile machine manufacture which arose from the township of Keighley and influenced the future of loom construction for the ever-increasing number of challenges and opportunities found in the textile mills during the next two hundred years.

The short-comings of a suitable British educational system were blamed for the inadequacies or inconsistencies of Britain’s commerce seen during 1867. This national concern became especially apparent after the poor showing of British textiles at the Paris International Exhibition of 1867 where French textiles were seen and considered to be superior than the textiles produced in Britain. Furthermore, industrial competition from France and Germany had also shown how important education was in their society during the 1890s. A series of successive government interventions and investments in technical and university educational provisions were taken to ensure that the workforce had access to high-quality teaching, educational facilities and training which allowed them to compete with their overseas competitors (See Table 1).

	University	Technical Education
1891	16,013	148,408
1901	17,839	285,444
1911	26,414	767,121
1921	34,591	1,400,000
1931	37, 255	1,020,991
1938-39	50,000	

Source: (Sanderson 1993)

Table 1. Growth of technical educational establishments in Great Britain 1891 - 1939

Even though these measures were taken in Great Britain, Germany continued to hold a monopoly in aniline dyes, having overtaken Britain’s position in the manufacture of dyestuffs (Wrigley, 1986).

Some theorists have advanced this point and suggested that the First ‘Industrial Revolution’ [c1760 -1840] had progressed in the way it had because of the decisive role that science had played (Bekar and Lipsey, 2004). It was Hall who underlined the importance of science when he proclaimed that:

> “if science had stopped dead with Newton, technology would have halted with Rennie, or thereabouts. The great advances of later nineteenth century technology owe everything to post-Newtonian science” (Hall, 1962, p. 511).

Subjects such as science, particularly chemistry, and science-related subjects were beginning to be considered extremely significant. The introduction of a technical and science-related curriculum in many of the country’s educational institutions resulted in an upward swing in students studying these subjects (Edgerton, 1996, p. 20). These science-based subjects proved to be crucial in the development of synthetic or aniline textile dyes which not only replaced natural dyes but were quickly incorporated into the worsted textile trade. Synthetic or aniline dyes allowed the rest of the working population or society at large to have bright colours added in to their fabrics which up to this point had been the prerogative of the wealthy or influential classes (Forster and Christie, 2013). Moreover, natural dyes had been quite costly to manufacture whilst synthetic or aniline dyes were found to be much cheaper to produce. This development in synthetic dyes created a society-wide trend for consumerism because of an increased production of brightly-coloured goods as well as encouraging the middle and working classes to take up home-based dress-making (Forster and Christie, 2013). Furthermore, as a response to the introduction of brightly-coloured goods to the lower classes, certain members of the wealthy classes began to indulge or adopt subtle colours. This reaction became a supercilious form of protest by the wealthy classes against losing their colour status in fashion.

1.4 A brief review of some notable technological advances in textile machinery during the ‘Second Industrial Revolution’ [c1870-1914]

The primacy of knowledge and science as the ‘springboard’ to technological developments in the First Industrial Revolution [c1760-1840] remained at the heart of the ‘Second Industrial Revolution’ [c1870-1914], where a:

> “large number of new technologies were invented. These inventions heralded a period of approximately 70 years of ongoing, rapid technical change” (Atkeson and Kehoe, 2001, p. 1).

Moykr has contradicted this view and claimed that the period after 1870 was “not marked by great breakthroughs” (Moykr, 1998, p. 12). Instead, he argued that during this period, the best marketed and most significant invention was the American-made, treadle-operated Singer sewing machine, invented by Isaac Merritt Singer [1811-1875], which consisted of interchangeable parts. Moykr did, however, add that after 1870, certain textile machinery such as the Lister-Donisthorpe ‘nip’ comb and Heilmann combing machines had gone through a concentrated period of technical improvements. Ninety-four years previously, S. B. Hollings, the first editor of the British textile journal - The Wool Record - had underlined the importance of wool combing and the contribution that wool combs had brought to the worsted industry. In a series of questions which he posed to several important Bradford wool combers of the day, they confirmed to him that:

> “the art and science of wool combing has been the greatest blessing that has ever come to the wool trade of the world. It goes without saying that wool combing by machine has placed certain yarns in the hands of manufacturers and enabled them to turn out certain fabrics which could never have been made out of the old hand combed wools” (Hollings, 1904, pp. 332-333).

Moreover, Moykr had also mentioned the importance of ring spinning frames, invented in the United States of America, which were incorporated into spinning mills. Up to the introduction of ring spinning, mill spinning had been undertaken by skilled spinning mule operatives. Eventually mule spinning was replaced by the ring spinning method which used a different spinning application. Mule spinning frames used the rollers and rotating spindles to impart twist. Ring spinning used a continuous spinning approach rather than an intermittent application. Furthermore, the spinning twist from a ring spinning machine came from the free rotary movement of the small metal clip called a ‘traveller’ invented by Addison and Stevens in 1829. This ‘traveller’ or metal clip had the added feature of not only ensuring the guiding of the thread but also the winding of the thread on to the bobbin.

Even though these textile processing machines were introduced and significantly improved, Moykr seemed to have overlooked or dismissed the fact that Hattersley’s had brought out various looms which at the time were already acknowledged as ground-breaking both in their mechanisms and applications during the period 1890-1939. Examples of Hattersley’s weaving looms will be mentioned and discussed later on in this thesis.

1.5 The rise and developments of the worsted industry in Bradford and textile machine-making in Yorkshire - a brief overview.

During the last quarter of the seventeenth century, the geographical location of wool/worsted processing, situated in East Anglia and the West Country, was eventually displaced and centralised in Bradford, in Yorkshire following the decline of the worsted trade in Norwich, East Anglia (Heaton, 1920). Within a short period of time, Bradford developed into the centre of worsted processing and distribution and became better known as '*Worstedopolis*' (Cudworth, 1888). This new status and title could be attributed to certain determining factors namely:

i. The gradual introduction of both spinning machines and weaving looms into the textile areas of Bradford.
ii. The demise of the worsted industry in Norwich, East Anglia due to a lack of mechanisation in its industry.
iii. Bradford had begun to gradually replace the wool processing role that Norwich, East Anglia had held in England over a number of year (Heaton*,* 1920).
iv. Slow adoption and transformation from artisan into mechanisation.
v. A perceived market threat from the cotton processing area of Lancashire and the risk of cotton displacing wool.

This transference to and subsequent *loci* of the worsted industry in Bradford, during the 1770s, heralded the beginnings and development of many different types of machine-making in key towns throughout Yorkshire. According to Cookson (1994, p. 23), not only did early millwrights lay down the foundation for a textile machine-making industry but they also began to investigate new forms or ways of mill work as well as machine construction. These millwrights were:

> "credited with a pivotal role erecting and equipping early factories … equipping early factories…recruiting members of various trades…to build the machinery in situ."

The beginnings of a machine-making industry took some time to fully develop in Yorkshire. During the early development of the textile machine manufacturing industry, independent and itinerant local millwrights would be commissioned and instructed to construct rudimentary textile machines but would mainly assist on the structural or installation of motive power transmission necessary to run the stationary steam engines in the mill (Cookson, 1994). Even so, Bradford mill owners were not completely reliant on these workers. Instead, they had the option to draw on expertise, advice and the supply of machinery parts from neighbouring geographical areas such as Lancashire or the West Country textile machine manufacturers (Cookson, 1994). Some Yorkshire cotton, flax, silk or wool processors, however, still preferred to rely on their own in-house millwrights. Other trades, such as joiners, clock makers and blacksmiths, were eventually subsumed into the mill's growing technical workforce whereas some manufacturers chose to rely on technical documents or have access to lists of available '*peripatetic*' workers. Unfortunately, not all textile machine parts brought in to be assembled by the in-house millwright workforce proved to be high quality. This situation was further compounded by some in-house mechanics who were unfamiliar or lacked the necessary technical knowledge to assemble the different textile parts or machinery brought in from afar (Cookson, 1994).

The practice of mill owners or wool producers making their own machines continued from the late 1770s to approximately 1805 (Cookson, 1994, p. 32). Eventually, a dedicated group with specialist skills in engineering, metal-working and mechanical skills began to evolve within the worsted industry in Keighley. During this time period, the emphasis, by many worsted mill owners, who had previously undertaken the construction of their machines, began to switch to buying in the necessary types of machinery made by dedicated specialist manufacturers. In her research, Cookson has recorded that by 1805 "twelve of the eighteen early machine-making entrepreneurs [in Keighley] had left the industry" (Cookson, 1994, p. 65). By the middle of the nineteenth century, a wide spectrum of technical, financial and commercial specialisms had developed in the worsted industry which ranged from inventors to innovators and machine manufacturers to entrepreneurs.

1.6 Worsted industry and machine manufacture in Keighley

During the late eighteenth century, the so-called 'Industrial Revolution' ushered in the permanent alteration and status of many local Yorkshire towns from agrarian and handicraft economies into an industrial infrastructure together with the phenomenon of rapid urban growth. It is interesting to note that the township of Keighley was reputed to have woven woollen cloth as far back as the sixteenth century. In the early days of Keighley's industrial development, cotton had been the fibre which the local textile artisans had processed. Interest and commitment to cotton processing was soon eclipsed by wool which was seen to be important for the worsted trade in Keighley as well as the neighbouring town of Bradford and its environs. During the nineteenth century, the township of Keighley began to increase the influx of working machinery in its textile mills. By 1876, the township of Keighley had amassed "301,000 spindles and 6,452 looms … [and] 4000 mechanics, moulders and other iron workers" who formed the engineering workforce (Rhodes, 1911, p. 7)

The township of Keighley also began to concentrate on supplying the neighbouring town of Bradford, commonly known as the '*Worstedopolis*' of wool processing, with pre-prepared, innovative textile machinery. One such company which became synonymous with textile loom manufacture was Hattersley's who were based in the township of Keighley.

1.7 The origin and history of Messrs., George Hattersley and Sons Limited.

In 1784, Richard Hattersley, originally from Eccleshall, Sheffield, began his career in engineering following an apprenticeship at Kirkstall Forge [one of the oldest forges in Britain] situated outside Leeds. Once he completed his apprenticeship, he left to set up Stubbing House Mill in Aireworth, Keighley specialising in the manufacture of nuts, screw nails and bolts and sold them around the immediate area. Within a short period of time it became known as "Screw Mill" (The Textile Weekly, 1951, p. 1342). With the foundation of the company in 1789, Messrs., Richard Hattersley and Sons brought together a workforce which consisted of nineteen employees arranged into three tiers. The first tier comprised the owner Richard Hattersley and two other colleagues who were the company's actual skilled employees. In the second tier, the workforce consisted of a number of apprentices made up from members of the Hattersley family and the last tier were un-skilled, non-permanent staff used whenever there was a need or build-up of outstanding work (Cookson, 1994).

As Messrs., Richard Hattersley and Son's reputation began to grow, the company looked to widen its engineering output by manufacturing and selling much needed rollers, flyers and spindles to a growing network of local and regional fibre spinning customers. Prior to 1805 Hattersley's was supplying practically every millwright in Keighley with these products (WYAS Bradford, 32D83/5/1). In 1801, Messrs., Richard Hattersley and Sons Limited., also embarked on supplying "bolts, chisels, wedges and plates [together with] agricultural equipment to [prestigious customers such as the politician and statesman] Lord George Henry Cavendish" [1754-1834] (Hodgson, 1879, p. 242).

A temporary reversal of fortune seemed to have affected Messrs., Richard Hattersley and Sons when they embarked on the construction of machinery parts. Some customers, such as the machine maker, Berry Smith [worsted and cotton] machine manufacturer of Keighley, seemed to be content with their acquisition of rollers, spindles and flyers and invested a considerable amount of money buying these items (Hodgson, 1879). Cookson, on the other hand, has recorded that some of the Messrs., Richard Hattersley and Son's textile parts were considered to be not fit for purpose or to the satisfaction of some of their customers. Consequently, Messrs., Richard Hattersley and Sons received many complaints from their customers (Cookson, 1994). A company like Messrs., Richard Hattersley and Sons was always obliged to evaluate its business strategy and try to maintain or secure their customers' loyalty and on-going satisfaction (Fornell *et al.,* 1996). Continuing customer loyalty and product satisfaction ensure that a company has and is able to increase a firm customer-base and support as well as ensuring the ability for future market expansion (Khadka and Maharjan, 2017).

In 1829, Richard Hattersley, the owner of Messrs., Richard Hattersley and Sons, passed away and his son George took over the running of the business. From the 1830s, Messrs., Richard Hattersley and Sons started to diversify the scope of their business by manufacturing looms, for the new up and coming worsted industry, which they considered to be a more profitable commodity and venture. Furthermore, by doing this, the perceived expectation would be that the volume of adverse complaints, regarding the poor quality of manufactured parts, would cease and the company's reputation would be restored and not continue to suffer.

In 1834, the firm of Messrs., George Hattersley and Sons Limited., was commissioned to build a loom which they developed into the first worsted power loom. Unfortunately, whilst on its journey to a mill in Nab Wood, Shipley, both the transporting vehicle and the worsted power loom were attacked and destroyed by a group of disgruntled hand-loom weavers or *Luddites* [textile workers who had an abhorration of any form of new, mechanised machinery]. One view of this sheer wanton behaviour by the *Luddites* was considered by one historian, Eric Hobsbawm, as a form of 'collective bargaining by riot' (Taylor and Walton, 1971). The *Luddites* were afraid that their jobs and incomes would be at risk or compromised by the proposed introduction of this new type of mechanised weaving (The Textile Weekly, 1951). Despite this unexpected industrial sabotage, the firm of Hattersley's was able to manufacture and replace the destroyed worsted power loom. From 1834 onwards, Hattersley's began to specialise in and became renowned for the construction of looms and preparing machines.

The two important textile machine manufacturers to evolve out of this period and eclipse all the other makers in the township of Keighley were Hattersley's [looms and preparing machines] and Prince-Smith who merged with Hall-Stells in 1931 to become Prince-Smith and Stells [wool-combing, drawing and spinning]. Their sustainable growth ensured that the township of Keighley became a *locus* for the construction and subsequent business centre for future sales of worsted processing machinery. The fortunes and longevity of some of the firms, who started their machine-making businesses more or less at the same time as Hattersley's were short-lived. These firms did not manage to survive into the middle of the nineteenth century because of different mitigating reasons. Some firms which disappeared or abandoned what they had been doing undoubtedly experienced some form of economic down turn, some ceased completely whilst others preferred to change their business entity choosing instead to process fibres rather than manufacture looms or spinning frames (Cookson, 1994, p. 66).

1.8 The importance of 'industrial clusters'

One significant factor which has gained prominence with many policy-makers and researchers alike is the importance of 'industrial clusters' and their role in local, regional and international commerce and growth as well as the part they play in stimulating the evolution of new industries (Porter, 2000). It was Cbakravorty *et al.,* (2003) who stressed the historical origins and commonalities of 'clustering' across many nations. They described these as follows:

> "Industrial clustering is a process that has been observed from the beginning of industrialisation. From the cotton mills of Lancashire and automobile manufacturing in Detroit, to the textile mills of Ahmadabad and Bombay and the tanneries of Calcutta and Arcot, even the casual observer can visually discern the evidence on industrial clustering by industry type" (Cbakravorty *et al.,* 2003, p. 3).

To gain a better understanding of 'industrial clusters', a key starting point is to review a definition of this phenomenon. Martin and Sunley (2003) recognised the problems or difficulties that researchers may have in securing a definition of 'industrial clusters'. They noted that "we know what they [clusters] are called, but defining an 'industrial cluster' exactly what they are is much more difficult." Despite the problem of not having a standard, universal definition, Jacobs and De Man argued that "different dimensions are of interest" (Jacobs and De Man, 1996). Subsequently, several theorists have put forward different definitions and perspectives on the concept of 'industrial clusters' (See Table 2).

Theoretical Overview	**Key Factors**	**Theorists**
Classical theory	External Economies	Marshall (1890)
	Location of Industries	Weber (1929)
	Links between industries	
Geographical Overview	Distribution of economy	Krugman (1991)
	Distribution of income	Fujita and Thisse (2002)
	Distribution of wealth	
Specialisation Overview	Industrial Organization	Brusco (1982)
	Cultural Organization	Storper (1995)
Innovation Overview	New Knowledge	
	Learning versus Knowledge	Lundval (1992)
	Creation of Knowledge	Maskell (2002)
	Creation of Innovation	
Competition Overview	Regional Competition	Porter (1990)
	Co-operation and threats	
Dynamics Overview	Knowledge, education, research	Romer (1986)
	Monopoly versus competition	Henderson (1995)

Source: (Bekele and Jackson, 2006)

Table 2. Selected perspectives of 'industrial cluster' by key theorists

Some theorists such as Doeringer and Terkla have emphasised the importance of geographical location but have not mentioned the importance of the linkage or the correlations of firms within a location. The definition which will be used in this chapter has been put forward by Blandy (2002). He defined 'industrial clusters' as a:

> "geographical concentration of competitive firms in related industries that do business with each other and that share needs for common talent, technology and infrastructure" (Blandy, 2002, p. 15).

'Industrial clusters' assumed a greater importance as an economic mechanism, allowing firms to promote their skills and products as well as offering a multitude of useful opportunities. It is also important to note that academic investigations have been carried out on the role of 'regional clusters'. Enright (1993) has described 'regional clusters' as a collection of firms which are geographically situated close to each other.

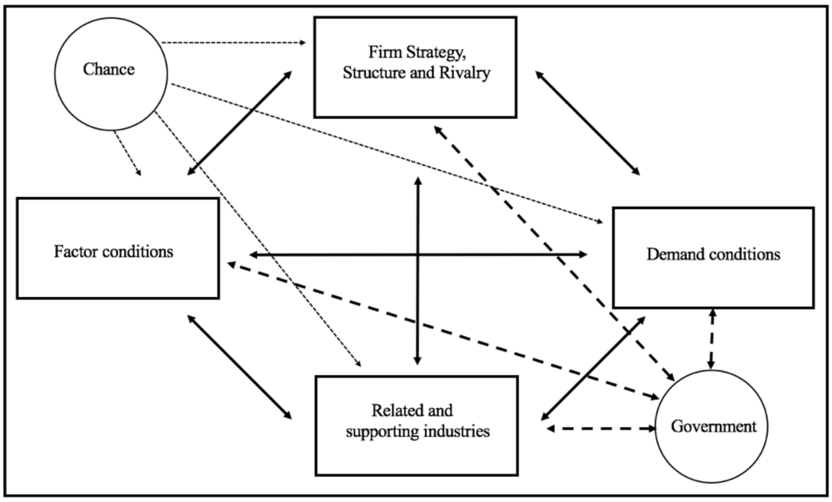
Although interest and research (Martin and Sunley, 2003) have been growing on the importance of 'industrial clusters', academic research or any meta-data seems to have overlooked the direct industrial relationship that Hattersley's in Keighley had with the neighbouring town of Bradford.

The study of generalised 'industrial clusters' has continued to interest both academic and industrial economic researchers for over a century. It was Arthur Marshall [1842-1924] who, in the 1870s, introduced the concept or idea of an 'industrial district'. Marshall maintained that an 'industrial district' represented a designated location where a number of firms could be found with a readily available workforce, designated suppliers and expertise (Marshall, 1920).

Further progress on 'industrial clusters' was undertaken by Dahmén who postulated that 'industrial clusters' were actually "sets of factors … which are closely interconnected and independent" (Dahmén, 1991, p. 126). The conclusions drawn from Dahmén's findings were not to consider 'industrial districts' as an actual theory but to consider them more as a template or checklist (Dahmén, 1991).

Dahmén also introduced the idea of dynamism between the 'positive' and 'negative' transformation found in an industry. When examining the 'positive' transformation, the occurrence was governed by situations which would "increase and make headway into new fields of profitable activities" (Dahmén, 1993, pp. 22-23). In the case of a 'negative' transformation the occurrence would occur when there was "a declining demand" (Dahmén, 1993, p. 23).

One researcher, who has also studied and advanced the subject of 'industrial clusters', is Porter. In the research undertaken Porter showed how important it was not to focus on the "economy as a whole but on specific industries and industry segments" (Porter, 1990, p. 9). Furthermore, Porter demonstrated how 'industrial clusters' could meet the interests, requirements and needs of different firms within an industrial region. Porter went further and advanced his thesis through his analytical framework. When Porter introduced his 'diamond' model he demonstrated how a country's 'industrial clustering,' operated against the background of the dynamic interplay of key variables which engender competitive advantage (See Figure 4).



Source: (Reproduced from Porter, 1990)

Figure 4. Porter's 'Diamond' Model

Porter delved even further into this topic and formed what he termed binary and advanced factor breakdown; classifying this as basic and advanced. The basic factor encompassed areas such as an unskilled and semi-skilled workforce, climate, geographical location as well as natural resources. Conversely, advanced factors comprised of an educated workforce (Porter, 1990, pp.76-77). Advanced factors were also attributed to designated, key industries or firms. These specialised factors, according to Porter, provide the firm or the nation with a clear commercial lead over factors which are deemed to be generalised (Porter, 1990, p.78).

Enright outlined in his research that 'natural' factors such as location, mineral and natural resources can be of great benefit to the firm in both its prospective, commercial output and the establishment of an industry (Enright, 1990). In the case of Hattersley's, this factor proved to be imperative. The close geographical proximity of the oldest and largest British worsted loom manufacturer was important to Bradford, the largest wool processor in the world, first and foremost for the on-going supply of innovative weaving machinery. Both towns were to benefit, develop and expand from this industrial inter-relationship which ranged from the 1780s into the twentieth century. The success of Hattersley's loom also assisted many other firms around the country and abroad to develop their business and commercial output.

Ketels outlined what he considered to be important aspects of 'industrial clusters':

1) The close interaction of firms sharing mutual 'resources'
2) The mutual sharing of 'common' aims or objectives
3) Continual collaborations found and adopted in a cluster
4) Significant success is achieved by a designated contributors of firms within the 'industrial cluster' (Ketels, 2008).

Employees who act within an 'industrial cluster' also have the ability to interact and engage with different firms and form special relationships resulting in advantages for different firms (Roberts and Enright, 2004). In their research, Lines and Monypenny (2006) recorded the many benefits that 'industrial clustering' brings to a district or region:

1) Productivity and innovation is improved. Simmie noted the importance of the inter-linking connections between "suppliers, producers and customers" (Simmie, 2005).
2) Investment results in an increase of 'goods'
3) Clustering brings an expansion of knowledge and insights into technical subjects
4) A direct response which is formed by trust (Turok, 2003) located within the company towards the designated requirements and knowledge (learning, communication and collaboration) found in an 'industrial cluster'.
5) Greater understanding of the different variables or opportunities found in an economy
6) Many advances in incentives
7) A well-developed platform for increasing and expanding knowledge (Monypenny, 2006).

One important pattern which is evident is that key innovative firms tend to be concentrated in urban localities. 'Industrial clusters' have become a very important factor for local, regional and national commerce and economics. Many factors such as historical development, firm ethics or values, geographical location, natural and mineral resources, urban society, size of the firm, specialisation, intellectual and technical knowledge, diffusion of inventions, innovations and technology have all played an important part in the economic creation and development of an 'industrial cluster'.

1.9 Summary

'Industrial clusters' provide many local industries with a united business and commercial framework as well as providing a mechanism for accelerating the rates of urbanisation as well as assisting in the promoting and marketing within the industry. This important framework provided Hattersley's with the advantage of being able to continue with the promotion of its products as well as building on a legacy of innovative weaving looms.

Knowledge is an important factor which is developed in 'industrial clusters'. According to Porter, the advancement of knowledge is gained through direct competition or inter-firm rivalry (Porter, 2003). Rivalry between firms also ensures the production of innovative machinery as well as increasing a firm's productivity. This feature was clearly evident in the competitive rivalry which existed between Hattersley's, Sowden and Hodgson looms.

‘Industrial clusters’ continued to strengthen the many linkages between the different firms operating in the processing of worsted textiles. The rise and fall of prosperity and productivity would have been reflected by the output from the many firms within a regional area.

Engineering skills began to be developed and refined. Located in these geographically-based ‘industrial districts,’ industrial expertise had been developed over the years. Even so, the fortunes of the firms within an ‘industrial cluster’ were transformed during the First World War [1914-1918] from commercial enterprises to ‘managed’ textile establishments. The War Office dictated to those nominated firms such as Hattersley’s the quantity of munitions needed for the war effort. It is not surprising to find that some firms had to pause their commercial activity until the end of the war.

Chapter 2: Methodology undertaken to investigate the company of Messrs., George Hattersley and Sons Limited., loom machinery manufacturers of Keighley (1890-1939).

2. Introduction

When undertaking a formal investigation into any subject, the most important first step a researcher needs to consider and ultimately adopt, is a systematic research method, appropriate data collection procedures and an informed philosophical approach. Creswell (2013, p. 20) advocated the four philosophical beliefs or paradigms which should always be included in any research methodology design. These themes are as follows:

> "… ontology (the nature of reality), epistemology (what counts as knowledge and how knowledge claims are justified), axiology (the role of values in research), and methodology (the process of research)."

Jongbo (2014, p. 87) championed the idea that "good research design helps prevent frustration by provid[ing] the glue that holds the research project together through a structured plan."

A well-structured, methodically-designed and rigorous research paradigm will always provide an effective means of systematically accessing historical subject-matter relevant to the focus of a study. Following this rigorous approach will inevitably necessitate locating pertinent, often fragmentary primary and secondary source material from a range of venues. While it is tempting to overly rely on secondary sources which can be readily accessed via electronic means, inter-library loans or books, the principal motivation taken for this study was to critically examine all the extant primary sources of George Hattersley and Sons Limited., held in various universities, libraries, record offices, archives and museum collections. I scrutinised original business letters, loom production ledgers, exhibition awards (highest and gold medal, awards), notification leaflets, patent data, loom catalogues, order books and miscellaneous Hattersley documents. In the approach selected for this study, which is arguably the most effective, I set about assembling as wide a sampling of sources as possible- not just accessing the obvious references, but gleaning information from *anyone* and *anything* which would help to formulate a clearer, understanding of the historical context. While the importance of assimilating original, primary sources alongside secondary sources was of the guiding principle of my research paradigm, the importance of analysing extant cultural artefacts of the period cannot be overstated. Material sources, regardless of size or condition, when carefully examined and evaluated alongside historic archives and records, also provide an invaluable opportunity to reconstruct the reality of the historical period in which they originally belonged.

This approach to incorporating 'material culture' in a study is, on occasions, denied to many researchers. As a former museum curator, access to original, working Hattersley looms and in-house technical support, offered me a unique insight into the 'essence' of these radical mechanisms. On the one hand, a 'visual' investigation enabled me, first and foremost, to better appreciate how well it had been engineered. Where other researchers are often left with the challenge of trying to understand how a museum machine works when the only reference to it is a short description on a museum label, I was fortunate to experience unrestricted live demonstrations to better understand not only the technical inventiveness and innovative design of Hattersley's loom engineering but also to better appreciate the knowledge and skill requirements of the loom operatives of the day. This unique *experiential learning* opportunity, along with direct contact with other, similar Hattersley objects, reflects Batchelor's research interest in which he views museum artefacts as a cultural example seen through the research filter of an invention, type of material (how it has been created), its purpose and its ultimate marketing, and the removal of any bias (Batchelor 1994, pp. 139–143). Although these cultural artefacts, which Kertemelidou posits have been manufactured "at a given time and space" (2018, p.136), are of historical importance, judicious interpretive skills are needed to ensure potential 'bias', strengthen the validity of the investigation, and contribute new knowledge to this area of research.

2. 1 The research paradigm and definitions

There are many ways of defining or classifying research. For some researchers, any investigation into a subject becomes an orderly approach to discover, reconfigure and push forward the boundaries of hidden knowledge (Gratton and Jones, 2009). An investigative approach should always allow the researcher to make the subject material acceptable and understandable to the reader (Mukkerji and Albon, 2015). Conversely, some investigators have looked at research in terms of a systematic review or the examination of many studies covering the same subject which is known as 'meta-analyses' (Babbie, 2002). In an overview of the research paradigm, The State of Australia University Research ERA National Report (2015) have proposed the definition of research as the:

> "creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies, inventions and understandings. This could include synthesis and analysis of previous research to the extent that it is new and creative" (2015-16, p. 3).

Furthermore, research and the collection of research data undertaken can be greatly influenced by a number of external factors (Kivunja and Kuyini, 2017). Numerous factors such as costing of undertaking research data, unrealistic time factors, researcher's bias and the type of language used in formulating the research data can affect or directly influence the outcome of the research data.

2. 2 The definitions of research

Numerous investigators have analysed the concept of 'research' and put forward their own definition. A limited selection of operational definitions is shown here:

i. Research becomes a method of finding out or pushing forward the boundaries of knowledge (Gratton and Jones, 2009).
ii. Research becomes a process or procedure to acquire, classify, quantify and make sense of the data or findings (Leedy and Ormrod, 2001).
iii. Research becomes a concerted effort by researchers to discover answers to questions in an organized manner (Saunders *et al.,* 2007).

Research remains a very important investigative tool in the quest to find answers, facts, underpin an argument or establish some form of authoritative point of view. Researchers, such as Crotty (2013) and Ellis (2013), have shown that certain criteria or methodologies have to be in place for research to be or become effective, manageable or successful. The effectiveness of methodologies must be honed to conform to the subject material being investigated (Crabtree and Miller, 1999). Characteristics of a good research methodology always involves universal determinants such as precision, impartiality and relevance (Crotty, 1998).

For any research to be considered appropriate and successful requires it to be designed in such a way as to have a direct impact between the nominated audience and its specific user groups (Penfield *et al.,* 2014). Research usage and impact in different disciplines such as academic, social, cultural and industrial circles may produce different outcomes whenever it is used. Moreover, there are many ways raw data can be extrapolated, stored, interpreted and used (Makani, 2015).

Research, as a method, strategy or process, produces some fundamental implications for the investigator. The extrapolation of any research data during a programme of studies can also be influenced by determinants such as the individual's evaluation, future career prospects (Tenopir, *et al.,* 2011; Fecher, *et al.,* 2015), the mis-management of data by fellow researchers as well as the accessibility of data (Kim and Zhang, 2015). Likewise, new knowledge can also be gleaned from a number of outcomes such as products, investments, improved efficiency, improved processes, reduction of risk, publications and information (Duryea *et al.,* 2007).

2. 3 Investigation and review of different research methodologies

There are many different methods of researching a subject. Each selected method is often chosen through [an] "objective and systematic method of finding [a] solution to a problem" (Kothari, 2004, p. 1) as well as the researcher's confidence, interest and familiarity with the chosen investigative tool (Creswell, 2003). This issue was addressed by Kothari (2004, p. 2) who grouped his selection of different research methods into five categories each emphasising their distinct characteristics:

i) Descriptive versus Analytical
ii) Applied versus Fundamental
iii) Quantitative versus Qualitative
iv) Conceptual versus Empirical
v) Other forms of investigations

The methodology found in *descriptive* research uses the approach of the "survey and fact-finding enquiries" (Kothari, 2004, p. 2). Unfortunately, the disadvantage of this type of methodology is that the researcher is unable to determine or regulate the *cause and effect* or the *variables* involved. The *analytical* research method tends to be used because information and data is readily available which allows the researcher to investigate and critically assess the information.

Niiniluoto (1993, p. 2) cited OECD's interpretation of *applied* research as the "pursuit of knowledge with the aim of obtaining a specific goal." *Applied* research is particularly useful if a theory is being put together or when researching an issue with the intention of presenting an overview of the subject being investigated. The opposite approach to *applied* research is the *fundamental* or *basic* research methodology which is primarily theoretical and is interested in furthering knowledge and understanding of the subject under investigation.

Two important research methods often used are the *quantitative* or the *qualitative* methods. The *qualitative* method is often used when investigating the reasons behind certain actions or motivations. *Quantitative* method is concerned with extrapolating or using numerical data. Table 3. shows the key differences between the *qualitative* and the *quantitative* methods which uses the four *dimensions* or subject areas - *assumptions, purposes, approach and research* as advocated by Firestone (1987, p. 2).

Kothari (2004) has commented that researchers will discover that there are many variations of investigation surrounding his five distinct groupings. What becomes crucial is whether the researcher undertakes a long view or *longitudinal* approach to his research or concentrates on a narrow or specified timeframe. Carduff *et al.,* (2015, p. 2) state that *longitudinal* research is:

> "…about exploring change, but what changes occur (if any) are dependent on the context of the study."

Further discussions into research methods reveal two main approaches, namely *exploratory* or *historical.* If the researcher chooses to adopt the *exploratory* approach, more often than not, this approach is usually concerned with exploring or discovering the issues as well as providing a greater awareness of the subject material rather than justifying a theory (Cooper and Schindler, 2006). Furthermore, this approach provides the researcher with data which is rich in content and crucial to the research (Cavana *et al.,* 2001). Utilising an historical research methodology is to consult historical data, documents and sources which will provide an explanation of the decisions taken in the past and the outcomes.

Quantitative Methodology	**Qualitative Methodology**
Assumptions May be single, part or tangible Investigator and investigated independent Factors noted and relationship assessed Method important Investigation is objective	**Assumptions** May be several, constructed or holistic Investigator and investigated indivisible Complex factors difficult to assess Subject to be investigated important Researchers impose own values
Purposes Obtain generalisations Ability to predict Relationship between two factors	**Purposes** Obtain information in context Ability to predict Appreciation of different factors
Direction of approach Methodology begins with hypothesis Determination of methodology Deductive approach Analysis from data Data seen in numerical terms Theoretical write-up of investigation	**Direction of approach** Methodology ends with hypothesis How methodology is applied Inductive approach Investigation into pattern Limited use of numerical data Descriptive write-up of investigation
The function of the researcher Researcher to remain unbiased Research approach shown as objective	**The function of the researcher** Researcher to show inclination Research approach shows affinity

Adapted from Lincoln and Guba (1985); Glesne and Peshkin (1992); Sechrest and Sidani (1995)

Table 3. Quantitative versus Qualitative Methodology

Researchers using the *conceptual* research approach tend to adopt this method when discussing or incorporating a theory which has an abstract nature or background. *Empirical* methodology is underpinned by the quest to extrapolate any data which can be formulated by the researcher's keen observation. This approach should provide the researcher with a very strong verification of any formulated theory (Kothari, 2004, p. 4).

All these research techniques, with their complimentary or particular investigative characteristics, are fundamentally important to the researcher when evaluating any proposed research methodology. Rebolj (2013, p. 34) has claimed that "the more classifications we are familiar with, the better and easier we can categorise our own case study". The role of the researcher is to take these different research techniques and judiciously select, with great care, the appropriate ones and incorporate these into the research methodology. Some research techniques will be applicable to the subject matter being investigated whilst other techniques will not. The research methodology, which is formulated and then applied directly to the investigation, will have taken into account why it has been selected, why and how the data will be collected and how the results will be analysed and presented. Careful selection of a flexible research technique will minimise any potential error or bias (Kothari, 2004).

2. 4 Rationale for selecting and developing a 'single case' study

The 'single case' study has been shown to be particularly useful when examining industrial companies which may have been successful (Siggelkow, 2007; Stake, 1995) or not so successful (Easterby-Smith *et al.,* 2009). Such a case study, which has a long and widespread history in different disciplines, has been seen by certain researchers as being particularly flexible, challenging (Cope, 2015) and useful when investigating an individual or unique company (Hyett *et al.,* 2014). Some researchers have argued that the use of case studies is not a diluted form of experimental design. Instead, it is a different type of research strategy which has its own design features (Cook and Campbell, 1979).

Ozcan *et al.,* (2017) itemised their interpretation of key factors which, they argue, make the 'single case' study an important investigative tool; these researchers singled out the key factors which demonstrated the importance of case studies as a means of researching a subject:

1) The 'single case' study provides the researcher with an overall understanding and overview of organisations and how they interact within their sphere of direct influence.
2) Every 'single case' study allows the researcher to have an insight into the complexities of the organisation which would be difficult for anyone not involved in research.
3) The unique, extracted information from the organisation is not suitable for the researcher to place it into a category of multiple case studies but acceptable for the development of a theory when using only a 'single case' study.

Furthermore, any investigation using the 'single case' study model provides an ideal opportunity for longitudinal research (Yin, 2014).

Past research has shown that questions such as "how and why things emerge, develop, grow or terminate over time" can be answered by 'single case' studies (Langley *et al.,* 2013, p. 1).

Stake (1995, p. 16) claims that when using an *intrinsic* case study, "the case is dominant; the case is of highest importance." The investigation of Hattersley's (1890-1939) as an *intrinsic* study has not previously been undertaken studied. In this respect, the subject-matter demonstrates both an academic interest and uniqueness for researchers, providing a rich fount of new knowledge which offers further possibilities for academic discussion and future research.

To investigate any individual textile manufacturing company such as Hattersley's based in Keighley and the Yorkshire textile manufacturing industry, the extant primary and secondary sources were assessed and used. Primary sources included existing original documentation and manuals whilst secondary sources incorporated a number of bibliographic sources such as personal correspondence, foreign, national, regional and local newspapers, trade magazines or journals (such as the Textile Manufacturer, The Wool Record and Textile World, Textile Journal of the Institute Proceedings and Abstracts, Journal of the Bradford Textile Society, The Textile Recorder, The Textile Weekly, The Journal of Economic History), official Government reports, theses, academic papers and textile-related books. The researcher will have to carefully scrutinise the merits of the myriad of different methodologies available and make an informed choice in order that it "best serve[s] and support[s]" the most appropriate method of research (Yazan, 2105, p. 150).

2. 4. 1 The 'single case' study: an assessment

It has been estimated that by 2007, approximately 25 different case study definitions have gained prominence in academic research (Wynsberghe and Khan, 2007). Researchers have increasingly articulated that the case study has become:

> "… more than simply conducting research on a single individual or situation. This approach has the potential to deal with simple through complex situations. It enables the researcher to answer "how" and "why" type questions, while taking into consideration how a phenomenon is influenced by the context within which it is situated" (Baxter and Jack, 2008, p. 556).

Nevertheless, there remains an on-going argument that there is no universal definition for case studies (Miles and Huberman, 1984) which researchers can agree upon (Wynsberghe and Khan, 2007; Easton, 2010). When investigating a subject, some researchers have claimed that the use of the case study has not been well-defined, often ignored (Thomas, 2011) or not properly understood as it should be (Yin, 2002). When a case study is selected or about to be used, many researchers may have an unclear idea of what it represents and how it differs from other types of qualitative research or approaches (Merriam, 1998). Gustafsson (2007), claimed that there was no universal definition which encapsulated the role of case study research. This viewpoint was also endorsed by Solberg Søilen and Huber (2006). It was also claimed by one researcher that the case study has become a "definitional morass … Evidently, researchers have many different things in mind when they talk about case study research" (Gerring, 2006, p.17). Notwithstanding this, Gustafsson (2017, p. 2) went on to define the case study as an:

> "intensive study about a person, a group of people or a unit, which is aimed to generalise over several units."

With the introduction of Gustafsson's definition, researchers have continued to discuss and clarify what is meant by a case study from a methodological perspective. Yin (2009, pp. 638-650), who has been closely associated with investigations into case study methodology, defined this research tool as a theoretical:

> "empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"

Cresswell (2002, p. 61), on the other hand, considered the case study as a method for a:

> "problem to be studied, which will reveal an in-depth understanding of a 'case' or bounded system, which involves understanding an event, activity, process, or one or more individuals"

This in-depth case study of Hattersley's will draw attention to and understanding of a complicated phenomenon as well as critically supplementing existing knowledge in the area of diffusion, technological innovation, and change such as the automatic loom which fundamentally influenced the Yorkshire worsted manufacturing industry. The selection of an in-depth case study should not be viewed as the sole method but rather as a design framework which is underpinned by a number of different investigative methods (Simons, 2009). The methodological approaches for this research study have been drawn from the theories and practices highlighted in the aforementioned academic publications.

As a starting point, evidence was traced and brought together from a number of primary sources such as order books, patents and business records, this thesis examines, challenges and offers new knowledge collected and collated from the various determinants which have influenced the Yorkshire worsted weaving looms manufacturing industry.

2. 5 The issues of reliability, viability and rigour in a 'single case' study

Silverman has described reliability as ''the degree of consistency with which instances are assigned to the same category by different observers or different occasions'' (Silverman, 2005, p. 210). Investigation into different case studies must always be underpinned by a high degree of reliability, viability and rigour (Campbell, 1975; Yin, 1981) or by the *credibility* of the methodology the researcher intends to use (Silverman, 2006). Failure to incorporate these three key variables into any research methodology will render any case study investigation to be markedly flawed. Morse *et al.,* have declared that without reliability, viability and rigour, any research undertaken will be “worthless, becomes fiction, and loses its utility” (Morse *et al.,* 2002, p. 14).

Reliability or *consistency* is vital to the success of one of the most important concepts when designing and evaluating any investigative methodology (Brink, 1993). According to Denzin and Lincoln (1994), reliability constitutes an integral part of any formal research and attempts to remove the possibility of any error or random error which could affect the results. It was Merriam who posited that:

> “the more times the findings of a study can be replicated, the more stable or reliable the phenomenon is thought to be” (Merriam, 1995, p. 55)

Validity is an important quality component to any research as it provides the study with “accuracy and truthfulness” (Van Manen, 1990; Bond, 2003, p. 192). The inclusion of validity into any design of research methodology also ensures that any potential bias may be controlled (Mishler, 1990).

For any methodology to be effective and free from criticism, rigour must always be the cornerstone of research design. It was Feagin *et al.,* who stressed that:

> “irrespective of the type, purpose, unit of analysis, or design, rigour is a central concern in case study research” (Feagin *et al.,* 1991, p.7)

Scandura and Williams (2000, p. 1263) have insisted that “without rigour relevance in … research cannot be claimed.” Several researchers have also stressed the importance of this underlying principle and highlighted the attributes of rigour when used in case studies (See Table 4).

Researchers	**Principles underpinning rigour in case studies**
Guba (1981)	Truth, consistency, applicability and neutrality
Lincoln and Guba (1985)	Credibility, dependability, transferability and confirmability
Agar (1986)	Credibility, accuracy and the acknowledged authority of the researcher
Kirk and Miller (1986)	Consistency of findings, stability of time in a determined period
Brink (1991)	Credibility and stability

Source: (Johnson and Rasulova, 2016)

Table 4. Different attributes underpinning rigour in research

The adaptation of any ‘single case’ study model can be viewed in two ways. First, a rigorous and comprehensive approach is needed in which key, analytical techniques are used to ensure that the new knowledge gained is reliable and promotes a better understanding. Second, the research techniques selected can make sense of the new knowledge by a course of investigation. From the investigation, a body of principles and observations can be formulated to use, predict or comprehend the behaviour of a company or its business outcomes.

2. 6 Selecting and developing the case study data

The importance of the subject matter cannot be underestimated. Yin argues that the case study can undertake two key functions, namely to confirm or question an assertion (Yin, 2002). These two investigative factors have a fundamental significance to any research. When using the *intrinsic* model, the subject is selected because of its uniqueness and not because it conforms to other industrial examples. Some researchers conclude that the selection of any subject under investigation revolves around both their unique nature and the interest they generate (Stake, 1995). Accordingly, Ridder has discussed how practically no effort is made to produce or outline a theory. Instead, particular factors are investigated. Ridder (2017, p. 296) has reasoned that the *intrinsic* approach to case study is not to:

> "identify abstract concepts and relationships; [instead] the specific research strategy lies in the observation and description of a case and the primary method is observation, enabling understanding from personal and vicarious experience."

Some researchers, who have debated the validity of this method of collecting data have concluded that it is "messy, ambiguous, time-consuming, creative and fascinating" (Marshall and Rossman, 1999, p. 150). To progress any case study requires it to be rigorously analysed. This case study aims to redress some of the under-representation of the history of Yorkshire's textile industry. The researcher will also need to carefully collate, analyse and interpret the extrapolated quantitative data. An important feature of gathering data is the necessity for it to be validated, collated and grouped so that different thematic factors can be extracted, analysed and interpreted meaningfully.

Every case study investigation will ultimately generate a significant volume of rich-data. Once the data is collected, it needs to be sorted and scrutinised with a view of extracting the key themes which will become the points of discussion at a later stage. Some researchers lay great stress on ensuring that certain factors need to be considered such as observing the dynamics between one event and another and the subsequent resolution of the investigation (Miles and Huberman, 1994).

Once the data has been analysed and synthesised, the results provide a useful insight and understanding of how different factors impacted on the firm over a period of time and the reasons why it reacted in the way it did. Key issues and findings will be evident from the case study investigation. Care must always be taken to ensure that any extrapolated data from the case study must not be 'manipulated' to fit any assumptions or objectives previously made. To avoid any potential 'bias' and strengthen its validity, the data will need to be 'triangulated' or looked at from multiple or different levels or methodologies. This approach should provide an unbiased overview or validity to the investigation. Furthermore, the relevant extrapolated data and its subsequent interpretation must provide the reader not only with new information but also show how the conclusions were reached. According to Yin (1989) and Stake (1995), they believe that the underlying framework of the case study must continually focus on answering the research questions.

2. 7 Collect, analyse and evaluate the 'single case' study data against the *PEST* analysis framework tool

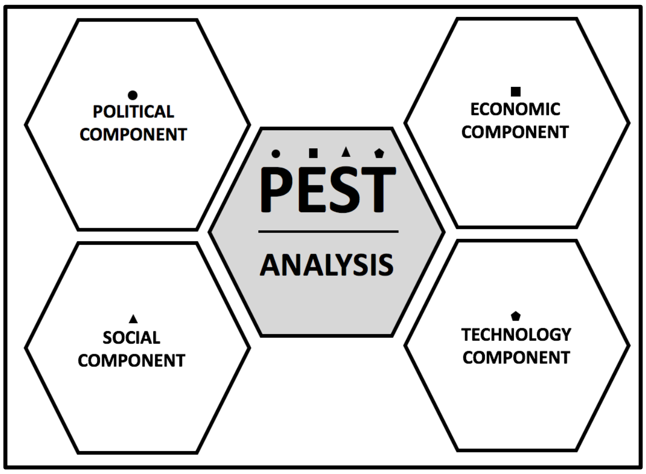
The investigation of Hattersley's will be undertaken by an in-depth 'single case' study which will reveal the many fortunes, technological developments and challenges of the company, information which has never adequately been documented and rigorously analysed in the past. This case study aims to critically supplement existing knowledge in Yorkshire's textile industry particularly where very little academic research has been carried out previously, not least, on the history of the firm during the period 1890 to 1939.

This research will use a multitude of secondary sources and employ the Political, Economic, Social and Technological (*PEST)* analysis framework tool to reveal the important and innovative technological contributions made by this nationally-important loom manufacturing company. The findings of this thesis will be assimilated into existing research in this subject area with a view of eliciting critical reviews and generating further academic discussions.

As an investigative tool, the *PEST* analysis framework is a tried-and-tested method in establishing a clearer understanding of how a market expands as well as identifying the external forces which can affect it (Kotler, 1998). The different 'macro' external factors which may have an impact on a textile company can be evaluated as an overview and breakdown assessment (see Figure 3). Moreover, the *PEST* analysis framework tool has been used in conjunction with Porter's 'Five Competitive Forces' (1979) strategy [a managerial strategy used to discover potential commercial competition] This investigative tool was devised by Porter who believed that the *SWOT* analysis, an integral tool used in planning (Kotter, 1994), was both "unrigorous" and "*ad hoc"* (Argyres, and McGahan, 2002, p. 44).

The *PEST* analysis framework tool can also be used as a *SWOT* [an acronym for *Strengths, Weaknesses*, *Opportunities* and *Threats*) analysis or matrix. It is also important to note that the

PEST analysis framework tool is always used before any *SWOT* analysis and not the other way around (Abdullah and Shamsher, 2011, p. 1477).



Source: (Sammut-Bonnici and Galea, 2015)

Figure 5. *PEST* analysis framework

Political (P)

The political component in the *PEST* analysis framework tool shows the involvement or influence of government or policymakers in the commercial and economic affairs of many organisations or companies. Key political influences and decisions are important because they can have a direct bearing on the trade an organisation may undertake. Typically, these will be tariffs, union involvement, taxes or fiscal policies.

Economic (E)

Economic determinants are central to the understanding of a firm's decisions and actions because they can influence a company's long-term commercial standing. The fluctuating economic rationale such as foreign exchange rates, labour costs, inflation etc., can affect or have an adverse effect on the purchasing power or sales of a manufacturing company.

Social (S)

Any industry and its trading market is dependent on its workforce, their expectations and cultural norms. If the industry is affected in some way, the working population dynamics such as age or buying potential of products from abroad may alter with any migration away from the manufacturing area. Furthermore, if there is high unemployment the workforce and industry will suffer

Technological (T)

This component has a significant influence on the success of industry and the workforce. A manufacturing company such as Hattersley's prided themselves as being leading innovators whose business acumen was key to their successes as "the oldest firm of loom makers in the world" (The Textile Weekly, 1951, p. 1342). The success of these types of manufacturing companies were dependent on a sustained inventive and innovative culture and an effective marketing/sales strategy.

One useful method of summarising the different questions to the various categories of interest is to arrange them into a grid (Thompson and Martin, 2006). The *PEST* analysis framework tool can also be seen to highlight three distinct areas before any marketing takes place. These three distinct areas are:

1. Internal factors such as internal suppliers and customers
2. Micro factors which reveal a 'satellite view' of the type of external competitors and competition (Ward and Rivani, 2005, p. 4)
3. Macro factors which includes *PEST* analysis framework tool - *Political, Economic, Social* and *Technological.*

Furthermore, the *PEST* analysis framework tool enables a company to develop its industrial strategy, expand its investigation overview and develop or refine their decision-making (see Figure 5).

Political Factors	**Economic Factors**
Industry's attitude and any changes International textile trade Reaction of British textile press to foreign imposed tariffs Foreign trade Trade response to foreign imports Import restrictions (quality and quantity) Competition responses by British industry Response by British vested interest groups to foreign tariffs Patents / Intellectual property law	Labour costs of domestic textile machinery Trade flows and patterns of new imports Price fluctuations Consumer confidence on new imports Foreign tariffs on loom exports Economic response of home market to new imported products
Social Factors	**Technological Factors**
Attitudes toward imported goods Attitudes toward foreign product quality Fashion and fads Purchasing habits of industry Labour/social mobility Attitudes to textile manufacturing work Textile work demographics	Basic textile manufacturing infrastructure Rate or speed of loom technological change Research and development Loom technology competition Loom technology output found in industry Access to newest loom technology New foreign loom developments

Source: (Adapted from Kim-Keung Ho, 2014)

Table 5. Amended *PEST* analysis framework table

2.7. 1 Advantages of using a *PEST* analysis framework tool

i) One of the benefits of using the *PEST* analysis framework tool is that it can demonstrate possible trends which may be seen as short-term and long-term influences (Fleisher and Bensoussan, 2003). These trends can affect a company's commercial outlay if protective tariffs are imposed which did impact and affect Hattersley foreign sales.

ii) Furthermore, any change to a company can be affected by one factor directly affecting another factor e.g. a political factor impinging on another factor such as economic factors. In other words, foreign tariffs which are imposed by one country can make the sale of a competitor's imported products, made in another country, too expensive to sell.

iii) The *PEST* analysis framework tool is versatile when added to other managerial strategies, such as the *SWOT* analysis or Porter's Five Competitive Forces strategy. A company can discover what are the strengths, weaknesses, threats and opportunities their products are faced within an aggressive commercial market.

iv) Using the *PEST* analysis framework tool gives the researcher a holistic picture or the 'big picture' (CIPD, 2014).

v) The *PEST* analysis framework tool is a useful tool when determining how different determinants affect any change or risk. Once the findings are discovered, the company may use the findings to plan any long-term marketing strategy (Johnson *et al.,* 2009).

vi) Any perceived commercial assumptions will be altered by facts or findings gleaned from the *PEST* analysis framework tool and the results will be used in any strategic planning.

vii) The use of the *PEST* analysis framework tool allows the user to study the commercial market and gain a greater awareness in strategic thinking (Fleisher and Bensoussan, 2003).

viii) The *PEST* analysis framework tool has the advantage of being simple and easy to use and only requires a designated time period to carry out any investigation.

ix) One of the benefits of the *PEST* analysis framework tool is that it can assist in a company's *SWOT* analysis (Fleisher and Bensoussan, 2003).

The case study format analysed and interpreted against the *PEST* framework provides a robust and rigorous approach to the investigation and understanding of Hattersley's as an important textile machine manufacturer. In this modified *PEST* analysis framework, a 'geography' determinant has been included as an additional investigative variable. This new determinant will add an extra dimension to the study wherever it is deemed to have a key importance to a fuller understanding of the focus of the area of study, thus allowing the researcher to appraise and reveal the key attributes, such as the location, development and changing patterns of textile engineering in Keighley, which made it a leading economic, manufacturing and trading centre from 1890 to 1939. It was during the beginning of the so-called 'Industrial Revolution' when the rapidly-growing industrial centres of Bradford [worsted], Huddersfield [fancy woollens and worsted], Dewsbury, Batley, Morley [heavy woollens], Halifax and Leeds allowed Hattersley's to develop and become an important machine manufacturer, servicing a world-wide weaving loom market as well as pushing forward the boundaries of weaving innovations.

2. 7. 2 Limitations of the *PEST* analysis framework

The *PEST* analysis framework tool, although very useful to a company's commercial strategy does have certain limitations:

i) One aspect of the *PEST* analysis framework tool is that the findings are out of reach from an individual organisation (Fleisher and Bensoussan, 2003). Any change is determined by externally inspired influences such as governments, policy makers, economics or technological innovation.

ii) The volume of information gleaned can, on occasions, prove to be overwhelming. Subsequently, the researcher may spend far too long trying to make sense of the data whilst the end result or any subsequent projections may prove to be divergent in conclusion.

iii) Some researchers have reasoned that there is a disadvantage when using the *PEST* analysis framework tool on its own. To extract a more comprehensive overview, the *PEST* analysis framework tool should be used in association with other management strategies such as the *SWOT* analysis (Cox, 2021).

iv) The rapid development of change and development in society may be so sudden that it will not be picked up thereby preventing any future anticipation or careful strategic planning.

v) If strategic planning is undertaken by assumptions or guesswork any future planning may not be as accurate as it should be.

vi) For the *PEST* analysis framework tool to be effective requires it to be undertaken and tested on a regular basis (CIPD, 2014).

vii) Peng and Nunes (2007, p. 230) have argued that a *PEST* analysis framework tool is:

> "far from being precise and clearly circumscribed analysis framework. There are almost unlimited number of variables that may emerge from each dimension."

2. 8 Limitations of the 'case study' approach

When a case study or any other method is selected for research purposes, certain limitations may be inherent in its design or methodology. Maoz (2002) claims that the use of a case study allows the researcher to use it without any regard to the construction or adoption of the intended methodology. What occurs, according to Maoz (2002, pp. 164-165) are:

> "case studies [which] have become in many cases a synonym for free form research where anything goes"

According to some researchers, the weakness of using the case study centres on its inability to repeat studies (Wiersma, 2002). The data identified from the behaviour of one company, individual or phenomena or circumstances may not be obtained or replicated in another similar company, individual or phenomena.

Generalisation in the absence of key data may undermine the validity of this research method. This is one of the areas where planning a 'single case' study is deemed to be deficient (Sharp, 1998; Tellis, 1997; Woodside, 2010). Mintzberg (2005, p. 10) has noted that without:

> "… generalising beyond the data, no theory. No theory, no insight. And if no insight, why do research?"

Case studies can also be undermined by the temptation to "generalise from the conclusions, models or theory developed from the selected case" (Voss *et al.,* 2002, p. 201).

Preventing designs weaknesses	**Pointers for minimising risks**
Selecting an inappropriate case study	Develop greater knowledge of case study
Accumulation of inappropriate data	Focus research methods to the aims
Not defining the parameters of the case study	Ensure that methodology is made clear
Not incorporating the rigour factor	Ensure that triangulation is undertaken
Not observing any ethics in the case study	Careful control case study sources

Source: (Adapted from Crowe *et al.,* 2011)

Table 6. Guiding principles when undertaking research in a case study

Table 6. shows the important features that Crowe *et al.,* (2011) has advocated and placed on the researcher. These factors or issues will allow the researcher to gain a better conceptual grasp of the many complexities found in the case study.

2. 9 Summary

In conclusion, having carefully considered the methodological approaches highlighted in the aforementioned literature as well as evaluating the merits of the case study format, the proposed case study methodology, together with the modified *PEST(&G)* framework analysis tool, will underpin this research. According to Freeman (1984), a case study represents the ideal methodology for examining any innovative process or any historical developments found in a nascent industry. Flyvbjerg (2011) goes further and notes that a great deal of case study research in areas such as education, history, psychology and social sciences have produced important findings and results. Any intended research must ensure that the case study's rationale is incorporated and carried out. The investigation of Hattersley's (1890-1939), will be seen as an attempt to:

> "illuminate a decision or set of decisions, why they were taken, how they were implemented, and with what result" (Schramm, 1971, cited in Yin, 1989, pp. 22– 23)

Chapter 3. Technological change: An overview of key determinants which support and progress economic change.

3. Introduction

The importance of concepts such as technological change, innovation, invention, imitation, and diffusion continue to be a source of great interest and considerable debate to the industrial and economic historian, especially when investigating the role and effects of industrialisation and economic growth. According to Rosegger, interest and subsequent study on technological change has gained a growing interest in more recent times. Scholars have examined the notion of technological change and defined the concept in many different ways (Rosegger, 1996). Researchers, such as Mansfield (1972) emphasised the need for a better understanding on what is meant by technological change when it is applied to economic growth and productivity.

In the course of researching this subject area, it soon became apparent that scholars have not reached a consensus on a simple, relevant or universal definition which has been accepted by the wider academic community. For instance, Schmookler (1966) termed technological change as *the terra incognito* [trans. unknown territory] in the study and understanding of economic theory whereas Ibrahim (2012, p. 3) has put forward his viewpoint by describing technological change as an:

> "… incremental change in the quality and quantity of knowledge and ideas that are applied in the stream of activities to enhance the social and economic well-being of the society…"

According to Romer (1990), it was Mokyr (1990, p. 3) who viewed the phenomenon of technological change as one of the most powerful forces of change found in the annals of economic history. The underlying importance of technological change has also been considered as the:

> "…central factor in the industrial development of most advanced industrial nations; not only technical change in its most narrow form - the rate of advance of industrial knowledge - but also and primarily the broader concept of technological change including the actual diffusion of existing technologies" (Soete, 1985).

Marx also recognised the importance of technological change as the means by which the capitalists were able to increase their profits as well as obtaining supplementary benefit from their industrial processes. In his writing, Marx highlighted the clearly defined differences between factory machines and tools as well as stressing the dominant rise of machines over the role of repetitive manual labour (Marx, 1976).

Similarly, a different form of production is created which would underpin the original 'technical foundation' (Marx, 1976). This factor, according to Marx, was the basis for when 'capital goods' were being produced. He postulated the view that capital goods represented goods which have been manufactured by mechanised machinery. This type of production, in turn, allowed the manufacturing sector to occupy a key role in a society's technological development (Tregenna, 2013). Marx continued to focus his attention on the ever-congruent relationship between science and technology in the field of production which he labelled 'revolutionary'. He claimed that:

> "by means of machinery, chemical processes and other methods, it is constantly transforming not only the technical basis of production but also the functions of the worker and the social combination of the labour process" (Marx, 1976).

Rosenberg (1992), commenting on Marx's theories, noted that technological change also made it possible for monies coming in from any sales to be offset against the materials expenditure. In his Theory of Economic Development, Schumpeter argued that technological change was essentially 'new combinations' (Schumpeter, 1934). This term encapsulated the idea of introducing new products, methods, new markets, securing the supply of material to be used and then continuing the establishment of the organisation. Schumpeter not only emphasised the importance of 'new combinations' but also 'discontinuities' which he argued could not be arrived by moderate changes to existing products or processes. Similarly, Schumpeter proposed the idea that technological change was dependent upon two factors, namely a change in the techniques used in production as well as the technology used to instigate any change. Furthermore, when technological change occurs it alters the relationship between economic "inputs and outputs" as it changes the different demands needed to perform and grow (Grübler, 2003, p. 40).

3.1 Characteristics of technological change

When discussing technological change, one of the key variables, which allowed industry and society to transform itself, was knowledge supported by a regular progression of inventions. Mansfield *et al.,* (1971) and Jewkes *et al.,* (1958) noted that once an invention (if or when it is registered) makes its inaugural debut, it can then be classed as an innovation. Notwithstanding, these inventions provide society, as well as industry, with a combination of new processes, range of skills, knowledge and products. Inventions are not always formulated by one solitary, creative inventor or 'genius' working alone but can emanate from many directions – R & D facilities [Research and Development], industrial research organisations, universities as well as individuals. Once an invention or technological knowledge is registered as a patent it can become or act as a barrier to any intending imitation or copying.

In the 1992 report compiled by the OECD [Organisation for Economic Co-operation and Development], attention was drawn to how a technical knowledge-base was derived from technological change. Moreover, key determinants within a geographical locality were instrumental in both the build-up and development of technological change which in itself is vital to the success of establishing a sound, technical knowledge-base. It is also important to note that the knowledge-base in an engineering setting will be totally different from a knowledge-base in a scientific institution. Firms such as Hattersley's were successful in accumulating a considerable pool of knowledge for the development of in-house skills and training. An interesting feature of the diffusion of technological change is the continual ability to improve or refine the product or the process. Arthur (1989) argued that by adopting one form of technology, such as a wooden hand loom, it would be possible to develop or refine this rudimentary textile machine further still.

Paradoxically, if the developer chose to abandon the initial product, such as the wooden hand loom, the result of this action could lead to the development of a new, improved product, such as the power loom, automatic loom or a rapier loom. Arthur (1989) continues to develop this argument by claiming that the technological change gains momentum because it follows a particular trajectory of diffusion or adoption. With this in mind, technological change can sometimes introduce radical inventions. Conversely, these in turn may jeopardise a firm's technical output because of the risky action and reaction to existing products and processes. Radical inventions replace existing products on the market. Sahal (1981, p. 20) commented that radical innovations are in existence because of 'numerous innovations' and the various stages of improved modifications which ultimately led to becoming one technological advance. It was Usher (1954, p. 68) who argued that the development of the steam engine was undertaken over a period of time and used several inventions which was provided by a host of different inventors:

> "The history of the reciprocating steam engine involves at least five strategic inventions: the atmospheric engine of Newcomen; the low-pressure engine of Watt; the high-pressure engine of Trevithick and Evans; the steam engine locomotive of Hackworth and Robert Stephenson; the compound engines."

Consequently, the radical invention can also produce de-skilling [reduction or elimination of skills] in a workforce as well as removing whatever financial funding has gone into the project. Such an outcome inevitably leads to an enforced period of anxiety in management and respective workforce (Hughes, 1987). The introduction of any radical invention can also provoke rival firms to amend any existing plans or policies to counter the introduction of radical inventions.

Any technological change brings forth potential advantages and conversely risks to firms, to the immediate market and to their respective competitors. The primary intention for any firm is to

recoup a profit on the costs of production of any new invention. Unfortunately, even though a new product entering the market can bring about advantages to the firm, it can also have the opposite effect, and lead to disadvantages or risks (Teece, 1986). Economic wealth may not be guaranteed in the short-term.

Freeman (1992) investigated how technological change impacted on the techno-economics of a country. An interesting example of such a ‘change’ would be the unifying of power and materials, namely steam and metal, which allowed technological change to develop into new areas. In textiles, wooden looms were replaced by cast-iron framed looms which were then powered by stationary steam engines.

3.2 The study of innovations

The area of innovation had been known since the eighteenth century but never fully investigated. It was not until the 1930s, when the subject of innovation began to be investigated accurately and accepted as an important area of research. Many theorists from different disciplines began to recognise its importance as a complex strand of study in such areas as business and economics. There was also an increased awareness of how useful it had become in stimulating the interest of economists, policymakers and industrialists (Dodgson and Hinze, 2000). Some researchers have discussed the significance of innovation as a two-way interaction between individuals and firms who will manipulate, exchange, refine or originate create new knowledge (Fischer, 2006).

According to Hall (2004), there are three main determinants - innovation, invention and diffusion - which are critical to the understanding of technological change in industry. These determinants were vital to the success of the development of the worsted manufacturing industry of Yorkshire.

In 1911, the economist, Schumpeter, outlined these key factors is his book entitled the *Theory of Economic Growth: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. He argued on the primacy of innovation as a major driving force in economic theory.

3.3 Schumpeter’s viewpoint of technological innovation

Swedberg (2007) has argued that Schumpeter’s theory on innovation, as well as entrepreneurship, continues to be the most interesting of all the theories that surround the topic of entrepreneurship. Schumpeter was convinced that any form of economic development had to be underpinned by a product or a process system. He opined that within the economic system there was what he called a ‘source of energy’ (Hanusch and Pyka, 2007). This ‘source of energy’ or innovation could alter or change the equilibrium of an economy.

The most important addition to the idea of an innovation was Schumpeter's 'entrepreneur' (derived from the French word *entreprendre*), which became central to his work on innovation. Schumpeter also considered the entrepreneur to be an economic agitator or innovator who became integral to the progress of '*any'* innovation. Furthermore, the entrepreneur had the ability to:

1) Demonstrate initiative or command mastery grip of a situation
2) To encourage new firms to develop
3) Engage with financial affairs when undertaking a task or project
4) Motivate to undertake a project and will continue exploiting it until it is completed or the entrepreneur deems it necessary to stop (Scherer, 1984, pp. 13-14).

The entrepreneur had the ability to manage, alter or develop new markets as well as influencing the consumers and altering perceptions of new products (Brown, 1992). Schumpeter (1912) argued that the driving force of entrepreneurs was to provide 'new combinations of knowledge' brought on by innovations when introduced into the marketplace. Following on from Schumpeter's work on innovation, Jamieson (1989, p. 505) stressed that the introduction of innovations and new technology has been:

> "influenced by a commercial bias [which] has come to mean the creation of new marketable commodities."

The ultimate aim of innovations was to dislocate or alter the equilibrium of the economic or consumer market. This altered equilibrium would be caused by a radical innovative interruption brought upon by entrepreneurs. Schumpeter was very clear about the versatility of the 'new combinations of knowledge' brought about by innovations (Schumpeter, 1912, 1934).

Schumpeter viewed innovations as being instrumental in initiating the following factors:

i) Launching a new product;
ii) Launching a new or original means of production;
iii) Establishing a new economic market;
iv) Acquiring a new supply of resources or raw materials;
v) Establishing or eliminating any monopoly or industrial system.

An additional advantage not mentioned by Schumpeter was the relationship between innovation and the creation of new occupations or jobs. Although innovations created new markets, they were also crucial to the direct setting up of new processes, the formulation and granting of patents, new methods of production and the formation of a workforce.

One example of how a pre-Schumpeterian innovation could alter a manufacturing industry came from the American inventor of the cotton gin, Eli Whitney [1765-1825], from the demonstration which took place in America.

In 1801, Whitney's experiment involved the dismantling and re-assembling of a number of artillery guns from a collection of interchangeable parts. This demonstration prompted the United States of America's Federal Government to order standardised, designed components for use in heavy military weaponry. What was particularly interesting was that Whitney's demonstration did not require any additional technical training, scientific research or research and development. Instead, Whitney's innovative vision demonstrated that manufacturing practices could be structurally amended or altered by careful thought and application. This reconfiguration of the manufacturing practices resulted in the beginning of the assembly line process (Woodbury, 1960).

In the history of economic research, it was Schumpeter who, in his writings, stressed the importance of entrepreneurs and innovations or 'new combinations' as the main driving force in a static economy (Schumpeter, 1934). The versatility of his interpretation of innovation had allowed researchers from different disciplines to interpret the subject of innovation according to the needs of their subject. Scholars have considered and conceptualised the subject of innovation and how innovation influenced productivity and growth. Since the term innovation was introduced by Schumpeter in the 1930s, there has been a plethora of diverse interpretations on the subject of innovation which have been developed in different disciplines (see Table 7).

Disciplines	Total	Dates
Business and management	18	1966 - 2007
Economics	9	1934 - 2004
Organization studies	6	1953 - 2008
Innovation and entrepreneurship	9	1953 - 2007
Technology, science and engineering	13	1969 - 2005
Knowledge management	3	1999 - 2007
Marketing	2	1994 - 2004

Source: (Bargheh, Rowley and Sambrook, 2009)

Table 7. Different definitions of innovation recorded between 1934 - 2007

The information in Table 7**.** clearly shows how different scholars have tried to define the meaning of innovation according to their disciplines. For instance, Thompson (1965, p. 2) noted that innovation was the "generation, acceptance and implementation of new ideas, processes, products or services."

Meanwhile, Rogers (1983, p.11) defined innovation as "an idea, practice or object that is perceived as new by an individual or other unit of adoption." Also, the Oxford Dictionary of Business and Management defined innovation as a 'new approach to designing, producing, or marketing goods that gives the innovator or his company an advantage over competitors' (Law, 2006).

Unfortunately, while all these definitions have their own merits, all the definitions exclude any mention of a timeframe which gives the impression that innovation occurs without any specified time constraint. What they all note, however, is the importance of 'newness' to an innovation. The OECD (2005, p. 31) has attempted to provide a definition of innovation which many scholars and institutions have generally adopted. They defined innovations as:

> "The implementation (commercialisation) of a new or significantly improved product (good or service), or process, or a new marketing method, or a new organisational method in business practices, workplace organisation or external relations"

This OECD definition brings together and extends Schumpeter's original contributions. Within the OCED definition are the four components which underline innovation - product, process, organisation and marketing. Two other factors remain very important which are input (measuring capacity) and output (measuring the results) (OECD, 2005). As in the case of all the definitions of innovation, the limitation in this model appears to be an absence of a definite time period in which an innovative design is released into a market.

One important, pioneering theorist, who had also delved into the area of innovation, was the sociologist, Rothwell (1992). Inspired by the earlier work of the scientist, Vannevar Bush (1945), Rothwell introduced his five generations of innovation based on what was happening in the United States of America. His first generation of innovation centred around the importance of technological developments in the areas of science and technology during the 1950s and mid-1960s. This is often called the linear model which follows innovation from the scientific input to design and engineering to production then marketing and then sales (Rothwell, 1994).

The second generation revolved around the importance and needs of the market which became the main impetus of the innovation processes. All this was dependent on the ideas that were being presented by the business market. The important factor here was that the market governed the ideas and needs required to govern Research and Development contributions giving rise to the expressions 'market pull' or alternatively, 'demand pull'.

In Rothwell's third generation of innovation during the 1970s-mid 1980s, emphasis was placed on the close consolidation between a firm's pool of knowledge, technological capability and the marketing process.

The fourth generation from the 1980s to the mid-1990s focused on the integration between the customer and supplier. A good example of this is the automotive manufacturing industry being able to introduce into the market new Japanese cars in a specified time (30 months) whilst American manufacturers took twice as long. This effect could be described as a disruptive effect in the market place.

The fifth generation from the 1990 onwards concentrated on the integration of different systems together with a stronger emphasis of networking within the market. Furthermore, the fifth generation articulates the changing nature of technological change (Rothwell, 1994). Different aspects on the theory of innovation began to be examined with from different perspectives.

3.4 Definitions of technological innovation - radical innovation - incremental innovation - disruptive innovation

In terms of economic growth and increased standards of living, technological change together with innovation, continues to play an important role in local, regional, national and international economies (Gold *et al.,* 1980). The interest and investigation into innovation has subsequently proliferated and developed into many areas of research, such as competence elimination versus competence improvement (Gatignon *et al.,* 2002), to technical innovation versus administrative innovation (Daft and Becker, 1978).

This section will examine the four types of innovation found in business - innovation - radical innovation - incremental innovation and disruptive innovation. All these types of innovations not only differ from each other but also have their own particular characteristics which determine future behaviour of products, processes or services when introduced into a company or business setting.

The two most important types of innovation are incremental [small scale] and radical innovations [large scale] (Hill and Rothaermel, 2003). Scholars have investigated and highlighted the differences between incremental and radical innovations and have found clear distinctions (Szymanski *et al.,* 2007). This distinction was attributed to the terminology which was used to describe how radical innovation was viewed from different disciplines.

Furthermore, a combination or multitude of diverse skills were required to differentiate between incremental and radical innovation (Holahan *et al.,* 2013).

Study	Terminology & Definition	Selected Examples
Tushman and Anderson (1986)	**Technological discontinuity**: Offers sharp price performance improvements against other technologies	Jet engines; transistors; float glass method in making glass
Henderson and Clark (1990)	**Radical innovation**: Based on a different set of engineering and scientific principles - to open up new markets and applications	Electrically- powered ceiling fans progressing to central air conditioning systems/units
Rosenberg (1994)	**Major innovation:** Provides framework for many innovations - dependent or complimentary to the original innovation	Electric power plants, transistors, computers
Helpman (1998)	**Radical innovation:**	Bronze, printing press, electricity, X-rays, radio, astronomy
Chandy and Tellis (2000)	**Radical product innovation:**	Quartz watch, fluorescent lamps and personal computers
Leifer, McDermott *et al.,* (2000)	**Radical innovation:** An established approach which offers the potential for improvement	Magnetic resonance imaging (MRI), cell phones
Dahlin and Behrens (2005)	**Radical invention:** Criteria often involving - novelty - uniqueness - future impact on technology	Oversized tennis racquet, wide bodied tennis racquet

Source: (Slocum, and Rubin, 2008)

Table 8 Definitions of radical innovations

3.4.1 The importance of Radical Innovations

No universal definition of radical innovation has been found in academic papers. (Dahlin and Behrens, 2005). This absence of definition was probably attributed to the fact that many other researchers, from different disciplines, have adapted their theories on radical innovation around their particular areas of interest. Scholars such as Baregheh *et al.,* (2009) focused their researches on price performance or cost which has subsequently grown in prominence and appears to be one of the key determinants affecting existing products or methods of production by means of radical innovations. What is important is that radical innovation can be seen as a departure from the norm or practices which are currently in use (Ettlie, 1983). Instead, when discussing radical innovation, researchers look to its attributes.

Shown in Table 8 is a list of definitions along with a selection of different examples of radical innovation which underlines the complexity of this concept and the difficulties in reaching a universal definition. This, however, does not preclude the researcher from understanding the variety of different examples of products produced by radical innovations. The importance of radical innovations proved useful in attempting to meet the requirements of the organisation, customers or end users and market (Jansen *et al.,* 2006).

Radical innovation could be examined on three different levels. They could be seen in terms of a new approach to technology (product), new systems of delivery or service to the user and finally a combination of both approaches (Tushman and Nadler, 1986). In order to understand or distinguish radical innovation (sometimes described as discontinuous innovation) two researchers (Dahlin and Behrens, 2005) have proposed three key characteristics:

i) Any invention must not bear any resemblance to any previous inventions and must reflect its novelty.
ii) Any invention must not bear any resemblance to any existing inventions and must continue to be novel.
iii) For the invention to be successful, it must be adopted so it has the potential to bring about a positive change to any future patented inventions (Success of this factor depends on enabling factors such as right time, markets and the culture being receptive to change).

When introduced into a market, radical innovation often carries a high risk (Kaluzny *et al.,* 1972). The introduction of *any* radical innovation signifies a departure from current methods or systems (Duchesneau *et al.,* 1979). In addition, radical innovations attempt to expand on knowledge that a company may not possess at a particular time (Danneels, 2002).

Radical innovation, or as it has been described a 'break from the past' (Garcia and Calantone, 2002), possesses the ability to remove or alter existing knowledge with new knowledge and novelty (Acs, Anselin and Varga, 2002; Strambach, 2002). This knowledge transformation will cause the company to structurally re-define itself by abolishing old-fashioned techniques and introducing new processing methods and new markets (Damanpour, 1991; Subramaniam and Youndt, 2005). An example of this reconfiguration would be the transition from traditional looms to power looms in a textile mill. Furthermore, a concerted effort by a firm involved with radical innovation must consider the formation of a learning strategy required by its workforce together with the creation of a knowledge base.

Radical innovations were considered different, novel and quite often very expensive when introduced as well as being prone to a high incidence of failure (Sandberg, 2011). Introducing radical innovations was often viewed as an aggressive, risky and complex reaction (Story *et al.,* 2014). One such adverse example could be seen during the agricultural revolution which took place in eighteenth century Britain.

During this period of upheaval, many innovations and practices, such as four-crop rotation, the introduction of new crops and the horse-drawn seed press, were introduced into farming which rendered many of the farmworkers, and their archaic practices, surplus to requirements.

Consequently, this caused an unexpected surfeit in redundant farm workers who could now be transferred or co-opted into the textile mills and factories which were beginning to sprout up in and around the new, burgeoning northern mills towns in Great Britain. With radical innovations proving risky when introduced, what tended to be adopted was the knowledge which had been generated. This knowledge and technological advancement proved to be more important as it could be subsequently gauged, applied and absorbed by rival competitors.

3. 4. 2 The importance of Incremental Innovations

Incremental innovation, which constitutes a greater part of innovations found in many industries, tended to be formed around resources and knowledge which were already in existence. As a result of this, incremental innovation, which extended or added a boost for more innovations, could be seen to operate in small, steady, refined steps which could be applied to processes, methods, systems and products. These gradual steps could also improve the operation, performance, efficiency and impact of the processes, methods, systems and products as well as reducing the costs of production or performance (Garcia and Calantone, 2002).

Moreover, one incremental innovation, in one part of a process, could affect another part of the process by the development of specific innovations such as the introduction of the automatic loom. These incremental innovations proved particularly effective when taking advantage of or exploiting knowledge which was currently available (Danneels, 2002; Subramaniam and Youndt, 2005). Furthermore, these steady, low-risk, incremental steps provide an improved commercial value to the product (Baregheh *et al.*, 2009). The benefits of incremental innovations were considered, by many economists, to be very important to industry.

Incremental innovations focused on products designed to make them more user-friendly, provided a guaranteed, regular supply, ensured the cost of production could be reduced as well as providing a product with an enhanced reliability and sustainability. One interesting feature of incremental innovations ensured that economic advantages and radical innovations were introduced and adopted. This feature could be seen with the introduction of electronic appliances such as televisions, computers and mobile phones. When these appliances were introduced into the commercial market, they were considered to be very expensive to buy and to manufacture. Over the course of time, incremental innovations have allowed these appliances to fall in price both in the sales and also in the manufacture (UNIDO, 2016).

3. 4. 3 The importance of Disruptive Innovations

Disruptive or disruption innovation was a phrase coined by Christensen, which continues to baffle the general public ever since it was introduced (Raynor, 2011). In a study undertaken between 1993 and 2016 on citations from many different academic disciplines, over 66,773 general type articles mentioned disruptive innovation (cited by Christensen *et al.,* 2018).

The origin of disruptive innovation arose from an anomaly entry of a 'product' into the market which was identified by Christensen (1997, 2006; Christensen and Bower, 1996; Christensen and Raynor, 2003). He discovered that certain factors in the computer disk industry were taking place during the period 1970-1990. In his research, he discovered that leading firms in the computer disk industry would react positively with an innovation if it improved performance. This fact was seen when a disruptive innovation was introduced into the computer disk industry which did not improve performance but had different specifications such as being smaller and lighter in construction, Christensen observed that the firms which had introduced these computer disks seemed to flourish whilst firms which had used and promoted the original type of disks did not succeed. Christensen applied this observation to different technologies and noticed that the same results would happen as had occurred in the disk industry. After examining a number of firms, Christensen concluded that many of these firms could flood their respective markets with products which were more sophisticated, smaller and cheaper than the customer required or the market needed. This over-sophistication of a product in a market created an opening and market share for new participants. Any market share remained a key indicator for any type of business. The consequence of the introduction of a new product caused some of the older, established firms to lose their long-established percentage of the total sales over a specified period of time. Even though disruptive innovation had been introduced by Christensen and has entered the business lexicon, there has still been a lack of agreement with any definition put forward.

Some scholars have argued that Christensen had never provided a universally-agreed definition. When using disruptive innovation, Terris (2006) claimed that users could not tell the difference between a product which was underperforming to an inferior performing product. Other critics of this viewpoint argue that disruptive innovation has been overused for any product which threaten the business market.

This over-reliance of Christensen's terminology may cause future researchers to use the term unwisely in their research work. Furthermore, it may cause some scholars to erroneously and indiscriminately build on Christensen's disruptive/disruption theory.

3.5 The definitions of invention and imitation

Since the early twentieth century, the concept of *invention* and *imitation* has preoccupied various key researchers including Pigou (1924), Schumpeter (1939), Schmookler (1960), Manchlup (1962), Kuznet (1962), Fagerberg (2004) and many others. Technological change continues to be underpinned by theories surrounding invention, imitation and innovation and the differences between all of them.

What has become apparent in academic research is that there appears to be no consensus between researchers on an agreed definition of invention. It was readily evident that there were so many different ways of defining the term depending on the nature of which academic discipline in which it was utlised. In many cases, great emphasis was made on the exceptional *genius* who had the ability to introduce new inventions into society. An early definition of invention was provided by the American curator and anthropologist Mason in 1895:

> "… finding out originally how to perform any specific action by some new implement, or improvement, or substance, or method … Every change in human activity, made designedly and systematically, appears to be an invention…" (Mason, 1895, pp. 13-14).

The concept of invention has been associated closely with creative activity in the field of technology. During the first part of the twentieth century, a number of researchers began to focus their attention on the concept of invention (Pigou, 1924; Hicks, 1932; Robinson, 1938), even though the term invention continued to be confused with the term innovation. It was approximately fifty years later when a researcher, Roland, submitted a paper to the journal *Technology and Culture* that the author attempted to comment and differentiate between the use as well as the different meanings of the terms *invention* and *innovation* (Roland, 1977). Soon after the submission of Roland's paper, the editor of the journal took a different approach and sent a reply to the author claiming, that in his opinion, the author's view on the subject of invention versus innovation was not generally accepted by many scholars, claiming that invention was only a small component of a greater part of innovation. Roland remained convinced that the term invention should possess its own definition and should be differentiated from innovation. In his paper entitled 'Problems of Definition' Roland stressed that it was advisable to:

> "…use the two terms invention and development with the understanding that innovation is part of development – along with testing and compromise. This way we can still use the terms invention and innovation in their traditional sense and, at the same time, apply them meaningfully to the process of development. Invention and innovation are relative. Context determines whether an idea is one or the other or both" (Roland, 1977, p. 511).

Since Schumpeter began publishing his work on the subject of innovation in the 1930s, interest and research into innovation and new technology revealed a correlation between the two and interest into the subject increased dramatically. Although much has been written on the subject since the 1930s, it appears that little or no universal agreement has been reached on a standard definition of innovation or new technology. Furthermore, it is not surprising to find that a variety of scholars from different disciplinary backgrounds have viewed and adopted the subject of innovation or new technology from their own perspectives.

3.6 The dual interaction of imitation and invention on innovations

Innovation, invention and imitation, or what Gabriel Tarde (1969) called 'fundamental social acts', are essential to economic growth and productivity. According to research undertaken by two researchers (Grossman and Helpman, 1991), technological progress was underpinned by two key determinants - innovation and imitation. The pairing of product and process had always been attributed to innovation whilst imitation had always been matched to risk-free plagiarism and taking or stealing existing practices or technologies from elsewhere. Further investigation often reveals a determination to introduce new products using the intellectual property of the knowledge base which is available. Consequently, the study of imitation may have been undervalued or neglected in place of innovation. Imitation has been considered to be a form of secondary innovation (Peng and Liu, 2003). Two researchers have commented that, on the whole, many firms, given the opportunity, would embark on innovations or incremental innovations which would be determined by cost. If imitations proved to be expensive to realise, the focus would be switched to developing innovations (Katz and Shapiro, 1987).

It is interesting to note that with the onset of economic development, certain countries such as Korea, Thailand and China have been labelled as following a strategy of imitation whereas economically-developed countries in North America, Japan, European countries and Australia, follow a policy of development and innovation (Acemoglu, Aghion and Zilibotti, 2002). Many developing or emerging countries used the process of imitation as a means of catching up to the major economically-advanced countries (Amsden, 2001). This situation could involve either direct imitation of the product or intellectually imitating the product. When Mansfield *et al.,* examined a number of patents, they discovered that 60% of all patents, which were considered to be appropriate for registration, were subsequently imitated four years later (Mansfield *et al.,* 1981).

Beginning in the late nineteenth century and through to the early twentieth century, the concept of 'invention' began to stimulate the interest of academics from different disciplines. Academic investigation soon discovered that from the fourteenth century till the beginning of the nineteenth century, the meaning of invention had been linked to the idea of '*newness*' (Malerba and Orsenigo, 1997) or more often than not, with novelty or something having novelty. Further research showed that by the mid-fourteenth century, the origin of the word 'invention,' was associated with 'a finding or discovery, namely with regard to knowledge, or science [knowing]' (Godin, 2008, p. 14).

In 1895, the American curator, ethnologist and anthropologist, Mason (1895, pp. 13-14) defined invention as:

> "…finding out originally how to perform any specific action by some new implement, or improvement, or substance, or method […] Every change in human activity, made designedly and systematically, appears to be an invention."

This approach to invention, was reflected in many of the works of many anthropologists, archaeologists and ethnologists at the time, and signified a belief that any technological progression could be equated with the development of society at large.

One of the first scholars to examine technological change was Schumpeter who took the concept of invention and incorporated it into his idea of the commercialisation of technological change. Even so, he seemed to 'downgrade' the importance of invention by arguing that the:

> "… making of the invention and the carrying out of the corresponding innovation are, economically and sociologically, two entirely different things…The social processes which produces inventions and…which produces innovations do not stand in any invariant to each other and such relations as they display is much more complex than appears at first sight" (Schumpeter, 1939, pp. 85-85)

Technological inventions and innovations were very useful but what was also required was a body of knowledge which would accompany any technological diffusion. Knowledge could be an awareness of the type of technology found elsewhere, the means of adapting other technologies from other sources and the dissemination of technical knowledge (Robertson and Parimal, 2007, p. 720).

Schumpeter still considered invention important and included it in his theory of technological change which he placed into three sections: invention, innovation and imitation (Johnston, 1966). Being an economist and social scientist, Schumpeter (1939, p. 84) perceived innovation in terms of an economic activity and argued that invention was not a prerequisite of innovation. He proposed that:

> "Innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation, but produces of itself … no economically relevant effect at all" (Schumpeter, 1939, p. 84).

The development of any form of new or improved technology always begins with the creative or inventive process (an idea, a sketch or a model for a new improved device) and then, if the invention is considered commercially viable, is followed by innovation, which will attempt to convert the concept into a commercial success (Freeman, 1974). It was Tann (2015, p. 94) who described invention as a "process; a new device or product; a new material technology, chemical or process, devised and developed with inspiration, study and experiment". Wiener (1996) has gone further and has broken down the act of invention into four key factors or steps which enables a product to be commercialised:

i) A creative process must be undertaken.
ii) Materials must be made available for new technology to be developed.
iii) A relevant communication channel must exist between what he calls the 'philosopher' and the 'artisan' [inventor and worker].
iv) The development of any invention relies on the person who is in line for financial gain must go on to create some form of 'economic value' or growth (Wiener, 1996; Toner and Tomkins, 2008, p. 169).

Kline and Rosenberg (1986) have put forward the argument that innovations need to go through a transition from adoption to exploitation. In their research they suggested that innovations may undergo many key transformations during their life cycle whilst inventions may prove to be economically more important in the latter stages of development than at the start of their evolution.

According to Schumpeter (1934, p. 66), any form of commercialisation of a service or product:

> "… begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process or service to the marketplace."

Invention or the concept of invention was viewed by some researchers as a two-part solution. This idea was consistent with Utterback's idea (1971) of invention which involves the creation of an idea as well as the problem-solving process. This notion has been taken further by incorporating it with the need to utilise existing knowledge. This in turn would make full use of the technical know-how or production facilities to fulfil this apparent need (Gopalakrishnan & Damanpour, 1997). Wilson went further and suggested went further and suggested that a sizeable quantity of technological inventions was simply the usage of previous or long-established skills (Wilson, 1958).

3.7 Technological Diffusion

Diffusion is an integral determinant whose central role cannot be underestimated. Research into the subject of diffusion has shown how important it is for gauging the spread of any successful introduction of technology as well as propelling any new product, services, management or practices into society or economies (Stoneman, 1985). In his writings, Hall (2004) noted that if diffusion did not take place or was absent, any innovation would not produce any economic effect.

Technological diffusion always starts with the introduction of an innovation (product, process or service) which is then 'spread' into society (Mukoyama, 2003). This viewpoint was further endorsed by Hall (1994) who argued that any technical or technological change always requires the direct input of innovations. Moreover, a time-dynamic speed factor and successful method adopted with diffusion will ultimately influence and contribute to the engine of economic growth as well as business success of a country or society. The successful diffusion of an innovation will not only have a profound influence on the economic growth of a society but will also have an effect on the decision-making of managers, marketeers, industrialists and policy-makers.

Rogers (2003, p. 5) made a detailed examination of diffusion in well over 508 studies and subsequently viewed this concept in terms of a "process in which an innovation is communicated through channels over time among the members of a social system" (Rogers, 2003, p. 5). From this extensive research, he formulated his theory on a unified definition which he presented in his influential book - *Diffusion of Innovations* - first published in 1960. Rogers argued that four distinct variables were crucial for any ideas to diffuse. These four important variables were innovation, communication channels, time, and a social system. Thus, his seminal research could be described as an attempt to investigate how these four key factors and other factors play a part in the adoption of a designated product or a process.

Rogers (1983, p.11) defined innovation as an "idea, practice, or object that is perceived as new by an individual or other units of adoption." For this to be spread or diffused and adopted, Rogers postulated the notion that communication was crucial for "messages [to] get from one individual to another" (Rogers, 1983, p. 11). This view point was refined by Rogers and Kincaid (1981) who emphasised that communication represented a two-way approach rather than a one-way communication. Furthermore, any communication which was diffused would provide the receiver with new *ideas*. Wilkening (1956, p. 361) went further and argued that the spread of information, which Rogers had demonstrated, could be broken down into three distinct strands:

1) Individuals or groups who begin a process of recognising any impending change of circumstances.

2) A process of decision-making by the individual or groups to decide the validity of adopting the innovation.
3) Once the innovation has been accepted, the individual or group could decide how to implement the innovation
4) Furthermore, diffusion could also be applied to the replacement of an older technology with a newer one (Hann and Jackson, 1981).

Technological change and innovation continues to reconfigure the influence of technology and innovations on business, markets and society. These two key determinants continue to command the interest of scholars, affording them with opportunities to extend their knowledge of the subject in new areas of research. Similarly, researchers will continue to debate the versatility and importance of concepts such as invention, imitation, and diffusion.

The use of the following terms, technological change, innovation, invention, imitation, and diffusion, all carry subject-specific definitions when used in different disciplines such as business, academia, economics, management and industry. In order to incorporate a definition which will be used in this research study, many different interpretations, taken from a multitude of disciplines, have been carefully consulted and considered. The variety of definitions which have been reviewed and selected support the development and understanding of the research matter. It is envisaged that an informed choice of selected definitions will allow the researcher to demonstrate clarity, provide a meaningful context as well as addressing any academic and historical disparities.

The selected definitions presented in Table 9. demonstrate some of the key features found in technological change, innovation, invention, imitation, and diffusion. Citations are located adjacent to the quotation provided. It is envisaged that these citations will give an understanding and interpretation to the material under investigation.

Selected Definitions	Sources
Technological change – "technological changes are envisaged as having taken place when a tool, a device, a skill or a technique, however unknown or well-known elsewhere, is adopted by an individual in a particular community and is regarded as new by members of that community."	(Hodgen, 1952, pp. 44-45)
Innovation– "an outcome and a process and is the implementation of new machines, processes; new systems and products, for financial gains or other benefits."	(Tann, 2015, p. 94)
Invention– a "process; a new device or product; a new material technology, chemical or process, devised and developed with inspiration, study and experiment ."	(Tann, 2015, p. 94)
Imitation– "Imitation is a common form of behaviour that arises in a variety of business domains. Firms imitate each other in the introduction of new products and processes, in the adoption of managerial methods and organizational forms, and in market entry and the timing of investment."	(Lieberman and Asaba, 2012, p. 366)
Diffusion– a "mechanism that spreads successful varieties of products and processes through an economic structure and displaces wholly or partly the existing inferior varieties."	(Sarkar, 1998, p. 131)

Table 9 Selected definitions of innovation recorded between 1934-2000

3.8 Summary

The investigation into concepts such as technological change, innovation, invention, imitation, and diffusion has continued to be an invaluable research tool for policy-makers, industrialists, technologists, economists and researchers. This chapter has examined and discussed some of the major contributions to the theories of technological change by many of the leading researchers and investigators. A review of the research published in many academic papers has shown that technological change and innovation have markedly benefited society as well as providing a positive and significant impact on trade, economic growth, knowledge, improved work skills, procedures and productivity.

The thought-provoking observations made by a number of the researchers in this chapter have also demonstrated how differing examples of innovation have now assumed a particular or specific role in business.

Other researchers on the subject have focused on the internal or external factors which may play a part in slowing the immediate entry of a product or restricting its success. Tariffs or costs are usually two key factors which hinder or assist in the favourable outcome of a product. Successes may be attributed to a number of different factors, not least a highly-educated workforce, a secure investment and an appropriate cost regime.

The result is organisational change as well as the re-design of a training or education programme with the expectation of an improvement in work skills. A close examination of the different factors which underpin the notion of innovation has shown that that there is no *one* perspective which explores fully the main determinants of innovation and how it affects the 'key inhibitors and exhibitors' (Kaur, 2010).

Chapter 4: The dynamic interdependencies of invention, innovation, technological change and diffusion in the Yorkshire worsted industry (1890-1939): A brief overview.

4 Introduction

This chapter will begin by discussing the historical development of the Yorkshire worsted industry. Furthermore, it will focus and examine two key objectives. The first objective will be to review some of the important inventions and innovations adopted and diffused in the Yorkshire worsted industry, between 1890 and 1939, from the ever-changing nature or dynamics of the cotton industry in Lancashire and abroad. This chapter will only examine and comment on the two largest Yorkshire worsted machine manufacturers - Hattersley's and Messrs., Prince-Smith and Stells Co., Limited (hereafter cited as Prince-Smith and Stells). The second objective will be to undertake two investigations of particular inventions and innovations which culminated in great commercial value for each firm.

4.1 The importance of invention, innovation and diffusion

The focus of the previous chapter was to examine how the development of any form of new or improved technology always begins with the creative/inventive process and that, if the invention is considered commercially viable, this is followed by innovation, which will attempt to convert the concept into a financially successful process or product. The chapter also briefly surveyed Rothwell's research in this area in which he identified that there were *five* generations of innovation in which each generation did not replace or remove the previous one, but instead, integrated itself to the next one, each stage impacting on a company's commercial competency and economic growth.

In this chapter, the two investigations on the Raper autoleveller and Northrop automatic loom will clearly show how closely aligned these machines are to Rothwell's first and second-generation step model taken from the 5-generational model.

The initial steps in the development of the Raper autoleveller can be seen clearly against the confines outlined in Rothwell's first-generation model, which he called the 'technology push model' [see Figure. 4].

Rothwell (1992) saw all the interlocking processes as a linear progression, from the creative side and through to the sales of the product.

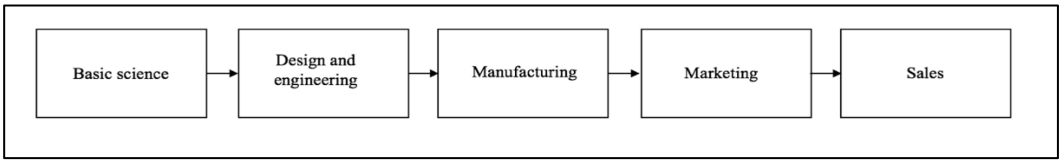


Figure 6. Rothwell's technology 'push model' linear progression seen in the development of the Raper autoleveller.

This diagram shows very clearly the linear progression of Rothwell's technology 'push model', and is an invaluable point of reference in understanding how the Raper autoleveller and Northrop automatic weaving looms could fit into his 'Interactive model' as there was a need for the product, especially in the American textile market. The development and promotion of the Northrop automatic loom was dependent on the firm of Draper Company which shared the vision and had full control of their inventors, the result of which was the subsequent marketing of the Northrop automatic loom.

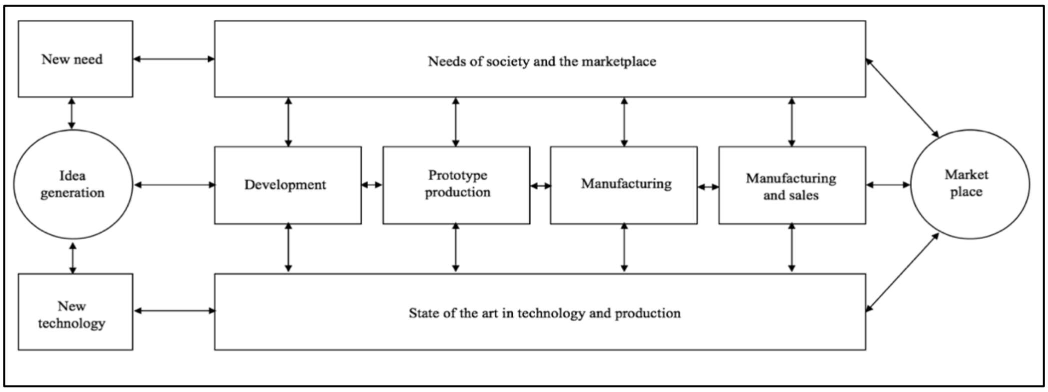


Figure 7. Rothwell's 'Interactive model' linear progression seen in the development of the Raper autoleveller.

In Figure 5. a more detailed outline of Rothwell's 'interactive model' shows the clear developmental stages from the initial idea stage to its final end stage into the textile market place. The many variables acting on the product at each stage reflect the rigour and quality checks needed to ensure that each new product progresses without too many fundamental issues and reaches the mutually-agreed standard required by the firm and the textile customer. Framed against Rothwell's 'interactive model' is a perfect understanding of the linear progression of the Raper autoleveller from invention to finished product.

4.2 The role of invention in the innovation of the Raper autoleveller and the Northrop Loom

In the previous chapter, the concept of innovation was briefly explored against the background of technological change and shown how it established itself once an invention had been registered. Mention was also made to how technological change is underpinned by the creative inventors whose inventions allow industry, commerce and society to transform itself.

The objective of this chapter is to investigate specifically the role of inventors in the innovation of the Raper autoleveller and the Northrop loom.

The first investigation looks at the Raper autoleveller and the lone inventor and the second investigation examines the invention of the automatic weaving loom, in particular the Northrop automatic loom, which integrated the collective efforts of a group of inventors [J. H. Northrop, C. F. Roper, W. F. Draper. G. O. Draper, E. S. Stimpson and J. W. Keeley] (Draper, 1905) who all worked on, developed and ultimately promoted the Northrop automatic loom.

These factors will become more apparent in the two short investigations and show how invention and innovation promoted the Raper autoleveller and the Northrop automatic weaving looms. Inventors and invention had been at the very core of the development of the Yorkshire worsted machinery. In an annual address at the Bradford Textile Society, Sir Kenneth Lee (Messrs. Tootal Broadhurst Lee Co., Limited) summed up the importance of research and invention by declaring that:

> "Invention has accomplished many things, no one of which has been ultimately to create unemployment. Rather the opposite. It has cut the cost of production and so enabled higher wages to be paid. It has multiplied the work each worker can do. It has reduced physical toll; it has increased the variety of goods men can make; it has increased the opportunities of employment" (The Yorkshire Post, Tuesday, November, 17th, 1936).

All the inventors involved in the Raper autoleveller and Northrop automatic weaving loom were assisted by entrepreneurs who furthered these inventions by commercial means whether this was by investment, marketing or direct involvement, development or exploitation of the machine.

While invention and innovation are clearly an integral part of this linear process, one cannot overlook the last determinant in the exploitation of a product which is diffusion. A useful interpretation and understanding of technological diffusion, as suggested by Sarkar (1998, p. 131), was a

> "mechanism that spreads successful varieties of products and processes through an economic structure and displaces wholly or partly the existing inferior varieties".

These three determinants - invention, innovation and diffusion - will provide a useful reference point to the historical background and explanation of the technological change which affected the Yorkshire worsted industry during the years 1890 to 1939.

4. 3 An historical overview of Yorkshire worsted industry

From the twelfth century onwards, wool and wool processing secured a prominent commercial role in Great Britain's wealth and growth. Up to the eighteenth century, wool processing had relied on a flourishing 'domestic system' sometimes referred to as the 'cottage industry' or 'outwork system', much favoured and practised in the rural heartland of Yorkshire. This system of work was highly dependent on a family structure where most of the processes, which were labour-intensive, were carried out in the family home or hamlet except for *fulling* which was one of the first processes to be mechanised by water power. [Fulling required the cloth to be scoured or washed to remove any impurities such as grease or natural oils from the fabric as well as stabilising the fabric before it was finished]. The original task of fulling involved the treading or walking on cloth which was immersed in water (Keighley, 2010). Mechanical fulling stocks, on the other hand, were water-driven and pounded the cloth with wooden hammers or stocks. These mechanical fulling stocks replaced human involvement and reduced the amount of time needed to *full* cloth than if a person was intensively engaged in fulling. Carus-Wilson maintained that in the case of the woollen fulling process, it had undergone a process of innovation during the thirteenth century which he classed as an "industrial revolution…destined to alter the face of medieval England" (Carus-Wilson, 1941). This notion that early mechanised fulling represented an 'industrial revolution' is perhaps too ambitious a statement as the process of fulling represents only one part involved in the processing of wool.

Although a woollen 'domestic system' of wool processing had existed from the twelfth century onwards in Yorkshire, in Lancashire, the 'domestic system' was eventually replaced by a workforce familiar with old forms of processing to one able to operate new textile machinery, innovations, organisation, techniques and a 'new mode of production' (Landes, 1969). It was during the start of the so-called 'Industrial Revolution' [c1780-1820] when the greatest rate of change occurred and invention and innovation began to take hold and radically alter the urban, social, industrial and economic landscape of Lancashire and much later Yorkshire, turning parts of it from an arable to an industrial county. Geels claims that collectively, society, establishments and technology all develop and progress in approximately the same period of time (Geels, 2005).

The successes of Lancashire's new work practices did not go unnoticed as within a short period of time, new innovations and modes of organisation were introduced, diffused and adapted from this region's flourishing cotton industry into Yorkshire. The early, innovative machines, which became revolutionary breakthroughs and played a dominant role in the textile industry as well as influencing the Yorkshire worsted industry, were Kay's flying shuttle [1733], Hargreaves' spinning jenny [1764], Arkwright's water-frame [1765], Crompton's spinning mule [1779], Cartwright's loom [1785], and Robert's power loom [1830].

At the onset of the so-called 'Industrial Revolution' [c1780-1820] Lancashire's textile engineering industry, looms and spinning frames were built in the local mills or factories and powered first by water, and eventually by steam. By 1814, textile machine engineering foundries began to appear both in Burnley and Blackburn supplying the local cotton industry with textile machinery (Lawton, 1955). Over a period of time, this idea of a local manufacturing textile machinery industry [Howard and Bullough of Accrington, Lancashire] supplying a neighbouring industrial town [Manchester] with cotton processing machinery was central to the success an important factor for the future development of the cotton industry. This arrangement of one industrial town supplying another industrial town with textile machinery eventually diffused into Yorkshire. Further diffusion led to industrial machine manufacturers being established in Keighley in Yorkshire by the early 1800s.

From 1800 onwards, the two most important worsted textile machinery manufacturers in Yorkshire were Prince-Smith (founded in 1795) and Hattersley's which were both based in the industrial town of Keighley. In 1931, Messrs., Prince-Smith and Son Limited., merged with Hall and Stells Ltd. Both companies continued to manufacture different types of worsted processing machinery, ranging from warping mills, spinning machines, to combing machines and weaving looms. These two worsted machine manufacturers, Prince-Smith and Stells and Hattersley's also began to invest time and effort into inventing and innovating their textile machines as well as supplying the local worsted manufacturers and, in the course of time, exported them around the world (Keighley, 2010). Moreover, the creation of new or improved worsted textile machines and innovations encouraged the growth of a textile manufacturing industry which arguably became the largest in the world until the beginning of the First World War [1914-1918]. Great Britain's lead in textile engineering markets was eventually eroded by the United States of America and Germany (Milnes, 1935, p. 373). Without the involvement of sustained diffusion, any innovative textile machinery would have had little or no direct effect on the local, regional or national economy (Hall, 2004, p. 2).

The role of diffusion and its impact becomes particularly significant when examining any process which demonstrates how an individual, institution or society adopts a new or improved technology. This scenario is also true when an older technology is replaced with a newer one (Hann and Jackson, 1981, p. 10). Indeed, much of the mechanical invention of these years was simply the result of utilising technical skills (Wilson, 1958). This skills-base, technical and mechanical understanding of worsted textile machinery became evident with the many incremental innovations patented by Prince-Smith and after their merger in 1931, Messrs., Prince-Smith and Stells and Co., Limited. Even so, many areas in worsted production still continued to be influenced by machinery invented and built outside Yorkshire.

In Heaton's book - *the Yorkshire Woollen and Worsted Industry* - from the earliest times up to the 'Industrial Revolution' (Heaton, 1965, p. 323), he noted that: "when the big textile inventions had proved their worth in the cotton trade they were adopted very slowly in the West Riding industry."

This reluctance by many mill owners to integrate new textile machinery into Yorkshire, machines such as the Northrop automatic loom and ring-spinning machine, continued from the last quarter of the nineteenth century and into the first quarter of the twentieth century. Worsted manufacturers continued to be suspicious of new, diffused machinery which was not Yorkshire-made. Instead, they chose to buy or use existing Yorkshire-made machinery as they considered it to be the best in the world. This situation is notably due to a Yorkshire sense of British supremacy of textile machinery that the northern textiles areas had enjoyed from the so-called 'Industrial Revolution' [c1780-1820] to the beginning of the First World War [1914-18].

By the early twentieth century, Yorkshire had moved away from the Lancastrian-based machine influence. During this time, textile machines were substantively automatic and very reliable. The reliability found in British and foreign-made textile machines were creating new work patterns and practices especially found in Continental Europe. During the 1920s, Dutch textile firms were imposing a forty-four hours working week. Czechoslovakia introduced a forty-eight hours working week (Textile Manufacturer, October, 28th 1928, p. 353). In order to do this, it was important that textile machinery needed to be robust, efficient and not prone to breaking down.

One area of improvement to further increase the machine's efficiency / reliability and make the fibres more parallel was in the area of drawing, a key process in the worsted weaving process. It reduces the *sliver* from thick, rope-like sliver into a thin or reduced sliver. The main (and most popular) type of drawing used in the Yorkshire worsted industry was the Bradford, English or Open system. This drawing system used a variety of wools which had been oil-combed and of a fixed length. The Bradford, English or Open system was in competition with many other foreign-based methods of drawing. One such method was the French, Continental or Porcupine system which tended to concentrate on short wools which had been processed without the addition of oil-based combing (See Table 10.).

Open Drawing	Continental Drawing
Sliver is best controlled by twist	Sliver is twistless
No mechanical control	Porcupine control
Draft of wool sliver with oil	Draft sliver better without oil
Humidity not required	Humidity becomes necessary
Different size of bobbin on different machines	Same size of bobbins on several machines
Single end found on bobbins	Two ends found on bobbin
Reduced doubling	Uniform doubling
Drafts controlled by fibre length	Draft is never exceeded
Sliver gradually is reduced	Sliver is drafted quickly

Source: (Brearley and Iredale, 1980)

Table 10. Table showing the difference between the Open and Continental drawing used when drafting wool sliver.

Although there was an American system or gill drawing, the adopted methods found in the worsted industry tended to be either the Continental or the English worsted system of drawing.

In 1929, Prince-Smith and Stells introduced their new system which they called the Anglo-Continental worsted drawing system (see Table 11.). This system of worsted drawing attempted to process wools which were not of a standard length and were still oil-combed but could be mixed in with dry-combed wools (see Table 11.).

O. P. S. Creel	24 small balls
Intersecting Gill Box	2 heads 2 balls
Intersecting Gill Box	2 heads 2 balls
1st Drawing Box	5 heads 5 balls
2ndt Drawing Box	10 heads 10 balls
3rd Drawing Box	7 heads 14 balls
4th Drawing Box	10 heads 20 balls
Reducing Frame	5 24-spindle

Source: (The Textile Manufacturer, April, 1933)

Table 11. A typical set of worsted drawing machines used in the Anglo-Continental system

The set of worsted drawing system would be for 8 to 25 drams per 40 yards. Unfortunately, this new system of drawing introduced by Prince-Smith and Stells proved not to be successful and was short-lived in usage. Although Prince-Smith and Stells managed to add certain refinements into the Anglo-Continental drawing system the English system proved to be ideal for lustre type yarns whereas the French drawing system continued to be suitable for short wools. One feature which proved essential was the continual use of humidification for both oil-combed and dry combed tops (The Textile Manufacturer, April, 1933, p. 149).

4. 4 Messrs., Prince-Smith and Stells and Co., Limited., in the 1930s

During the 1930s**,** Prince-Smith and Stells attempted to solve the problem that had long pre-occupied the Yorkshire worsted industry. The problem stemmed from a lack of young workers entering the spinning profession as well as a realisation that there was a declining birth rate which was compounded by a school-leaving age which had been raised.

To address these challenges, mill owners introduced the larger yarn packages in worsted spinning as a means of eradicating the problem of staff shortage or at least lessening the perceived difficulty (The Textile Manufacturer, May, 1933, p.183). In introducing these new measures, larger spinning packages would reduce stoppages when doffing. This, in turn, would result in a reduction of doffers. With fewer workers, the manufacturer could introduce more spindles which in turn would ensure lower wage bill. Even so, Prince-Smith and Stells realised that different worsted manufacturers spun yarn with different counts. Consequently, it would be impossible to construct one machine which could accommodate every spinning situation. To overcome this problem, Prince-Smith and Stells introduced three ring spinning frames - ‘Parawind’, ‘Velox’ and the ‘Magnum’.

The introduction of these three worsted ring spinning frames was also a direct challenge to the existing cap, mule or flyer spinning frame found in Yorkshire worsted mills or factories. Even though the ‘Magnum’ spinning frame could operate at the same spinning speed of a ring or cap spinning machine, the ‘Magnum’ was shown to be quite versatile. It could spin counts from 48s to 56s at 6000 rpm or counts from 48s to 70s at 6000 rpm onto paper tubes.

The ‘Velox’, on the other hand, could spin single yarns of 40 counts or for finer yarns up to 58 counts onto paper tubes. For heavy worsted yarns up to 48 counts, the spinning frame would operate at 4000 rpm Prince-Smith and Stell’s third spinning frame the ‘Parawind’ was used to spin from 48 to 70 counts. Depending on the range of counts which were being spun, the spinning frame could run at a speed of 6500 rpm (The Textile Manufacturer, May, 1933, p.183).

Many Yorkshire firms, such as the ones listed in Table 12. began to concentrate on dedicated worsted processing machines such as worsted combs [Holden, Lister and Noble], carding machines [Prince-Smith and Stells] or weaving looms [Hattersley’s].

Types of Comb	Types of Wool used in combing
Lister Comb	Lustre wool and hairs
Holden Comb	Fine crossbred wools and merino of good staple length
Noble Comb	Coarse low crossbreds to fine merinos
Rectilinear Comb	Shorter wools of fine crossbred and merino quality

Source: (The Textile Manufacturer, January, 1956)

Table 12. Type of wool used on different combs

4.5 Messrs., Prince-Smith and Stells and Co., Limited., and spinning frames

Soon after the merger of Messrs., Prince-Smith and Sons Limited., with Hall and Stells Ltd., in 1931, the chairman of the new company, W. Prince-Smith, stressed:

> "that it had been impossible to secure any return on capital invested… [and now they would be] …in a much stronger position to fight foreign competition and to take up new lines that appear suitable" (The Yorkshire Evening Post, February 27th, 1931).

A few months later, the Leeds Mercury newspaper reported that Prince-Smith and Stells claimed that they were 'the only firm in the world of any importance, who devote[d] their entire activities to the manufacturing of worsted machinery' (Leeds Mercury, September 14th, 1935).

Whether this claim is true will always remain open to discussion and require further research. Prince-Smith and Stell's output was concentrated on wool-combing, spinning and drawing machinery. Furthermore, the publicity department of Prince-Smith and Stells promoted the idea that, in some situations, Prince-Smith and Stells had secured foreign contracts on the strength of the 'high quality of the product' manufactured by the company which, in turn, was a testament to the high standards and skill that the British workforce possessed (Leeds Mercury, 14th September 1935). This publicity made a huge impact on many Yorkshire worsted manufacturers who preferred to rely and invest in British-made goods or machinery and continued to do so for many years (Keighley, 2010). Furthermore, the Yorkshire worsted manufacturers were content to rely on a 'British' work approach which would draw primarily on the worker's skill on a machine such as a comb or mule rather than the American notion whereby the machine was the dominant force and the worker would forego his skill in place of the machine's efficiency.

The mechanisation of spinning was to undergo numerous trials before the introduction of different types of spinning frames into the worsted industry which were found to be ideal for new fibres, man-made or different qualities of fibre which were required by the domestic and overseas markets. Lancashire was the neighbouring geographical area where many of the textile machines and spinning inventions had been invented and then slowly diffused and adapted into Yorkshire.

Spinning frames such as flyer, cap, mule and ring [the four main types of spinning frames found in Yorkshire] were selected for the kind of results they could achieve as well as the types of wools with which they were best suited.

The Yorkshire worsted industry tended to specialise in spinning both long staple Colonial and British wools (Keighley, 2010). This Colonial and British centrism was different in France where short wools were favoured and processed. In France, the spinning mule was the main machine used whereas it was only used in the British wool industry when spinning the short fibres used in textile manufacturing. This disapproving view of using the spinning mule in British mills was contradicted by J. H. Bates of Thomas Ambler and Sons, Ardsley. In an enlightening address given at a Bradford Textile Society meeting, he pointed out that:

> "… mule spinning was carried on in England not because we were imitating France … mule spinning increase of plant in this country was a necessity because spinners found there was a much larger outlet for mule-spun yarns in England than English machinery could supply … it was the sincere intention of British spinners to try and cater for the trade of our own country…" (Textile Journal, 1923, p. 43).

The adoption of the ring spinning frame was an innovation which seemed to lag behind in both the cotton and worsted industries. It took a long time before it was eventually introduced into the worsted industry in 1832. Even though it underwent many improvements during the 1870-1880s, it was not readily accepted by Yorkshire worsted manufacturers. The ring spinning frame worked on the principle that the imparting of twist and winding on of yarn was achieved by the circular and continuous movement of a traveller or small metal clip. In mule spinning, the action was intermittent and twist was imparted by spindles and rollers. When the ring spinning frame was introduced in Britain, it was handicapped by the spindle speed which was determined by the speed of the traveller. If the traveller was subjected to a greater speed than the one at which it was supposed to run, it would generate heat and fly off. Excessive speeds would also cause the traveller to succumb to wear and tear. This problem was eventually resolved with the introduction of the self-lubricating ring. The ring spinning machine continued to be viewed as having certain inherent problems. Yorkshire worsted spinners considered that the spindles on a ring spinning machine could only run effectively at a maximum speed of 5000 rpm and spin yarns that had counts which ranged from 16 to 36.

Ring spinning frames used in British mills or factories, according to Yorkshire spinners, needed to spin fibres that were under 40 counts and anything above 40 counts could not produce a superior result which the British spinner could obtain from mule spun yarn (Jewkes and Gray, 1935, p. 121). In a research paper of 1981, Lazonick concluded that in 1913, 87% of ring spinning frames could be found working in American cotton mills or factories whilst in Britain only 19% adopted it (Lazonick, 1981).

4. 6 Messrs., George Hattersley and Sons Limited., - inventors

This section will only briefly examine the inventive skills of certain inventors who worked at Hattersley's and made key discoveries or breakthroughs.

The twentieth century saw a significant number of Yorkshire inventors emerging from firms such as Hattersley's and producing a wide variety of textile looms and warping machines which were not only for the domestic market but also for export. It is interesting to note that certain ex-employees of Hattersley's went on to invent a range of dobby mechanisms, preparing, warping and weaving machines for the Yorkshire worsted industry and much later, the American textile industry [A fuller discussion and explanation of Hattersley inventions, innovations and machinery manufacturing output will be discussed in Chapter 7].

Hattersley's, the firm which claimed in their publicity literature to be one of the oldest worsted weaving machinery manufacturers in Yorkshire, also proved to be a 'creative hotbed' for innovation. Among the inventors was Frank Leeming who began his career with Hattersley's, after a while, left to set up his own company. When his company closed, he moved to Messrs., George Hodgson and Sons Limited., Frizinghall, Bradford. After leaving their employment, he spent the next eleven years, until his retirement, with the British Northrop Loom Co Ltd., as their Yorkshire representative. During his long career, he invented many loom mechanisms, including the Leeming Box Motion and the Leeming rotary dobby. Most important of all, his dobby was fitted onto the Northrop automatic loom (Shipley Times and Express, 15th May 1937) the result of which was this dobby made a significant contribution to innovations in weaving and cloth production.

Simeon Schoon Jackson was another ex-Hattersley's employee who played an important part in the Yorkshire and American worsted industry. For 30 years, Jackson was employed with Hattersley of Keighley in Yorkshire. Whilst with them, he invented many loom improvements for worsted weaving looms ranging from compensating head-gears to pick-finder devices. In an interview given to the Yorkshire Evening Post in the late 1920s, he explained that he had worked at the Hattersley works where he had his "…first experience in the making of automatic looms" (Yorkshire Evening Post, Monday 10th October, 1928).

By 1904, he had left Hattersley's and began working at the Stafford Company of Readville in the United States of America. Whilst Jackson was with them, he invented the Stafford automatic shuttle-changing loom. When interviewed in 1928, he recalled that:

> "…it has been on the market in America only two years when we got a big half million-dollar contract to supply 1,100 of the looms to the Dan River Mills, in Virginia. The loom has been very extensively used ever since chiefly in cotton weaving, although it is applicable to fine worsted weaving. The machine was taken up in this country only in March this year" (The Leeds Mercury, September 11th, 1928).

One inventor, whose original contributions to weaving are often overlooked and yet were ground-breaking, was Jas Hill who began his career with the firm of T. and M. Bairstow, Sutton Mills, near Keighley in Yorkshire. By 1867, he left to join the firm of Hattersley's and patented over a hundred inventions which continued to make incremental improvements in weaving and proved to be of commercial value. Some of his patents included the Keighley dobby [an easy to use mechanism which allows a greater variety of weaves], the rising box loom, the skip box loom and the coating loom (Bradford Daily Telegraph, 30th December 1898).

4. 7 Investigation 1: Raper autoleveller

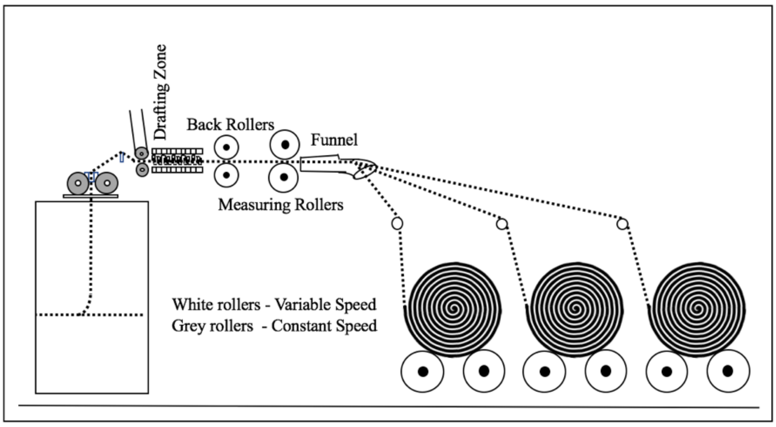
For many years, worsted combers, drawers and spinners had been continuously faced with a lack of fibre control supplied by a textile machine's front rollers. The end result was that these rollers could not guarantee a constant delivery of sliver which was regular in thickness and the weight equally distributed (Prince-Smith and Stells, 1954, p. 1). During the worsted combing, drawing and spinning stage, the fibre ends, found in the wool top, continued to remain or become irregular and this problem increased as the fibre was converted into a yarn (The Textile Manufacturer, 1953, p. 9). One of the earliest attempts to resolve this irregularity of fibre ends appeared in an American patent (US 305,654) registered to Abel Atherton in 1884 (Wegener and Bechlenberg, 1961).

A considerable time elapsed before any attempt was made to resolve the problem of irregular thickness and uneven weight found in the processed sliver. In 1937, George Raper, the Director of Isaac Holden and Sons Ltd, Bradford, decided to find a solution to this problem of inconsistent delivery of sliver which had persisted in causing irregular fibre thickness and an uneven weight distribution. Farnie (1965, p. 83) recorded that that the original idea of working on this problem came from an encounter Raper had had with 'a combing overlooker [who had] tried to teach him how to detect variations in the thickness of a sliver by touch'. Raper realised that, in the case of hand-spinning, a draft was provided and controlled by the experience of a spinner. On further examination, Raper concluded that the draft was dependent on what type of fibre was passing between the spinner's fingers or drafting zone (The Textile Manufacturer, 1953, October p. 9).

In 1937, Raper undertook an extensive world tour of the textile industry. On his return, Raper took the decision to resign his directorship of Isaac Holden and Sons Ltd, Bradford and began work on trying to reduce the irregular variations found in combed top sliver thickness (Birmingham Post, Sept 22, 1954). Although he held a degree in engineering, he felt it necessary to learn the practical skills of fitting and turning. This was the period in Raper's life when he began working on this project in an attempt to solve the many variations, found in combed top sliver. The task he had set himself proved arduous and there were times when Raper almost gave up. When interviewed by the Birmingham Post (Sept 22, 1954), he recalled that 'I was down to my last £120 and applied for a job in New Zealand. Luckily, I did not get it, for shortly afterwards, two firms began taking an interest."

After two years of intensive research, he came up with a solution which involved developing "a simple wheel and groove through which the sliver ran, the wheel feeling the thickness."

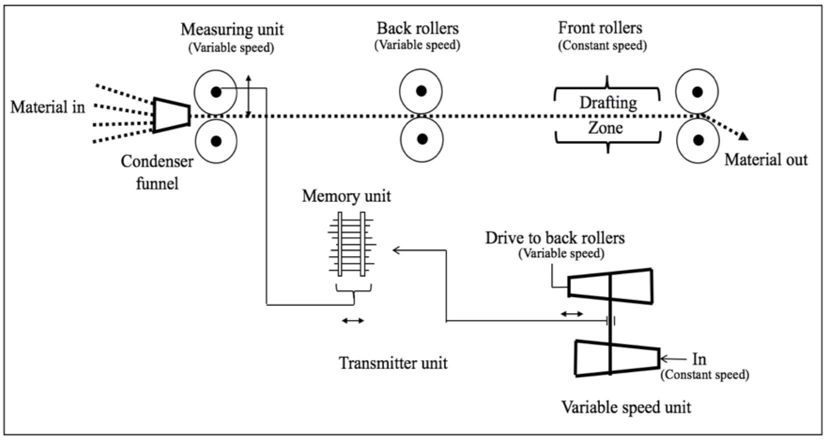
(Keighley, 2007). A side elevation of the Raper autoleveller is shown in Figure 6.



Source: (Prince-Smith and Stells and Co., Limited., 1954)

Figure 8. Side elevation of the Raper autoleveller.

The operation of the Raper autoleveller which the Textile Manufacturer described as a "selective drafting device" (October, 1953, p. 24) involves taking the sliver from the creels and then guiding it through the funnel towards the measuring rollers. At this point, these rollers begin to measure the cross-sections of the sliver which are moving towards the drafting zone. Recordings are made of any variation in the thickness in the sliver in the form of a 'pattern line' found in the relay unit. All recorded variations are kept until they reach a pre-determined point situated in the drafting zone. Once this is reached, the recorded cross-section of the sliver is relayed to the transmitter unit. The transmitter unit's function is to control the variable speed. Furthermore, the unit which controls the variable speed also regulates the draft on the Raper autoleveller by carefully adjusting the back roller speed. A schematic representation and progress of the fibre showing all the component parts of the Raper autoleveller is shown



Source: (Prince-Smith and Stells and Co., Limited., 1954)

Figure 9. Schematic representation of the component parts found on the Raper autoleveller

"Trials under mill conditions" (Keighley, 2007, p. 100) were to last for four years. The success of Raper's invention ensured that the drawing process would have many advantages. These would include a reduction of the processing of the sliver from seven or eight operations to two or three, less employees were required, the amount of waste was lessened, a reduced amount of power needed and less space required to install the Raper autoleveller (Oxtoby, 1987, p. 71).

By 1951, Raper's invention was licensed to the Textile Machinery Makers Ltd [a collection of cotton and worsted machine manufacturing companies who merged together in 1931]. Moreover, the company of Patons and Baldwins Limited., [manufacturers of knitting yarn] began a series of trials on the Raper autoleveller, or as it was originally known the 'Pressure Drafter', in their mills or factories (Tolson, 1954, p. 128). Two years later, Prince-Smith and Stells started to manufacture 'pre-production models' of the Raper autoleveller.

In an interview given to the Yorkshire Post newspaper, R. Chiles, the Managing Director of Messrs., Prince-Smith and Stells remarked that there was an intense battle amongst textile manufacturers for international markets and he hoped that this new mechanism would propel Britain ahead of its international competitors (The Yorkshire Post, 22nd September 1954). By the time the Raper autoleveller was put into full-scale production by Prince-Smith and Stells over 177 Raper autoleveller units, each costing £4,000, had been installed in British and overseas mills or factories (The Yorkshire Post, 22nd September 1954). By 1960, the figure had risen too over 7,000 Raper autoleveller units had been installed (Keighley, 2007, p. 101). Table 13. shows the different countries across the world which adopted and successfully used the Raper autoleveller in their respective industries

Raper autolevellers used in Europe	Raper autolevellers used outside Europe
Austria	Argentina
Belgium	Australia
Denmark	Canada
Eire	Chile
Finland	China
France	Egypt
Germany	Formosa (now Taiwan)
Great Britain	Hong-Kong
Greece	India
Holland	Israel
Italy	Japan
Norway	Mexico
Poland	New Zealand
Portugal	Pakistan
Spain	Peru
Sweden	South Africa
Switzerland	United States of America
U. S. S. R	Uruguay

Source (Keighley, 2010)

Table 13. Raper autolevellers purchased and used in and out of Europe

The national and international success and diffusion of the Raper autoleveller, described by the Textile Manufacturer (August, 1949, p. 363) as a 'brilliant invention', resulted in G. F. Raper, the inventor of the mechanism, being awarded the 'Yorkshire Gold Medal' in 1955. This medal was devised and gifted by an Addingham architect Mr. William Hoffman Wood who bequeathed £1000 in his will for the most valuable invention unconnected with warfare as well as to stimulate the interest of inventors and introduce new inventions. (The Yorkshire Post, 10th August, 1936). Raper was to eventually witness the realisation of his invention turned innovation, and when interviewed, sounded a cautionary warning that:

> "if the inventor, or his firm, can finance a small plant on revolutionary lines, and use the invention himself instead of trying to sell it to the whole industry, he will have more success" (Keighley, 2007, p. 103).

Following the presentation of the Hoffman medal at Leeds Civic Hall, The Lord Mayor of Leeds, Alderman Sir James Croysdale commented that 'we need brains in industry and anybody who could assist in improving the methods of industry deserved praise' (The Yorkshire Post, 4th November, 1955). This praise was reflected in the Textile Manufacturer (June 1955, p. 275) who reported that the Raper Autoleveller was considered to be "one of the most important developments in the past hundred years in wool textiles".

4.8 Investigation 2: From hand-loom to automatic weaving

With the arrival of the so-called Industrial Revolution [c.1780-1820], the Yorkshire worsted industry began a period of slowly coming to terms with the upheaval it had caused as well as the many new working practices and technological innovations which were being introduced. New factory towns were expanding, concurrent with a rapid upsurge of new technological innovations at a rate unimaginable fifty years previously. An evolving workforce began to migrate towards new employment opportunities.

The result was that this workforce had to forsake their traditional working practices for new, designated work schedules in factories. This transition resulted in many workers replacing their familiar homesteads and traditional work practices to working on new machinery and living in filthy and overcrowded accommodation with little or no sanitation.

Weaving continued to be essential in worsted fabric construction and industrial production. Furthermore, weaving in Great Britain had been mainly undertaken on large, cumbersome wooden hand-looms which were labour-intensive, slow in output and required the weaver to work at home. To mechanise these hand-looms, certain operational features had to be investigated and improved before they could be transferred over to a power-loom. For progress to occur, weaving loom speeds as well as linking up all the different mechanical movements found on the hand-loom had to be modified or improved. Before the 'fly shuttle' was invented in 1733 and introduced in weaving by John Kay of Lancashire, 'draw-boys' would lift the warps to allow the weft to go through the warp shed. It is believed that these 'draw- boys' could average twenty picks a minute. With the introduction of the 'fly-shuttle' the labour force was subsequently halved but most important of all, this new weaving mechanism allowed the weaver to weave fabric of different widths, increased the speed of weaving and produced a greater output than had been managed previously.

Inventors from Great Britain and Continental Europe produced different types of looms which were adequate but they did not resolve how to incorporate the many key operational features required for a mechanised loom. The inventor who is credited with inventing the power-loom was, Dr. Edmund Cartwright [1743-1823], who patented his idea in 1785. He decided to replace what had come before with a shuttle which would allow the weft to traverse across the warp by mechanical means. His first few attempts proved unsuccessful, but eventually, he designed a power-loom which consisted of a series of cams, levers and eccentrics which substituted the physical weaving actions of the weaver by mechanical means.

Once power-looms were introduced, the output of woven fabric was significantly increased and greater control of weaving was achieved by mill owners. Notwithstanding, the Yorkshire worsted industry continued to be slow in the adoption of the power-loom despite the continual improvements to weaving looms. Although the power-loom proved to be revolutionary, in its day, it was not accepted immediately into the Yorkshire worsted industry. Heaton (1965, p. 357) claimed that the power-loom took a firm hold in Yorkshire mills or factories between the period 1836 to 1845.

From the beginning to the end of the nineteenth century, many loom patents were registered, reflecting the many ingenious approaches undertaken by inventors to improve different mechanism on the loom such as shedding motions [1803], weft fork [1831], an early example of shuttle changer [1834], improved weft fork [1841], loom brake [1845], automatic let-off [1857] in an attempt to increase the efficiency of the loom. In the same year, the Keighley machine manufacturers, Hattersley's launched a dobby shedding machine which they called the 'Keighley' dobby or 'Heald machine' [a mechanical heald lifting device] which allowed the weaver to weave intricate weaves which could not be obtained from existing loom mechanisms.

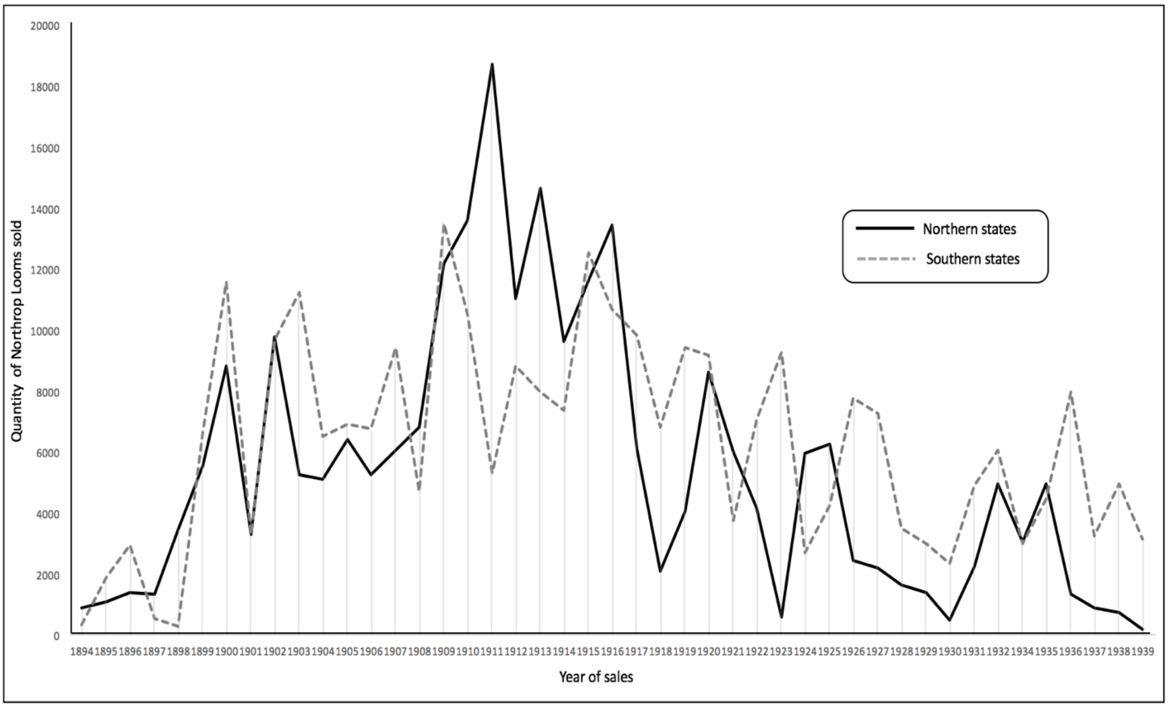
The company embarked on resolving one of the outstanding problems which had long troubled weavers. This was the replenishment or replacing of weft when it was exhausted following a period of weaving.

The replenishment of weft was particularly important to weavers as many of them would have had to oversee a maximum of three to four looms and the unforeseen breaking of the yarn would necessitate the stopping of a loom and time would be lost in joining the broken yarn and then starting up the loom again to continue weaving. The weft fork patented in 1841 by Kenworthy and Bullough, was a revolutionary mechanism which was used to detect any weft which snapped during a period of weaving.

During the nineteenth century, Yorkshire textile machinery, especially weaving looms, had been steadily gaining an international reputation. In support these claims, some of the British press continued to assert that the Continental European worsted weaving looms were inferior in quality to British-made looms. Yorkshire newspaper reports mentioned that German machinery was simply 'a copy' of English machinery [claiming that German firms] filed the parts of an English machine into patterns which actually retained the marks and numbers of the English maker' (The Leeds and Yorkshire Mercury, Monday, October 21st, 1901). From 1890 to 1939, many well-established Yorkshire machine manufacturers such as David Sowden and Son Limited., (est. 1856), George Hodgson Limited., (est. 1849), Samuel Dracup and Sons Limited., (est. 1825) and John T. Hardaker Limited., (est. 1890) continued to develop and patent looms, jacquards and dobbies.

Across the Atlantic Ocean, during the first quarter of the twentieth century, technological progress and new methods of mass-production were taking place, promoted by firms such as Henry Ford, Eli Whitney, Isaac Singer and Cyrus McCormick. These new, innovative techniques had originally evolved from the American small arms industry whose methods were soon applied to the sewing industry and bicycle industry. In order to obtain a seamless inter-industrial integration or transfer of one method into another, close collaboration needed to be forged between the manufacturers of machine tools and other manufacturing industries. During this ‘transference’, any technical problems would be examined, resolved and the knowledge and experience would be communicated to the recipient machine makers. Eventually the mass production methods used by Henry Ford [1863-1947], Eli Whitney [1765-1825], Isaac Singer [1811-1875] and Cyrus McCormick [1809-1884] began to be adopted by other firms throughout the United States of America (Hounsell, 1985).

In 1895, the Massachusetts textile firm of Draper Company, a leading manufacturer of high-speed ring spinning frames, introduced to the cotton industry arguably their most important invention - the Northrop automatic loom, sometimes called the ‘wonderful loom’. [An automatic loom was a loom which could replenish a new ‘weft or filling’ for a spent cop or broken thread]. The inventor, who was instrumental in the invention of the Northrop loom, was an ex-Hattersley’s employee called James Henry Northrop [1856-1940] who had emigrated to the United States of America in 1881. During his time with the Draper Company, Northrop invented and worked on many loom devices including the Northrop automatic loom. By the end of the year, approximately 300 looms made by the Draper Company were working in the American cotton industry (Textile Recorder, 15th May, 1895, p. 12).



Source: (Feller, 1966)

Figure 10. Sales of Northrop automatic looms in US Northern and Southern States

Although the Northrop automatic loom continued to be widely used in the cotton mills of United States of America (41,700 looms) other countries also began to purchase and use these machines. One scholar has argued that the determinants which influenced the purchase and use of Northrop automatic looms centred around the fact that more factories were being built in the deep south in the United States of America and that the type of fabric woven tended to be coarser (Feller, 1966, 1974). The countries which had been influenced and then imported Northrop automatic looms were countries such as Canada (488 looms), Switzerland (38 looms), Russia (100 looms) and Mexico (99 looms), had been convinced by the Northrop's weaving commendations (Keighley, 2010). At the start of the First World War [1914] the number of Northrop automatic looms, found in American cotton mills (see Figure 10.), had increased to 286,000 looms. This innovative loom was fitted with a warp-stop motion which was very accurate when applied, as it did not depend on weights and lever as it was designed with a positive let-off, a feeler motion and an original bobbin winder (Draper, 1905). All these features ensured that the weavers did not have to intervene when stopping the loom to replace a spent cop. During the period 1840 to 1890, thirty-one patents were filed in an attempt to solve the problem of shuttle replenishment on a loom. Twenty-three patents had originated from England while only eight had been filed in the United States of America. Every single one proved to be inadequate or unsuccessful in application (Mass, 1989, p. 894). By 1905, the Draper Company were promoting their up-to-date Northrop automatic loom which had a number of additional weaving features such as a "warp stop-motion with a simplified knock-off, a double fork to prevent thick and thin places, the simplest take-up ever devised…improved Draper-Roper let-off and a new device called the Anti-bang [a mechanism which prevents a breakage if the shuttle gets caught]. We call it [new Northrop loom] the J model" (Draper, 1905, p. 40).

During the last quarter of the nineteenth century, the local British press had been generally very complimentary about American textile inventions, extoling their excellence in construction, although they continued to insist that "hundreds of American mills [were] almost entirely fitted up with Keighley machines" (The Leeds and Yorkshire Mercury, October 21st, 1901). Unfortunately, this disinterest continued to be reflected in the British northern textile areas of Lancashire and Yorkshire (The Todmorden Advertiser, July 19th, 1901). Within a decade, over 200,000 Northrop automatic looms had been accepted and incorporated into American cotton mills (Copeland, 1911, p. 747). Whether it continued as a consequence of British disinterest or resistance, this stance persisted right through into the twentieth century. Berg takes the view that "technological change and the expansion of manufacturing took shape with this diverse climate of enthusiasm and resistance." (Berg, 1994, p. 6) Enthusiasm from American mill owners began to accept the Northrop automatic loom as opposed to the continual resistance of the British textile manufacturers which seemed to be content with their existing machinery, improvements to machinery or just relying on their old or worn-out machinery. It is recorded that by 1914 that 40% of all looms in the United States of America had switched over to being automatic looms whereas in Britain, only one to two percent were automatic.

The introduction of the Northrop automatic loom proved to be a valuable deterrent to an occupational health problem which had beset American and British textile weaving firms. This problem was colloquially known as '*failing to catch the cop'* and involved female weavers sucking the thread from a new cop through the eyelet of a shuttle to replenish it if the shuttle was spent (The Textile Manufacturer, January, 1934). All manner of contaminants were inhaled which spread the transmission of contagious diseases such as tuberculosis and deformities to the mouth. These weaving practices were beginning to cause some concern. This practice was later dubbed '*shuttle kissing'*. The innovative Northrop automatic loom according to research was supposed to eliminate these problems. Dale et *al.,* (2007), claimed that it was not until 1910 when the Northrop automatic loom was modified which ended the dangerous practice of '*shuttle-kissing'*. Although the innovative Northrop automatic loom was to eventually diffuse into the textile industry, 80% of these unhygienic practices of '*shuttle-kissing'* continued in Lancashire until 1937 (Cotton Factory Times, June 18th, 1937). This problem was not as acute as it was in Lancastrian mills because in Yorkshire, weaving firms used smaller shuttles which could be manually threaded by the index finger and thumb. If this *mal* practice of '*shuttle-kissing'* did continue, the likelihood is that this would only be found in the weaving of fine worsteds or if angora weft was being used to weave fabric (The Textile Manufacturer, January, 1934).

The popularity of the automatic loom continued to rise and by 1936, had risen to 36% whilst Britain interest had risen to approximately 3% (Mass and Lazonick, 1990). Even so, resistance in acquiring Northrop automatic loom continued and it was some years before the Yorkshire textile industry would accept a percentage of Northrop automatic loom in its mills.

During 1901, two other British made-looms were introduced into the British textile market. These two looms went onto to rival the Northrop automatic loom. The ‘self-shuttling’ loom was invented, patented and manufactured by Hattersley’s in Keighley in 1901 and was entered the textile industry during the 1904 Bradford Exhibition. It was also claimed that this loom “was the first automatic loom to be worked commercially in this country… and has passed the experimental stage” (Leeds Mercury, 27th May, 1904). The Lancastrian loom to rival both the Hattersley’s and Northrop automatic loom was invented by Bernard Crossley of Burnley. Each of the three looms had been designed to replace the spent shuttles by different mechanisms.

In the specially-built Northrop automatic loom, a spent cop was immediately replaced into a shuttle when a weft thread was broken. On the other hand, the Hattersley loom, replaced the spent shuttles in approximately 2 ½ seconds. Instead of the shuttle remaining on the loom, a mechanism allowed the loom action to slow down and then the shuttle would be quickly ejected and then replaced by another shuttle from the side. Hattersley’s had patented their weft-replenishment device in 1900 [Pat. 22, 253]. The Lancastrian Crossley or Burnley loom was even quicker than the Hattersley and the actions of removal and replacing the shuttle were activated from a double door located at the base of the loom.

Both British loom manufacturers claimed that they were cheaper than their American rival and both shuttling mechanism or the replacement of the spent shuttles were versatile enough to be added to any loom in mill or factory use. All three looms tasked with replacing spent shuttles ensured that the weaver could oversee 16 or more looms. Moreover, the cost of weaving and time allocated to replace the spent shuttle would be significantly reduced. Certain Yorkshire critics also argued that for the Northrop automatic loom to perform at its best, it was necessary to have good warps and weft (The District News, April 19th, 1907).

The British textile industry (cotton or wool) seemed initially to prefer their own, home-built looms as opposed to the American Northrop automatic loom. The Textile Weekly (June 14th, 1929, p. 381) noted that:

> “England thinks she is the only country which is right and all the others are wrong. Our Tommy is the only one”.

This arguably unfounded belief that British textiles industries seemed to know what was best was a view not taken up in Continental Europe. In Continental Europe, countries such as Holland, Germany, Belgium and Italy, who had adopted Northrop automatic looms, would employ weavers to oversee from 32 to 40 looms Northrop automatic loom whereas in the United States of America this figure would rise to 72 looms per weaver (The Textile Weekly, June 14th, 1929, p. 381). In the northern textile areas of England, the trade unions had insisted and restricted weavers to oversee up to 24 automatic looms. Furthermore, in Continental Europe, the Northrop automatic loom was weaving sixteen hours out of twenty-four hours a day. According to one report in the Textile Manufacturer (1928, October, p. 353) an Italian firm “ran 1600 looms with thirty-two weavers on one cloth for twenty-four hours [and the] night shift is run in darkness with one man for ninety-six looms.” The northern British textile industries did not or chose not to run their looms like their foreign competitors. Many weaving manufacturers noted that the Northrop automatic loom were underpick looms. With this being the case, it was appropriate for the installation for weft mechanism whereas the Lancastrian cotton manufacturer would require a large expenditure to buy the entire loom as their cotton looms were of the overpick kind (Burnley Express, 10th July, 1901).

Midgley, of Bradford Technical College, was also highly critical of claims made of new methods involved in automatic weaving. On closer examination, Midgley noticed that automatic looms could only accommodate one uniform size of spool or cop which was unsuitable when using it on a worsted spinning frame (The Yorkshire Post, July 31st, 1924). Furthermore, Yorkshire manufacturers were highly critical that the early types of Northrop automatic looms were unable to work on any pick-and-pick product (Rainnie, 1965, p. 81).

In a lecture given to Bradford Textile Society, A. F. Fletcher laid great emphasis on the fact that unlike Lancashire where the automatic loom was judged on the quantity of production, Yorkshire worsted processors gauged the viability of having an automatic loom on the ‘low cost of production’. Although Fletcher, highlighted many good points about automatic looms such as cop changers, the simplicity of the weft replenishing mechanism, the efficiency of the loom and the number of looms that could be overseen by one weaver, he commented on the apparent resistance to the automatic loom. He believed that this resistance to the automatic loom came from trade unions, weavers and overlookers (Fletcher, 1931/34, p. 36). In a question-and-answer session at the end of the lecture Professor Midgley remarked that Bradford processors suffered with different sizes of spools which could range from 3 ½ to 7 inches in size. This lack of standardisation on Bradford textile machines would prove difficult if automatic looms were to be used. It was felt by northern textile processors that they would have to invest a considerable amount to re-equip their weaving sheds.

At this time, there was a widely held belief that British engineering know-how was superior to American engineering. This point was reinforced by one newspaper in Yorkshire who optimistically praised the superiority of Yorkshire engineering in a short article:

> "Meanwhile, there is every case for satisfaction that England will not be outstripped by America in a branch of engineering for which Yorkshire - and Keighley in particular - has so long been celebrated" (Leeds Mercury, 21st October, 1901).

Across in Lancashire, one correspondent sent to the local paper - Burnley Express (3rd July, 1901) his impressions of choosing or endorsing British automatic looms:

> "I may say I have seen both [Hattersley and Burnley loom] the above looms at work and consider the Hattersley loom by far the best, although it is only fair to say that its first cost is much higher than that of the Burnley invention".

The innovative Northrop automatic loom, with its weft replenishment mechanism, was introduced into the textile industry in 1895 and by 1930, 90% of all American weaving companies were using them as opposed to 5% in Britain. The diffusion of techniques or products such as the Northrop automatic loom stimulated great strides by many foreign companies to develop a version of their automatic looms. This diffusion of new textile machinery allowed foreign companies to invest and stimulate a demand for their products.

The Swiss textile firm, Rüti, brought out their own version of the Northrop automatic loom whilst Japanese companies, such as Toyoda and Sakamoto, were able to demonstrate their automatic loom with a weft replenishment mechanism.

Many developments were undertaken to refine different mechanism found on the loom from underpick, automatic weft replenishment, automatic loom stop motions, positive and negative let-off motions. Although the Northrop automatic loom was to prove an important advance in loom design when it was introduced, further advances and development were considered essential to increase efficiency and productivity. By improving the efficiency and productivity of the loom the textile weaving manufacturer hoped that the production costs would be reduced.

Developments in loom design continued with their emphasis on efficiency, versatility, reliability and speed. Aspects of the weaving loom were continually investigated, improved and developed. This outcome may have been attributed to rising costs in manpower, reliability of loom design as well as the continual competition from foreign competitors.

The weaving process was radically altered; from once having a wooden shuttle at the heart of its operation, the new machines had evolved into '*shuttleless*' weaving looms. Two modern approaches were now adopted. In the direct method, the weft is propelled by air, water or solid friction. The weft in the indirect method is carried by a bullet or gripper projectile.

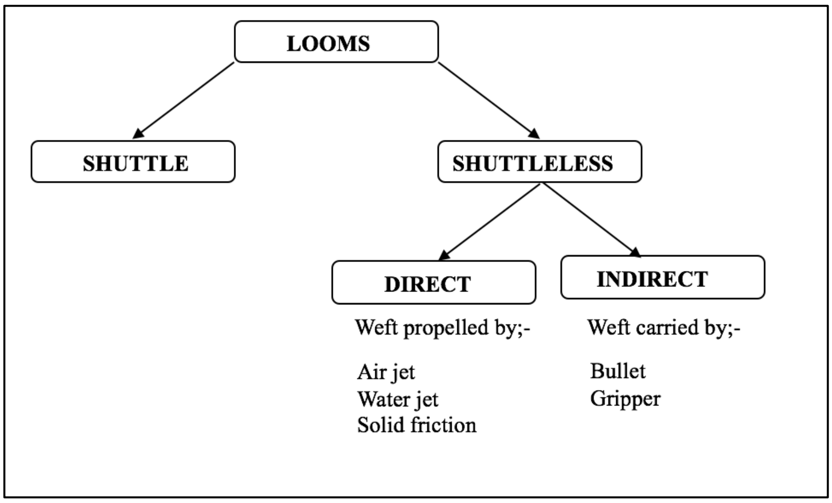


Figure 11. Illustration showing the future developments of the weaving loom after 1939.

After the Second World War [1939-1945] loom speeds or the production in picks per minute were increased and ranged between 160 and 195 picks per minute. These weaving looms were manufactured by companies such as Hattersley's, British Northrop Loom Co., Limited and Crompton Knowles Loom Works. Continental European manufacturers such as Dornier, Sulzer and Saurer also increased their weaving loom speeds from 160 to 280 picks per minute. Furthermore, weaving widths on looms were also increased. Many other mechanisms on shuttle looms were also investigated and improved such as the warp let-off, weft insertion, picking, cloth take-up, warp shedding, stop motions for broken warp or weft which incorporated a weft fork as well as warp drop wires. Mechanical systems controlling these mechanisms were slowly replaced by electrical systems which would stop the loom.

4.9 Summary

Invention, innovation and diffusion have assumed an important role in the Yorkshire worsted and machine manufacturing industry. In the early days of pre-industrial and post-industrial revolution, Yorkshire's textile industries were dependent on Lancastrian machines and inventions. Cotton was being processed in certain parts of Yorkshire so Lancastrian machinery did not need a fundamental refinement. Later on, techniques and processes changed and textile machines were developed and created purely for the worsted industry.

Technological inventions and subsequent innovations were very useful but what was also required was a body of knowledge which should accompany any technological diffusion. Knowledge could be an awareness of the type of technology found elsewhere, the means of adapting other technologies from other sources and the dissemination of technical knowledge (Robertson and Parimal, 2007, p. 720).

Yorkshire machinery makers were fortunate that the main invention and subsequent innovations in worsted combing were undertaken in the mid- nineteenth century. These economic circumstances and Britain's primacy in this industry allowed the market to be controlled and developed, not least by the Yorkshire-based worsted technology which was exported all around the world. Over time however, as foreign competitors secured a foothold in this trade market, circumstance were to challenge Yorkshire textile industry dominant position. Countries such as Germany, France and the United States of America eventually superseded the Yorkshire textile machine manufacturing industry when they introduced their own textile machinery. This forced the Yorkshire textile machine industry to replace their existing machinery with superior, new machinery - Northrop for weaving and French or Rectilinear combs for Noble, Holden and Lister combs. In the case of worsted combing, this also involved the changeover from wet combing to dry combing.

Yorkshire traditionalists and worsted processors were convinced that machines which went faster did not mean that they were better or more efficient. Furthermore, the foreign competition which the Yorkshire worsted industry, manufacturers and processors alike, had to face was a competitor who had invested in up-to-date equipment. In the case of American competitors, they were prepared to invest in their machinery owing to the fact that their workforce costs were higher than the Yorkshire textile industry. This lack of investment by Yorkshire industrialists was shown clearly by the fact they were still operating from buildings that had been built in the nineteenth century. German and American competition had invested in research whereas the Yorkshire textile industry tended to neglect or leave it to some enterprising inventor [G. F. Raper] to realise some invention which would eventually be exploited (James,1990 p.140). Industrial production and industrial supremacy in Britain continued to slip whilst other countries began to compete and ultimately dominate the British market. In 1899, general figures for British textiles accounted for 40% of trade. By, the late 1930s, competition from abroad had reduced this figure to 20% (Tysznski, 1951, p. 283).

The United States of America industry and technology had been slowly rising since the end of the end of the American Civil War [1861-1865] and by the turn of the twentieth century had eclipsed Britain's industrial position (Chandler, 1980). The Official Report on the Paris Universal Exhibition 1867, concluded that the British wool industry could slip behind its competitors if they did not keep up with new work techniques. Noted engineers like Charles Siemens (1883-1883), complained that British employers, especially those who had been involved in engineering, seemed to be ‘more prejudiced against innovation than his foreign counterparts’ (Dintenfass, 1992, p. 14).

Industrial ‘conservatism’ was deeply-rooted in the worsted and machine manufacturing industries. Machine manufacture was clearly impeded by systems, methods and technology which were considered antiquated. This gradual demise of British industry was echoed by Toynbee (1939) who declared that this:

> “technological handicap [will be] gauged by the plight in which our British industry finds itself to day.”

The *PEST* analysis framework tool will be used in subsequent chapters to assess how different external factors influenced and impacted on the worsted textile trade. The Political, Economic, Social and Technological external factors form the key determinants in the standard *PEST* analysis framework tool. In this research, a Geography determinant has been added to the importance of the locality on this nascent industry.

Chapter 5: Invention, innovation, technological change and diffusion: A case study of the Yorkshire worsted manufacturing industry (1800-1939)

5 Introduction

Carr has reasoned that:

> "History consists of a corpus of ascertained facts. The facts are available to the historian in documents, inscriptions and so on, like fish on the fishmonger's slab. The historian collects them, takes them home, and cooks and serves them in whatever style appeals to him" (Carr, 1961, p. 23).

This chapter discusses the different influences which contributed to the rise, development and progress of the innovative, technological changes and diffusions that occurred in the Yorkshire worsted manufacturing industry at around the time of one important British historical watershed period, which some historians have labelled the 'Industrial Revolution'. In the 'Age of Manufactures', Berg deconstructs the phenomena of industrial development which she refers to as a "period of transition" (1985, p. 9). The chapter will conclude with an analysis of the worsted industry in Yorkshire using the *PEST (&G)* framework.

Clark (2005) has argued that between 1760 and 1860 there were four different revolutions which took place more or less at the same time. He claimed that these revolutions were: - 'Industrial Revolution', 'Demographic Revolution', the 'Agricultural Revolution' and the 'Transport Revolution,'

This chapter will examine only the aspects of the so-called 'Industrial Revolution' which affected the Yorkshire worsted industry and a selection of the key innovations which occurred during this period. Pollard (1998) has called into question the continual use of the term 'Industrial Revolution'. He argued that investigations into the subject would find the use of the phrase 'Industrial Revolution' to be an event which had *not* taken place. Other researchers were also interested in examining the definitive time period of the widely-accepted dates denoting the 'Industrial Revolution'.

Palmer and Armitage (2014) looked at the timeframe between 1760 and 1815, a period firmly within the dates which commonly denote the so-called 'Industrial Revolution', and termed it the 'Age of the Democratic Revolution.' During this period of dislocation, societies throughout Europe and America saw their old traditions being systematically eroded whilst being replaced by the rise of an urban, industrial society. The period commonly referred to as the 'Industrial Revolution' also swept away, or as Berg (1985, p. 5) called, it an imposed "*euthanasia*" onto the domestic or cottage system of manufacture and replaced it with the factory system. Along with the creation of the factory system came the disruption in the quality and volume of home-based textile processing. In a Textile Institute Jubilee Conference address, Sir Walter Puckey noted that the so-called 'Industrial Revolution' introduced a number of adverse factors:

> "…the large factory under one roof, the break-up of family relationships, the division and degradation of labour [and] it introduced the machine…" (Puckey, 1960, p. 450)

Geraghty also added that when factories were introduced, new systems were implemented and featured:

> "… more intensive supervision; new compensation schemes based on time rates, fines or bonuses; and disciplinary systems that attempted to balance worker incentives …" (Geraghty, 2003, p. 538).

The so-called 'Industrial Revolution' ensured that all production as well as the home locality were switched to a designated environment where specialist processing activities would be carried out (Weber, 1920). Mathias took this idea further and when he argued that the so-called 'Industrial Revolution' was not really a revolution but more of a collection, sequence or series of factors which affected the '*status quo'*. In other words, he defined the so-called 'Industrial Revolution' as "a fundamental redeployment of resources away from agriculture" (Mathias, 1969, p. 2).

This chapter will also briefly examine the importance of some of the transformative innovations before and after 1800, within the period of the so-called 'Industrial Revolution'. The relevance of patents and exhibitions in the promotion of worsted innovative technology will also be discussed and the chapter will provide a conclusion of the findings.

5.1 The importance of the 'Industrial Revolution' to worsted processing

Hudson (2004) recorded that during the course of the eighteenth century, the West Riding of Yorkshire grew to dominate the British production of woollen and worsted cloths, yarns and machinery. This domination soon eclipsed the importance and production which had emerged from the older centres of East Anglia and West Country. Up until 1770, Norwich had secured two distinct advantages in worsted processing. Firstly, this town, prior to 1770, was described as the:

> "second [city] in the kingdom" and on the "point of opulence, commerce, manufacturers, and number of inhabitants" (Oldfield, 1792, p. 288).

Secondly, the worsted industry had become very important providing the county of East Anglia with great prosperity as well as holding the country's premier position in worsted production. This point was confirmed by Baines who noted that Norwich was viewed as "the seat of the chief manufacturer of the realm" (Baines, 1970, p. 121). The organisation of the Norwich industry had become centred around its guilds and their sales markets, which were not yet fully developed (Lloyd Prichard, 1951). The Yorkshire worsted industry, on the other hand, had the advantage of having a readily-available, cheap labour force. Furthermore, Bradford had the capacity to produce fabrics which were less expensive. Norwich had looked to foreign markets as a direct response to the competition from the Manchester cotton industry. Seeking to outperform their northern competitor in these new overseas markets, little did they realise that a greater challenge lay ahead. The Napoleonic wars (1793-1815) were an unexpected commercial disaster which plunged the Norwich worsted trade into a crisis (Lloyd Prichard, 1951). Its intended markets were now compromised. Other external factors were also instrumental in undermining Norwich's premier position as a worsted processing centre. Intense competition and cheaper worsted fabrics being manufactured by Yorkshire's mills as well as raw materials which had to be bought in from afar became economically unviable. To compound the situation further still, the rising population in the northern counties were in sharp contrast to Norwich's falling population; paradoxically, many of the weavers from Norwich decided to migrate to the places where worsted cloth was being woven (Keighley, 2010). This resulted in the loss of its commercial markets. Sugden (2016) recorded that in England and Wales, the demographics of the workforce showed that over ninety per cent of fathers worked in worsted processing.

The rise of the West Riding of Yorkshire as an industrial centre for worsted textile production was, according to Jenkins, determined by the so-called 'Industrial Revolution'. This, in turn, formulated the industrial system which had then brought about what is now known as the factory system (Jenkins, 1993).

One of the key determinants throughout the eighteenth and nineteenth century was the continuation of technical development and breakthroughs in textile machinery. As the factory system progressed, it began to play a crucial part in the formation of a structured, worsted processing industry, brought together by the introduction of mechanised, innovative technology and the specialisation of different industrial processing tasks under one roof.

One of the difficulties for any historian is to put forward propose a universally-accepted date for the period known as the 'Industrial Revolution' which took place in Yorkshire. Rostow maintained that the economic growth during the so-called 'Industrial Revolution' occurred between 1783 and 1802 (Rostow, 1960). He labelled this period as the "great watershed in the life of modern societies" (Rostow, 1960, p. 7). A number of researchers such as Jenkins have pointed to 1780 as being the start date for the mechanisation of carding and scribbling which was important to the processing of woollens (Jenkins, 1993). Jenkins choice of this specific date would appear to be purely arbitrary as Richard Arkwright had already brought out a patent for an improved carding machine in 1775 which encompassed a crank and combing mechanism

(Vasudevan, 2005). Moreover, during and after 1780, some worsted or woollen processes, such as spinning and weaving, were still being undertaken by hand in spite of mechanisation and the introduction of the factory system. The German philosopher, historian and revolutionary, Friedrich Engels (1820-1895), summed up the progress of the so-called 'Industrial Revolution' on the country as a sequence of graduated, improving technical steps instead of a rapid progression (Engels, 1993). Crafts put forward the argument that Britain was "already relatively industrialised" by the first quarter of the eighteenth century (Crafts, 1985, pp. 61-62).

5. 1.1 Technology

One of the earliest diffused technological machines, which entered Yorkshire during the onset of the so-called 'Industrial Revolution', was Hargreaves' spinning jenny. As the spinning process become mechanised, the impending consequences was that the process would eventually replace both hand-spinning and intermittent spinning by a single band wheel, cottage or great wheel introduced in England c1298 (Born, 1977). A key development of the spinning wheel came later with the Saxony wheel with the flyer and treadle board, invented in c1520. The advantage now was the treadle board on the Saxony wheel allowed the spinner to spin and wind wool continuously as well as regulating the draft with both hands and imparting twist to the spun yarn (Baines, 1970). According to James, the reason why spinning machines were introduced in 1780 was as a direct result of the quantity of yarns required by weaving looms used in Yorkshire (James, 1857).

For weaving looms to operate at their maximum and profitable efficiency, there was a requirement for an abundance of unbroken spun yarn to be available. The insufficient quantity and quality of yarn became critical and many of the mills in Yorkshire had to go as far as East Anglia to meet the demand (James, 1857). Engels (1993, p. 18) noted that:

> "…this invention [spinning mule] made it possible to deliver more yarn than heretofore. Whereas, though one weaver had employed three spinners, there had never been enough yarn, and the weaver had often been obliged to wait for it, there was now more yarn to be had than could be woven by the available workers... Now that the weaver could earn more at his loom, he gradually abandoned his farming, and gave his whole time to weaving ..."

Although spinning jennies, invented by James Hargreaves of Lancashire, were to become popular in Yorkshire after 1790, there were still technical problems with the processing of yarn. Worsted yarn was much stronger than other processed fibres and because of the robust nature of worsted yarn, there was a tendency for it to cause a considerable strain on the workings of the spinning jenny which Moykr has labelled this as a "micro invention" (Moykr, 1990, p. 13). To circumvent this problem, Clapham argued that:

> "worsted lent itself in a way that woollen did not to the process of spinning worked out by Arkwright [in Derby using water frames]" (Clapham, 1907, p. 141).

The mechanisation of spinning was based upon the introduction of different types of spinning frames into the Yorkshire worsted manufacturing industry. These were found to be ideal for new fibres or different qualities of fibre which were required by the home and overseas markets (Clapham, 1906). Lancashire was the neighbouring geographical area where many of the textile machines and spinning inventions had taken place and then slowly diffused and adapted into Yorkshire. Although many of the textiles machines were originally made of wood, a change of construction began to take place. As Mantoux (1961) noted, innovation in metal processing throughout the industrial areas accelerated the transition from wooden-based textile machines into all-metal textile machines. Spinning frames such as flyer, cap, mule and ring were ideal and selected for the kind of yarn results they could achieve.

The Yorkshire worsted manufacturing industry tended to specialise in spinning both long staple Colonial and British wools. Spinning was different in France. They preferred short wools. Consequently, different approaches to spinning had to be adopted. In France, the spinning mule was used whereas it was only used in the British wool industry when spinning the short fibres or noils. Processing the short wools was found in the woollen industry. This view or perception of using the mule was contradicted in an address given by J. H. Bates of Thomas Ambler and Sons, Ardsley at a Bradford Textile Society meeting. He reflected that**:**

> "… mule spinning was carried on in England not because we were imitating France … mule spinning increase of plant in this country was a necessity because spinners found there was a much larger outlet for mule-spun yarns in England than English machinery could supply … it was the sincere intention of British spinners to try and cater for the trade of our own country…" (Bates, 1923, p. 43).

The processing of spinning became an important factor for the domestic and overseas market. Furthermore, with ever-changing choices of fashion and design, attempts were made to accommodate these needs in Yorkshire.

5.1.2 Bradford: the development of the Yorkshire worsted manufacturing industry pre-1800-1850.

Although Bradford was to eventually develop into the "Worstedopolis" of the worsted trade (Cudworth, 1888, p. 3) or arguably, the worsted textile processing capital of the world in the late nineteenth century, worsted processing in Yorkshire can be traced as far back as the thirteenth century. From this period onwards, three areas were soon established as textile manufacturers' centres – the West Country, East Anglia and West Yorkshire (Smith, 1953). Crouzet called this period, where a wool industry existed before industrialisation, as "an industry without industrialists" (Crouzet 1985, p. 4).

Up until the last quarter of the eighteenth century, Bradford had continued as an agricultural, Yorkshire market town. When comparing Leeds to Bradford, the antiquarian chaplain Leland remarked to Henry VIII that although Leeds was "a praty market … [it was] not as large as Bradford and not so quik" [but] standith much by clothing" (Lund's Directory, 1856, p. 2). Interestingly, by the turn of the twentieth century, the Bradford Post Office Directory more or less reaffirmed Leland's view when in reference to the changing economic status of Bradford, they stated that the city was far from:

> "…being a comparatively insignificant town, Bradford has risen to be the metropolis of the worsted industry, and has enjoyed a commercial prosperity scarcely equalled by any other portion of the kingdom…" (Bradford Post Office Directory, 1912, p. xi).

With the arrival of industrialisation in about 1798, Bradford began its transformation from a Yorkshire market town into one of the fastest-growing industrial towns in Great Britain. Alderson has described Bradford's urban development as the "product of the Industrial Revolution" (Alderson, 1986, p. 11). This changeover from a market town to an urban township also gave rise to an accumulation of many social ills, such as overcrowding, substandard housing, deplorable sanitation, poor ventilation, lack of piped, clean water and an explosion in the birth rate. Although extremely important to its eventual development from an agricultural market town to an urban landscape, these factors will only be discussed briefly in this chapter.

In 1846, George Weerth (1957, p. 169), a German visitor arriving in Bradford, was so appalled at what he saw that he recorded this observation:

> "… Every other factory town in England is a paradise in comparison to this hole … In Bradford, you think you have been lodged in no other place than with the Devil incarnate. If anyone wants to feel how a poor sinner is tormented in Purgatory, let him travel to Bradford …"

Despite Weerth's negative observation, Bradford continued to expand geographically, industrially, commercially and demographically. An interconnected infra-structure of geographically-based variables such as water supplies and navigable transport routes, iron ore and coal deposits, iron ore manufacturing firms and good road and rail networks became very important. All these variables were instrumental in transforming Bradford from a small Yorkshire market town into an industrial centre specialising in the refinement of textile machinery, processing and production of wool into worsted cloth.

It is also important to note that with the coming of industrialisation, the township of Bradford experienced an increase in its population growth, having become a beacon for migrant workers from many towns far and wide.

In the first UK census taken in 1801 (Duke-Williams, 2017), the total population of Bradford was recorded as 13,264. By 1851, the population figure saw the sharpest rise to 103,778 (Richardson, 1976). Although the Bradford population increased throughout the nineteenth century, the rate of demographic expansion never matched the increase that had taken place during the first fifty years of the nineteenth century.

5. 1. 3. Social development and the entrepreneurial generation

A noticeable social development of Bradford as a worsted processing centre was the evolution of the "self-made entrepreneurial generation" or elite class (Koditschek, 2016, p. 94) which became involved in the exploitation of inventions and innovations as well as being instrumental in the decision-making which affected urban growth and the stimulation of the local, national and international economies. Two such men involved in the development and invention of the mechanised comb were Samuel Cunliffe Lister (1815-1906) and Isaac Holden (1807-1897). Lister and Holden were instrumental in setting up short-lived tea plantations in India and factories in St. Denis, Croix and Rheims in France (Honeyman and Goodman, 1986). This self-made entrepreneurial or elite class soon assumed a prominent role in the cultural, social, economic and familial fabric of the town giving rise to the town's political and public-spirited economic leadership. Many members of this entrepreneurial or elite class shared church or religious links as well as, at times, being active members of the same clubs, societies or political parties. By the mid-nineteenth century the entrepreneurial class in Bradford comprised "70% individuals who had come to Bradford, whilst 76% were under 50 years of age" (Koditschek, 2016, p. 165). Other celebrated personalities such as Titus Salt (1803-1876), James Drummond (1810-1891), James Behrens (1806-1869), Robert Milligan (1785-1862) and Henry Forbes (1794-1870) who symbolised the wealth and high status achieved by this entrepreneurial class, also demonstrated similar levels of paternalistic leadership and philanthropic work in Bradford and its environs, across other parts of the country and abroad.

With this synergy of key determinants impacting on the township of Bradford, it was worsted processing which eventually replaced the local agrarian economy with an industrial economy (De Vries, 1994) as well supplanting the premier position of industrial prominence of the burgeoning iron industry in Bradford. A number of outstanding iron working companies had already sprung up around Bradford and were establishing a reputable name for the quality of their work. These companies were Emmetts Iron Works (founded 1782), Bowling Iron Works (founded 1788), Low

Moor Iron Works (founded 1791), Shelf pig-iron works (founded 1792) and Bierley pig-iron works (founded 1811). The two most prominent ironworks which had secured an international reputation were Low Moor Iron Works and Bowling Iron Works. Mayall observed that:

> "… the ironworks in the neighbourhood of Bradford are universally known. The manor of Royds Hall, together with minerals under the estate was purchased from the last proprietor in 1788, by the ancestors of Messrs. Hird, Dawson and Hardy, who originally established the celebrated Low Moor Iron and Coal Works, now the most important in the north of England…" (Mayall, 1867, pp. 167-168).

5.1.4 The contributory factor of iron-works and production to the development of Bradford as an industrial centre

Low Moor Iron Works was particularly notable not only to early engine construction but also for manufacturing military ordnance equipment, especially cast iron shot and cannon manufacture used in the Napoleonic wars (Low Moor, 1906). Bowling Iron Works was renowned for having the "purest, sulphur-free coal and excellent materials" (Cox, 1999, p. 17). The cast iron produced at Bowling Iron Works was highly-prized and was considered ideal for the metal framework structure needed for the naval hospital in Port Royal, Jamaica in 1817. The hospital was designed by a 'design team' led by Edward Holl, the innovative and pioneering architect from the Navy Board. By the time Holl had finished his design and subsequent construction of the hospital, he had become the most "experienced architect in the use of cast iron at the time" (Cox, 1999, p. 17). In fact, Bowling Iron Works and Low Moor Iron Works respective reputations for the production of their good quality iron became extremely well-known throughout Yorkshire, Great Britain and abroad. The growing importance of Low Moor Iron Works was immortalised in an 1829 poem written by John Nicholson, a wool sorter, popularly known as the Airedale poet (Keighley, 2010):

> "… When first the shapeless sable ore
> Is laid in heaps around Low Moor,
> The roaring blast, the quiv'ring flame,
> Give to the mass another name:
> White as the sun the metal runs,
> For horse-shoe nails, or thund'ring guns …
> No pen can write, no mind can soar
> To tell the wonders of Low Moor…" (Hird, 1876, p. 265).

The location of iron works in the Yorkshire area was instrumental in accelerating the demise of the East Anglian worsted manufacturing industry. Iron works such as Bowling Iron Works and Low Moor Iron Works were able to provide Yorkshire industrial establishments with stationary steam engines and "heavy machinery" (Sigsworth, 1958, p. 15). Unlike East Anglia which had to continually invest in transporting in all its much needed raw materials, the Yorkshire worsted manufacturing industry was able to benefit from vast deposits of coal, much sought-after iron ore and fast flowing water courses situated around the county.

5.1.5 The impact of coal-rich reserves on Bradford and its environs

Bradford was also in a favourable location, the geographical advantages of which proved to be crucial for developing heavy industry. Beneath the geographical/geological areas of Bradford and neighbouring environs were much sought-after deposits of coal and iron ore (see Figure 3). The variable quality of these deposits also affected their commercial value. Soft Bed coal, according to Richardson, tended to be of a "fair quality and the seams occupied between "16 to 20" in thickness" (Richardson, 1976, p. 3). The Better Bed coal seams were considered to of better quality to Soft coals and could be found in seams located between "240 and 285" feet below key areas in Bradford (Richardson, 1976, p. 3). Furthermore, this type of Better Bed coal seam, according to Green possessed:

> "… a bituminous … dense, bright in colour and singularly free from sulpher, phosphorous and other impurities which unfit a coal for smelting purposes. It is chiefly used by the iron companies for the purpose of the furnace and the forge …" (Green *et al,* 1878, p. 132).

Moreover, Better Bed coal had better heat transmission or thermal transmittance because of the reduced content of sulphur or impurities.

According to the report compiled by the Select Committee on Coal (1871), the peak of coal mining occurred in 1866 when 46 collieries operating in Bradford mined 1. 9 million tons of coal. This impressive statistic demonstrates how coal mining from the Bradford area accounted for approximately one fifth of the total Yorkshire output for that year. Bradford's coal production was second to Leeds who mined more although they had almost twice as many coal mines. Expansion of the coal trade became evident and coal was purchased and sent to different parts of Great Britain (Richardson, 1976).

Up to the last quarter of the eighteenth century, demand for coal had been negligible. This very quickly changed with the rise of industrialisation which was accelerated by the so-called 'Industrial Revolution'. Demand for coal used to power the burgeoning ironworks and textile industries increased exponentially. Coal became especially important as a commodity for smelting iron used in the local ironworks. By the end of the eighteenth century, coal eventually replaced charcoal which up to this point had been used as the main fuel. (Hyde, 1977). What was particularly noticeable by the economist Adam Smith (1723-1790) was that the industries involved in processing or manufacturing tended to be localised around to the areas where large deposits of coal were located (Smith, 1811). The added consequence of using coal resulted in the reduction in the need for wood which had been used as fuel and had proved to be expensive. Additionally, combustible fossil fuel such as coal became an integral commodity for raising steam in stationary mill engines which ran the looms and spinning frames. With the development of steam engines, mines around Yorkshire began to use 'atmospheric' steam engines used widely in Cornish tin mines where they had been used to pump out underground mine water. Innovations during the eighteenth century were occurring in many different industries. Stationary mill engines underwent continual, incremental improvements to their designs and with this came an increase in power and efficiency.

5. 1. 6. The impact of a network of inland waterways on Bradford's economic growth.

The availability of water was vitally important in the development of Bradford as an industrial centre. In the early days of mill construction, efforts were made to site worsted processing mills on the banks of fast-flowing rivers. Unfortunately, not all rivers were fast-flowing and so a new form of energy supply was urgently needed to power the spinning frames and weaving looms installed in the mills.

During the onset of the so-called 'Industrial Revolution', the construction of canals around the country proved to be an indispensable form of transporting goods between towns as well as assisting in the promotion and development of economic growth. In Yorkshire, a number of local Bradford merchants, involved in the extraction of minerals, recognised the need to open up a navigable waterway into Lancashire. The primary intention was to stimulate the local Bradford economy by selling their textile products as well as coal extracted from local Bradford coal mines and limestone, which was an important building component used to make mortar.

With this mind, the idea of the Leeds-Liverpool Canal was realised. The construction of Bradford Canal was only one of the critically-important factors which assisted Bradford's economic expansion. Other economic factors underpinning Bradford's economic development was the road and rail transportation infrastructure (see Figure 2) (Richardson, 1976).

5.1.7 The socio-economic impact of an emergent road and railway infrastructure on the Bradford's worsted industry

In the early days prior to industrialisation, road transport was the only means of transporting goods from one venue to another, from one town to another or to and from the sea ports. The road systems were rudimentary and could be traced back to the medieval period. Needless to say, as the maintenance of these roads was inconsistent; they were forever in need of repair. It fell to the local landowners or religious orders to maintain their upkeep. In order to upgrade the state of the roads, an act in 1663 was passed by Parliament to ensure the roads were properly maintained. This scheme seemed to work and other Parliamentary Acts were passed ensuring that the momentum of upkeep was continued. Toll roads with turnpikes were soon imposed and a fee was collected when a traveller on foot, by wagon or on horseback used a particular stretch of road. In time, local merchants together with local landowners began to realise the value of building stretches of road which would be economically favourable to them and their respective businesses because it decreased the journey times between towns (Bogart, 2005). Levy rates were dependent on the fees that the Turnpike Road Act had advised.

Although important to the future development of the worsted industry, some of the local users were highly critical of the turnpike roads. One local Bradford historian observed that:

> "…about this time (1745), commodious roads began to be formed in these parts, in place of the narrow packhorse lanes. The turnpikes were, by the lower class, universally regarded as an obnoxious regulation, more adopted for the convenience of the wealthy portion of the community, whose carriages could hardly pass on the old roads, than the benefits of such class…" (James, 1855, p. 155).

Throughout the next century, successive governments funded improvements to the road transportation network. Pawson argued that both Parliament and the Turnpike trusts proved to be "an uncontroversial administrative innovation" (Pawson, 1977, p. 118).

Although the road and canal transportation systems were deemed to be fit for purpose, the Bradford entrepreneurs were keen to exploit the commercial possibilities of other transport links; they now considered that the town should have a link to the port of Selby. Railway freight was less costly than sending finished products by canal or road. Geographically, both the canal and road system tended to follow a transport system which was based on a flat geographical route and did not include high ground (Richardson, 2002). The limitations of this level of transportation based on the geographical landscape could be removed and amended with the introduction of a railway network. Leeds already had railway links but if the worsted industry was to flourish and succeed, it was necessary to construct or extend the railway link or infrastructure. The versatility of the railway system now gave the mill owners a greater the freedom to locate their mills and industrial centres anywhere and not be forced to locate them in the valley bottom. Although there were many strategic and financial obstacles to overcome during the early part of the nineteenth century, it took another fifty years or so before Bradford managed to establish a railways link to centres like Derby, Rugby and London. This link promoted the growing stature of the Yorkshire worsted textile trade with the rest of the country and abroad (Keighley, 2010). Communication links allowed the steady diffusion of textile machinery into the worsted processing areas, supported neighbouring towns such as Keighley to build up an industry of textile engineering as well as opening up productive financially-rewarding, communication links with the rest of the country.

5.2 Bradford: "Worstedopolis" - The rise and development of the worsted industry post-1800

In the previous section, some of the key geographical variables which influenced the development Yorkshire worsted manufacturing industry were examined. The focus of this section is to assess the innovation and diffusion of textile machinery post-1800. Howes takes the view that innovation was a:

> "process with many steps, from noticing an opportunity for improvement, to designing a solution, implementing it, and then adjusting it further" (Howes, 2017, p. 7).

The sequence of steps highlighted in Howes' interpretation of innovation can clearly be seen in at the onset of the mechanisation of Yorkshire's worsted manufacturing industry. During this developmental period, different types of machinery were incorporated into the worsted industry. Spinning and weaving machines, which had originally been used in the Lancashire cotton manufacturing industry, were adopted and adapted to the requirements in worsted mills.

Berg (1985, p. 6) takes the view that:

> "…Technological change and the expansion of manufacturing took shape with this diverse climate of enthusiasm and resistance…"

On the other hand, Sigsworth (1958, p. 188) observed that:

> "… Changes in machinery [were] taking place … in which innovations were constantly occurring, were the direct result of many factors …"

Some of these factors, according to Sigsworth (1958), which affected the development and diffusion of machinery were as follows:

1) The development of spinning, weaving and combing machines were undertaken and in the case of developing combing machines a close working arrangement between local entrepreneurs and inventors working together.
2) A gradual breakaway from the manual operation to the mechanical operation. This is seen in particular with spinning but in particular with mechanical combing overriding hand combing and weaving.

3) Competition from abroad dictated new techniques and products. This competition resulted in new approaches being taken to counter the competition.
4) With the introduction of new mechanised machinery, the power and efficiency were improved.
5) Expansion of mills which increased the need for reliable textile machinery needed to process fibre into worsted cloth.

John James (1841, p. 280), Bradford's local historian, maintained that:

> "… the inability of obtaining from the common wheel the necessary supply of yarn to meet the continually increasing demand, led in Bradford, as in other places, to the introduction of spinning-machines…"

Over the centuries, spinning had been undertaken by hand, it was during the start of the so-called 'Industrial Revolution' in about 1787 when the first local worsted spinning mill was built in Addingham, near Bradford. Even though hand-spinning continued, it was only a matter of time before this was superseded by the mechanised form of spinning. So by 1820, hand-spinning, which had been practised over many centuries, had come to an end as a commercially-viable trading activity. (Clapham, 1910). The construction of a spinning mill in Addingham, soon prompted other spinning mills to be built. Further improvements took place in spinning with the increase of rollers which allowed the spinning of higher counts of yarn or finer yarns. Sigsworth argued that:

> "…in terms of technological development, the story of the worsted industry during the last two decades of the eighteenth century belongs mainly to spinning…" (Sigsworth, 1958, p. 5).

James mentions a number of innovations which assisted spinning during the 1830s onwards (James, 1857). The introduction of the 'dead' spindle instead of the 'fly' spindle produced two results. The first being more output from the spindle and the second advantage was that now the spinner could spin higher counts of yarn or finer yarn. For the next twenty years, spindle speeds gradually increased from 1400 to 1800 rpm resulting in more yarn being spun. By the mid-nineteenth century, the cap spinning frame had been introduced which also allowed the operative to control both sides of the frame (Bradford Observer, 1861).

A constant source of controllable power was essential for the operation of mechanised spinning frames to be successful. So, at the beginning of the development of the Yorkshire worsted manufacturing industry, many of the spinning frames located in mills were powered by water.

James recorded that the first yarn to be spun by a spinning frame in a Yorkshire worsted spinning mill was in the 1780s (James, 1857). This reliance on water power proved to be inadequate as on occasion, yarn production could be unexpectedly interrupted if there was a problem with the flow rate of water, congestion in the river system or an absence of water (Giles and Goodhall, 1992). Eventually, this inefficient dependency on water power in areas which were sometimes prone to drought was replaced by a more efficient water-management system. Stationary steam engines, powered by measured amounts of water, removed the reliance of an unpredictable water supply.

It was Fairbairn (1861, p. 66) who commented that:

> "the machinery of mills …may be generally divided into three classes: - the *prime mover*, from which the power is derived for keeping the machinery of the mill in motion: the *transmissive* machinery or *millwork* (shafting, gearing etc.,) by which the power obtained through the prime mover is distributed over the different parts of the mill… and lastly, the *machines,* technically so called, by the special operations of the mill in the preparation of its manufactures are carried out"

5.3 Power transmission in the industrial worsted landscape

Designated areas were set aside in the textile mills for the stationary steam engines to provide power transmission via the central line shafting. Then through a variety of shafts, belting and pulleys located on different floors (if the mill was multi-floored) the power would be transferred to the belts and pulleys which would drive the spinning frames. Yorkshire mills tended to have "rope, belt or cable drives" as a means of transmitting power (Giles and Goodhall, 1992, p. 160). Over the course of time, many different types of stationary steam engines would be improved and then replaced by reliable, individual electric drives, during a period of electrification, to power spinning frames, weaving looms and ancillary textile machinery. In 'Wool City', Keighley recorded an observation he made when visiting Young Street Mills which was about to be sold in 1959. In the auctioneer's catalogue, there was an entry for an 800 horsepower engine that had been operational for sixty-four years at the mill and had stopped only once to have a bearing replaced. As Keighley (2007, p. 107) pointed out, Bradford-made machinery were "built to last."

Sigsworth noted that companies such as Hattersley's had started their manufacturing company specialising in non-related textile items producing implements for the local agricultural industry in 1789 (Hodgson, 1879; Sigsworth, 1958). Within a short period of time, however, they switched their processing to the new emerging Yorkshire worsted manufacturing industry. Hattersley's adapted well to the challenges of this new industrial landscape and over time became market leaders specialising in innovative looms, improving their skills and knowledge base and manufacturing textile machinery (The Textile Journal of Australia, 1928).

5.3.1 Combing innovations

Innovation was important to combing. Historically, the combing machine was the last type of textile machine to be invented or perfected (Honeyman and Goodman, 1986). Much of the combing of wool fibre, prior to the so-called 'Industrial Revolution', had been carried out by hand combers. In 1801, Edmund Cartwright patented his combing machine which was nicknamed '*Big Ben*' in reference to a famous prize fighter's boxing technique.

This mechanical movement could be seen in the design of the comb's *crank lasher.* The design of the comb *crank lasher* was to emulate the kinematics of the human arm. It worked on the principle that the '*arm*' on '*Big Ben'* fed the main comb with wool. Despite its originality, the success of '*Big Ben'* attempts at combing wool was short-lived. Needless to say, efforts were made to overcome '*Big Ben'*s mechanical flaws which centred around its inability to comb "finer qualities" of wool (Burnley, 1889, p. 127). Although many inventors such as Platt, Collier and Preller took on the challenge to resolve '*Big Ben*'s' problems it was not until Isaac Holden, Samuel Cunliffe Lister together with George Edmond Donisthorpe examined closely the comb's earlier problems before finding a solution in 1845. The Lister-Donisthorpe patent included "the use of screw gills combined with the use of drawing-out detached quantities of fibres therefrom" (Killick, 1905, p. 15). Although this comb was not initially successful, Lister-Donisthorpe went onto to rectify all the defects by ensuring that "the longer fibres [could] be adapted to the Bradford trade" (Killick, 1905, p. 16). This was made possible by replacing the "oscillating opening and shutting or jaw nipper for the withdrawing nipper" (Killick, 1905, p. 16). Additionally, this allowed the nipper mechanism to approach the gill comb, grip and close on the projecting sliver and pull out a tuft of wool and the back of the tuft was combed. Killick described the remaining combing process noting that:

> "… the tuft being detached and carried forward thus half combed on an oscillating arm entered the wool in front of the nipper from below, and carried off the tuft to, and deposited it on, to be withdrawn, …in a continuous and uniform sliver of combed wool…" (Killick, 1905, pp. 16-17).

The Lister comb was licensed to be constructed by the Leeds firm, Messrs. Taylor, Wordsworth and Co, and an early example was exhibited at the 1851 *Great Exhibition of the Works of Industry of all Nations* (commonly known as the Crystal Palace) where it was favourably received. MacLeod noted that Lister's financial monopolistic control in the development of wool combing machines ensured that he would receive:

> "… £1000 for every machine made and sold for him by Taylor, Wordsworth & Co. of Leeds. It provided an opportunity, in particular, for the employees of user firms, lacking capital of their own, to retain a stake in the sales of their invention …" (MacLeod, 1992, p. 295).

Progress on the rapidly developing technology and refinement of the combing machine continued and by 1888 the local newspaper commented that:

> "…in combing machinery, for instance, owing to the acceleration of the speed at which the dabbing brush can be run – and this is the determining factor – production has increased by 20% to 30%..." (The Bradford Observer, 31st December, 1888).

Each of the British combing machines proved to be useful in the type of wool they were processing. Noble combs proved to be very versatile, especially capable of combing short wools (Anon., 1913). Unfortunately, the Holden 'square motion' comb was too complicated to operate and their usage was soon limited and only used by some wool processors (Brearley and Iredale, 1980). Holden combs were limited to "very fine Merino" wools (Jenkins, 1972, p. 100). These type of combs tended to be used mainly by Messrs., Isaac Holden and Sons Ltd, in Bradford who employed three hundred combs in their works. The Donisthorpe-Lister comb proved to be well-suited for long staple wools, alpaca and mohair wools (Jenkins, 1972, p. 100).

European and American competition of combing machines continued to be economically troublesome for the British textile machine manufacturers. The main competition came from the Heilmann '*grip* or *nip*' comb originally made for the cotton trade. Much later, it was adapted for combing short wool. Its versatility was that it could also be adapted for flax and silk combing. Although the Heilmann comb was widely used in Europe, it posed a threat to the combs manufactured by Donisthorpe and Lister. In due course, Donisthorpe and Lister were embroiled in litigation with Heilmann over infringements on the similarity of machine comb design. Notwithstanding, the Heilmann comb was not used in Britain before 1851 (Burnley, 1889). Following Heilmann's successful litigation, the patent rights of his comb were eventually sold to Messrs., Akroyd and Titus Salt who promptly sold the patent rights to Lister. Accordingly, Lister's business acumen ensured that his rival's (Heilmann) comb could not establish a foothold in the British textile market and at the same time secured a monopoly of his comb. The purchase of the patent rights was subsequently followed up by a handful of cotton firms in Lancashire doing the same and paid £30,000 for the patent rights whilst Marshalls, the Leeds flax processors, paid £20,000 (Waterhouse,1935).

From the United States of America came the Whipple combing machine. It was described by some commentators as a comb which was influenced by the Heilmann comb model. Killick noted that the Whipple comb was "regarded in the trade as nothing more than a modification of Heilmann's method" (Killick, 1905, p. 40). Even so, litigation was soon enacted over infringements of the Whipple design to the Lister comb. Although the case for the Whipple was upheld in the High Courts, interest in the Whipple and other combing machines eventually petered out leaving the Lister-Donisthorpe and Noble comb as the main combing machines which were used in British combing mills (Killick, 1905).

5.3.2 Jacquard weaving

Different fabrics made of various worsted products and combinations were in great demand. This reflected the ever-changing textile markets as well as a response for new types of woven fabrics.

At the same time, the diffusion of textile machines continued as textile machines from abroad were brought into the home markets to meet the consumer demands in the supply of woven figured cloths. One such example was the jacquard engine which proved to be ideal for weaving complex, figured fabrics. In a presentation given to a Select Committee in 1835, Guillote (1835, Q811) stated that:

> "… I am making Jacquard machine by the hundreds for all parts of England … For Yorkshire I am particularly engaged at present making them for merinos and damasks… The demand commenced about eleven years ago and has become much more acute in Yorkshire… I received an order for one machine in order to make an experiment; it succeeded, and the consequence was an order from the same individual … and there was a demand at any price from everybody..."

Arguably, the most likely reason for the success of the jacquard, prior to Guillot's proclamation, is that the jacquard loom had undergone some improvements before it was launched into the worsted trade in Bradford.

Even though technological progress in mechanisation seemed to advance at a constant pace, there were certain processes in the Yorkshire worsted manufacturing industry where such technical advances to improve existing machines were more challenging. One such example, as indicated by Mokyr, was evident when:

> "… spinning carded wool [which] proved difficult to mechanise…which resulted in a mixed system (production being carried out in a domestic setting whereas other processes carried in industrial factories)" (Mokyr, 2001, p. 6).

In 1888, the local Bradford newspaper noted the developments of the wool textile machinery used in the Yorkshire worsted manufacturing industry:

> "…Carding machinery is likewise run much faster, while in spinning, a higher class of machinery has come into use, designed to run at a higher speed and less wear and tear. The demand for increased speed all round has led to a very wise adoption of ring spinning and combinations of ring and cap…" (Bradford Observer, 31st December, 1888).

Textile technology was constantly changing. Textile machines which were adopted into the Yorkshire worsted manufacturing industry tended to be retained for a very long time. Even into the mid 1960s, Noble combs were still being used until Sir James Hill and Sons became the first firm to switch to the French combing system, declaring that the Noble combs had reached their "optimum productive capacity" (Keighley, 2007, p. 140).

5.3.3 Patents and textile exhibitions

The word 'patent' owes its origin to the Latin word 'patere' (to be open). In the New Palgrave, a dictionary of Economics (2007, p. 1), patents have been defined as the:

> "legal right of an inventor to exclude others from making or using a particular invention …[or] sometimes termed an intellectual property right".

Alternatively, Leibovitz argued that a patent was one "way of maximising social welfare by providing incentives for inventors to increase the stock of applied technical knowledge in society (through protection) and discouraging inefficient redundancy of inventive effort (through disclosure)" (Leibovitz, 2002, p. 2256). Mansfield has taken this point further and stressed that the patent system "is at the heart of our nation's policies toward technological innovation" (Mansfield, 1986, p. 173).

The earliest example of patents and patent law can be traced back to a statute passed in Venice in 1474. This use of patents was important in the promotion and protection of new inventions as well as providing benefits to Venetian society. The statute outlined the protection that it gave to inventors in Venice:

> "… Be it enacted that, by the authority of this Council every person who shall build any new and ingenious device in this City, not previously made in our Commonwealth, shall give notice of it to the office of our General Welfare Board when it has been reduced to perfection so that it can be used and operated. It being forbidden to every other person in any of our territories and towns to make any further device conforming with and similar to said one, without the consent and license of the author, for the term of 10 years…" (Mandich, 1948, p. 176).

This practice of awarding patents was considered useful and deemed to be important enough to be adopted by many countries in Europe. Many, but not all, countries readily accepted the worthwhile nature and benefits of patents system in terms of promoting economic growth (David, 1994; Boldrin and Levin, 2008). It was not until the reign of Elizabeth 1st in the sixteenth century that patents were formally used in England.

Kent (2007) considered patents as a ‘crucial ingredient’ of the so-called Industrial Revolution, not least in how patents affected the technological development of Yorkshire worsted machinery manufacturing industry. MacLeod and Nuvolari claimed that “industrialisation promoted the patent system” (MacLeod and Nuvolari, 2010, p. 21). Patents were essential when determining how inventions and innovations would perform and affect technological progress or change, as well as assisting in the nation’s economic growth. In 1795, Bentham (1748-1832), the philosopher and political reformer, recorded that patents were considered as:

> “… as a recompense for the encrease given to the general stock of wealth by an invention, as a recompense for industry and genius and ingenuity, is proportionate and essentially just. No other mode of recompense can merit either the one or the other epithet. The only mode of bestowing upon an inventor a recompense for his invention otherwise than by a patent, is by giving him a sum . . . Is the reward [given] in this [form] proportionable to the service? It may be so: but against its being so there is infinity to one...” (Stark, 1952, p. 68).

In essence, patents continued to provide the inventor with at least three key benefits (Orsenigo and Sterzi, 2010, p. 3):

i) Provides the inventor with a means of protecting his idea or invention from any form or attempted imitation.

ii) Patents become a means of releasing information about the invention which permits further investigation, exploitation or exchange of ideas.

iii) Patents ensure the commercialization, control of patents rights and the careful avoidance of patent information duplication.

Ashton (1955) is often credited with the oft-quoted phrase that the ‘Industrial Revolution’ was “… a wave of gadgets that swept over Britain after 1760, a string of novel ideas and insights” (Ashton, 1955, p. 42). Whether they were ‘gadgets’ as Ashton claimed, or pure inventions, or innovations, the underlying factors were the property rights that patents provided. Ashton did elaborate on his ‘wave of gadgets’ by stressing ‘that it was not only gadgets … but innovations of various kinds – in agriculture, transport, manufacture, trade and finance – that surged up with a suddenness for which it is difficult to find a parallel at any other time or place’ (Ashton*,* 1955).

Patent law during this period also allowed the inventor to hold a number of entitlements, such as a time-determined monopoly over his invention rather than any external body holding supreme rights, as well as assessing the granting of monopoly by an independent review body. This legal accord was far removed from the unrestricted free-for-all situation at beginning of the so-called ‘Industrial Revolution'. Up to the eighteenth century, copyright and patents, tended not to be as clearly defined by the legal profession. It was during the two conventions held in Paris (1883) and Berne (1886) (Reichmann, 1994), respectively that the two distinct terms - copyright and patents - were finally made explicit.

Arguably, the critically-important first-steps in the process of innovation took place initially within a small number of key industries but within a short space of time started to take hold in other sectors of the economy in what was described as "on an ever-widening front" (Landes, 1969, p. 78). During the so-called 'Industrial Revolution' many technical innovations were under way in different industries such as mining, transport, printing, motive power and textiles. It is important to note that agricultural innovative development took place before the advent of the period of industrialisation. Despite these agricultural innovations, many workers who had been working on the land switched their employment to textile and other emerging heavy industries (Pollard, 1998).

Patenting was always expensive. In 1852, an act entitled the Patent Law Amendment was introduced. It now made the application for patent much cheaper than it had been. One key factor became noticeable. For a sum of £25, a patent could provide a protection throughout Great Britain albeit for a short while. To extend protection for periods of 3, 7 and 14 years, additional payment would be required. Likewise, the reduction of payments for registering patents did not prove to be a success. Lerner (2002) noted that in 1875, it was nineteen times more expensive to hold a British patent than an American patent. Even so, from 1852 to 1880, the Patent Office still made two million pounds in profit with a reduced volume of registered patents. The Textile Institute Proceeding and Abstracts, (1919), recorded that between 1855 and 1906, 10,696 patents were registered. Moreover, the Textile Institute Proceeding and Abstracts concluded with the four factors which determine the necessity of using patents:

> "… invention, capital, labour, plant or establishments. Unless we have someone with enterprise, invention is useless; labour, thus, can only come in after invention has been made and capital invested. There is no particular reason why these four factors should not be intermeshed with a recognition of their interdependence one upon the other…" (The Textile Institute Proceeding and Abstracts (1919, p. 351).

Exhibitions were very important in showcasing many new innovations although not all were patented. Data gleaned from trade exhibitions at home and abroad indicated which countries, with or without patent laws, were represented at trade exhibitions and were successful with their prize-winning, high-quality products. According to Moser, 11 % of British patented items, on show at the 1851 *Great Exhibition of the Works of Industry of all Nations* (as the Crystal Palace was commonly known), had been patented even though "15 % of British exhibits that won prizes for exceptional usefulness and quality were patented, compared with 11 percent of average-quality exhibits" (Moser, 2013, p. 27). It is interesting to note that the inventors patenting their inventions felt they could share their knowledge with fellow inventors although there were occasions or situations where this was not possible. This reluctance could range from protectiveness of the intellectual property by the inventor, to a country, such as Switzerland, not having a patent system in force or a means of preventing a competitor from sharing the intellectual property (Horstmann, MacDonald, and Slivinski, 1985).

5. 3. 4 Trade shows and Exhibitions

The success of trade exhibitions would not have been possible without a concerted, publicity mechanism which promoted these trade exhibitions over a period of time. In excess of 65 commissions were formed to publicise the 1851 exhibition held at the Crystal Palace, Hyde Park in London (Auerbach, 1999). Furthermore, the exhibits which appeared at the Crystal Palace were deemed to be important and the best examples of the class they had been placed in were then subsequently entered into a catalogue which was to become a "book of reference to the philosopher, merchant, and manufacturer" (Auerbach, 1999, p. 94). An interesting observation of innovations exhibited in the Crystal Palace revealed certain negative perceptions which manufacturers held about American innovations. Once these American products were on display, the opinion of manufacturers and visiting public soon changed and these American innovations gained the visiting public's admiration and respect for ingenuity and design (Moser, 2016).

5. 4 Summary

The history of the Yorkshire worsted manufacturing industry was best summed up by Heaton in his study of the Yorkshire woollen and worsted from the earliest times up to the so-called 'Industrial Revolution'. From his investigation, he concluded that:

> "…the Industrial Revolution … is used to imply solely the invention of machinery, and the application of steam, for it was these two factors which constituted the real revolution, and were the cause of many of the other developments. The inventions of Arkwright, Hargreaves, Cartwright, and the rest comprised the first step; the discovery of iron, coal, and steam power was the second…" (Heaton, 1920, p. 282).

This chapter has discussed the key factors which determined the rise and success of the Yorkshire worsted manufacturing industry. Integrated geographical factors such as coal, a road and rail infrastructure and a supply of water (for industrial and navigational use) became integral in creating an economic platform in which the innovation and diffusion of machinery took place.

Patents were very important to the eventual registration of innovative textile machinery. Burnley records that the one of the mechanised wool comb invented in the mid-nineteenth century was manufactured by Taylor, Wordsworth and Co of Leeds under license from Samuel Cunliffe Lister (Burnley, 1889). The company already held 16 patents for machine improvements in 1888 even though they had others on file which had elapsed. Lister acknowledged the debt he owed to

Reverend Edmund Cartwright [1743-1823] by stating that his work was an incremental improvement to the comb. He commented:

> "… The first combing machine that I actually invented was the *square-motion* machine which I patented in 1848. This again, was only an improvement upon Cartwright, but it is still one of the best fine-wool machines…" (Lister, 1901, p. 236).

Some textile machines, which were eventually diffused into the Yorkshire worsted manufacturing industry, were not done so for reasons of how efficient they were or how well they were designed. In fact, some of these machines were not even accepted because they were either foreign or incapable of undertaking the task of combing certain kinds of wools. In the case of the Heilmann or French comb, H.W. Peel in an address to the Bradford Textile Society, countered this misapprehension of "we can't deal with it [Heilmann or French comb] in Bradford" by noting that:

> "… the old prejudice that French combs would never make headway in this country owing to the difficulty in selling the noil is fast dying out, as the demand recently for this type of noil have been great ..." (Peel, 1923-24, pp. 66-7).

The diffusion of this comb was also discussed and mention was made of the viability of the Heilmann comb. Peel mentioned that:

> "…From that time [1858] the French comb began to fall into disuse, in the country of its origin, but, on the other hand, perfected by the genius of Schlumberger it held the field in Germany for many years. It must be remembered that the Heilmann machine will comb cotton, a feat that none of the better known machines, including the Noble, will perform…" (Peel, 1923-24, p. 62).

In terms of inventions, many machines underwent a series of incremental improvements over a number of years. Each inventor would work on the past failures of the previous inventor to resolve outstanding issues. Evidence given by P. R. Hodge, civil engineer, before the House of Commons in 1857 concluded that:

> "… the present spinning machine which we now use is supposed to be a compound of about eight hundred inventions. The present carding machinery is a compound of about sixty patents…" (cited in Textile Institute Proceeding and Abstracts, Vol. x, 1919, p. 350).

The technology found in worsted textiles continued to be developed and marketed both in Britain and overseas. Two main manufactures of textile machines were Hattersley and Prince-Smith and Stells of Keighley, based in Yorkshire.

5. 5 An analysis of the Yorkshire worsted manufacturing industry (1800-1939 utilising the *PEST (&G)* analysis framework

The *PEST (&G)* analysis framework provides a structured approach in better understanding threats that could befall a company thus allowing it to prepare or create a strategy of overcoming any perceived or actual threats. If a company wishes to exploit a new market it needs to analyse the trading market methodically and how to implement the forces of change needed to affect or alter the intended trends.

In the first instance, it gives the industry or policymakers an insight into the relevance of using it to understand or determine the direction the company wants to adopt. Secondly, it will allow the company to recognise and acknowledge the situation, background and knowledge currently available. Furthermore, the results or observations gained from using this diagnostic tool tend to be achieved over an extended period of time.

Finally, the *PEST (&G)* analysis framework enables the company to draw upon the data and observations obtained and then formulate a response or strategy based on the data which they have extrapolated.

5.5.1 Political

Government changes in the implementation of policies can often cause disruption or instability to the general disposition of the working population. It has long been established that if workers in one country undergo a period of hardship which is subsequently accompanied by a strikes, slumps in trade and unemployment, many workers may choose to emigrate to a more prosperous country where they perceive it to offer more opportunities for betterment (Johnson, 1913).

Tariffs have always served a purpose of reducing any trade deficit, protecting home markets and counterbalancing any foreign trade competition (House of Lords, 2019). Many European countries were already using this type of financial levy and high tariff rates (see Table 14.) but it was the introduction of the protective measures of the McKinley Tariff Act (1890) and Dingley Tariff Act (1897) which severely undermined British and European exports to the United States of America. Britain's almost unchanging, zero tariff rate from 1875 to 1913 is in sharp contrast to the variable tariff rates (often punitive) imposed by its main competitors in the same period (see Table 14.) Porter has described this phenomenon as "the essence of formulating competitive strategy is relating a company to its environment" (Porter, 1985, p. 3).

	Manufactured Goods				All Goods
Country	1820	1875	1913	1931	1913
Austria-Hungary	-	15-20	18-20	24	18-23
Belgium	6-8	9-10	9	14	6-14
Denmark	25-35	15-20	14	-	9
France	-	12-15	20-21	30	18-24
Germany	8-12	4-6	13	21	12-17
Italy	-	8-10	18-20	46	17-25
Japan	-	5	30	-	N/A
Russia	-	15-20	85	-	73
Spain	-	15-20	34-41	63	37
Sweden	-	3-5	20-25	21	16-18
Switzerland	8-12	4-6	8-9	19	7-11
Netherlands	6-8	3-5	4	N/A	3
Great Britain	45-55	0	0	N/A	0
U.S.A.	25-55	40-50	44	48	33

Source: Kozul-Wright (1995); Bairoch (1993); Shafaeddin (1998).

Table 14 Duties placed by United States of America and European Competitors on goods from 1875 to 1913.

During the nineteenth and early part of the twentieth century, limited immigration began to take place from different parts of Britain (Ireland, Yorkshire, Hampshire, Cheshire, Scotland and Lancashire) to the United States of America) (Johnson, 1913). Opportunities for a better life sought by skilled and unskilled Bradford textile workers from Yorkshire, seemed a more favourable alternative to the adverse social conditions and economic situations found in local textile towns. For instance, Charles Bailey, a skilled weaver from Yorkshire who emigrated to the United States, had transferable skills much needed in American textile mills. Following his emigration, he was subsequently employed in New Falls, New York to install Jacquard looms (Vugt, 1999, p. 82).

One approach taken by some British companies to counteract the impact of the American tariffs was to invest and establish branch factories in specific wool manufacturing areas in the United States of America. As is often the case with imitation in economics, Belgian and French mill owners soon adopted similar strategies and practices and also began to establish factories in the United States of America. French and Belgian workers were soon emigrating abroad.

The British wool processors soon established a mill village called *Greystone* situated in North Providence, Rhode Island. Considerable funding and financial investment had been provided by Joseph Benn of Beckside Mills, Great Horton in Bradford, England. The intention of setting up a company in Rhode Island was to produce alpaca, mohair and worsted cloth, as good as, if not superior to the fabric which had been made in Bradford or by the parent company of Joseph Benn of Great Horton, Bradford. Alpaca had become popular through the efforts of Titus Salt in 1836 although he was not the first mill owner to process alpaca into a fabric. (Walton, 1841). It was Charles Dickens who reworked Salt's discovery of 'dirty bales of frowsy South American stuff' which he made famous a story called 'The Great Yorkshire Llama' in the 1852 edition of Household Words (Dickens, 1852, p. 39).

Emigration to Rhode Island from Yorkshire was particularly significant. Within a short time, the Yorkshire presence became well-established and the Bradford press soon named the worsted textile town of Lawrence the "Bradford of America" (Jowitt, 1991, p. 3). By 1874, the creation of a mill village presented the owners with a problem of how to redress the lack of technical skills to produce the central to the production of high-quality lustre fabrics. This shortfall in skills was remedied by drafting in trained Canadian and Bradford textile workers able to operate the machinery. This transatlantic migration inevitably brought about a depletion of technical skilled workers in? Bradford's worsted textile processing.

.

The protectionist tariffs imposed by the United States of America ensured a period of accelerated economic growth and protection of its home-grown textile industry. This approach of protectionism allowed the United States of America to nurture and develop its growing technology, boost its prosperity, improve the trade balance and match the trade supremacy the British had and then exceed Britain's GDP (Shafaeddin, 1998). This was at the expense of many developed European countries.

5. 5. 2. Economic

Hudson has speculated that up to the 1820s, many local textile workers and visiting clothiers tended to construct their own working machines. If for whatever reason this was not possible mill owners tended to employ the services of local craftsmen to manufacture the necessary equipment such as looms (Hudson, 1989).

Following the impact of an industrial factory system during the first quarter of the nineteenth century, the emphasis switched from locally-made textile machines made by craftsmen to industrially-made textile manufacturers such as Hattersley's or Prince-Smith and Stells of Keighley.

Interestingly, in addition to various marketing strategies used by these firms to publicise their new products, this period also saw an increase in the advertising and purchase of second-hand textile machines by direct sale or by auction (Garett, 1986). This practice by mill owners, who preferred to purchase second-hand or used machines for as long as they could, continued to do so right through into the nineteenth and twentieth century.

Competitive market forces which generate economic growth are key drivers to the success of industry. Up to the 1870s, economic growth had been gradually developing. After 1875, Yorkshire textiles had been very slow in countering severe competition from the European mainland and changing their mode of fashion fabric production. Yorkshire found that European competitors were producing softer all-wool, worsted cloth whereas towns such as Huddersfield and Bradford favoured and continued to weave a cheaper worsted mixture (cotton warp and worsted weft). This approach, taken by Bradford's worsted manufacturers, produced a number of adverse repercussions consequences for the Bradford trade. Trading in foreign markets was becoming less viable and a waning interest in Bradford-made textile products resulted in a switch from foreign markets to domestic markets. The Bradford trade also realised that the emerging challenges from foreign competition were challenging established processing techniques. This was particularly evident with the competition from France which used rectilinear combing machines and spinning mules. To compete on equal terms, Bradford worsted industry would have had to change their industrial processing which they were not prepared to do. Instead, the worsted trade in Bradford switched their focus away from women's fashion and developed "a mass market in men's suitings and over coating, and furnishing fabrics" (Jowitt,1991).

Financial security and stability is crucially important to the productive state of the textile industry, not least in the remunerative obligations it has to its workforce. As with other industries, Jowitt and McIvor recorded how the fluctuating wages in the Bradford worsted trade affected its workforce. He noted:

> "One weaver will now mind in two looms as much as 11,000 to 12,000 ends for practically less wages than were once paid for minding two looms with a matter of 800 ends each" (Jowitt and McIvor,1988, p. 97).

The level of poor wages which textile workers were receiving continued to blight the worsted industry as shown by the balance of operatives in the worsted industry. More female workers were employed than male workers but pay inequalities were disproportionate, favouring male operatives who earned more because of their technical skills (Board of Trade, 1908-1913). For instance, in 1901, there were 1702 male workers involved in wool sorting whereas in 1905 only 45 female workers were involved in wool sorting. Of all the wool processing (see Appendix 3A-3H) jobs, wool sorting was better paid than many other mill jobs. Wool sorters typically earned 37 shillings per week which was considered a good wage (Board of Trade*,* 1908-1913). Furthermore, many of the skilled jobs were not made available to the female workers. This restriction ensured that the women workforce, many of whom were not married and ex-half-timers, continued to earn considerably less than their male counterparts. Furthermore, mill owners viewed their female workforce as a cheaper form of labour to their male workforce.

5. 5. 3. Social

In the *PEST (&G)* analysis framework, the social determinant allows the researcher to examine the different perspectives and values of the workforce in the organisations in which it operates.

Lazonick (1979) highlights its importance of this social dimension by noting how the introduction of the self-acting mule into the factory spinning system impacted on the workforce. Lazonick maintained that the involvement of the mule spinners had to be considered in conjunction with an understanding of 'craft control' (Lazonick,1979). This cultural determinant was governed by the attitudes of the mule spinners had adopted and the traditional skills that they had acquired over time. Mule spinners who operated the spinning mule, maintained a very high regard for the skills that they had perfected when processing fibre into yarn on a spinning mule (Rule, 1987, p. 99). Conversely, spinners who were involved in hand-spinning proved to be very resistant to change brought about by the introduction of mechanised mule spinning. These spinners were protective of their skills and treated their knowledge and work culture as a substitute for property (Rule, 1987, p. 99). Even so, the future of machine spinning was inevitable as both the spinning mule and water frame were too large to be accommodated in the household so the hand-spinners were forced to leave the home and go working in a factory which had been created during the period of industrialisation (Bythell, 1983).

This 'craft control' could also be seen in the early techniques of wool combing which was undertaken by hand combers who were very proud and protective of their techniques and abilities. They used basic tools such as hand combs or *kam-broitches* made of ash (Briggs, 1905, p. 56), a pad-post, a pad, a *jinny* (or jenny), horn ring and a comb pot used to warm the combs (Briggs, 1905). Furthermore, the 'craft control' factor also encouraged a specific, local language which began to be developed which allowed hand combers to describe their art of wool combing or *kemming* (Briggs, 1905, p. 56). Once the mechanisation of combing took place, many of these hand combers were forced to seek unskilled jobs. From the 1860s, many of these workers went through a period of 'retraining' (Garrett, 1986). During this period many of these out-of-work hand combers were forced to send their wives and offspring to work in mills (Garrett, 1986). This fluctuating workforce was not beneficial to the worsted trade as a large proportion of operatives were inexperienced and poorly paid.

During the period known as the so-called 'Industrial Revolution' many different groups had decided to settle in Bradford. They included the Irish, migrants from many English counties, Jews and Germans. Most of these groups had been already been working in textiles in their original home localities and consequently became involved with the many specialisms found in Yorkshire worsted processing. According to the 1851 census, many of the Irish listed in the census switched their occupations from hand weaving to hand combing when they reached Bradford (Richardson, 1965).

Furthermore, the working population of Bradford was adversely affected by a series of acute problems. Hand processing practices, involving most of the family, were soon replaced by mechanisation. Some jobs, which had been well paid previously were now replaced by machines which were more productive and efficient than hand processing methods.

	1780	1800	1804	1814	1815	1820	1822-4	1826-9	1830-3	1838
Power Loom	-	-	-	-	-	-	-	-	-	90s
Hand Loom	65s	65s	95s	200s	175s	120s	140s	110s	100s	70s

Source: (Bowley, 1902, p.108)

Table 15. Comparison of Power Loom workers versus Hand Loom workers 1780-1838

Prior to the 1850s, (see Table 15) the skills and experience of the hand loom weavers were well remunerated, and in the absence of mechanisation, these workers assumed a prominent role in the industry. According to Bowley (1902), the turning point which effected a sharp economic turnaround was the year 1838. This was the period when the power loom had begun to establish itself in this industry and for the first-time, the power loom workers were earning *more* than hand loom weavers (see Table 15). This diffusion of the power loom continued and by 1855, completely displaced the hand loom work who had lost their income, livelihoods and more importantly perhaps, their standing in society (see Table 16).

	1855-8	1860-61	1863-8	1871	1872	1874	1876-7	1883	1891	1901
Power Loom	85s	90s	95s	95s	145s	135s	125s	115s	95s	100s
Hand Loom	-	-	-	-	-	-	-	-	-	-

Source: (Bowley, 1902, p.108)

Table 16. Comparison of Power Loom workers versus Hand Loom workers 1855-1901

Another fundamental change which affected this group was that many of the worsted processes were taken away from the outlying areas and became concentrated in one location. Equally, the location of the mills prompted builders to construct housing around the mills. This in turn caused a migration of agricultural labourers to move from their homestead into the industrial towns.

Even though the worsted industry was poorly remunerated compared to other industries in Bradford, jobs for women continued to be restricted to unskilled jobs. Mill owners preferred to pay women a lot less than their male workforce. Skilled jobs were reserved for their male workforce. Even though women tended to be poorly paid, their motivation was to take on textile jobs to supplement the family income. The low wages paid to women were also reflected in the wages the half-timers [children] received. These factors of very low wages, poor working conditions, limited skills and occasional work created a period of continuing poverty in Bradford.

5. 5 4. Technological

It was Mokyr who argued that “the key to the ‘Industrial Revolution’ was technology and technology is knowledge” (Mokyr, 2002, p. 29).

For a firm or industry to progress and succeed, technological improvements increase the technical knowledge and skills-base which bring about these changes. Moreover, new technology improves productivity and efficiency as well as reducing production costs of an industry. Cronin has argued that:

> “Technological development was inseparable from social development and … control over technology was integral to control over the labour process. Job familiarisation replaced craft training; the emphasis was on the manning of repetitive machine operations” (Cronin, 2001, p.33).

The importance of research into machine development cannot be underestimated for any industry, in particular the worsted manufacturing industry. Access to technical literature and patents allow other engineers in the industry the possibility of making further incremental modifications and improvements in machine development. They are now able to investigate and develop the machine further still. Bradford’s rapid technological development in worsted machinery was spearheaded by a group of pioneering, textile inventors who were instrumental in ushering in improvements and designing new types of worsted textile machinery.

It is not surprising to find that the introduction of any new machinery has the potential to influence a locality’s preference or acceptance of an industry’s commercial direction.

In Snowden’s novel, ‘*The Web of an Old Weaver,’* published in 1896, the central theme was how technological advances in power loom innovations and diffusion were rapidly changing the lives of these workers. The hand loom weavers considered these new machines to be a threat to their livelihood, work practices and culture. Snowden (1860-1947) was sympathetic to the traditional ways of life of the hand loom weavers but seemed to concede that this relentless technological development was making a huge difference to work practices. He wrote:

> "Weaving is a simpler job with power-loom, and an easier that is all. But, bless me, with hand-looms it was horse work" (Snowden, 1896, p. 66).

Other factors have revealed how new technology could determine a specific technological processing direction. One such example was the introduction of a '*Witch* engine' in Huddersfield. An account of its importance to the Huddersfield weaving trade was noted by the Leeds Mercury in 1829. It underlined how the Huddersfield weaving industry was influenced by the "*Witch*" capability:

> "One branch of the fancy trade has, however, been considerably revived by the introduction of machine called a *Witch*, which enables the weaver to beautify the cloth with a great variety of flowers … and employs a proportional number of looms" (Crump and Ghorbal, 1967, p. 121).

Capital investment in firms allows inventors to influence and change the direction of the industry with their innovative ideas. One such influential, Bradford inventor, innovator, textile industrialist and businessman was Samuel Cunliffe Lister [1815-1906], sometimes called the "*Prince of Toil*" (Keighley, 1989, p. 19), and later appointed a life peer (Lord Masham in 1891) for his many achievements. Checkland noted that Samuel Cunliffe Lister:

> "became one of the great figures in Bradford, not adverse to expounding his own merits, publicly doubting that there was a man in England who had worked as hard as he had" (Checkland, 1966, p.119).

His capacity for inventiveness and ingenuity was seen in an early invention of a fly shuttle which was instrumental in producing a "silk figure on a plain ground" (Anon, 1901, p. 234). In 1842, he continued with another invention which was a machine which could fringe shawls (Anon, 1901). Keighley noted that Lister was:

> "one of the nation's greatest industrialists [and] had spent his entire life amongst inventions and [had] registered more patents than any man in England" (Keighley, 2007, p. 6).

Inventors such as Samuel Cunliffe Lister were also keen to collaborate with fellow engineers as well as invest in developing new, improved machinery. Increased investment of time, effort and money ensured that technology continued to evolve as well as re-shaping industry-based skills. In an address to the Philosophical Society of Glasgow, Lister had declared not only his commitment to his many innovations and inventions but that he had invested approximately "£600,000 on new ideas" (Keighley 2007, p. 6). This commitment to textile technology was recognised in 1886 when Samuel Cunliffe Lister was awarded the *Royal Albert* medal for distinguished merit in promoting 'Arts, Manufacture and Commerce' (Taylor, 2008). Samuel Cunliffe Lister's influential standing as a key figure in textile processing ensured that he became the only worsted inventor and textile manufacturer to receive this award in the late nineteenth century.

From the mid-nineteenth century onwards, practically all of the British worsted industry was located in the West Yorkshire comprising towns such as Bradford, Leeds, Huddersfield and Halifax (Wright, 1982). The worsted industry in the West Yorkshire was greatly assisted by neighbouring towns such as Keighley who were able to provide the burgeoning textile processing industries in Bradford, Leeds, Huddersfield and Halifax with different types of combing machines, spinning frames and looms capable of weaving natural vegetable, animal protein and eventually man-made fibres.

The move away from traditional hand-processing operations towards an industry-wide programme of mechanisation in the worsted industry attracted the interest, effort and money from many talented inventors and innovators. These challenges did not come without considerable risks, not least with capital investments needed to fund such projects.

Two independent inventors, Ross and George Edmond Donisthorpe [1809-1875] of Leicester, were both left financially ruined. Notwithstanding, Donisthorpe's endeavours very soon reached the attention of Samuel Cunliffe Lister who recognised the value of Donisthorpe's attempts to create a wool combing machine. After many months of working alongside Donisthorpe, Lister was able to produce a combing machine which was subsequently purchased by some of the leading Bradford firms. By 1848, Lister was able to develop what he termed, "the first combing-machine" (Anon, c1906, p. 236).

Holden's interests and tenacity in understanding and resolving the problems he came across in textile machinery can be seen in a letter sent to a correspondent in which he noted:

> "… I study much to find out the defects of the machinery and general plans about our works and go cautiously to the work of reformation and improvement … It is my ambition not to be behind any man in this country in my knowledge and management of the worsted trade and manufacture if diligence can affect it. To diligence and perseverance, I owe what I have attained…" (Holden, 1832, p. 37)

Holden also played a very important part in many of the innovations in the processing of wool. In his French works situated at St. Denis, France, he was the first to introduce two “baths and rollers” (Burnley, 1889, p. 368), in the scouring (washing) of wool. This scouring method was soon widely used in the worsted industry. Although this method was not patented, Holden did patent an improvement to scouring in January, 1857 (Pat. No. 278). Scouring was undertaken in three large containers or baths which ran on rails along a track (Burnley, 1889, p. 368). At Alston Works, his English works, he adopted four processes whilst at his French works in Croix, he augmented the washing of wool to five operations.

Holden also switched his attention to the carding process and became the first wool processor to incorporate “two lickers-in with the opening rollers” (Burnley, 1889, p. 392). This operation was undertaken in his works at St. Denis and as it proved so successful Holden that patented this operation in 1857. Moreover, Holden continued experimenting with the construction of the carding engine by enlarging the opening rollers to “eighteen inches and the doffers to 40 inches” (Burnley, 1889, p. 392). Following a conversation by a Mr. Bateman who visited Rheims and Croix in 1860-161, Holden took his advice and added a burring roller to the lickers-in found on a carding engine. The function of the burring rollers was to remove impurities from wools such as vegetable matter (VM). The failure to remove the vegetable matter (VM) contamination could have an adverse effect on the price of greasy wool if or when it is sold because the wool yield would be lower than expected (Bownass and Hogan, 1988).

One key feature of the history of Yorkshire’s wool textile industry was centred on the ability of financing of new equipment, plant and to some extent machinery (Jenkins, 1972). Many mill owners tended not to invest in their machinery or plant. This lack of capital investment and commitment was to continue through many decades from the nineteenth to the twentieth century. Despite British inventors introducing new textile machinery, foreign competition very soon caught up and surpassed Yorkshire’s primary position in textile processing. Even so, it was not unheard of to find nineteenth century textile machines still being used in the twentieth century. The economic fortunes of many local businesses seemed to vary from one decade to another. This was further compounded by machinery and plant depreciating during the First World War (Jenkins, 2003). Eventually American weaving looms and European processing textile machines replaced Yorkshire-made machines.

5. 5. 5. Geographical

The added, variable proposed in this *PEST* analysis framework is Geography, a key determinant which provides a better clarity and understanding as to the reasons why the worsted industry chose to locate itself in Yorkshire and how this choice of locality led to the establishment of 'industrial clusters'.

The nature of 'clusters' had become very important to the economic development and expansion of Bradford as a worsted centre in the region, leading worsted manufacturer in the country and not forgetting its leading position as the "Worstedopolis" of the worsted trade in the world (Cudworth, 1888, p. 3). Certain determinants were crucial for Bradford and Yorkshire to assume the *loci* of the worsted manufacturing industry (Rainnie,1965). Smith makes the point that industry may not be centralised as one unique entity but can extend into a number of different entities which can be found in one particular geographical area (Smith, 1950). One of the earliest references outlining localised industries can be found in Marshall's *The Pure Theory of Domestic Value* (1975) and later discussed in *Principles of Economics* (Marshall, 1920). In the 1990s, Porter highlighted the role, contribution and importance that 'clusters' played in economic geo-industrial development (Porter, 1998). Ironically, even though the notion of clustering was always deemed to be important, no universal definition of cluster could be found.

According to Martin and Sunley (2003), a review of the definitions on the notion of 'clusters' showed that this was an abstract concept for academic researchers as it did not provide a universally-accepted definition. Porter (1998) defined 'clusters' as companies and institutions which were or have been closely linked or bound by their specialised involvement in a subject matter.

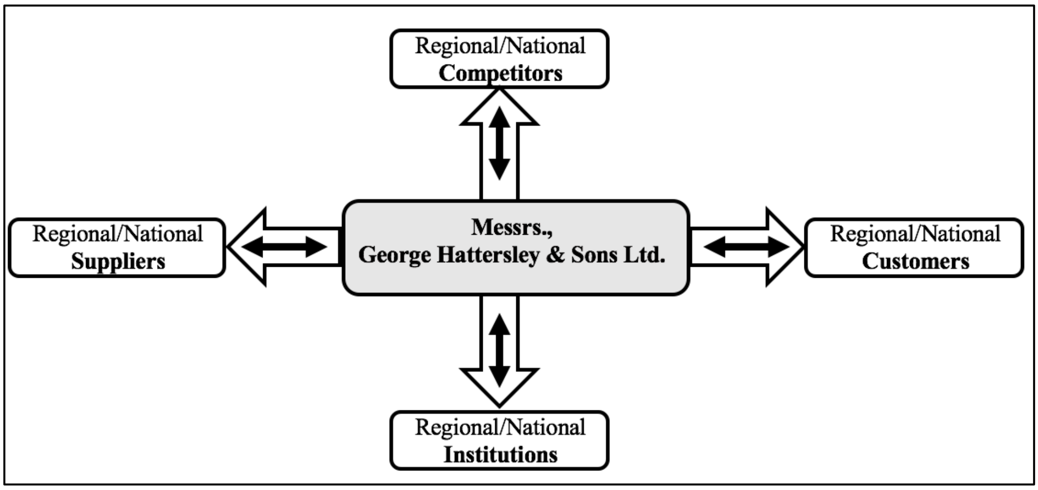
It was Iammarino and McCann (2016, p. 1023) who proposed that:

> "industrial clusters are distinguished in terms of the nature of firms in the clusters and of their relations and transactions undertaken within clusters."

Malmberg and Maskell (2002, pp. 430-431) have posited that:

> "There is a lot to learn about the proximity and place in economic processes by trying to pinpoint the driving forces that make for the agglomeration in space of similar and related economic activities."

Whilst there may be no single, accepted definition of 'clusters', it is very clear from some of the examples highlighted that the essence of this concept constitutes the close proximity or relationship to suppliers of machinery, services, a skilled workforce and raw materials. This close inter-locking chain of providers would form the framework of 'clusters'.



Source: (Adapted from Schiele, 2008).

Figure 12. Components found in Porter's Cluster Model

As can be seen in Figure 10, Hattersley's were very skilled in their ability to achieve financial success and prominence in their 'industrial cluster' for the enterprising ways in which they interacted with their competitors, customer base, their supply chain and supporting institutions at regional and national level.

Swan and Prevezer have noted that 'clusters' represent a large conglomeration of companies all working in one key geographical locality (Swan and Prevezer, 1998). According to some researchers, 'clusters' evolve strategically over the years or become dependent on three major factors. Ketels and Memedovic (2008, p. 378) have argued that "geography", "value creation" and the "business environment" are the key components which are important to an economic environment. One important contribution that 'clusters' produce is a particular, specialised workforce which have specific work skills (Marshall, 1961). It was not unusual to find workers who had specialised or inventive skills migrating to different workplaces if the incentives or rewards proved tempting. This phenomenon was examined by some researchers who argued that any movement of key or important workers would be instrumental in creating a centre which in turn would generate a considerable amount of invention and innovation (Feldman, 1999; Breschi and Lissoni, 2001).

5. 6. Findings of the *PEST(&G)* analysis; a summary

This chapter examined the five key *PEST* determinants - Political, Economic, Social, Technological and Geographical *PEST(&G)* which had a direct effect on the Yorkshire worsted manufacturing industry. What became evident in the course of examining the growth of the Yorkshire worsted manufacturing industry against each these five key determinants was a clearer understanding of the many external influences and transformative events which took place in this region from 1800 to 1939 and how the industry reacted.

Politics and the efforts of countering crippling tariffs such as the McKinley tariff, considered one of the "highest and most thoroughly protectionist tariff ever enacted by Congress" (Stanwood, 1903, p. 264), undermined Britain's exports. Furthermore, the consequences of an economy under stress had instigated or prompted emigration as well as a loss of technical skills, as in the case of Hattersley's and other Yorkshire industrialists. Berthoff (1953, pp. 28-29). underlined this point by noting that:

> "British immigrants to industrial America directly transfused the skills and experience of the premier industrial nation of the early twentieth century into the veins of the rising giant of the twentieth."

This point was endorsed by Rosenberg who argued that waves of British and European emigrants were instrumental in bringing over much needed skills, expertise and technology from Europe to the United States of America. These in turn boosted the commercial productivity of American business (Rosenberg, 1972). The United States of America's economic policy, according to Irwin, was that tariffs placed on imports had been imposed to safeguard their own domestic market, ensure substantially higher wages as well as keeping and increasing the American workforce (Irwin, 2007). The logic and effect of imposing high-rated tariffs was investigated by Wells (1867, p. 37) who noted that tariffs:

> "will soon distribute itself throughout the whole community, and will eventually manifest itself and reappear in the shape of an increased price for all other forms of labour and commodities; thus aggravating the very evil which in the outset it was intended to remedy"

An interesting insight into the key motivations which compelled Yorkshire textile workers to emigrate to the United States of America was made more transparent when this 'migration' was analysed against the technological determinant of the PEST(&G) framework.

This was the opportunity of personal advancement and escape from their penurious lives. On the one hand, unskilled migrant workers were offered job opportunities in the manufacturing industries. The incentive for these workers was that they were willing to accept wages which were considerably lower than skilled workers. On the other hand, the migration of skilled Yorkshire workers caused a direct transfer of skill and knowledge and advanced the speed of manufacturing in the United States of America. Berthoff (1953, p. 41) makes the point that the:

> "owners of British factories crated their machinery and left for New Jersey with their workmen."

The introduction of the steam engine, used to power machinery, caused an indirect motivation for emigration. The reason behind this impetus was based on the changing conditions of specific work localities, some of which were situated in the south of England. Ravenstein (1985, p. 198) has described this phenomenon of migration as the "universal displacement of population … [who set off] in the direction of the great centres of commerce and industry". With the exploitation and extraction of coal situated in the North of England, many workers, including unskilled workers and children flocked there to find employment. The result was that people who did not leave these depressed agricultural areas in the south became predisposed to emigration (Snow, 1931).

Yorkshire textile processors were often reluctant to purchase new textile machines. One typical example is of a loom [Hattersley's] being used over many years which was found in Messrs., W. E. Yates, worsted and woollen manufacturers in Bramley, Leeds. When one the weaver's retired from there, it transpired that she had been working on the same Hattersley loom for over forty years. Many other Hattersley looms still in operation were also found in this particular mill. The 'long service' phenomenon of these Hattersley looms being used at home and abroad was noted by one overseas commentator:

> "one of a number of old looms made by George Hattersley and Sons Ltd., of Keighley and known to have given exceedingly long service in the mills in which they are used" (The Textile Journal of Australia, 1928, p. 343).

The *PEST(&G)* analysis framework highlighted how migration was considered to be an important factor the development of Bradford as an industrial centre. Snow (1931) set himself two key questions on the reasons why people migrate and outlined the motivations for doing so:

1) What factors attract workers to another country or environment?
2) What factors causes workers to be sent away from one country or environment?

Depression in the agricultural and the hand combing sector was a major impetus for emigration abroad. In the early days of the depression, these workers discovered that their wages were beginning to fall. By the mid-nineteenth century, most of the poor relief around Bradford was concentrated on the plight of the hand combers who subsequently became dependent on this charitable financial support.

The introduction of mechanisation caused some emigration to take place. It was the hand loom weavers who experienced a loss of their skills as well as the loss of clients for their finished products. Mechanised weaving and spinning were able to provide the finished product much quicker and cheaper. Unemployment would always be a determining factor for workers deciding to emigrate to a country which offered better pay and prospects. In some areas, the Chamber of Commerce encouraged emigration to the United States of America and Canada (Snow, 1931).

Although a large proportion of emigration took place in the early years of industrialisation during the nineteenth century, the pace of emigration from Bradford fluctuated depending on the state or fortunes of the worsted industry. From the mid-nineteenth century, a government organisation and certain independent organisations were set up in Bradford to advise, encourage and facilitate schemes for emigration (Bradford Observer, 1847).

All the factors mentioned throughout this chapter have shown the many social, economic, and industrial constraints experienced by the Yorkshire worsted processing industry. Fashion played an important part in bringing new challenges, often detrimental to the worsted industry. Clapham goes even further with the challenges brought about by the changing fashions when he bemoans the loss of the "broadcloth trade" (Clapham, 1906, p. 522).

Textile production seemed to go through phases. By the mid 1870s to 1890s Bradford's worsted industry was subjected to the 'Great Depression'. Foreign textile competition became acute but concentration on the home market proved to be more promising. In this period, the number of textile workers, power looms and spindles tended to fluctuate. One interesting aspect of British government policy was to 'liberalise' its trade, encouraging free trade. This trade policy encouraged both output of yarn and cloth as well as providing an increase in exports to trading countries. Unfortunately, tariffs from overseas countries impaired British worsted exports and by 1932 had forced Great Britain to suspend its free trade agreement (Bairoch, 1993, pp. 26-28). Yorkshire worsted textiles would continue to go through a period of trade uncertainty and fluctuations until the beginning of the Second World War (1939-1945).

The industrial history of a region is by definition a complicated phenomenon determined by an inter-connected synergy of key factors directly and indirectly influencing the developments of the area.

The major challenges of undertaking such an historical research centre around making judicious choices on which sources to explore, how best to study these areas objectively and present the findings without any bias. For this reason, there is a requirement to adopt the best-suited research tool to undertake a diagnostic investigation.

This chapter set out to examine the effects of technological innovations on the economic growth and development of the Yorkshire worsted manufacturing industry, synthesising extensive research from a number of specialist areas including history, geography, entrepreneurship, technological innovations and economics.

It used the *PEST(&G)* analysis framework, the key external determinants of which would lead to a better understanding of how an interplay of all these factors impacted on this nascent industry.

These *endogenous* variables are important because they allow the researcher to explain the outcomes by undertaking an analysis based on a variety of factors. They show whether a single, dominant variable or a number of key variables cause a particular effect.

Of the five determinants used in this chapter which explored the invention, innovation, technological change and diffusion in the Yorkshire worsted manufacturing industry, the *two* main determinants, which were key driving forces were the economic and the technological variables.

Examined through the lens of the economic and technological determinants allowed the researcher, in the first instance, to make a distinction between economic growth and economic development in the Yorkshire worsted manufacturing industry. Where the former showed how the demographic trend of the Yorkshire worsted manufacturing industry saw an increase in population as well as an increase in the quantity and the value of the goods/services it provided, it is worth pointing out at this stage how the social determinant of the diagnostic tool highlighted the fact that economic growth did not necessarily lead to a qualitative improvement in the life of workers, not least in the disruption of the quality and volume found in traditional home-based textile processing and the dislocation of family groups migrating to these urban areas which were found to be already densely populated and developed.

These two key determinants clearly demonstrated how over time, the economic/ technological changes in the industry, were both evolutionary and cumulative. In this respect, these two, dominant factors showed how the industry-wide strategies for funding technological innovation and forging an inter-connected network of lucrative business relationships were a means of competing (and in some cases surviving) in a climate of rapid socio-political changes. Of particular interest was realising how the technological and economic factors gave rise to a class of entrepreneurs whose impact on the large and small firms in this textile area played a crucial part in ensuring a well-functioning regional economy.

Chapter 6. Messrs., George Hattersley and Sons Limited., loom production 1890-1939

6. Introduction

This chapter examines a number of factors crucial to the development of Hattersley's which arguably contributed to the firm being regarded as an important textile manufacturing establishment in Great Britain and the rest of the world. Many aspects of Hattersley's output, such as loom inventions, innovations, manufacture and external economic factors has been overlooked and it is hoped that this chapter will redress this omission.

6.1 Weaving

Weaving has been an important factor in the processing of fibres such as wool, cotton, jute, hemp, silk, flax into a woven fabric. Although the art of weaving can be traced back thousands of years, no one can legitimately claim to know what the actual date was when weaving was established or invented. What is unquestionably true is that the process of weaving had gradually evolved from coarse hand weaving to basic hand loom weaving technology and finally to weaving on all-metal looms. With the arrival of the so-called 'Industrial Revolution' Toynbee, 1969), weaving on all-metal looms became more advanced in their mechanisms as well as in their production and these looms would now operate almost independently thereby reducing constant human activity.

6.2 Weaving motions

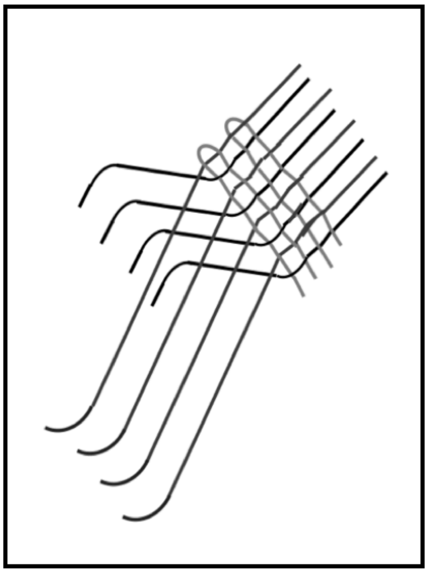
The techniques of weaving can be summarised into three distinct procedures - primary, secondary and tertiary motions. These three procedures or motions were integral to the process of all-metal loom weaving and to future improvements in design, invention, improvement and manufacture of looms. For weaving to take place, the interlacing of warp and weft (or two different sets or classes of yarns) must take place (Ashenhurst, 1907, p. 50). The warp yarn, situated on a loom, runs lengthwise whilst the weft yarn runs horizontally. These warp threads arrived at the loom after they have gone through the warping stage. This procedure involved laying a number of pre-determined threads, all the same length, side-by-side (Ashenhurst, 1907, p. 51).

6.3.1 Primary weaving motions

The primary weaving motions used on a loom involved the following operations

1) Shedding - This procedure was where the warp threads into two or more layers, had been placed into healds. These healds were suspended from a frame called a harness. A number

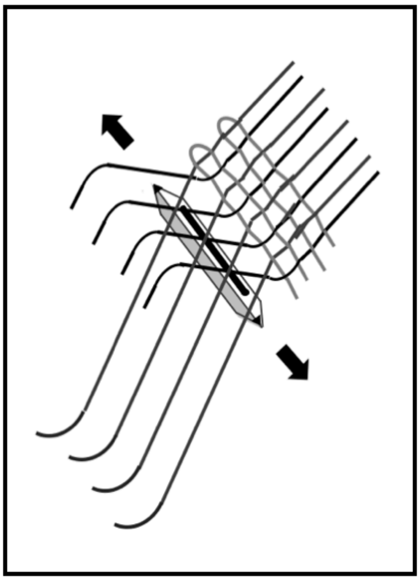
of warp threads were lowered and raised. The action of dividing the warp threads produced a space, tunnel or gap which weavers called a shed.



Source: (Adapted from University of Florida, textile learner)

Figure 13. Shedding in weaving

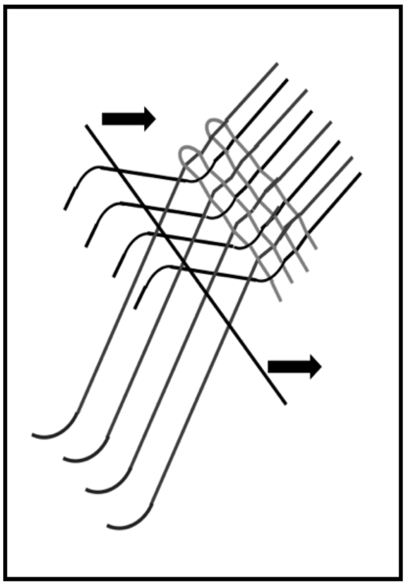
2) Picking or weft insertion - was where the shuttle carrying the weft thread was propelled from one side of the loom to the other side of the side. When this was achieved the technical term *weft* was replaced by the term *pick*. This occurred when it had completed its passage to the end of the shed. The raising of the warps was dependent on a pre-determined weave pattern arranged by the firm's management whilst the speed of the wooden shuttle carrying the pick was attributed to the loom machine manufacturer.



Source: (Adapted from University of Florida, textile learner)

Figure 14. Picking or weft insertion in weaving

3) Beating-up - ensured that the weft threads or pick, located across the shed, were pushed against the on-going woven fabric by means of a reed after each journey of the shuttle (Midgley, 1932).



Source: (Adapted from University of Florida, textile learner)

Figure 15. Beating-up in weaving

6.3.2 Secondary weaving motions

Weaving also involved secondary motion which involved the letting-off and take-up procedures. The letting-off or warp control related to how the warp yarn thread was delivered from the warp beam to the location where weaving would take place. Delivery of the warp yarn thread had to be at a constant rate so it could release the warp from the flanged wooden, warp beam in an orderly way. Take-up or fabric control related to how the woven fabric was directly wound onto the fabric beam in an orderly, regulated manner.

6.3.3 Tertiary or auxiliary weaving motions

This tertiary or auxiliary weaving motion was used to describe the importance of a warp stop motion located on a loom. A warp stop motion mechanism ensured that if a fault such as a broken warp yarn thread snapped, the loom would automatically be brought to an immediate stop (Midgley, 1932, p. 232).

6.4 Shedding mechanisms

Shedding is an extremely important function in the weaving process. There are three types of shedding undertaken on different weaving loom applications which will be discussed briefly below.

6.4.1 Tappet looms

The simplest examples could be found on tappet looms where one shuttle box sits beside each loom (Brearley and Iredale, 1980). These tappet looms tended to produce a type of shed which was basic and geared towards a simpler weaving design. Moreover, the use of the tappet loom produced two possible forms of shedding - a negative and a positive shedding. In negative shedding the tappet was only allowed to go in one direction. In other words, the heald could only be made to go down or up and were located under the loom healds or the actual weaving frame (Roberts, 1936). In positive shedding however, the heald was allowed to go in both directions and are positioned on the outside of the loom. The type of woven fabric, such as worsted serges, gabardines and suitings, was woven on a tappet loom and used a maximum of eight healds (Brearley and Iredale, 1980).

6.4.2 Dobby looms

Dobby mechanisms were adopted when the weaver had to use more than eight healds and four boxes at each end of the loom (Brearley and Iredale, 1980). These looms tended to have between 10 to 36 healds. Furthermore, when used on a loom, dobbies could be sub-divided into either a wheel or lever dobby. Depending on the choice the weaver made on lowering or raising the healds, the mechanism could be said to have a negative or positive dobby (Brearley and Iredale, 1980). This type of mechanism became particularly useful when weaving different types of worsted fabrics. A negative dobby was often associated with the weaving of light to medium worsted dress fabric. If a weaver was required to weave a fabric such as a heavy worsted coating, a positive dobby was used. Although there were many forms of dobby used on a loom, Table 17, shows the most common type of dobbies in use.

Single -Lift Dobby	Single-acting Machine	Controlled from the Top Shaft	Forms a Bottom Closed Shed
Centre Shed Dobby	Single-acting Machine	Controlled from the Top Shaft	Forms a Centre Closed Shed
Keighley Dobby	Double-acting Machine	Controlled from the Bottom Shaft	Forms an Open Shed
Blackburn, Shorrocks or Wire Dobby	Double-acting Machine	Controlled from the Bottom Shaft	Forms a Semi-Open Shed
Knowles Dobby	Positive Dobby		Forms an Open Shed

Source: (Wilkinson, 1915)

Table 17. Types of dobbies found in general mill use

6.4.3 Jacquard looms

These looms, with their jacquard attachments, were used when weaving fabric which required a floral or complicated figured pattern. The complexity or variety of the weave design could only be found on a jacquard loom and could not be matched or used if the weaver had to use a tappet or a dobby shedding mechanism. Different types of worsted and fancy fabrics were often woven on a single or double-lift single cylinders and single or double-lift double cylinders (Brearley and Iredale, 1980).

6.5 Inventions and inventors

Progress in the developments of innovative machine mechanism designs was essential to ensuring not only increased sales and a reduction in production costs but also a wide range of high-quality yarn and cloth (Draper and Raper, 1955).

Historically, the push for improving many of the yarn and fabric processing textile machinery had occurred during the mid-nineteenth century and had slowed down by 1914. Emphasis was placed on the improvement of quality to the processing of key aspects of textile processing namely 'top-yarn and fabric rather than the production costs' (Draper and Raper, 1955). Furthermore, certain textile-related inventions had, on occasions, required an overview of existing textile practices. Draper and Raper (1955) gave the example of when automatic looms were introduced. The originality of the automatic looms required an alternative mechanical approach to weaving. In effect, new practices were needed for weft preparation and old methods needed to be reviewed (Draper and Raper, 1955).

Mokyr (1990) insisted that the two drivers of economic growth, invention and innovation, were dependent on three key factors:

i Inventors and prominent inventors and their inventions

ii Improvers of inventions which Mokyr labelled as *tweakers.* This group of workers could ensure the improvement of the invention.

iii Skilled improvers which Mokyr classed as *implementers.* This group of workers were extremely skilled and could construct and ensure the smooth running of the machines.

It can be argued that Hattersley's workforce possessed all of Mokyr's three categories. Throughout their long history, Hattersley's would respond proactively to outside influences in order to improve their products and satisfy the needs of their customers. Technical staff associated with the firm would often elicit and encourage manufacturers and overlookers to offer suggestions and improvements as a means of channelling this experiential knowledge to upgrade the loom or other textile machines. This ability to make incremental improvements assisted in the promotion, manufacture and effectiveness of the textile machine as well as providing an on-going, in-house programme of technical improvements in manufacturing skills for Hattersley's workforce.

6.5.1 Hattersley's key inventors

This section on inventors employed at Hattersley's is neither meant to be exhaustive, nor definitive. Instead, it shows some of the noteworthy inventors who were instrumental in the continual success of Hattersley's, their involvement in the development of looms, dobbies and loom mechanisms and the important role they played in the British and foreign machine manufacturing industry. Arguably no other textile machine manufacturing firm in Great Britain could claim to have such an invaluable body of inventive staff who were able to not only develop their own ideas within the firm, but also to develop and transfer their inventive skills to other foreign firms.

During his long tenure as head of Hattersley's, Richard Longden Hattersley, the eldest son of Hattersley's loom makers and Messrs., George Hattersley and Sons Limited., worsted spinners and manufacturers based in Mytholmes, Haworth, became well-known as an inventor and promoter of the firm of Hattersley's loom makers, in addition to being an improver of worsted textile machinery and a good judge of inventive talent.

One member of the team of talented inventors, who worked at the firm of Hattersley's and developed many of the textile machinery, was James Hill, renowned as an inventor in the worsted textile manufacturing industry. He began his employment with Messrs., T. and M. Bairstow, Sutton Mills, Sutton-in - Craven, West Yorkshire, in 1843. After twenty-four years with the firm, he joined Hattersley's and became involved in improving weaving machinery. His most famous contribution to weaving was the first power loom (1834), Dobby mechanism (1867), Dobby or

Heald Machine (1876), the Coating Loom, Revolving box (1856), and the Rising Box Loom, made in 1866, to "weave checked [fabric] of medium weight" (60^{th} Congress, 2^{nd} Session, Dec, 1909).

During Richard Longden Hattersley's tenure at the firm, he worked alongside many inventive employees. One such employee was Simeon S. Jackson who began his apprenticeship there and over the course of thirty years, invented many loom improvements for worsted weaving looms ranging from compensating head-gears to pick-finder devices. In an interview given to the Yorkshire Evening Post in the late 1920s, he explained that he had worked at the Hattersley works where he had his "…first experience in the making of automatic looms" (Yorkshire Evening Post, Monday 10th October, 1928).

From 1904, Jackson decided to pursue his career in the United States of America where he was employed by the Stafford Company of Readville, Boston in Massachusetts. Whilst Jackson was with them, he invented the Stafford automatic shuttle-changing loom. When interviewed in 1928, he recalled that:

> "…it has been on the market in America only two years when we got a big half million-dollar contract to supply 1,100 of the looms to the Dan River Mills, in Virginia. The loom has been very extensively used ever since chiefly in cotton weaving, although it is applicable to fine worsted weaving. The machine was taken up in this country only in March this year" (The Leeds Mercury, September 11^{th}, 1928).

Within two years, a $500,000 contract was secured for the manufacture of 1,100 loom to be used in the Dan River Mill, in Virginia. The popularity of this loom was eventually adopted by mills in Great Britain. It was the firm of Vickers based in Crayford, Kent which, under license, were allowed to manufacture the loom for the international textile market.

Arguably, one of the most important inventors to leave Hattersley's was James Northrop [1856-1940] who left Keighley, Yorkshire and emigrated to the United States of America. Whilst in America, he joined the textile manufacturing firm of Draper, Hopedale in Massachusetts. During his time with the company, he invented the Northrop Spooler Guide which aided the loom's efficiency. More inventions followed, the culmination of which was the - Northrop automatic loom. During the spring of 1889, Northrop, who was working on different inventions, was assisted by a fellow inventor from Yorkshire, in England.

After six months of intensive work, Northrop had prepared a loom which was capable of operating at 150 picks per minute. During this period, a team of talented inventors were assembled in March 1889 to work on a new type of loom. The group consisted of Ira Draper (inventor of the first self-acting loom temple); E. Stimpson (inventor of the self-threading shuttle); Wm. Draper and G. Draper; G. Roper (inventors of the automatic let-off motion and J. Northrop (the inventor of the battery for providing an endless supply of weft bobbins ensuring that the loom did not have to be stopped) (Journal of the Textile Institute Proceedings, 1933, p. 72).

By 1890, over 100 Northrop automatic looms were trialled and recorded weaving cotton in Seaconnet Mill (later known as Clover Leaf Mill) in Fall River, Massachusetts. The loom's popularity and efficient production rate ensured that up to twenty-four looms could be managed by one weaver. Within the space of two years, over 24,000 looms had been built and installed in American cotton mills. By 1902, news of the loom's versatility had reached Great Britain and the British Northrop Loom Company was founded to produce, under license, automatic Northrop looms (Journal of the Textile Institute Proceedings, 1933, p. 72). Up to that date, British firms interested in the Northrop automatic loom had to contact the company of Northrop directly if they wanted to purchase looms. (Pourdeyhimi and Jackson, 1986, p. 102). Over time, the Northrop automatic loom secured its reputation as a competitive rival to the other type of automatic looms such as Hattersley's, as well as becoming the leading producer of automatic looms. Mass (1990, p. 234). Mass also recorded that by July 1965, the Draper Corporation, who at this stage of the development, had become so successful that not only did they become the largest textile manufacture in the USA, but also the largest industrial corporation in the USA.

Another of Hattersley's prominent inventor was Frank Leeming. He began his career with Messrs., Leeming, of Bradford, who were power loom manufacturers, and then went on to further his inventions with Messrs., George Hodgson and Sons Limited., (hereafter cited as Hodgson's), and Hattersley's. Whilst he was there, he rose to prominence and became the manager of the firm for a number of years.

During his working life, Leeming invented many useful textile mechanisms. Arguably, Leeming's most important invention was the Leeming Box Motion and the Leeming Rotary Dobby. The Leeming Rotary Dobby proved to be so successful that it was incorporated in the Northrop automatic loom as well as securing Leeming great prestige. It is not surprising that Leeming eventually became the Yorkshire representative of the British Northrop Loom Co. Ltd., Leeming was to remain with the firm for the next eleven years before he retired.

All these inventors proved to be pioneers in the development of many looms used in textile mills and continued to invent and innovate bringing success and kudos to both Northrop's and Hattersley's.

6.5.2 Importance of patents and fees

The assessment of patents continues to be a very useful, well-documented measure of providing an analysis of the role of invention in industry. It was Sir George Croydon Marks, M.P. (1919, p. 351) who claimed that the "textile industry was founded and developed on, and is still maintained in, inventions". The patenting of inventions together with their renewals was greatly assisted by the cost during the late nineteenth and twentieth century. Even though the cost was higher in Britain than in the United States of America, inventors continued to register their inventions. Following many years of parliamentary debates, the cost of patenting was eventually reduced by the Patent, Designs and Trade Marks Act in 1883. The fee was reduced from £25 to a £4 registration fee and £150 fee for renewals (Küegler, 2016). It also condensed the various steps needed (the time period went from six to nine months) as well as extending the examination of any patent application (Küegler, 2016).

From 1919, the term allowed for a patent to be registered was sixteen years. Though costly at the outset, over time, the fees for registering of patents were lowered. By keeping the patent fees at a certain level the intention was to supress any inferior quality from being patented (Küegler, 2016). These reductions in costs greatly assisted many textile firms to patent their inventions and improvements, not least Hattersley's.

6.5.3 Patent infringements and litigation

In a market economy, the concept of invention and innovation are fundamental to growth (Geroski, 1989; Romer, 1990). As inventors began to invent and innovate, they also began to register their inventions or intellectual property (IP) for the purpose of commercialising their efforts. Sell noted that the importance of patents could be seen to revolve around three key areas:

i) What constitutes patent 'property', who owns it and the ever-changing sphere of responsibility of 'ownership, authorship and invention'.
ii) Patents reveal the continual changes 'in the organization, production and distribution of technology'.
iii) Patents demonstrate 'institutional changes' (Sell, 2004).

Patents became essential to the inventor and industrialised societies. Inevitably, when registering any invention, the inventor was allowed to protect the exclusive intellectual rights as well as entering into some form of licensing agreement or even the possibility of selling the patent rights (Hagiu and Yoffie, 2013).

To explore this idea further, once the patent was registered and filed, it provided the inventor or assignee with "the exclusive rights […] for the protection of an invention (a product or a process)"

(European IPR Helpdesk, 2018) for a limited period of time. It also became beholden to an external public management and governance to provide legal protection for the technical information. The legal protection prevented any third party from "commercially exploiting - making, using, offering for sale, selling or importing the invention" (European IPR Helpdesk, 2015). This protection was only provided for a short period of time which attempted to ensure that the technical information was not infringed in any way by the enforcement of rights through civil, penal and administrative' legal channels. Even so, the rights of the patentee or the intellectual property became prevalent to litigation over originality or infringements.

In the course of any registration, there is always the potential for one inventor, either defendant or plaintiff, to legally contest or assert his rights to any actual, implied or inferred, infringement of his invention through the law courts. Bessen and Meurer have claimed that the high cost of registering a patent may have been a disincentive for registration (Bessen and Meurer, 2005). Consequently, careful consideration was always taken by firms to avoid any patent infringement because any legal action may result in adverse publicity, intermittent delay in production or simply negative publicity.

This section of the chapter will examine a typical and untypical patent infringement case in which Hattersley's were directly involved. From 1890 onwards, there were many legal patent disputes found in the High Courts of Justice, some of which featured Hattersley's patent infringements and disputes. It must be noted that they were not the only textile manufacturing companies to bring their disputes into the law courts. Notwithstanding, this section of the chapter highlights the more prominent legal disputes in which Hattersley's was involved such as with one of their own employees (1891) and Messrs., George Hodgson and Son of Frizinghall Works [1902-1906], Bradford.

In 1891, Hattersley's were subjected to one of the most noteworthy legal patent disputes involving one of their ex-employees. The plaintiff, James Hill, had been a past employee, inventor and improver to many textile machines, such as positive and negative dobbies and self-locking skipping boxes, which Hattersley's had patented and manufactured. From the onset, the company had paid him two shillings royalty per loom and much later paid him £20 for retrospective royalties (Bradford Daily Telegraph, October, 1891). This 'financial' arrangement was never written in any legal document. As Hill continued providing Hattersley's with his inventions and innovations, he kept pursuing his claim for this unwritten agreement to be written down and for royalties for his 77 textile inventions to be recovered. Coincidentally in 1889, just at the time that the firm had become a limited company, the directors questioned Richard Hattersley the progress made to resolve Hill's outstanding claim who informed them that it was still ongoing. By 1890, Hill's attempt to find an amicable resolution had failed and his employment with Hattersley's came to an end (Bradford Daily Telegraph, October, 1891).

After a lengthy court hearing, the Judge presiding in the Hattersley's and Hill case concluded that between 1882-1890, Hill had received £3.10s per week and 2s. 6d a week on royalties on all the patents he had co-registered. The Judge concluded that all the inventions had been licensed with the consent of Richard Hattersley and that the arrangement fell under the rules of an 'assignment of contract'. This was where the assignor passed his rights and obligations to a nominated party.

All patent infringements took time to resolve and were often very expensive to undertake. Hattersley's were also involved in a convoluted case involving their competitors, Hodgson, who they had accused of infringing a patent, No. 8000 ('*improvements to dobby looms for weaving'*), which had been registered in 1897 by inventors Richard L. Hattersley and Simeon S. Jackson. Unfortunately, at the court hearing, the presiding Judge ruled in favour of Hodgson claiming that they had not infringed the patent and he adjudicated that Hattersley's patent was invalid because their submitted patent had been badly written.

Hattersley's decided to contest the court ruling and on this occasion the Court of Appeal (comprising the Master of the Rolls and the Lords Justices) overturned the original decision claiming that Hodgson's had actually infringed the patent and granted Hattersley's an injunction against Hodgson's. During the ongoing court proceedings, Hodgson's took the decision to modify the original patent whilst continuing to claim, in court, that the patent shown on the specifications was basically the same as it was before the modification. Hattersley's objected very robustly claiming that an infringement had taken place and an order by the courts was issued to sequester the blueprint drawings. Moreover, the courts decided to call in an independent textile assessor who concluded that the patent had been infringed. or as he called it 'a colourable imitation'. The judgement and court costs were given in favour of Hattersley's (the successful party) whilst sequestration was placed on hold and would only be triggered if the patent was infringed following the court ruling. Hodgson's were still convinced that they had not infringed the patent and appealed against the original judgement. They were left with no alternative but to pursue it through the House of Lords. Unfortunately, Hodgson's appeal failed and their Lordships decided in Hattersley's favour, awarding them costs. This patent infringement case took a while to resolve, cost both firms a considerable amount of time and money, and lead to adverse publicity. The local Bradford newspaper waggishly dubbed this case as the "Great Dobby Case" (Bradford Daily Telegraph, March 1906, p. 2). This dispute eventually became a footnote of patent history when Hattersley's took over the company of Messrs., George Hodgson, Loom Manufacturer, Beehive Mill, Bradford in 1930.

6.6 Hattersley's key loom inventions

In the publicity material issued by Hattersley's in 1915, great emphasis was placed on the variety of looms that they produced, 'of every description' (Wilkinson, 1915). The section of this chapter will examine a selection of Hattersley's most influential inventions, technical breakthroughs and innovations. Hattersley's continued to patent their loom inventions and improvements as a matter of course. Different Hattersley inventors either worked alone or in partnership to register their patent, making them one of the most successful loom machine manufacturers in Great Britain. Table 18. shows the continual flow, regularity and proficiency of the yearly registration of Hattersley's patents taken from 1886-1917 records.

Patent	1886-1893	Patent	1894-1899	Patent	1899-1905	Patent	1905-1911	Patent	1911-1917
1980	**1886**	1557	**1894**	16110	**1899**	7452	**1905**	21941	**1911**
2018	**1887**	3959	**1894**	17135	**1899**	8939	**1905**	24065	**1911**
4002	**1887**	22141	**1894**	24839	**1899**	18859	**1905**	5922	**1912**
7257	**1887**	25236	**1894**	165	**1900**	24887	**1905**	7048	**1912**
19525	**1887**	25237	**1894**	8535	**1900**	26833	**1905**	7049	**1912**
3044	**1888**	9843	**1895**	22523	**1900**	14654	**1906**	19747	**1912**
4572	**1888**	15197	**1895**	22678	**1901**	22654	**1906**	27467	**1912**
8602	**1888**	16534	**1895**	22769	**1901**	6154	**1907**	27469	**1912**
8773	**1888**	18627	**1895**	24441	**1901**	16550	**1907**	28795	**1912**
13859	**1888**	22928	**1895**	2622	**1902**	21152	**1907**	21874	**1913**
3909	**1889**	24781	**1895**	13577	**1902**	2095	**1908**	22956	**1913**
5599	**1889**	8066	**1896**	14376	**1902**	2363	**1908**	23160	**1913**
1762	**1889**	11281	**1896**	14620	**1902**	9608	**1908**	29924	**1913**
3034	**1889**	11774	**1896**	16508	**1902**	14211	**1908**	6242	**1914**
7325	**1889**	23430	**1896**	20959	**1902**	20521	**1908**	8092	**1914**
437	**1890**	8000	**1897**	10142	**1903**	13363	**1909**	10553	**1914**
2809	**1890**	9228	**1897**	12135	**1903**	5856	**1909**	2211	**1915**
3194	**1890**	20604	**1897**	14047	**1903**	6481	**1909**	3160	**1915**
1778	**1891**	9741	**1898**	19484	**1903**	30116	**1909**	9656	**1915**
7575	**1891**	12055	**1898**	24763	**1903**	14529	**1910**	9656	**1915**
2917	**1892**	21260	**1898**	3173	**1904**	28003	**1910**	11700	**1915**
3213	**1892**	22063	**1898**	7778	**1904**	3059	**1911**	15224	**1915**
3897	**1893**	24033	**1898**	24327	**1904**	8651	**1911**	102246	**1916**
4165	**1893**	665	**1899**	22802	**1904**	16390	**1911**	103354	**1917**
3196	**1893**			5510	**1905**	20493	**1911**	103367	**1917**

Source: (West Yorkshire Archives)

Table 18. Registration of patents by Hattersley 1886-1917

6. 6.1 Hattersley's weft-replenishment mechanism

The notion of an automatic loom in the textile industry was not a new concept. Its historical development could be traced back to the mid-nineteenth century. Many inventors had tried to develop or perfect an automatic weft-replenishment mechanism during this time. Some may have succeeded in producing small incremental improvements whilst a fraction of inventors may have abandoned the patenting of their ideas as a consequence of a number of factors, such as cost, possible patent infringements or a managerial strategy to hold back on new improvements because of potential competition. A fuller overview of the development of the weft-replenishment mechanism, with emphasis on the Northrop automatic loom can be found in the paper of Pourdeyhimi and Jackson published in 1986.

Date of Patents	Specification No.	Name of Patentee	Type of Device
1834, Mar. 20	6579	J.P. Reid and T. Johnson	Shuttle-changing
1840, Oct. 22	8664	Charles Parker	Shuttle-changing
1852, April. 28	14,092	William Newton (agent*)	Shuttle-changing
1857, April. 13	1046	Patrick McFarland	Cop-or Bobbin changing
1860, April. 4	861	Thomas Ingram	Cop-or Bobbin changing
1860, Nov. 14	2787	Julius Boeddinghaus	Shuttle-ejecting
1861, Feb. 5	301	John Leeming	Bobbin-changing
1862, Feb. 17	419	H. and R. Crawford and R. Templeton	Shuttle-changing
1863, Jan. 27	239	J. Edmondson and T. Ingham	Cop-or Bobbin changing
1864, Mar. 17	688	J. Edmondson and T. Ingham	Cop-or Bobbin changing
1864, July. 19	1803	John Maynes	Cop-or Bobbin changing
1865, Feb. 2	293	John Maynes	Cop-or Bobbin changing
1865, Sept. 20	2395	Joseph Edmondson	Shuttle-changing
1866, Jan. 1	1	J. Bullough and W. Rossetter	Shuttle-changing
1866, April. 16	1069	Alfred Vincent Newton	Shuttle-changing
1866, Sept. 6	2292	John Bullough	Shuttle-changing
1866, Oct. 13	2654	William Rossetter	Shuttle-changing
1868, July. 28	2366	John Bullough	Shuttle-changing
1868, Sept. 10	2788	John Maynes	Shuttle-changing
1869, Sept. 28	2820	John Bullough	Shuttle-changing
1870, May. 26	1530	Benjamin Cooper	Shuttle-changing
1872, Mar. 12	757	A.M. Clark and P. Heilmann	Shuttle-changing
1874, May. 1	1542	J.H. Johnson from A. Villeminot	Shuttle-changing
1877, Jan. 27	356	J.S. and B.A. Raworth	Semi-automatic shuttle - changing
1888, Mar. 12	4850	Jacob Jucker	Shuttle-changing
1891, June. 23	10,633	A.G. Brookes from W.F. Draper	Cop-bobbin changing
1891, June. 23	10,634	A.G. Brookes from W.F. Draper	Shuttle-changing
1891, June. 23	10,635	A.G. Brookes from W.F. Draper	Cop-bobbin changing
1894, Apr. 26	8251	H. Bourgeois	Shuttle-changing
1894, Oct. 2	18,611	G.O. Draper	Cop-or Bobbin changing
1894, Nov. 27	22,939	A.G. Brookes from W.F. Draper	Cop-or Bobbin changing

Source: (J. T. Taylor, 1909)

Table 19. Patent developments of the weft replenishment mechanisms

Furthermore, the wool staple used in woollen and worsted weaving presented a technical problem in weft-replenishment. During the nineteenth century, this type of weft-replenishment mechanism was used in low to medium cotton weaving areas in Lancashire and was considered ideal for the changing one type of weft colour. This operation was dependant on the weft fork which regulated the changing of one type of weft to another. Unfortunately, this was not possible when weaving woollen or worsted fabrics because the different examples of weft-replenishment mechanism used in the wool industry was always blamed for missing picks found in woollen or worsted fabric. Remedial work, therefore, would became necessary and any unnecessary cost for remedial work would also have to be added to production costs.

According to the Patent Office records, the earliest Letters patent specification, comprising of 69 pages and over 35,000 words (20th March, 1834, No. 6579) for an automatic weft-replenishing mechanism, was attributed to Messrs., John Paterson Reid and Thomas Johnson, who originated from Glasgow. Many other inventors continued developing and experimenting with improvements to cop or bobbin changing on a loom. This all changed when Patrick McFarland of Perth registered his Letters patent specification in 1857 (13^{th} April 1857, No. 1046). McFarland (1857) described his invention as having:

> "arrangement by which a loom is made to supply its shuttle or shuttles with fresh weft when the weft last placed in the shuttle or shuttles has become broken or exhausted"

This was a prototype for an automatic weft replenishment mechanism or cop-changing mechanism. In the Textile Journal it notes that:

> "the most successful English loom at work at the present time is the one made by Hattersley Ltd., the invention that was patented in 1857 by Patrick McFarlane." (Textile Journal, Sept, 1902, p. 63)

Table 19. highlights the many attempts that different inventors (together with their patents), who endeavoured to perfect the weft replenishment mechanisms. Some were to prove commercially successful; others were soon forgotten.

Even so, this fact is contrary to the existing weft replenishment mechanism for the Hattersley and the Northrop automatic loom which was already established in the textile machine manufacturing market. Furthermore, it had taken almost half a century to emphasise the importance of the inventor and his novel weft replenishment mechanism.

Hattersley's registered their weft-replenishing mechanism in 1900 (Pat. No. 22, 523). It was not too long before it became the most commercially-used weft-replenishing mechanism found in British weaving mills because of its effective and novel shuttle-changing mechanism. It operated on the principle that if the shuttle weft came to an end or was exhausted, the loom would stop for the shuttle to be replaced and once the weft was replaced, the loom would be restarted automatically. This action allowed valuable time for this operation to take place. The changing of the shuttles could be activated by either the weft-fork or the weft-feeler. This mechanism created a six-fold operation which was activated on the Hattersley loom. Firstly, the Hattersley loom came to a stop (2) this then raised the shuttle-box fender (3) the shuttle was then ejected (4) once the shuttle was discarded another full shuttle was replaced into the shuttle box (5) the shuttle-box fender which had been lifted in lowered into the same position before the replacement shuttles were activated. This innovation also prevented any fresh loaded shuttle to enter the shuttle box (6) the loom was then re-started which began a new cycle of weaving (Taylor, 1909, p. 217).

In addition, a careful developmental consideration had been taken to allow little or no tension on the loom mechanical parts. Added to this was that the loom was designed to operate at the correct maximum speed. A typical Hattersley loom of "36 inches reed-space would operate at 150 picks per minute." Moreover, any Hattersley loom which was weaving at a speed of 180 picks per minute, would allow the loom to come to a stop for two seconds (Taylor, 1909, p. 217).

One of the advantages that the Hattersley loom had over the Northrop automatic loom was that the Hattersley loom was able to use the same shuttle as found on the type of power looms which were still being used in weavings mills. Unfortunately, the Hattersley automatic shuttle changing loom, introduced in 1902, was well-suited to figured warp weaving but could *not* handle the switching of one weft colour with another weft colour (Textile Recorder, 1902, p. 364).

Northrop looms, on the other hand, required "essentially the use of shuttles of special construction that [were] capable of self-threading the weft" (Taylor, 1909, p. 200), The Leeds and Yorkshire Mercury recorded that there were approximately 60,000 to 70,000 looms "known as the Northrop" found in American mills (The Leeds and Yorkshire Mercury, Oct 1901, p. 7). Even so, the newspaper noted that although many Northrop automatic looms could be found in Germany, Belgium, France and many other countries in Europe there were no Northrop automatic looms to be found in Great Britain.

By 1901, thirty-four Letter patents had been registered. The interest in weft replenishment mechanism in automatic loom continued and by 1904, the number of Letter patents had increased to 163. In a talk given in Todmorden on the automatic loom, the lecturer, Abraham Crabtree underlined the importance of the automatic loom by declaring it to be the:

> "most important loom improvement introduced during the last 50 years, and it was likely to have far-reaching effects. Since about 1840 there had been no great changes in the power-loom which had very materially increased the production of the weaver" (Todmorden & District News, Sept, 1902, p. 8).

Crabtree continued his talk by placing the automatic looms into three categories. The first category was defined as a loom (Seaton) which had a continuous quantity of weft located at the side of the loom with the result that both shuttle and cop were 'dispensed with'. In the second category (Northrop), the bobbin or cop was replaced whilst in the shuttle. The third category (Hattersley) was totally different because it had its shuttle replaced. Crabtree added that, in his opinion, the Hattersley's was the "most successful" loom of all (Todmorden & District News, Sept,1902, p. 8).

It was in 1902 when Hattersley's introduced their automatic looms. They claimed that this type of loom had proved to be very successful when introduced to British weaving mills (Textile Journal, 1902). The incorporation of this type of automatic loom was recorded in a visit to the firm of W. H. Guthrie and Co. Ltd, Carrfield Mill, in Todmorden by the Textile Manufacturer (May, 1903, p. 145). They noted that:

> "After twelve months [of] continuous work on a practical scale, this firm can show the exact position and definite capacity of the automatic loom … The shed contains 160 looms of the Hattersley automatic type (shuttle-changing), all being overpick, with the exception of one underpick, which was put down among the others for observation purposes. The looms were running at 180 picks per minute, although after an alteration of the engine for the purpose of ensuring a more even drive, they are about to be speeded up to 200. For the last year these looms have been weaving plains, twills, jeannettes and sateens, each weaver minding eight looms."

The automatic loom remained one of the many looms that Hattersley's manufactured. It is particularly striking that Hattersley's preferred to concentrate on the manufacture of many different looms which catered for the needs of their local, regional, national and international customers rather than concentrate on producing one type of looms. Their approach to manufacturing looms may be seen as pioneering, innovative loom designs (see Appendices 5-22).

6.6.2 Hattersley's and the smallware loom (or narrow fabric)

When Hattersley's introduced the smallware (or narrow fabric) loom into the textile industry they claimed their novel loom had many advantages over other looms. Unlike many other looms of the smallware category, this particular loom was almost automatic and Hattersley's claimed that it produced a superior fabric without breaking down. This machine was described as a loom which could weave anything ranging from wool, cotton, mercerised cotton, silk, linen to very coarse derived yarn. Hattersley's also maintained that the loom could be operated over a period of twenty-four hours which would prove ideal for any weaving firm. Additionally, they asserted that their loom would require little maintenance, have little or no wastage and would prove to be inexpensive to run.

The Hattersley smallware loom was reputed to carry more weft on its bobbins than other smallware looms. This innovation would reduce time and cost when winding yarn as this smallware loom carried more weft on its bobbins (The Manchester Courier, Sept, 1906). With the bobbins having more weft, it was felt by the manufacturers that only two bobbins would not be in operation at any time if the loom stopped. This was much better than other looms which, when coming to a standstill, would result in a maximum of sixty bobbins standing idle (The Manchester Courier, Sept, 1906).

Hattersley's stressed that no extra cost would be incurred when setting up new shift patterns. The looms could be integrated into two shifts as well as operating during meal times without requiring the attendance of weavers. Hattersley's went further and declared that if these looms were left to run unattended during official meal breaks, they would still be running at between 50-70% efficiency. The Manchester Courier (Sept,1906) reported that a quantity of these looms had been installed in a mill in Tamworth, Staffordshire and records were kept on their reliability. The records revealed that half of the operational smallware looms never came to a standstill 'except during the day to refill the weft bobbins' (The Manchester Courier, Sept, 1906). This loom proved to be one of the best-selling looms that Hattersley's had ever produced.

6.6.3 Hattersley 'Standard Model' loom

Possibly the most successful pick and pick loom for woollens and worsted that Hattersley's designed and introduced was their 'Standard Model' loom. In a document prepared by Hattersley's, they outlined the criteria needed for the construction of a new type of loom. Their designers were encouraged to:

i. Design the best possible loom absolutely irrespective of cost, and
ii. Make no effort to use parts from older models of looms so often the design of a new loom has been spoilt by the incorporating of many parts from other models, to save the cost of pattern-making.

Subsequently, a series of recommendations was suggested to their designers who incorporated these factors to ensure that the Hattersley 'Standard Model' loom was different from other looms.

i. The loom had to be robust in its 'stationary parts, free from [any] vibration' which could affect the smooth running of a loom
ii. It had to run using 'less power' than other looms.
iii. The removal of unnecessary 'slot holes'.

To get around this problem of slot holes, parts on the Hattersley 'Standard Model' loom would be carefully assessed, machined and put together. Fastening would then be carried out by bolting the parts together inside the pre-determined drilled holes. This procedure ensured that the traditional long slot holes which would often result in fixed bolts becoming loose, affecting other parts or at worst breaking the parts, would be ended.

The design of the Hattersley 'Standard Model' loom incorporated new features such as phosphor bronze bearings which were positioned directly beneath the loom frame. Hattersley's claimed that this design feature was far superior to the traditional method of bolting the loom brackets to the sides of the loom. The Hattersley 'Standard Model' loom parts were also designed to be interchangeable (Hattersley letter, 1936).

To avoid unnecessary intervention by the weaving overlooker if the weaving loom broke down, the designers of the Hattersley 'Standard Model' ensured that the loom parts did not require constant calibration which was resolved by their careful design of the loom seating.

Additionally, the strategy adopted by the designers set about the replacing of the traditional cast iron box-frame, which held the rising box shuttles, with robust steel shafts. This feature ensured that the shafts were shatterproof. Furthermore, unlike the Hodgson and Dobcross loom which they had studied, the picker guide and spindle were constructed to be adjustable so that the traversing shuttle could be corrected when required. Hattersley's also claimed that weft breakages would not take place and that using this type of loom would guarantee that shuttles would last much longer.

In designing the 'Standard Model' loom, Hattersley's compared their version of a box motion to the Hodgson box motion already in use. Hattersley's stressed that although the Hodgson box motion was successful it had some inherent design problems.

Hattersley's began examining the operation of the picking motion. They concluded from their extensive findings that the overpick motion gave a better result than an underpick motion in terms of wear and tear both in the picking costs and the reliability and accuracy of the shuttle. Moreover, they concluded from their investigations that, until the 'Standard Model' loom was introduced, an overpick loom could only operate successfully with a picking spindle at the front of the shuttle box and the swell located at the back. Hattersley's continued with their advanced loom design by making the picking clutches, located on a square shaft, in steel and not cast iron.

Arguably, the most important and functional aspects found on the 'Standard Model' loom was the box loom motion. Hattersley's approach was to examine both the Hodgson and Dobcross box motions. In the case of the popular Hodgson loom, the box motion was manufactured in cast iron which according to Hattersley's was prone to breakages. The box motion found on the Dobcross loom used chains which had to negotiate a series of pulleys and corners when operated. This operation caused great wear and tear to the mechanism with the result that after a few years of operation, the box motion lift would be handicapped. Hattersley's concluded that this poor design was further compounded by the toothed wheels found on the box motion which were subjected to vibrating levers. These were not robustly made. Due to the nature of their construction, these levers would be subjected to being distorted after continual use. Hattersley's team of inventors rectified the weakness found on their competitor's box motion by increasing the size of their toothed wheels from solid steel blanks and making the levers much stronger.

Hattersley's who had invented and manufactured the world's first dobby in 1867 recommended that their 'Standard Model' loom use the inclined guided baulk type of dobby. It was easier to install, and more robust than the other types of dobbies being manufactured in Great Britain.

A particular feature found on the 'Standard Model' loom was the Hattersley positive worm let-off mechanism. Hattersley's claimed that their type of worm let-off mechanism was the most responsive which would ensure that any woven cloth would be evenly woven without any excessive blemishes or number of imperfections (Hattersley's correspondence with F. A Lodge, 1937).

One of the key features found on a Hattersley 'Standard Model' pick and pick loom was their patent automatic pick finding mechanism. The function of this device was to ensure that if the weft thread was interrupted or broken, in the course of weaving, the loom would automatically stop while all the shuttles would remain in their rightful locations. Furthermore, the loom's take-up motion would be correctly and mechanically adjusted. Hattersley's promoted the idea that any weft wastage would be reduced or eliminated and the final woven cloth would require very little remedial work such as mending because of the superior nature of their patent automatic pick finding mechanism.

After introducing the 'Standard Model' loom, Hattersley's won many plaudits and continued to publicise the versatility of the loom. In a letter to F. A. Lodge of Leeds (1937), Hattersley recorded that their 'Standard Model' loom had the advantage of having a:

i) Lower purchase cost.
ii) Lower cost of its upkeep.
iii) Maintained a better re-sale cost.
iv) Spare parts could be easily obtained as opposed to the Hodgson loom which tended to be difficult to obtain or at time almost obsolete or subject to undue delay.
v) Hodgson looms used 50% more power and operates at a lower speed than a Hattersley 'Standard Model' loom.

vi) Hattersley compared their ‘Standard Model’ loom with Hodgson looms having box and dobby chaining. The conclusion was that Hodgson looms were considered to be expensive, very heavy and prone to becoming very dirty when in use. On the other hand, Hattersley ‘Standard Model’ looms were publicised as being cheap, light and clean.

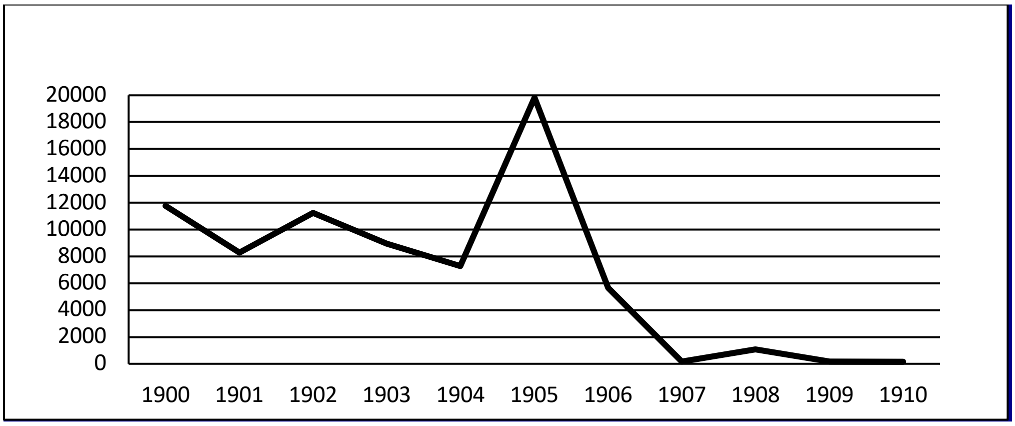
In a letter sent to Hattersley’s, F. A. Lodge of Leeds (1937) concluded that many British weaving firms were discarding Hodgson loom and favouring Hattersley ‘Standard Model’ looms. Table 20. shows some of the British firms which continued to favour ‘Standard Model’ looms over other looms:

‘Standard Model’ loom	J. & J. Crombie Ltd, Aberdeen
‘Standard Model’ loom	Abraham Moon Sons, Guiseley
‘Standard Model’ loom	Gibson & Lumgair Ltd, Selkirk
‘Standard Model’ loom	S. H. Rawnsley Ltd, Wilsden

Source: (Hattersley correspondence with F. A Lodge, 1937)

Table 20. Selection of firms favouring Hattersley ‘Standard Model’ loom

6.7 Hattersley’s loom production during the decade 1900-1910



Source: (Hattersley order books 1900-1910)

Figure 16. Looms produced during the period 1900-1910

The Leeds and Yorkshire Mercury of 1901 reported that textile manufacture had undergone a period of stagnation in Yorkshire. Competition and tariffs imposed by the United States of America had contributed to a trade depression. Even so, an increase in textile machine manufacture had taken place at the start of 1900 (The Leeds and Yorkshire Mercury, 21st of October, 1901, p. 7). Countries like the United States of America, Germany, France and even

Russia had been instrumental in the stagnation that had taken place. What the British textile manufacturers had found to their great annoyance was that their textile machines were being blatantly copied by the French and German manufacturers. The Leeds and Yorkshire Mercury (21st of October, 1901, p. 7) reported that:

> "Some years ago revolving box-looms were not patented in Germany and were imitated in every detail. Unlike the Continental, the American machinery is exceedingly good but it is for the most part copied from our own."

The American market had, by the middle of the decade, introduced their Northrop automatic loom which had been very popular and widely used in the American cotton mills. This revolutionary automatic loom invented by James Henry Northrop, an ex-Hattersley employee who had emigrated to America several years previously, was designed to replace a spent cop with a full cop without the weaver intervening or stopping the loom.

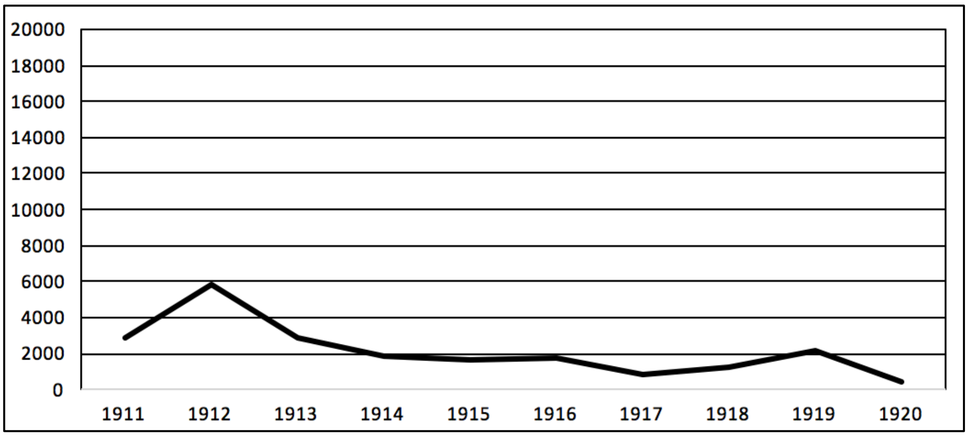
Hattersley's had, at the beginning of 1900, designed and manufactured a range of different looms:

> "of every description for weaving silk goods to carpeting and wire netting. After years of experimenting they have just completed a loom for weaving pile carpets without the use of wires, they have a new loom for weaving millers' wire-sieving and numerous small looms intended for special industries abroad" (The Leeds and Yorkshire Mercury, 21st of October, 1901, p. 7).

The graph spike shown in Figure 14. (1900-1910), shows the popularity and versatility of Hattersley's smallware (narrow fabric) loom. Paradoxically, this loom, which was the world's first smallware or narrow fabric loom, proved at the onset not to be very popular with many manufacturers. Hattersley's publicity emphasised how their smallware loom could be operated around the clock. Although the response by manufacturers to this loom had not been as encouraging as Hattersley's had wished, they took the unprecedented decision to promote the versatility of their loom in their own way. Hattersley's decided to purchase Cabbage Mills, located in Keighley, and duly installed it with their own machines. Once these looms were set up in Cabbage Mills, Hattersley's began the weaving of webbing for the car industry and tapes. A loom which could be operated continuously and without stoppage would eventually become very useful and sought after by weaving manufacturers, not least during the 1914-1918 war period. The Hattersley's smallware loom was to prove ideal and integral to the weaving of military-related items such as webbings (or puttees), tapes and ribbons for medals.

The year ended with an unexpected outcome when part of Hattersley's building caught fire. Fortunately, the fire was quickly extinguished before it took hold by the "Corporation's motor tender chemical apparatus" (Yorkshire Post and Leeds Intelligencer, Oct, 1910). Production eased off with the onset of competition from other competitors.

6.7.1 Hattersley's loom production during the decade 1911-1920



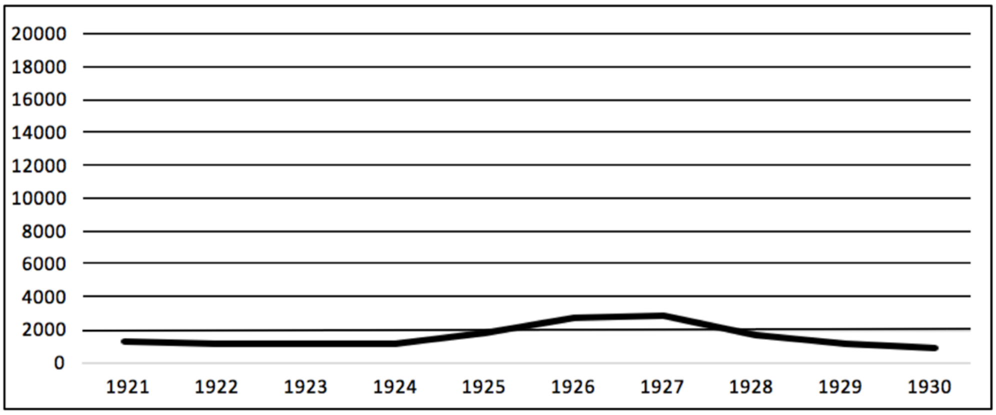
Source: (Hattersley order books 1911-1920)

Figure 17. Looms produced during the period 1911-1920

During the decade 1911-1920, Hattersley's continued to invent and promote their looms. Unfortunately, with the outbreak of World War 1 [1914-1918], their textile loom manufacturing had to come to an end. Consequently, with the onset of the 1914-1918 war, Great Britain embarked on an economic mobilisation and state control programme which resulted in the country's manufacturing industry switching from civilian work into essential war work. This economic mobilisation of World War 1 was summed up by Winston Churchill, the British Munitions Minister, in 1917 as a 'steel war' (Childs, 1999).

Following the declaration of war against Germany on the 4^{th} of August 1914, a Royal Proclamation was issued on the 5^{th} of August prohibiting the British public and business community from entering into any business deal or trading with the enemy (Lobban, 2014). Within two weeks of this proclamation, the Trading with the Enemy Act, 1914 was passed by Parliament. Towards the end of 1914, Hattersley's were prosecuted under the Trading with the Enemy Act, 1914 for continuing their business or trading with the enemy contrary to the regulations. Hattersley's were accused that around May $10^{th,}$ 1914 they had entered into a commercial contract for "10 gross [equivalent 1440] of compressed paper warping bobbins" (Manchester Evening News, Dec, 1914). A summons was also issued to their agents Messrs., Isherwood and Company. The case revolved around the legal presumption that a contract had existed between the defendants (Hattersley's) and Emil Adolff of Reutlingen in Wurttemberg, Germany. Hattersley's countered this claim by arguing that they had not undertaken any verbal or written business contract with Messrs., Adolff. Instead, the contract they had actually engaged into a contract with an agent called Messrs., Isherwood and Company. Once all the evidence had been heard, the presiding judge took the appropriate action and dismissed the case through lack of evidence. This particular case had little effect on the immediate business and production coming out of the firm of Hattersley. The years 1911-1920 reflected a period of steady production but with little or no increase in loom production.

6.7.2 Hattersley's loom production during the decade 1921-1930



Source: (Hattersley order books 1921-1930)

Figure 18. Looms produced during the period 1921-1930

The end of the 1914-18 war marked new changes in both Yorkshire, Bradford, Keighley and European textiles. Following the 1914-18 war, much of the textile industry production in Europe had almost come to a standstill. Sourcing raw materials, export markets as well as commerce had been interrupted. In this immediate post-war period, textile mills and machinery appeared not to be needed resulting in many business networks being lost. Furthermore, the currency of certain European countries such as France and Germany had depreciated to an all-time low and in the case of Germany, had become almost worthless.

Yorkshire, Bradford, Keighley and British textiles fared slightly better. Business organisations such as trade federations began to be set up. The Wool Textile Delegation, established in 1921, had been set up with a broad remit to assist in commercial activities, resolve financial or any legislation affecting textiles. According to one commentator, this organisation was instrumental in providing WIRA (Wool Industries Research Association), recognised and supported by the Empire Marketing Board, (Textile Mercury, 1928, p. 20) with a stable financial foundation (Keighley, 2007, p. 25).

The recruitment of skilled textile labour continued to blight the industry during the decade of the 1920s. Many young people seemed not to be very interested in joining the industry. New machinery was also needed which also highlighted the need for new skills. One commentator recorded that the "worsted loom…was practically the same as it had been 40 years before" (Keighley, 2007, p. 36).

The production of textiles during 1920 to 1930 proved to be the 'British industry's salvation' (Jenkins and Jenkins, 2003). British textile industry managed to continue providing the home market with their looms and products despite competition coming from abroad. Even so, the response in output, by the wool textile industry, was somewhat patchy. The volume of tops (long, combed worsted fibre), for instance, never matched the pre-1914-1918 levels. Jenkins and Jenkins argued that "no significant new technology was introduced to the industry in the inter-war years" (Jenkins and Jenkins, 2003, p. 995). This observation appears not to be accurate as Hattersley's had developed and introduced their very successful 'Standard Model' loom into the home and foreign textile market by the end of the 1920s.

The Leeds and Yorkshire Mercury journal (Dec, 1928) announced that 1928 had been 'a Poor Year for Coal and Textiles'. Even so, the journal was optimistic that the Five Counties Marketing Scheme, operating in Yorkshire, would embody a 'justified hope of improvement' to both the coal and textile industries in Yorkshire (The Leeds and Yorkshire Mercury, Dec, 1928). This scheme, which comprised the northern counties of Yorkshire, Nottinghamshire, Derbyshire, Lancashire and Cheshire, was authorised to control the selling prices of coal. Additionally, the scheme was also empowered to invigorate or increase the trade located in the Humber ports. The importance of this scheme could be seen in the Yorkshire export figures of 1928 showing 2,100,000 tons as opposed to 1927 figures which indicated that 1,400,000 tons was only exported (Hoar, 1930). This scheme helped the export of goods coming out of Yorkshire, Bradford and Keighley.

By the end of the 1920s, the Great Depression duly plunged Yorkshire, Bradford and Keighley textiles even further into a steep, downward, economic slump. Many voices echoed the shocking state that the Yorkshire textile industry had reached. In 1928, The Lord Mayor of Bradford, Alderman T. Blythe, alarmed at the state of the industry, expressed his concern. He pondered cynically that "for four years a Bradford trade boom has been confidently expected. The truth is, it will never come" (Keighley, 2007, p. 50).

Textile industries such as Prince-Smith and Sons Ltd (manufacturers of spinning and combing machines) and Messrs., Hall and Stells Limited., (manufacturers of finishing machines), both based in Keighley, were struggling because of adverse international factors such as a world-wide depression, "recent troubles in China, textile strike in Germany and all the labour problems in Australia" (The Leeds and Yorkshire Mercury, Dec, 1928, p. 6).

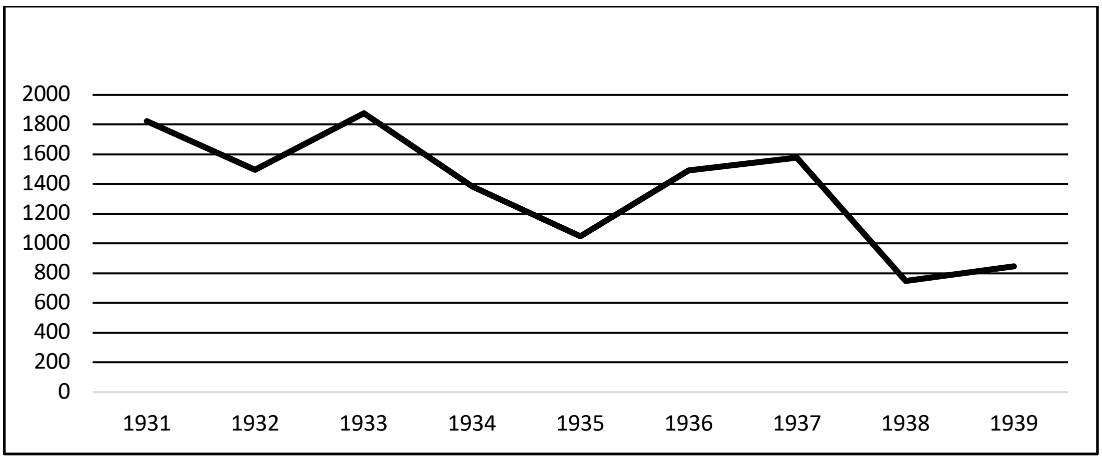
Hattersley's loom sales, to some extent, seemed to contradict this economic scenario. They claimed that they had been busy with orders from home and abroad. During this period, Hattersley's sold many types of looms such as the automatic loom, rising box loom, jute looms and plain linen looms. These looms were despatched to customers in Britain and Europe. Unlike many textile manufacturing firms in Yorkshire, Hattersley's steady rise in fortune during that decade seemed to be the 'exception rather than the rule' (The Leeds and Yorkshire Mercury, Dec, 1928).

The decade 1920-1930 witnessed Hattersley's continued progress in the production of a number of looms notably the 'Standard Model' loom and the heavy woollen and worsted loom which incorporated the Automatic Pick Finder. This new mechanism enabled a less-skilled weaver to oversee two looms without having to intervene if the weft snapped or was extinguished, thereby allowing the weaver to produce a superior type of cloth. Soon after the introduction of the 'Standard Model' loom, Hattersley's brought out a lighter version called the 'Light Standard Model' loom. In a letter sent in 1934 to Raceview Woollen Mill, Ballymena in Northern Ireland, the superiority of the 'Standard Model' loom was outlined by Hattersley who noted that the:

> "… 'Standard Model' loom of ours has been a great success, since its introduction in 1920…Today we claim that it is the most advanced design, the best constructed and the most economical of Pick and Pick loom for worsted and woollens on the market" (Hattersley letter to Raceview Woollen Mill, Ballymena in Northern Ireland, 1934).

At the end of 1930, Hattersley's made an approach to acquire Hodgson's, an old-established, loom-making firm, who had, over the years, been their one of Hattersley's rivals both in business and recent patent disputes. This takeover by Hattersley's may have been due to the fading economic fortunes of Hodgson's which caused them to become one of the casualties of the Great Depression (The Yorkshire Post, June, 1930).

6.7.3 Hattersley's loom production during the decade 1931-1939



Source: (Hattersley order books 1931-1939)

Figure 19. Looms produced during the period 1931-1939

The economic climate in Great Britain was still affected by the outcome and after effects of the Great Depression. At the beginning of the decade, Great Britain was still trying to recover from a lack of economic growth. This economic depression which was affecting Great Britain was somewhat patchy. Hattersley's, on the other hand, were rather fortunate, in that, at the beginning of the decade they experienced a boom in both sales and production. Additionally, they embarked on extensions to their North Brook Works in Keighley by purchasing Mantra Mills, a five-storey building located on South Street from Keighley Council. This building was adjacent to Hattersley's main building. This 'tactical' purchase according to Giffard Smith, a director of Hattersley's, had been undertaken to:

> "give us increased working floor space which we hope to need in consequence of having purchased Messrs., Hodgson's business and also to enable us to move certain processes from our existing works in order to make room for the storing of the whole of Messrs., Hodgson's patterns and other stock. As a result of the extensions we hope when trade revives to find employment for 200 men" (The Yorkshire Post, Jan, 1931).

Whilst this building construction was happening, Hattersley's were busy producing a large quantity of smallware looms, 'Standard Model' looms and dobbies which were much in demand. Hattersley's were reported to have been:

> "Fairly well-employed throughout the year and have got a good start off in the way of orders for the coming year. Home trade has improved in the last quarter, tariffs having brought orders" (The Leeds and Yorkshire Mercury, Dec, 1931)

Hattersley's began 1935 with the purchase of another of its rival - David Sowden and Sons Limited., loom makers of Shipley. The purchase did not include Sowden's land or its buildings. Instead, Hattersley's chose to transfer over to Keighley some of Sowden's staff and many of Sowden's loom patterns and parts which they would replicate where and when it was necessary to do so (Shipley Times and Express, Jan, 1935).

In 1935, trading in certain engineering sectors of textile manufacturing proved to be below par. Hattersley's managed to reverse this trend by introducing their new pick and pick loom. The response by the trade press and their customers proved to be very favourable. Furthermore, their improved artificial silk loom (rayon) seemed to meet all their customer needs and its design was very popular. Another dobby innovation that year seemed to attract a growing interest in Hattersley's sales (The Yorkshire Post, Jan, 1935).

During the period between the 3rd of September 1936 to 3rd of September, 1939 [declaration of the Second World War], Hattersley's declared the following sales and production figures which were very impressive given the fluctuating economic situation which befell Great Britain and the textile manufacturing industries during the 1930s.

TYPE OF LOOM	QUANTITY	VALUE
Woollen	1310	£206,236
Cotton	709	£53,683
Silk	415	£25,505
Jute & Linen	234	£13,903
Narrow Fabrics	275	£8,772
Domestic	433	£14,089

Source: (Hattersley order books)

Table 21. Reduction of looms between 3rd Sept, 1936 and 3rd Sept, 1939

6.8 Summary

From 1890 to 1939, Hattersley's continued to invent, innovate, improve and manufacture numerous loom models which were located and used all over the world. Moreover, during this turbulent, economic period, the looms that Hattersley's produced were designed and manufactured for all types of fibre yarn processing, ranging from natural staple to man-made fibres such as artificial silk or rayon. Throughout their long, illustrious history, Hattersley's inventive ability and well-constructed looms ensured that they were able to progress from a small Yorkshire firm to an industrial leader of international status.

As Hattersley's progressed from the late Victorian period into the Edwardian period and beyond, their looms became widely adopted in many textile mills scattered all over Britain as well as abroad. Many British mills dealing with Hattersley's tended to be satisfied with the looms, their efficiency and price that they repeated their loom orders over many years. Famous British mills such as Salts (Saltaire) Ltd, Lister and Co, Garnett Mills, Haggas, Ballantyne and many others continued to invest in Hattersley's looms. Many of Hattersley's looms were also reported to have been manufactured for use in countries like:

> "Norway and to Eastern Europe for [the] peasant industry and … Roumanian, Bulgarian and Serbian Governments" (The Leeds and Yorkshire Mercury, Oct, 1901).

According to Amit Mitra, the Secretary General of the Federation of Indian Chambers of Commerce and Industry (FICCI), exhibitions:

> "provide a unique networking platform …they help in promotion, marketing and publicity of participating companies" (The Economic Times, May, 2009).

With this in mind, Hattersley's were able to promote, publicise and market their many looms when they took part in many national and international exhibitions. When participating in these exhibitions they were able to gauge who their competitors were and where they were located. Brisk business would be conducted from their representations in these many exhibitions. One factor which greatly assisted Hattersley's was their continual accomplishments in winning the highest awards (see Appendix 1) which included first, special prizes and gold medals in many of the exhibition at home and abroad. At these exhibitions Hattersley's were able to showcase many innovative looms. One such innovation, which was introduced at the Franco-British Exhibition of 1908, was a Hattersley's 6 x 6 overpick box loom with a positive take-up motion which operated at a speed of 100 picks per minute became famous for reproducing a specimen tapestry showing:

> 'Bolton Abbey in the Olden Time,' the famous picture painted by Sir. Edwin Landseer in 1834, and engraved by Samuel Cousins in 1836' (Hattersley publicity material, 1908).

The actual specifications of the tapestry measured 34 ins x 26 ½ ins, and used 2,680 needles and 11,600 cards. It used 10,250 warp threads, 30 different weft colours and 175 'picks' per inch (The Leeds and Yorkshire Mercury, Feb, 1924). At this exhibition, Hattersley's were the only recipients for the Grand Prix award for weaving machines (Hattersley publicity material, 1908).

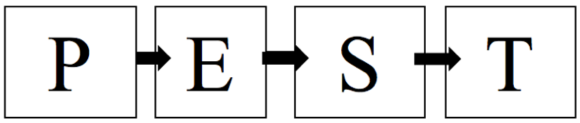
These awards, together with the exhibition area at their mill in Keighley, assisted Hattersley's in the promotion of their looms. Despite this level of marketing, the output was at times steady and at other times unpredictable. Their 'Indian adventure' as portrayed in an earlier chapter, deemed to have been a failure in time, effort and finance while the Outer Hebrides or 'Scottish adventure' could be classed as a success. These looms were able to assist in the further expansion of the tweed industry from being solely a domestic weaving industry to an export industry. Not only in fabric but also in loom manufacture.

Throughout the period 1890 to 1939, Hattersley's were able to invent and innovate new, technologically-improved looms for different textile yarns and processes despite many national and international hurdles, such as fiscal and monetary policies (interest cuts), foreign tariffs, competition, wars, depreciation of money, deflation and devaluation. Unlike other manufacturers who were unable to overcome these socio-economic challenges, Hattersley's resourcefulness and commitment to invention, innovation and diffusion secured their survival. Certain looms proved to be very important to the success of the company. The popularity of looms such as the domestic or narrow looms and mechanisms like the Keighley dobby and the 'Standard Model,' (see Appendix 2) with its overpick motion led one Scottish correspondent to report:

> "Our new Hattersley Standard looms are doing remarkably well … I have never seen looms whose motions I liked better and they turn out splendid work" (Scotch Tweed, Feb, 1925).

Unfortunately, as no Hattersley minute books exist for this period, it was very difficult to discover the true managerial direction or actions that Hattersley's would have taken at the time of each new product's entry into the market. Fortunately loom production records were available which allowed the extrapolation of graphs although they did not reveal any managerial discussions or direction in future production. What became evident, however, is that during 1890 to 1939, Hattersley's were still able to push forward the frontiers of textile loom design, reliability, technical knowledge and innovation with impressive regularity.

6.9 *PEST* (Political, Economic, Social, Technological)



Source: (Sammut-Bonnici and Galea, 2014)

Figure 20. *PEST* Framework analysis

This chapter examined a number of factors crucial to the development of Hattersley's which arguably contributed to the firm being regarded as an important textile manufacturing establishment in Great Britain and the rest of the world. The chapter investigated the production of different Hattersley looms and explored the innovative mechanisms invented during 1890-1939.

These developments, analysed and interpreted against the constituent determinants of the original *PEST analysis framework* listed below will show how Hattersley's resilience and fierce competitiveness enabled them to counter the many challenges in this period.

6. 9. 1 Political

During the period 1890-1939, the British textile manufacturing industry alongside many other industries was greatly affected by the enactment of protective import tariffs imposed by foreign trading markets. From the 1860s onwards, Britain had been in discussions with a number of European countries instigating a "most favoured nation" status [an economic advantage given by one country over another which will be given to any other countries signing the treaty agreement] (O'Rouke, 2000, p. 457). As well as ensuring a European business platform for the continuation of free trade, British economic policymakers were very keen to see the participation of other countries. The use and continuation of a free trade policy in Europe was to usher in significant changes by the late 1870s to the end of the First World War (1914-1918). Economic researchers have long argued that:

> "… in many countries, the phase from 1880-1914 saw a particularly marked increase in world trade in relation to production. 1850-1873 [had been] characterised by rapid technological progress and the growth of a modern transport structure, which facilitated trade growth at a time of almost uninterrupted economic expansion in Europe…" (Kaiser, 2005, pp. 563-564).

Cheap, foreign imports such as grain from Russia and the United States of America not only caused unfair competition in Europe but also began to secure a sizeable market share both for Russia and the United States of America (Kindleberger, 1951). Furthermore, following the cheap, injurious imports, many European countries decided to protect their own industries by enacting protective tariffs in order to protect their own domestic industries. In the case of the United States of America, a series of tariffs had been enacted during and after the American Civil War in 1861. The fluctuations of tariffs from a selection of trading countries can be seen in Table 22.

	1875-9	1880-4	1885-9	1890-4	1895-9	1900-4	1905-9	1910-4	**Average**
Australia	9.7	9.2	10.7	12.8	14.2	19.0	19.7	19.0	14.3
Canada	15.7	16.9	18.1	19.0	19.5	19.3	19.3	19.5	18.4
Denmark	11.9	11.6	12.6	9.2	9.0	8.1	6.8	5.0	9.3
France	5.2	6.0	7.9	9.7	10.4	8.6	8.5	8.9	8.2
Germany	3.7	6.1	8.2	8.9	9.3	8.4	7.6	7.0	7.4
Italy	7.9	8.3	9.0	9.6	10.2	10.8	11.7	11.7	9.9
Norway	10.2	12.6	11.1	11.2	11.6	11.7	11.5	12.8	11.6
Sweden	9.7	10.5	10.7	10.7	11.4	10.7	9.5	8.4	10.2
Gt. Britain	5.3	4.8	5.3	4.8	4.8	6.1	5.3	4.8	5.1
USA	29.4	29.1	29.9	23.5	22.7	26.8	23.0	18.3	25.4
Average	10.9	11.5	12.4	11.9	12.3	13.0	12.3	11.5	12.0

Source: (O'Rouke, 2000)

Table 22. Percentages of tariffs imposed during 1875-1904

What is particularly noticeable in Table 22. is the continuously low tariff rate adopted and levied by Great Britain, [the historical champion of Free Trade], more than half the average rate of the international trading nations combined. This is in stark contrast to the United States of America which began with the highest tariff percentage rate in 1875 only dropping a few percentage points by 1910-14. Up to 1909, most of the other countries who had levied tariffs never reached the same high percentage rates that the United States of America had imposed.

With these trends, Great Britain's grip on its premier position in world trade during 1883-1913 began to gradually slip whilst the United States of America and Germany's share of world trade began to steadily increase. In the same period, the percentage figures of other trading nations fluctuated between slight increases or decreases in their share of world trade (see Table 23).

	1883	1890	1899	1913
USA	3.4%	3.9%	9.8%	11.0 %
Great Britain	37.1%	35.8%	28.4%	25.4%
Germany	17.2%	17.2%	19.5%	23.0%
France	14.6%	14.5%	12.6%	10.6%
Belgium	4.8%	5.1%	4.9%	4.3%
Canada	0.1%	0.1%	0.3%	0.6%
Japan	0.1%	0.3%	1.3%	2.1%
Others	22.7%	12.1%	23.2%	23.0%

Source: (Lewis, 1957)

Table 23. Different percentage of World Trade 1883-1913

These high, restrictive import tariffs and the world share of the commercial market had an adverse effect on British commerce as well as financial problems. Industries, such as loom manufacturing in Great Britain, began to experience the effects of the high tariffs resulting in restrictive trading and a partial loss of export quotas. In spite of this, Hattersley's managed to deal with both colonial and foreign orders (The Leeds Mercury, Dec, 1928,).

An impending war, or the challenges presented by ever-changing international affairs, especially in 1937 and much later the period of 1939-1945 (Second World War), caused commercial uncertainty in many British industries. To overcome such external pressures, adaptability was important for any firm to survive and compete. One such example was in 1937 when Hattersley's secured contracts in the Far East (The Leeds Mercury, Dec, 1937). The turbulent political instability caused Hattersley's to pause its operations in the Far East and switch over its focus on domestic contracts. Hattersley's flexible commercial and trading arrangements allowed them to continue with and exploit other loom manufacturing contracts (The Leeds Mercury, Dec, 1937).

In spite of initial reservations by the British weaving industry, the automatic loom became paramount in textile mills. After the Second World War (1939-1945) the manufacture of automatic looms was undertaken by two key companies - The British Northrop Loom Company based in Blackburn (workforce <2000) and Hattersley's (workforce <600) in Keighley (Yorkshire Post, Nov, 1947). Judging from the near monopoly of automatic loom manufacture, it would be logical to assume that Hattersley's would continue with the expansion of their works in order to manufacture automatic looms. Although Hattersley's did have plans to extend their workshops and employ an extra 400 employees, it was *not* because of their involvement with automatic looms. Hattersley's needed to adapt their premises to take into account the many other types of looms they were already producing (Yorkshire Post, Nov, 1947).

6. 9. 2 Economic

The economic growth of a nation is dependent on many factors. Kitson and Mitchie (2014) have charted the industrial manufacturing periods in Great Britain which they concluded could be categorised into four distinct time periods. These four times periods were classified as follows - "the Age of Maturity [1870 to 1913], the Age of Uncertainty [1919-1939], the Age of Transition [1950 to 1973], and the Age of Decline [1973 to 2007]" (Kitson and Mitchie, 2014, p. 2). For the purposes of this chapter, only the first two periods mentioned, which straddle the time period chosen for this thesis (1890-1939), will be considered.

For a manufacturing industry to contribute to the economic growth of a nation within these two designated periods requires the appropriate acumen, commercial and business circumstances for supply and demand to function appropriately. These two important factors are underpinned by a network of other key factors important to a nation's economic growth. For instance, the supply chain requires factors such as cost, originality, quality of workmanship and effectiveness of the manufactured item. Demand is governed by how competitive the item is in comparison to other similar products in the market place. This factor, together with a competitive price for the product, governs foreign and domestic consumer behaviour.

With the aftermath of the First World War [1914-1918] and during the 'Age of Maturity', the price of British textile machinery had increased. Prior to the war, the cost price of looms had been £60 but by the end of the war, the price had spiralled to £600 per loom. According to Keighley, "delays in delivery were blamed on export markets" (Keighley, 2007, p. 28). Keighley also noted that one customer [Japan] had placed purchase orders, with manufacturing firms both in Lancashire and Yorkshire amounting to £1 million pounds. In the aftermath of the First World War [1914-1918], the progress of export and delivery was handicapped by orders placed with British firms resulting in full order books. This production backlog extended to a period of two years. To overcome this delivery delay, Japan decided to offer a higher price for a fast-tracked delivery (Keighley, 2007, p. 28).

The sales of both British finished textile products and machinery were compromised by the imposition of tariffs. Following the introduction of foreign tariffs, exports quotas fell and products were not as competitive as they had been.

Pressure was also placed on how well Hattersley's were able to manufacture cost-effective products which would remain competitive against the substantial tariff economic conditions.
The loss of competitive trade for Woollen and Worsteds together with Machinery and mill work can be seen in Table 24 which shows the variance between free trade and the imposition of tariffs

resulting in a loss or reduction in profits, a decrease in exports and a country's lower economic output.

	All Countries	All Countries	10 Tariff Protected Countries	10 Tariff Protected Countries
	1880	1900	1880	1900
Woollen and Worsted	21,488	21,806	13,526	11,475
Cotton	75,564	69,581	15,990	13,840
Machinery and mill work	9,264	19,620	5,797	10,892
Iron, steel including other metals	32,000	37,638	17,626	15,171

Source: (Ensor, 1992)

Table 24. Selection of British export values between 1880-1900 (in thousands)

6. 9. 3 Social

It was Feng *et al.,* (2015) who argued that the effects of marketing are very important to the performance of any manufacturing company when they promote their services and the respective value of their products. According to Nwokah and Ahiauzu (2008), for marketing to become understandable and successful, it needs to consider the following pointers:

i) Corporate approach - having a sizeable budget to undertake any necessary amendments or changes to the commercial market in which the company is involved.

ii) Competitive approach - ensuring a company has the necessary information to continue to be effective.

iii) Customers' needs - being aware of customers' needs in order which in turn provides an awareness of any changing trend or behaviour

iv) External variables - responding to external factors such as war, tariffs, strikes which may have a direct effect on any marketing.

From 1890 to 1939, set against the 'Age of Uncertainty', Hattersley's followed the above pointers and continued to manufacture and exploit the excellence, variety and versatility of their looms through numerous sales to weaving mills across the world and participation in British and foreign trade exhibitions. Over a course of time, teaching staff from certain local and national British textile institutions together with art colleges issued many requests to "renew or increase their number of" new or up-to-date textile machinery which boosted Hattersley's prestige for manufacturing weaving looms (The Yorkshire College, Leeds, 1899-1900, p. 6)

The positive corporate reputation that Hattersley's engineering had developed attracted the attention of the Ministry of Munitions in Britain which took the decision to award them a contract to manufacture a quantity of narrow-width looms. These looms were to be used to produce clothing for military use. Soon after, a mill was set up and staffed by personnel from Hattersley's who began producing military clothing. After the First World War [1914-18], Hattersley's needed to find an appropriate use for their looms. The idea of creating a mill in India and supplying the Indian-market with their international award-winning looms was considered. Nonetheless, although the looms were highly-regarded, there were occasions when even the very best publicity and marketing of a product did not match the intended outcome. It could be argued that the intended adoption, or 'non-adoption' of a Hattersley's loom in India proved to be a 'cultural' failure rather than for any technical or mechanical reasons. Surprisingly, this was despite the gold medal awards secured by Hattersley's at the Calcutta (1906) and Nagpur (1908) international exhibitions held in India. A number of Hattersley's domestic looms were purchased and imported into India by the Indian Department of Industries. Hattersley's were already exporting their looms to foreign markets and were hoping to break into the lucrative Indian market. Other semi and automatic looms such as the *Salvation Army* loom (picking and beating were undertaken by the use of the sley and shedding is accomplished by the action of the foot) and the *Chittaranjan* loom (similar to the fly-shuttle loom) were already in use in Indian weaving sheds. It was the intention of the Indian government to rapidly revitalise and mechanise their hand loom weaving industry (Venkataraman, 1936, p. 146). Nevertheless, the introduction of Hattersley looms proved to be unpopular with many Indian hand loom weavers. When the decision and choice of the Hattersley loom was examined, the explanations given were that these looms were:

i) Very costly to purchase when compared to Indian looms.
ii) Hattersley's looms were unable to produce the type of traditional Indian cloth.
iii) Hattersley's looms proved to be cumbersome and not appropriate to the "temperament" of the Indian weaver (Venkataraman, 1936, p. 146).
iv) Mechanism found on Hattersley were too sophisticated.
v) Hattersley's looms proved to be too costly to replace when loom parts wore out.
vi) India did not have a network of sophisticated power systems (mechanical or electrical) which consequently handicapped the use of all-metal looms.
vii) The warping and winding methods used in Indian weaving sheds proved to be unsuitable for the all-metal looms (Havell, 1912, p. 186).

Furthermore, certain contemporary commentators underlined the 'cultural' difference of using Indian-style looms as opposed to looms manufactured by Hattersley's. The main Indian-based critic of Hattersley's looms was Sir A. Chatterton [c1867-1958], Director of Industries in Madras, Professor and Consulting Engineer, who called the adoption of the Hattersley's loom the "dilettantism of the artists" (Venkataraman, 1936, p. 147). In effect, the Indian weaver did not feel comfortable weaving cloth on "heavy looms with iron frame(s) and complicated mechanism[s]" (Venkataraman, 1936, p. 146). Although several Indian provinces did use the Hattersley's looms, they proved to be unsuccessful and remained 'idle' in many weaving establishments even though the Indian government had been swayed by Hattersley's marketing strategy and exhibition successes. One of the key reasons that Hattersley looms had been selected was their involvement with "Roumania [where they had] revived the hand-loom weaving in the Balkan States" (Venkataraman, 1936, p. 147). Hattersley's never managed to get a firm industrial foothold in the Indian sub-continent. English-built machinery from companies such as Henry Livesey and Co., William Dickinson and Sons, Atherton Bros, Hacking and Co., and Robert Hall and Sons Ltd were keen to supply the Indian market. Although this lack of interest proved to be a setback for the firm of Hattersley's they were not deterred and continued to invent and innovate their looms and sell them at home and abroad.

6. 9. 4 Technological

During 1890 to 1939, Britain's manufacturing output started to decline and ended up lagging behind other manufacturing nations. The advantage Britain had held from the 'industrial early start' had been slowly eroded and ultimately lost. In 1870, Britain, the world's first industrial nation, was manufacturing at least one third of the world's products but by 1913, its industrial manufacturing position had declined to third position. Furthermore, contemporary commentators had noted that manufacturers in Britain seemed to be handicapped by the "dead-hand of their past achievement" (Veblen, 1915, p. 132). Extrapolating data taken from the Census of Production in 1907 clearly demonstrated that of all the industries, it was textiles, coal, engineering, iron and steel which contributed to 50% of all of Britain's output. Consequently, the textile industry was renowned for not actively renewing their looms for more up-to date looms, preferring instead to hold on to them. Notwithstanding, Hattersley's continued to invent, innovate and manufacture many different kinds of looms despite the economic vagaries of the British industry during the period 1890 to 1939.

Even though the company of Hattersley's had been described as having manufactured the "most successful loom at work at the present time", competition from the United States of America began to take place (Textile Journal, 1902, p. 63). The American competitor was James Draper and Son who introduced the automatic loom in the United States of America and soon after progressed to marketing their automatic Northrop automatic looms into the English market. This inroad into the English textile market soon captured both the attention of the international and local English press. One newspaper labelled the prospective introduction of the automatic loom as "The Battle of the British Market" (Daily Dispatch, 1902). In the article they argued that "Lancashire [would] be the battle ground for the automatic looms for many years to come" (Daily Dispatch, 1902). The Australian press pointed out that Hattersley's innovative self-shuttling loom was "well worth the careful thought and attention of every manufacturer in the trade" (Geelong Advertiser, 1902). Pourdeyhimi *et al.,* noted that Hattersley had developed a shuttle-changing loom which was capable of weaving warp figures [although it was] unable to change different colours or kinds of weft" (Pourdeyhimi *et al.,*1985, p. 128*).* Although Hattersley's introduced their version of the automatic loom into the textile market they preferred to manufacture many types of looms which used different fibres ranging from wool, cotton, asbestos, silk, flax, hemp and man-made fibre. In addition, Hattersley's also manufactured and sold and a wide selection of textile-related and miscellaneous machinery. Many of the products, with which Hattersley's were involved, can be seen in Appendix 5-22. (A selection of looms has been taken from Hattersley's 1914 Textile Machinery catalogue).

Hattersley's continued inventing, improving their looms and innovating despite regional, national and international problems with economic growth. In the 1920s, a design brief was given by the Hattersley's management to their designers to create:

i) The best designed loom that was possible
ii) The cost of design of loom was not to be a hindrance
iii) All Standard loom parts had to be original and any parts had not to be taken from any other Hattersley loom

Following on from this brief, the introduction of the Hattersley Standard loom in the 1920s brought considerable interest, sales and success to the company. The prestige of this loom was such that it sold in thousands and became one of the significant and well-known looms that Hattersley's ever built.

By 1935, technological innovations seemed to be the driving force of Hattersley's. During that year, they introduced their improved artificial silk or rayon looms which proved to be well received by the textile market (The Yorkshire Post, 1935). Three years later after the refinements to the artificial silk or rayon looms, Hattersley's introduced their much improved "new automatic self-shuttling box loom for the silk and artificial trades" (The Yorkshire Post, 1938, p. 25).

6.9.5. Findings of the *PEST* analysis; a summary

Throughout their extensive history. Hattersley's continued to invent and innovate bringing forth new and continually improved machinery. Part of their long-term success was the variety of machinery which they marketed. Their 1914 catalogue revealed that they manufactured a considerable array of looms and finishing machinery (see Appendix 4).

Adaptability was an important strategy the company adopted as a marketing strategy. This was especially evident when Hattersley's had to periodically switch from foreign to mainly domestic markets when confronted with a number of challenging issues. Hattersley's managed to overcome a number of these challenges which ranged from major overseas wars (1914 and 1939), trade tariffs (1890, 1894, 1897, 1905 and 1909), local strikes (Hattersley factory strike, 1892, 1896 and 1914) to periods of unemployment (1933).

Merton's work on technological developments reached the conclusion that there comes a point where the industry would reach a level of 'contentment' with its status quo, but then it would be confronted with a new insight to improve efficiency in the machine or personnel. He labelled this phenomenon as a "shift of attention" (Merton, 1935, p. 468). The importance of efficiency could only mean a growth in profits for any mill owner. As a consequence, this would present the prospective customer with a dilemma. Investment in new machinery would initially be useful but after period of time, the efficiency could reach a technological 'plateau'. This was to say technological development had reached its apex for that particular loom making further improvements difficult thereby requiring further investment. Consequently, the West Yorkshire mill owner tended to rely on the looms he had used for a number of years. This phenomenon was evident in the West Yorkshire textile processing trade. Some mill owners were content to rely on their looms which may have been in the mill for 50 years or more. Even though Hattersley's continued to be inventive and innovative against this stubborn resistance to 'change', the firm still found this "shift of attention" (Merton, 1935, p. 468) difficult to break down.

The technical excellence of Hattersley's looms is clearly demonstrated in the proverb - 'imitation is the sincerest form of flattery'. During 1901, Hattersley's discovered that the textile loom manufacturers in Germany were copying their looms or filing "the parts of an English machine into patterns which actually retained the marks and numbers of the English maker" (The Leeds and Yorkshire Mercury, 1901, p. 7).

Despite all the obstacles faced by Hattersley's throughout 1890 to 1939, their business and commercial portfolio, which continued to rely on new patented inventions and innovations, and enabled them to dominate the weaving loom market. Hattersley's effective, commercial marketing strategies enabled them to launch numerous, high-profile sales' drives and exhibition appearances throughout the world which showcased their wide array of innovative textile machinery and promoted the firm's technical expertise and assistance successfully. The result was that Hattersley's continued competitive success, in good times and bad, secured its prominence as a market leader in the world of loom manufacture.

In the broadest terms, industry is primarily concerned with the people and activities involved in collecting raw materials in a specific geographic location and making them into products in factories or providing a particular service. Industrial history is particularly interested in studying and understanding how these dynamic, transformative processes are brought about by the behaviours of, and influences on the cluster groups therein, the firms of which are connected by common trading and production patterns and close, collaborative inter-firm networks.

Evidently, with regards to how best to undertake an objective, unbiased study of this complex area, there is little doubt that the *PEST(&G)* analysis framework is an effective, diagnostic tool with which to carry out such an investigation.

The dominant role and impact of technology was the principal finding to come out of the analysis of how Hattersley's loom production was influenced by each of the five *PEST(&G)* determinants in the period 1890-1939.

The technological variable provided a flexible and powerful research method with which to conduct a cross-sectional analysis using a combination of primary source data and material culture/secondary source references to identify, describe, and interpret key technological developments within the firm and across the worsted industry.

From 1890 to 1939, Hattersley's continued to invent, innovate, and make both incremental and radical technical improvements to the numerous loom models which the firm manufactured. The technological determinant highlighted how inter-firm rivalries and competitiveness within and beyond the cluster group continued to stimulate inventiveness and innovation.

The relationship between invention, innovation, entrepreneurship, and regional outcomes is well-established. The technological determinant highlighted the extent to which successive innovations in loom technology played a pivotal role in the economic growth of both Hattersley and the Yorkshire worsted industry. All the key indicators of technological innovation, which typically include a skills and knowledge-base, inventors and designers in research and development activities, cross-fertilisation of ideas in scientific and technical journal articles and patent protection copyright, were at the heart of Hattersley's operation. An examination through the lens of the technology determinant showed how skilled and talented the firm's inventors were in solving technical issues and proposing solutions. The tenacity of their approach is impressive, not least in one example where a close investigation of the picking motion mechanism led to a deeper understanding of how the overpick motion gave a better result than an underpick motion in terms of wear and tear both in the picking costs and the reliability and accuracy of the shuttle. These comprehensive findings would eventually lead to innovatory loom designs

The economic and political determinants enabled the researcher to gain a more detailed understanding of how the firm's technological developments were very closely allied to both the political and economic environments and how the volatility in one and/or fluctuations in the other inevitably impacted adversely on Hattersley's and yet paradoxically, in a few instances, the technological determinant showed how some of the firm's innovative loom designs managed to counter both political and economic constraints . For example, the 'growth' spike in the graph of the firm's loom production sales at a time of economic stagnation in the period 1900–1910 categorically shows the huge commercial success of the firm's smallware (narrow fabric) loom. This versatile, efficient, well-engineered machine could operate around the clock, required little maintenance and produced a superior fabric without breaking down land with little or no wastage.

Similarly, twenty or so years later, the development, innovation and diffusion of Hattersley's 'Standard Model' loom in the period 1921-1930 contradicted an industry-wide economic slump in post-war loom sales. The technological advances in this cutting-edge design were impressive, featuring among other improvements, new mechanism which enabled a less-skilled weaver to oversee two looms and produce a superior type of cloth without having to intervene if the weft snapped or was extinguished. More importantly, the technical skills of the team of ingenious inventors meant that loom parts did not require constant calibration. This machine was arguably the firm's most successful pick and pick loom for woollens and worsted confirming once again how the firm managed to counter political, economic and social challenges in its long history and re-invent itself *synchronously* with its technological advances.

Chapter 7 An analytical case study examining the expansion and challenges affecting Messrs., George Hattersley and Sons Limited., loom machinery production (1890-1939)

7 Introduction

The objective of this chapter is to highlight and discuss the key determinants, namely the political, economic and social, technological and geographical influences, which shaped the commercial direction of Hattersley's and their loom manufacturing during four specific time spans (1900-1910; 1911-1920; 1921-1930 and 1931-1939).

This chapter will also examine the important variables, including 'industrial clusters' and tariffs which not only impacted on Hattersley's but remained crucial to the success and failures of Hattersley's as a textile machine manufacturing establishment.

7. 1 Messrs., George Hattersley and Sons Limited., and the importance of the 'industrial cluster'

Hardill has noted that the background to the "industrial base of West Yorkshire [was] evolved in association with the growth of the wool textile industry" (Hardill, 1990, p. 203). Furthermore, the financial foundation and successes of many Yorkshire industrial mill towns, such as Batley, Mirfield, Ossett, Morley, Leeds, Huddersfield, Dewsbury and Bradford, were reliant and built "on textile money" (Hardill, 1990, p. 203). Over the course of time, these mill towns were to develop into important and highly successful industrial textile processing localities or *clusters*. Marshall argued that this type of industry e.g. textile processing, was "concentrated in certain localities" (Marshall, 1920, p. 268) and in the local skills found throughout the various, discrete phases of the textile manufacturing process. It was Porter who re-introduced this concept of 'clusters' which he considered to be the:

> "…nation's competitive industries [which] are not spread evenly through the economy but are connected in what I term clusters consisting of industries related by links of various kinds…" (Porter, 2011, p. 131).

Lan and Zhangliu (2012) also outlined how important *clustering* was to industry. They claimed that 'entrepreneurial' clustering would generate a new *dynamism* in the cluster group typified more often than not by the as continuing the developmental aspects or needs of the clusters and the promotion of innovations.

In due course, this view of industrial 'clustering' became firmly established and recogniseable in the formation of certain industries which gradually developed in different parts of Great Britain.

Marshall maintained that these localised areas (or clusters) brought more benefits to the cluster group than those groups in less localised areas (Marshall, 1919). These advantages were typically, the transference of skills, the formation of subsidiary companies which could supply "implements and materials", machinery that was highly-developed and a readily-available, highly-skilled workforce (Marshall, 1920, p. 271).

Likewise, industrial 'clustering' soon became associated with specific textile processing regions. For instance, the interconnected network of factories and tradesman in the cluster group of Macclesfield (in Cheshire), enabled it to concentrate on silk whilst Lancashire's clustering became synonymous with the processing of cotton fibre. Dundee became known as the centre for the British jute industry, Belfast for the linen industry whilst Stroud was associated with blanket-making processes (Zimmern, 1918).

During the transformative period in the eighteenth century, several of Yorkshire's towns started to develop into large-scale, industrial manufacturing centres which eventually became associated with the worsted and woollen industry. Marshall recognised that the wool industry was the first industry to incorporate the "modern methods of massive manufacture" (Marshall, 1919, p. 600).

The Yorkshire's worsted, woollen textile processing and machine manufacturing industry's success was underpinned by the many innovations and versatility of textile machinery produced in Keighley, Yorkshire which could process different fibres such as cotton, wool, alpaca, waste silk, mohair and cashmere and much later man-made fibres (artificial silk/rayon). Brierley and Carter have termed this array of different textile processing techniques or sub-divisions as "extreme specialisms" (Brierley and Carter, 1914, p. 378). According to Sigsworth and Blackman:

> "greater specialisation in the worsted trade [located in and around Bradford] had been apparent since 1856" (Sigsworth and Blackman, 1968, p. 138).

Within a short space of time, the town of Keighley became *the* 'cluster centre' or *loci* for the concentrated and successful manufacture of worsted weaving looms, spinning and ancillary machines in Great Britain. From the nineteenth century onwards, many companies in Yorkshire began processing woollen and worsted cloth and the town of Bradford become known as "*Worstedopolis*" throughout the world (Jowitt, 1989, p. 95).

After the 1870s, the Yorkshire textile industry was subjected to external pressures from international influences such as the changing whims of women's fashion, the importance of fabric '*handle*' [the feel of the cloth by touch], new imported fabrics from France and foreign-imposed protectionism such as tariffs imposed by the United States of America and several European countries.

The imposition of tariffs not was not unexpected for some textile industrialists. Following a business trip to the United States, two directors from Manningham Mills [also known as Lister's Mill], Messrs., Graham Watson and José Reixach (Managing Director and Senior Director of Manningham Mills), were asked by the Bradford Observer if an American tariff would soon be imposed on Bradford textiles. They predicted that "there was (…) strong grounds for anticipating this" (Bradford Observer, 7th Nov, 1890).

Towards the end of 1890, the American McKinley protective tariff was subsequently imposed (Zebel, 1940), which severely affected Yorkshire machine manufacturers and worsted processors' economic standing in international trade. This made Keighley and Yorkshire goods, in general, more expensive to purchase. The introduction of the McKinley tariff also brought about a dispute which Laybourn labelled as "one of the most divisive issues in Bradford history" (Laybourn, 1992, p.117). This industrial dispute, along with labour unrest at Manningham Mills (one of the largest mills in Bradford), would eventually last nineteen weeks. The effect of the McKinley protective tariff cast a dark cloud of economic anxiety over many British manufacturers. Correspondence between Reixach and Samuel Cunliffe Lister [Director and owner of Manningham Mills] mentioned that the neighbouring and largest mill in Saltaire was undergoing economic hardship. He mentioned that out of "… 900 cloth loom only 300 were in use and out of 160 plush looms only 2 were in use for samples only …" (Correspondence from José Reixach to Samuel Cunliffe Lister, 11th of November 1890). Reixach placed the blame on the McKinley Tariff. The basis of this industrial dispute and subsequent strike was attributed to an announcement, [given by Reixach], that the McKinley Tariff would prevent Manningham Mills from sustaining "artificially high wages" (Bradford Observer, Dec, 1890) for its workers. In a subsequent letter sent by Reixach to Samuel Cunliffe Lister, he claimed that "…we have lost the American trade and with so few orders we may have a chance of getting the reduction through…" (Correspondence from José Reixach to Samuel Cunliffe Lister, 1st of December, 1890). When it was made public, the workers at Manningham Mills became skeptical and objected to the pronouncement that their wages were 'artificially high' (Bradford Observer, Dec, 1890) and went on strike. Although this acrimonious dispute brought out 5,000 workers (men and women) it was ultimately doomed to fail. Following the collapse of the strike, three main developments were to come out of the dispute.

First, the strike, caused by the imposition of the McKinley Tariff, had a far-reaching influence beyond the mills and on society and economics as a whole. It was instrumental in the emergence of the Independent Labour Party [I. L. P.]. Second, strong union representation was secured and strengthened. Third, the strike clearly demonstrated the gulf which existed between "capital and labour" (Laybourn, 1976, p. 34).

Hattersley's took a more paternalistic or benevolent approach towards their workforce than Samuel Cunliffe Lister had demonstrated towards his striking workers. The Keighley News (4th Aug, 1900) recorded Hattersley's maxim to his workers. Aware of the devastating impact the dispute had had on the relationship between managers and workers, and on textile production at Manningham `Mills, Hattersley told his workers to follow his advice and impressed on them:

> "… the necessity, the absolute wisdom, in your own interests, of never quarrelling with your employers. Work as hard as you can, make what you can, put by what you can, and buy what you can, and you will make far more money than be influenced by *outside* people…" (The Keighley News, 4th Aug, 1900).

According to Jowitt (1992), it was the Dingley Tariff Act of 1897 which had an arguably devastating effect on Bradford's American trade. Bradford and Keighley producers discovered that following the Dingley Tariff Act of 1897, trading markets, which had previously been open, were now restricted to Bradford and Keighley manufacturers. Demand for Bradford and Keighley-made goods had diminished; these products was proving difficult to sell abroad. The impact of this enforced economic downturn had a series of far-reaching consequences. Profits were now reduced, which in turn affected future investments in new machinery, innovations or plant purchase (Jowitt, 1991). Consequently, many Yorkshire textile manufacturers, including Hattersley's, began to lose their position as leading textile exporter's which had already been slowly been eroded by foreign competitors namely France, Germany and the United States of America (Skrabec, 2008).

Textile processing and machine manufacture remained very important to Keighley and Yorkshire. From the nineteenth century onwards, Hattersley's, together with Prince-Smith and Stells (manufacturers of high-class can gill boxes, and all kinds of textile machinery), contributed significantly to Britain's overseas trade in worsted textile machinery. Schlote (1952) noted that between 1902 and 1904, 66% of British manufactured goods, which were exported abroad, consisted of textile and iron products.

Several researchers, such as (Harley, 2014, p. 1), have claimed that many of the industries, which had been founded during the so-called Industrial Revolution [c 1780-1840], had "retained their comparative advantage until the First World War" over their main competitors such as Germany and the United States of America. In economic terms, to have a comparative advantage signified one manufacturing country's supremacy over another country by virtue of it fabricating a product more efficiently than a similar product. Gupta went further and argued that other factors could be shown to be integral in engendering a comparative advantage of a commodity from one country to another. Gupta listed four key factors which he believed to be very important and classed them as “(1) technological superiority, (2) resource endowments [natural or developed such as skills], (3) demand patterns [such as trade], and (4) commercial policies [national policies which determine commercial endeavours]” (Gupta, 2015, p. 10). Great Britain’s iron and textile trade, structured on and supported by the four key factors outlined by Gupta (2015) continued to maintain a distinct advantage over many of its overseas competitors. This industrial dominance lasted until the late 1880s. Economic crises, competition and market upheavals caused major shake-ups and changes to Britain’s industrial trade when in 1890, the United States of America overtook Britain’s supremacy in steel output as did Germany, three years later (Rooth, 1993).

7.2 Messrs., George Hattersley and Sons Limited., production data.

As the “oldest loom manufacturing company in the world” (Hodgson, 1879, p. 242), Hattersley’s had claimed that they were the also and largest employer (‘dominator’) found in Keighley. To be classed or described as a ‘dominator’ company implied that a particular company, such as Hattersley’s towered over a particular or “given industry in a region” (Drucker and Feser, 2012, p. 1).

The absence of any of Hattersley’s minute books, not only for the period 1890 to 1939 but also from its inception at the time of the French Revolution (1789-1794) was an obstacle. Though challenging, this setback was not insurmountable. These documents would have been an invaluable primary source allowing the researcher to gain an insight into these official written records and to have a much clearer understanding of the managerial decision-making processes in its corporate direction as well as commercial strategies, particularly in sales and production. A more holistic approach was undertaken in which all extant archive documentation on Hattersley’s was collected and collated before being analysed and interpreted rigorously and objectively.

The available raw production data used in this chapter (and in the previous chapter) was taken from Hattersley’s production books which spanned the period 1890 to 1939. Listed in these books were records of the production and sales of different looms, together with warping mills and ancillary machines. These machines were manufactured and sold locally, regionally, nationally and internationally. Throughout the period 1890-1939, and in spite of the positive publicity that they had secured on all types of manufactured looms, Hattersley’s continued to experience many fluctuations in sales in domestic and overseas trade.

As well as the uncertainties brought about in the economic and political arena such as, government quotas, foreign tariffs and wars Hattersley’s spells unproductive trade and sales could be attributed to inventions and innovations from international competitors, positive and adverse publicity and the loss of skilled, inventive staff and an aging workforce,

7.3 Inter-generational employment and workforce retention and continuity

Employees working for Hattersley's tended to be long-tenured with the firm. In July 1934, the Keighley News reported that, when combined, the number of years of employment of two employees (a father and son) could total 100 years. Indeed, long-tenured textile workers could also be found working in many Lancastrian mills. Southern asserts that this 'anomaly' was not uncommon among textile workers who could be found "working into their seventies [which] was regarded as another expression of pride" (Southern, 2016, p. 51). In a talk given to the Keighley Rotarians in 1951, Col. Smith outlined the many hurdles that Hattersley's had faced.

As far as human resources was concerned, Hattersley's seemed to have an ageing workforce throughout their long history. Not only was Col. Smith highly critical of this, it made him very skeptical of the company's future. He noted that:

> "…The engineering trade of this town, [Keighley] in my opinion, is going to be in a very serious state unless there is an alteration. We rely now almost entirely on our old skilled men. All our young men are going into soft jobs like chiropody or Government offices or something like that. They don't seem attracted to the engineering industry. If you took away all the men over 60 years of age, we should just cease to function; they are the back-bone of our firm" (West Yorkshire Archive Service, 32D83/59).

Problems also lay with the cost of the production of looms and the wages paid to his employees:

> "… In 1905 they were selling looms at £7. 10s each, and six years later was £310. The slump brought them down to £150 in 1923, but now they were up to £450… the wages of an apprentice were then 3s a week at 13 years of age, 4s at 15, 6s at 17 and 8s from 19 to 21…" (West Yorkshire Archive Service, 32D83/59).

The registration of patents and their realisation into actual working components also seemed to hinder textile machine manufacture in Great Britain. The Textile World Record journal in 1907 commented on the imbalance that existed between European countries and British textile machine manufacturers registering their inventions. One British textile industrialist, travelling abroad to Budapest in Hungary, noticed that a:

> "…large number of machines that he knew were not built in England and were not generally used there because of the high cost of importing them, he asked the mill owner about them and was astonished to learn that that they were built in Austria and cost less than similar machine cost in England. The machine was patented in England, but not built there…" (Textile World Record, Jan, 1907, p. 69).

The problem lay in the fact that many Continental European countries, such as Austria, expected the inventor to finalise the construction of the object and make the invention accessible for commercial use within three years, and sanction its usage for at least two years (Textile World Record, Jan, 1907). In Britain, however, textile inventors could withhold the manufacture or registration of their inventions for many reasons (a means of preventing rivals from knowing the details of a particular invention for tactical purposes or the cost of manufacture). It was, therefore, important to counter Continental Europe's approach to patents by revising or reforming the British patent system. These patent problems continued to beset British industry as well as Hattersley's for many years.

7. 4 Messrs., George Hattersley and Sons Limited., loom production during the decade 1900-1910.

By the beginning of the twentieth century, rapid and dynamic technological innovations, developments and improvements had achieved noteworthy results throughout the global economy. Many companies and trading nations would witness a transition from old-fashioned practices and attitudes into the adoption of new methods and procedures. Technological improvements spread into many diverse areas such as the transportation of goods and passengers and to the increase of international trade and productivity. Even so, reviews taken from technical literature on Great Britain's industrial premier position had reported that there had been a continual decline during the last quarter of the nineteenth century. According to Weiner (1981), Great Britain's past industrial supremacy could be attributed to an 'absence of new technology'. Researchers such as Romer (1990) and Moykr (2002) had maintained that a nation's economic growth was underpinned by two key factors - the continual introduction of innovations and the diffusion of relevant technical information.

In a presidential address given to the National Union of Textile Workers held in Bradford in 1930, Alderman Ben Turner [1863-1942] recalled the immeasurable contribution that Bradford and Keighley had made to world textiles. He noted, with some sadness, that:

> "It is no use disguising the fact that we have stocked other countries with our textile machinery, taught them our industry, and they are even becoming our competitors in many lands, so that our expert position is not as easy as it used to be" (The Shipley Times and Express, 1930, p. 8).

Notwithstanding, and contrary to the mention of the 'absence in new technology', the textile industry in Yorkshire continued to patent new inventions in worsted textile machinery between the period 1890 and 1939. Hattersley's were particularly instrumental in introducing cutting-edge, innovative loom inventions and technological innovations such as the self-shuttling loom also known as the Hattersley 'Automatic' loom (1900), the smallware or narrow fabric loom (1908) and much later the Hattersley 'Standard' loom (1920). The Textile Journal proclaimed that the Hattersley looms were by far the:

> "…the most successful English loom(s) at work at the present time…" (The Textile Journal, 1902, p. 63).

One factor which made this possible was Hattersley's decision to promote and display their looms at many international exhibition venues where they often won prizes or the *Grand Prix*.

Nonetheless, it was the Leeds and Yorkshire Mercury newspaper which reviewed the status of the Yorkshire textile manufacturing trade unfavourably (1901, Oct). They noted that different foreign competitors, such as the United States of America, Germany and Russia, had begun to erode the premier position found in the textile engineering trade that the Keighley machine manufacturing companies had built up over many years. Competition in textile markets not linked to the British Empire were already being compromised by Continental countries such as France and Germany and much later from countries further afield like Japan. One response to this external competition was demonstrated by the Bradford company of John Foster and Son who insisted that the loom manufacturers should increase the width of looms during 1878 and then limit the manufacture of narrow looms after 1880 (Sigsworth and Blackman, 1968). Competition from French fashion had put great stress on Keighley textile machine manufacturers. A committee appointed by the Bradford Chamber of Commerce summed up the state of affairs by claiming that:

> "… the worsted machinery we use in the district is not adapted for producing yarns similar to that used in the manufacture of the bulk of dress goods made in France" (Bradford Chamber of Commerce, Minute Books, Dec, 1903).

The manufacture of textile spinning frames and looms for the British woollen industry fared no better. In 1928, the Committee on Industry and Trade noted the gradual transformation by claiming that:

> "…since 1878 … the great reduction has been in the narrow looms, particularly those which before and up to 1904 were devoted to the production of dress goods … in 1878 a loom running at the rate of 50 picks per minute was the standard type, the 100-pick loom is now the characteristic loom of the Yorkshire tweed trade" (Survey of Textile Industries, Pt. III, 1928, p. 167).

According to Glover, the continual reduction in the manufacture and use of narrow looms had been attributed to a number of factors (Glover, 1959). The two main reasons hinged on the imposition of foreign tariffs, which reduced the share of British looms in foreign markets or manufacturing costs of British-made looms and the competition or apathy caused by looms which were now much improved or speedier than they had been in the past.

Additionally, during the first decade of the twentieth century, British fabrics and machinery seemed to have undergone a period of “deplorable stagnation” (The Leeds and Yorkshire Mercury, Oct, 1901). This intense competition from industrial competitors resulted in the workers from Hattersley’s being put on short-time working (The Yorkshire Post, Dec, 1900). According to Yorkshire’s regional newspaper, Germany was deemed to be guilty of industrial malpractice in having slavishly copied “in every detail” the revolving box looms used in Yorkshire (The Leeds and Yorkshire Mercury, Oct, 1901, p. 7). Even so, the Yorkshire regional newspaper lauded the United States of America for their “genius for mechanical invention” (The Leeds and Yorkshire Mercury, Oct, 1901, p. 7). Moreover, American manufactured textiles machines were also judged to be “exceedingly good” (The Leeds and Yorkshire Mercury, Oct, 1901, p. 7). In a number of American textile trade journals, criticism was focused on the absence of invention undertaken in Great Britain. The Textile World’s correspondent noted that:

> “… the English methods and customs tend to discourage originality of ideas…The attitude … towards inventors is largely one of toleration. They will listen to you and if you are not too lengthy will go over the pros and cons of the case, but in the end you are either asked to call again after your invention is a success” (The Textile World, 1903, p. 115).

Furthermore, a number of British textile opportunities and industrial practices and duties undertaken in mills were frowned on by the American textile trade press. The Textile World’s correspondent questioned why the British weaving trade had “no warp stop-motions, either mechanical or electrical” on their looms (The Textile World., 1903). The reason suggested was that all the best British textile inventors had emigrated to the United States of America where they were likely to benefit from a wider range of opportunities and more generous rewards for their endeavours.

During their long history, Hattersley’s had experienced American competition as far back as the 1860s with the invention, patenting and promotion of the ‘Crompton’ loom. This type of loom had proved to be an improvement on the weaving mechanism found on the Hattersley loom. The ‘Crompton’ loom had worked on the ‘closed shed’ cycle process which required all the warp threads to be raised and subsequently depressed after each traverse of the shuttle. Unfortunately, the ‘shed’ (the area created by the temporary raising and depression of warp threads) sequence often ended before the weaving cycle could take place. The underlying weakness was that this weaving process found on the ‘Crompton’ loom placed undue stress on the warp yarn leading to a reduction in speed of the ‘picking’ action. Crompton overcame this problem by introducing their version of the ‘open shed’, (the raising and depression of warp threads were kept to a minimum) the picking and ‘shedding’ motion was upgraded and helped by a greatly improved drop box. By the 1870s, this loom was launched in Great Britain by Messrs., Hutchinson and Hollingsworth, Dobcross of Lancashire (Glover, 1959). Although Hattersley had introduced the ‘Dobby Loom or Keighley Dobby' in 1867, the popularity of their looms had been replaced by the Dobcross loom. Hattersley's responded to the loss of the textile loom market share by launching their 'positive dobby' in the late 1870s. One researcher has argued that Hattersley's had manufactured their positive dobby:

> "… by using over and under connections essentially similar to those of the Knowles dobby" (Fox, 1894, p. 129).

Towards the end of the 1880s the British woollen weaving companies seemed to prefer using either the Dobcross or the Hattersley's looms (Glover, 1959). These two textile loom makers continued to innovate and register their patents and make incremental improvements and innovations to their respective looms from the 1880s onwards.

Overseas criticism was levelled at the British textile industry in the way weaving was undertaken in the mills. In the estimation of the American cloth manufacturers, unlike weavers in the U.S.A, the British weaver did not concentrate solely on the task of weaving, performing instead on a multitude of mill-based tasks. Typically, the weaver would:

> "…weft about the room, … unroll the cloth from the looms, inspect each yard of the piece, taking off the loose ends, etc., and carry the piece to the cloth booker where it was inspected and passed upon ..." (The Textile World, 1903, p.116).

During this decade (1900-1910), Hattersley's along with other British machine manufacturers were subjected to direct competition from American automatic loom manufacturers. Within five years of inventing their cop-changing loom, the George Draper Company and Sons of Hopedale had managed to reach sales figures of over 75,000 of these machines to mills in the United States of America. (J. Text. Inst, 1933). By 1902, this company took the unprecedented decision to set up the British Northrop Loom Company in Blackburn, Lancashire, and in so doing, became the very *first* foreign textile company to be set up in Britain (Farnie, 1990).

The rationale for making this move was to manufacture, distribute and acquire a market share of the British market. In its inaugural year as a trading company (1902), only *two* companies chose to adopt this radical loom. One of these companies (Messrs., Ashton Brothers and Co. Limited) installed 500 automatic looms in their mill – paradoxically, Gutherie and Co. Limited., of Portsmouth near Todmorden chose instead to have a number of Hattersley's looms with their shuttle changing features (The Textile Manufacturer, 1902). Towards the end of that year, George Draper and Sons Company went further and extended their influence by allowing the manufacture, under license, of these automatic cop-changing looms in both Switzerland and France (J. Text. Inst, 1933). Although there was considerable British resistance from the cotton and worsted areas against the adoption of these Northrop cop-changing looms, these looms proved to be very popular in Continental Europe (J. Text. Inst, 1933).

According to the American Survey of the British Manufacturing Industry, the only town in Yorkshire which chose to adopt the cop-changing loom in the 1920s was Huddersfield. The main reason given for preferring this loom over others was that weavers employed in Huddersfield and surrounding areas were men overseeing only one loom at a time [a similar weaving practice could be found in Scotland and the West Country] whereas the workforce found in Yorkshire mills tended to be female who looked after two or more looms (American Survey of the British Manufacturing Industry, 1920).

Competition from the United States of America in the manufacture of automatic looms was slow at the very beginning. Nevertheless, two of the largest textile companies, Hattersley's and Draper's, continued to work towards making their respective looms more efficient. In a lecture given in 1924 to the Bradford Textile Society, the speaker, Mr. Ernest Halliday, outlined the importance of efficiency. He stated that:

> "The human factor is much more important in weaving than in the other branches of the textile industry…Efficiency meant lowering the costs by increasing output - doing the work with the minimum of effort. It meant good planning good methods, good co-operation, team work, and '*esprit de firm"* (Shipley Times and Express, 1924, p. 3).

To achieve this, the number of looms, which were overseen by the weaver, was increased whilst at the same time and emphasis was placed in ensuring that the yarn did not break causing any unnecessary stoppage of the loom. The weakness of the yarn could be partly attributed to how well it had been spun before it was placed onto the loom beam. In the technical development of the loom, both Hattersley's and Draper's had upgraded the weaving capacity speed. Over time, this development in loom design was intended to increase and improve productivity. Holden concluded that:

> "If the weft yarn breaks on average once in 5000 picks then the loom will have to be stopped to piece up every 50 minutes when running at 100 picks per minute but every 25 minutes when running at 200 picks per minute" (Holden, 2014, p. 139).

This type of cop-changing loom had proved ideal for the American cotton market. In the United States of America, looms had been designed to run at a slower speed which allowed the American weaver to oversee more looms than their foreign counterparts. Holden reflected that when the Northrop cop-changing looms were introduced into the textile market, they were found to be an ideal loom for weaving hard-spun, ring-spun yarns (Holden, 2014). In a talk given by Mr. J. F.

Fletcher, of Keighley College to the Shipley Textile Society, the speaker speculated that one reason why the trade continued to be so bad in Great Britain could be attributed to the purchase and use of the automatic loom made and sold by the United States of America as well as to Britain's many foreign competitors (The Shipley Times and Express, Dec, 1931). Furthermore, he argued that:

> "In Lancashire, quantity of production was the greatest factor, in Yorkshire the quality of the production plus low cost of production was the great essential" (The Shipley Times and Express, Dec, 1931).

By the 1930s, the Northrop loom, which had been so closely associated with automatic weaving, became known as the 'automatic cloth producing machine' (The Textile Weekly, Feb,1933).

Although they had been a technical and market leader in loom design, Northrop automatic looms were being replaced by the Japanese Toyoda loom. It was claimed that in Japanese mills, the Toyoda loom represented one tenth of all working weaving looms (Burnley News, May, 1930).

In addition to having to counter foreign competition, British manufacturers of the innovative weaving looms and spinning frames had to contend with the inevitable competition created by a body of imitators, eager to appropriate a share of the new commercial market.

During the last quarter of the nineteenth century, Prince-Smith and Stells had achieved a sizeable inroad and stake in the American textile market. Although American companies, especially mills in Massachusetts, attempted to copy Keighley-made spinning frames, they always seemed to fail. According to Gibb, the American companies could not match the "work of the English fitter" (Gibb, 1950, p. 194). Even though the loom production of Hattersley's was adversely affected by the various tariffs imposed by the United States they continued to trade in the U.S.A as well as Continental Europe. Cole noted that in 1910 between "85% and 95% of worsted machines were of foreign origin - overwhelmingly British" (1926, p. 82). Hattersley's continued to build and trade through the imposition of tariffs but tended to concentrate predominately on the domestic market.

7.5 Messrs., George Hattersley and Sons Limited., loom production during the decade 1911 - 1920

The importance of trade exhibitions in a firm's calendar of marketing events cannot be underestimated.

The Textile Manufacturer underlined the importance of participation by claiming that "trade exhibitions are an economical way of first-hand knowledge of all the latest inventions in machinery and processes" (1933, June, p. 238). Knight (2001) has suggested that trade exhibitions would often provide a participating company with a recurring planned event (Ponzurick, 1996), ~~a~~ means of increasing their share of the trade market; the dynamic mechanism for future networking (Vandenbempt and Matthyssens, 1999) whether that was technical knowledge, information or acquired knowledge; careful use of materials and an appropriate assessment of future economic and political strategies. Trade exhibitions and the continual participation by companies proved to be also very important in publicising any new products as well as the promoting the cultural transfer of free trade (Kaiser, 2005). Furthermore, the winning of any prestigious award would bring unparalleled prestige, recognition and potentially a healthy order book. Obversely, the failure to win a prize could hinder or adversely affect potential sales (Tesar, 1988) or the most recent technologies (Rice, 1992; Rice and Almossawi, 2002). When asked about the worth of exhibitions, the Prince of Wales [1841-1910] saw the merits of attending exhibitions and commented that:

> "the benefits resulting from the display of manufactures at such exhibitions cannot be measured solely by the amount of direct orders received by individual exhibitors. Experience has shown that, even in the case of firms having an established reputation and world-wide connections, attempts to discontinue … have usually been followed by a diminution in the sales" (Bradford Daily Telegraph, May, 1909).

In 1911, Hattersley's submitted thirty weaving machines to the 1911 Roubaix International Exhibition held in France. One of their submissions was their ground-breaking loom which could weave a reproduction of Landseer's famous painting - '*Bolton Abbey in the Olden Times'* (The Belfast News-letter, Sept, 1911). For the quality and excellence of their looms, Hattersley's were awarded the highest prize - *Le Prix d'Honneur.* This award would have been sufficient for Hattersley's to include in their marketing as well as encouraging overseas interest and sales.

Not long after the award, the 1911 Roubaix International Exhibition jury decided to retract the award and presented it to a fellow exhibitor - Messrs., George Hodgson, Limited., of Frizinghall, Bradford - a company whose looms were "known wherever wool was woven" (Keighley, May, 2007, p. 63). This European award for innovative textile loom design was very important to the winner as it would ultimately provide the company with much needed international publicity, exchange of industrial knowledge, inventive prestige and potential sales. Hattersley's felt aggrieved and duly appealed insisting the jury should reverse their decision. Such bad publicity would not assist Hattersley's prestige in the loom-making industry and could cause a setback in production.

The 1911 Roubaix International Exhibition committee subsequently reviewed their decision and decided instead to give Hodgson's, the *Diplôme de Rappel de Grand Prix.* This decision and subsequent award was already taken because Hodgson's had been given a *Grand Prix* award in a previous exhibition which had occurred elsewhere. The prestige of the 1911 Roubaix International Exhibition was such that any *Grand Prix* carried its own industrial trade kudos (Bradford Daily Telegraph, November, 1911).

This success prompted Hodgson's to subsequently place a label announcing that they had won the *Grand Prix* at the 1911 Roubaix International Exhibition. Hattersley's felt that there had been a travesty of justice regarding the awarding of the *Grand Prix* and launched a legal challenge, through the French courts for considerable damages as well as demanding the removal of the 'offending' label which clearly stated that Hodgson's had won the *Grand Prix*. After some deliberation, the French courts awarded 500 French francs in damages together with a levy of 50 French francs for every day the label remained on show declaring that Hodgson's had won the *Grand Prix.* Much later however, the French courts insisted that the label be withdrawn forthwith (Bradford Daily Telegraph, November, 1911).

Hodgson's continued to feel aggrieved and decided to press for damages amounting to 500,000 French francs. This claim for compensation was dismissed by the French courts who ordered Hodgson's to meet all the costs for their unsuccessful action as well as publication costs which had publicised their *Grand Prix* award in two French publications (Bradford Daily Telegraph, November, 1911).

In the world of international trade, the notion or ideology of free trade or 'Cobdenism' [a philosophy espoused by Richard Cobden,1804-1865] had encouraged the removal of all trade tariffs or custom offices with a view of raising the prosperity of a country (Palen, 2017). This free trade very important after 1880 because Britain's export costs were being adversely impacted by foreign tariffs. By the 1890s, a counter movement objecting to free trade was established and became known as the 'Fair Trade'. This 'Fair Trade' movement was set up to bring in tariffs to protect agriculture as well as aspects of the British industry. Some commentators have argued that 'Fair Trade' was a form of countering foreign tariffs (Bhagwati and Irwin, 1987). A contemporary view taken by one commentator stressed that the imposition of free trade in Great Britain had indirectly caused exports to be revitalised, profits to decline and competition between Great Britain and its competitors to rise (Ritortus, 1899). Certain scholars have argued that:

> "…during the era of greatest free trade in continental Europe, 1873-1890, Europe was plunged into a depression as that of the 1930s - partly, it seems because of free trade . . . During this time, the United States, with its tariffs at historic highs, enjoyed one of its greatest bursts of sustained growth" (Lind, 1994, p. 22).

A 'Fair Trade' movement was set up by the National Fair Trade League [1881-91] consisting of interested representatives from the industrial and agricultural sectors. This movement had grown out of the depression which had occurred from 1873 onwards. Inroads by British exports were being handicapped throughout Continental European markets. British exporters found a:

> "barrier erected which the new-born industries were maturing in safety, for the day when they should be sufficiently strong to invade the British market" (Zebel, 1940, p. 165).

They agitated for "bargaining tariffs" or "reciprocity" (Irwin, 1994, p. 78). American commentators recorded the prosperity that their tariffs had produced. The Textile World Record noted that:

> "Not very long ago, when under the Cleveland-Gorman-Wilson Bill [1894] the industries of the industries of the United States lay prostrate, while an avalanche of foreign goods poured into the country… and now … England is passing through a similar period, it is well for us to realize that in a very large measure our prosperity is due to the exclusion of cheap foreign goods from the country" (Textile World Record, 1903, p. 70).

Unfortunately, the National Fair-Trade League [1881-1895] did not prove successful and was replaced by the short-lived, United Empire Trade League [1891-1903] which was actively promoted and spearheaded by the Member of Parliament and Secretary of State for the Colonies, Joseph Chamberlain [1836-1914]. Other members included Sir Henry Mitchell, of Bradford [1824-1898] and the Bradford textile magnate, Samuel Cunliffe-Lister [1815-1906] (Zebel, 1940, p. 165). Unfortunately, this 'protectionist movement' never managed to capture the spirit of the British producers or the working classes (Eichengreen, 1992).

According to Bairoch. the "best 20 years of American growth [1870-1890] took place in a period when its trade policy was protectionist' (Bairoch, 1993, pp. 52-53). Once protectionist tariffs were in place against foreign competitors, it was only a matter of time before a country's economy precluded and imports into its commercial markets. Buchanan (1998) went further and concluded that:

> "behind a tariff wall . . . the United States had gone from an agrarian coastal republic to become the greatest industrial power the world has ever seen – in a single century" (Buchanan, 1998, p. 224).

One measure, which had a significant influence on global markets, was the introduction of the American McKinley Tariff which was essentially a retaliatory economic *ad valorem* tax. The *ad valorem* [trans. according to value] tax was a tax imposed on goods or assets and expressed as a percentage. It raised the tariff on imported goods from 35% to 43% (Varian, 2017). The viewpoint taken by the fair traders was to apportion blame on the McKinley Tariff claiming it had brought an economic depression in England in 1891 (Zebel, 1940). Not only did this punitive tariff impose an economic boundary but it also diminished the British ‘market’ viewpoint on free trade. It also affected a direct, lucrative trade with the “British West Indies, South Africa, Australasia and Canada” (Palen, 2017, p. 396).

Moreover, companies in Bradford and Keighley attempted to prevent, as best as they could, the payment of American duties on their products. To avoid incurring tariff duties, Manningham Mills, situated in Bradford, attempted to stockpile their goods in American warehouses during 1899 and 1890 (Blewett, 2006). It is also interesting to note that Manningham Mills was not the only textile company to stockpile their goods in the United States of America during the 1890s. The Textile Manufacturer (1890, p. 470) noted that one cargo, valued at £36,000, which had been dispatched from Bradford, arrived in New York fifty seconds before the McKinley Tariff duties came into force. Protective tariffs such as the McKinley Tariff caused many textile companies and machine manufacturers to reassess their export strategy to the United States of America. The Textile Manufacturer’s cautionary advice to their Bradford manufacturer readership was that they should ensure the protection of Yorkshire skills and not to send any English machinery abroad (The Textile Manufacturer, 1890).

Consequently, this advice caused many British mills to reconsider their responses to the American protectionist tariffs. The reason was that these tariffs had been set at a high rate and according to Eckes (1994) not only had improved the economic status but also strengthened the economic growth of the United States of America. With these high protectionist tariff rates or duties, the idea was that the imported goods to the United States of America would be reduced and the local market share would improve. This economic tax would also allow local American manufacturers or “infant industries” (Irwin, 2000, p. 336), to have opportunities to grow, be protected and improve their productivity. Hattersley’s found that their different types of looms were proving more expensive to export thereby limiting potential inroads into the American textile market.

At the beginning of the First World War [1914-1918], many of the engineering sectors in Keighley, Prince-Smith and Stells and Hattersley’s together with their loyal customers such as Salts Mill, Isaac Holden and Sons Limited., Woolcombers Limited., Manningham Mills, John Fosters and Sons Limited., had switched their focus and output towards wartime production. (Keighley, 2007). The different type of machinery which Hattersley’s had manufactured and subsequently supplied to the domestic market in Great Britain very soon faltered. As the industries quickly fell into line with war work, the overseas trading markets which Great Britain had secured were soon lost. The Great War [1914-1918] presented the companies involved in loom-making with many problems such as the loss of skilled manpower, loss of skills due to enlistment, and the depreciation of “plant and machinery” (Jenkins, 2003, p. 995). According to some researchers, these trading markets were not recaptured until the 1920s (Horsewood, Sen and Voicu, 2008).

By 1915, all the industries in Keighley had been turned over to crucial war work which were concentrated around the National Shell Factory situated on Dalton Lane in Keighley (Dewhirst, 1974). This switchover from civilian work to war work necessitated the need to find 120 metalworking lathes. This task was assigned to the chairman of the Keighley and District War Munitions Committee, Harry Smith [Dean, Smith and Grace, Limited., Lathe Manufacturers, Worth Valley Tool Works] who was later knighted, in 1918, for his services to the war effort (Walford, 1920). Munition factories were very important mainstays for the war effort. Smith approached as many Keighley companies as he could which included, amongst others, Prince-Smith and Stells' and Hattersley's. From his many visits, Messrs., Prince Smith, Richard Smith (Messrs., George Hattersley and Sons Limited.,) and John Smith were invited to join the committee. The original idea presented to the War Office was to have a multitude of workshops distributed across Keighley, all undertaking munition work. This suggestion was rejected by the War Office. Instead, the committee opted for a large workshop situated in Dalton Lane, Keighley which had originally been occupied by the Cundall Gas and Oil Engine Company Limited., (Bradford Weekly Telegraph, May, 1915). A recruitment drive, via the local Labour Exchange, for workers to operate the metal working lathes, attracted many female workers. All these females were to be managed by a male manager, male foreman and a female superintendent (The Leeds Mercury, May 15th, 1915, p. 3). This workforce of female munition workers began to replace the male workers who had been recruited and mobilised to fight overseas. Harry Smith was to claim that his female munition workers "turned out more shells that would have won the battle of Waterloo" (Dewhirst, 1974, p. 115).

During the early years of World War 1 (1914-18), the Consul to Bradford, A. E. Ingram, included in an official publication sent to the Bureau of Foreign and Domestic Commerce, Washington, USA, a recent article which had featured in the Yorkshire Observer. It recorded that:

> "The prosperity enjoyed by the wool trade has not flowed from war orders exclusively. And yet the part played by war orders has been large, and to some branches it has been all important…Imports of fabrics have dropped to a mere nothing, and instead of fighting French competition Bradford has been supplying the French market to an extent unequalled since the time of the Franco-Prussian War…" (Supplement to Commerce Report, 1916, p. 1).

Much of this success could be attributed to the many kinds of textile machinery manufactured by the Keighley machine manufacturers. Despite the lack of manpower throughout the textile industry caused by the war, the importance of the Keighley machine manufacturing industry to the war effort was recorded later in the document:

> "…At Keighley (9 miles distant, with a population of over 40,000) the machine-tool trade has been busy, and most of the local machine shops have been working on Government orders. The textile machinery trade, which is an important local industry, has also been busy on orders…" (Supplement to Commerce Report, 1916, p. 9).

The fortunes of Hattersley's during the period 1911-1920 began with a court case surrounding their apparent dealings with the enemy which was a contravention of the Trading with the Enemy Act, 1914 (The Manchester Courier, 1914, p. 5). Three companies - Messrs., Clifford Limited., (Huddersfield), Messrs., John Birch and Company, (Radcliffe) and Hattersley's (Keighley) were summoned to attend a hearing at the Manchester City Police Court. Proceedings of each case together with the evidence was placed in front of the stipendiary magistrate. The first case was dismissed against Messrs., Clifford Limited., (Huddersfield), Messrs., John Birch and Company, (Radcliffe) were fined and ordered to pay costs whilst the case against Hattersley's (Keighley) was dismissed because the stipendiary magistrate had not received any supporting evidence to pursue the case (The Manchester Courier, December 23rd, 1914).

Conversely, as well as the adverse publicity which would have tarnished the reputation of the firm following a court fine, a guilty verdict risked bringing about a decline in domestic and international sales or at worst a loss or reduction of jobs or income.

Hattersley's managed to register their patents, continued manufacturing weaving looms and undertook War Office contracts until the end of the Great War [1914-1918]. Soon after, they reverted back to manufacturing textile machinery, developing the Hattersley Standard loom in the 1920s. Even though the Hattersley Standard loom became very popular, the problem continued with British cloth producers who were reluctant to invest in new weaving machinery. Keighley recorded that:

> "… higher prices were being asked for British machinery. Makers of British looms decided on an all-round price of £300 per loom. In pre-war days it had been possible to buy a loom for about £60 …" (Keighley, 2007, p. 28).

7. 6 Messrs., George Hattersley and Sons Limited., loom production during the decade. 1921 - 1930.

Foreign competition brought many challenges for British and Yorkshire textile machine manufacturer, not least in new fashion influences which led to a reduced market share. Wild (1972) has suggested that up to the mid-1920s many Yorkshire woollen and worsted based-companies tended to focus their energies on expanding domestic markets. Broadberry has gone further and suggested that companies were also dependent on trade markets found around the Empire which supplied short-term "output and employment" (Broadberry, 1997, p. 12).

During 1921, Hattersley's designed, developed and introduced their Standard Loom. Although the loom featured many additions which allowed the loom to weave complex weave structures, it did not fully secure the necessary appreciation and interest it was expected to reach. This unforeseen response may be attributed to the loom's novel design. Moreover, according to many loom tuners, the design of the loom included a number of mechanisms which they felt could not cope with the challenging demands found in many weaving sheds (The Textile Manufacturer, 1932). Following the introduction of the Standard Loom, a series of technical adjustments were necessary and subsequently undertaken. It would take over ten years before loom parts such as the swell boxes, overpick mechanism and weft fork on the Standard Loom were revised and improved.

When introduced in the 1920s, the construction of the swell boxes located on Standard Looms, were not made of 'malleable iron' and so they could not cope with the different sizes of shuttles used. An additional design problem was also noted. As the picker came into contact with the shuttle, it would, over time, succumb to deterioration. This design fault on the picker continued until improvements were made in the 1930s. The picker was redesigned in such a way that the obverse side could also be used by to propel the shuttle (The Textile Manufacturer, 1932).

By the 1930s, the front end of the overpicking shaft was repositioned behind the swell boxes and designed so that it was inclined. This design feature now ensured that the picking motion would move in an upward trajectory, which in turn increased the speed of the picker as well as the shuttle as it was propelled across the raceboard (The Textile Manufacturer, 1932). Furthermore, parts that were found on the picking tappet were reconfigured. When introduced in the 1920s, the picking tappet was constructed with a boss, shell and nose. By the 1930s, this feature of three parts was reduced to two. It was discovered that when weaving took place, two of these parts would disengage from the lower shaft or become worn through constant use (The Textile Manufacturer, 1932).

Originally, the Hattersley Standard Loom had one centre weft fork. Ten years later improvements were made by fitting two weft forks. They were placed as near to the selvedge as possible and by careful adjustments and connection to a rod which could be altered. The movements could then operate in harmony (The Textile Manufacturer, 1932).

By 1922, the fortunes of the industry went into decline. The worsted textile industry became susceptible to new competitors, seemed to falter against the ever-changing whims of fashion and demonstrated a lack of interest and commitment in purchasing new machinery (Bentley, 1970). At a hearing held by the Board of Trade Committee held in 1925, Mr. Hubert B Cordingley from Messrs., John Wright (Ingrow) Limited., Keighley reflected what many Yorkshire manufacturers already knew. He explained that many low-priced cloths produced overseas were woven on looms similar to the ones manufactured in Britain. He concluded that, although he had a large number of looms in his workplace, he had been:

> "inundated with small orders which have come to me entirely for one reason in preparation for the turnover of the trade from the Continent to Bradford" (The Nottingham Journal, Dec 9th, 1925).

One political and fiscal objective which the British Government adopted after the Great War [1914-1918] was joining the gold standard in 1925. The return to the gold standard or a 'global fixed rate' (Kitson and Michie, 1993) was to prove disastrous for the British economy. Not only did it lengthen the effects of the Great Depression, it also continued to promote a 'slow growth to the world's economy'. Moreover, this led to many industrial countries adopting 'deflationary policies' (Kitson, 2013).

In 1928, the consulting engineer, author and lecturer, Frank Nasmith [1879-1949], writing in The Textile Manufacturer trade journal, addressed his concern by outlining the perceived, adverse effects that foreign competition was having on the textile industries in Great Britain. Nasmith outlined the fact that although loom manufacture was expanding throughout the industrialised countries "little replacement [was] taking place" in Great Britain (Nasmith, Oct 28th, 1928, p. 535). This was totally opposite to what the foreign competitors were doing in their own countries. One of the consequences of this period was that one third of all looms found in British mills were stopped (Jenkins and Ponting, 1982, p. 996). This fact had a profound effect on Hattersley's. They were now limited in providing looms to an industry as well as reducing their stock of looms.

Criticism of the state of affairs regarding textile machinery in Great Britain was attributed in the main to the role that the trade unions played. Nasmith advocated that trade unions "should pledge their co-operation in effecting such economies in manufacturing as may be brought about by the introduction of improved machinery" (Nasmith, Oct 28th, 1928). From 1890 to 1939, the company of Hattersley's was in direct competition with many local and foreign competitors who played an adverse part in their production output.

Although the British textile manufacturing industry had always experienced periods of industrial trade depression it was not until the 1920s when it began to have a severe effect on Keighley and its many industries. By 1929, Hattersley's had been fully occupied in manufacturing looms until the last few months of the year. Subsequently, Hattersley's had begun to experience a slowdown of its manufacturing capacity. Even the manufacture of looms, which wove artificial silk/rayon which had been successful in the past, was now compromised by a trade depression.

Notwithstanding, this trade depression went onto affect British textile exports which ranged from 'tops to finished products' (The Leeds Mercury, Dec, 1929).

During the early 1930s, certain local industrialists viewed the Yorkshire machine manufacturing industry to have undergone economic tribulations over a number of years because of taxation and unemployment. In an interview, Mr. Arthur Smith, a director of one of the largest lathe engineering companies in Keighley, [Dean, Smith and Grace] was able to describe the economic situation the engineering companies were working under. He asserted that:

> "the industry of this country for a number of years had been bled white by the heavy taxation, and it is pitiable to-day to find firms having to be content with second-hand machinery which is more or less out-of-date" (The Leeds Mercury, Jan, 1930, p. 5).

This factor affected both heavy engineering and the textile machine manufacturing in Keighley. Mr. Arthur Smith concluded that:

> "Anyone in the engineering world who has travelled in Northern France and Belgium - where there is practically no unemployment - must have been struck by the amount of very latest machinery and the very latest works which have been built" (The Leeds Mercury, Jan, 1930, p. 5).

The director of Hattersley's, H. Giffard Smith, went further and added that:

> "he knew of hundreds and hundreds of looms 30 and 40 years old that ought to be replaced. The owners of them knew it, but were simply in the position of conserving what little they had" (The Leeds Mercury, Jan, 1930, p. 5).

One director from Merrall and Sons Limited., Haworth also highlighted the problems that many manufacturers faced noting that there was no government inducement for manufacturers to buy new machines. He suggested that if the British manufacturers were allowed a period of two to three years of protection, the industry would improve (The Leeds Mercury, Jan, 1930). According to Mr. H. Giffard Smith, he concluded that some of the problems troubling the textile machine manufacturing industry was the:

> "subsidising [of] any shape or form was wrong. If only our manufacturers could have some measure of protection against the dumping of foreign materials, they would need no assistance at all" (The Leeds Mercury, Jan, 1930, p. 5).

Even though the so called 'dumping of foreign materials' was going on, Mr. H. Giffard Smith was convinced that Keighley and Hattersley's textile workers were superior. He summed up this point by insisting that:

> "it is the result of a generation after generation working in power loom manufacture [and that] there should be this supply of labour with special advantages over other places" (The Leeds Mercury, Dec, 1931, p. 3).

Mr. R. Merrall, director of Merrall and Sons Limited., worsted spinners and manufacturer based in Haworth in Yorkshire, echoed this point and concluded that there was little or no incentive for any textile manufacturer to purchase or replace any old machinery for new machinery. To alleviate this problem, he suggested that a period of "safeguarding" was undertaken for a period of two to three years to help the worsted manufacturing industry improve (The Leeds Mercury, Jan, 1930, p. 5).

The regional newspaper [The Leeds Mercury] reported that the trading conditions up to November 1930 had allowed Hattersley's and other machine manufacturers to trade as best as they could. Even so, 1930 had been considered by Hattersley to have been worse than the previous years (The Leeds Mercury, Dec, 1930). The causes of this trade depression was blamed on financial problems such as protectionist tariffs emanating from Colonial countries such as Australia and Canada, a groundswell of political upheavals in Continental Europe and the disastrous economic stock market crash of 1929 which had signaled and speeded up what became known as the *Great Depression* [1929-1939]. This economic downturn was described by the British Chancellor of the Exchequer, Philip Snowden [1864-1937], as an 'orgy of speculation' (Papadimitriou, 1996). Furthermore, Hattersley and various machine manufacturing companies situated in Keighley suggested that they would recompense manufacturers if they scraped their old machines and replace them with more up-to-date machinery when the trade picked up in the next few years or near future (The Leeds Mercury, Dec, 1930).

In his presidential address to the National Union of Textile Workers held in Bradford, Ben Turner [1863-1942] reflected the adverse competition which had been imposed on textile machine manufacturing in Yorkshire and Britain. He stressed that:

> "It is no use disguising the fact that we have stocked other countries with our textile machinery, taught them our industry, and they are even becoming our competitors in many lands so that our expert position is not as easy as it used to be" (The Shipley Times and Express, May, 1930).

7. 7 Messrs., George Hattersley and Sons Limited., loom production during the decade 1931 - 1939.

The year 1931 saw an improvement in textile manufacturing in Keighley. Even so, there were still many issues facing the textile manufacturers and machine manufacturers. Some of the local industries continued to struggle filling their order books whilst other industries were not performing as well as they should have been. When interviewed, Keighley Alderman F. Dickinson was quoted as saying that "there is a better feeling in trade and industry. People are spending a little more and that is always a good sign" (The Leeds Mercury, April, 1931, p. 3). This never-say-die attitude was an attempt stand resolutely in the face of adversity in spite of a difficult economic situation.

In the textile machinery manufacturing industry, this sense of optimism was attributed to some textile manufacturers placing orders for replacement parts for their machines (The Leeds Mercury, Nov, 1931). Many other manufacturers, however, preferred not to invest in new textile machinery. Instead, evidence of a reluctance could also be seen during any scheduled textile mill refit where manufacturers chose to buy second-hand rather that new equipment or at worst preferred looms which would run at 70 picks an hour even though there were looms which could operate at 100 picks (The Leeds Mercury, Nov, 1931).

With the ever-changing fortunes of the town of Keighley, Hattersley's continued to develop and innovate their wide range of textile processing machinery. When interviewed, the Managing Director, Mr. H. Gillard Smith, from Hattersley's stated that the company's success for that year had been dependant on their "latest models of special looms for the artificial silk trade [which had] helped considerably to keep the works busy" (The Leeds Mercury, Nov, 1931, p. 3).

In 1932, the chairman of the British Textile Exhibition Committee of the British Industries Fair, Mr. Fred Mills, announced to the local paper that textile furnishings, which had been readily available from Continental countries such as France, Germany and Italy, were now being woven by looms manufactured in East Yorkshire, Lancashire, Scotland and Yorkshire. He added that:

> "While the home consumer has taken most of the increased production there has been a noticeable swing towards British textiles in world markets. Our share in the world's export trade is now growing instead of declining" (The Nottingham Evening Post, Dec, 1932).

By 1933, the regional paper was reporting an economic upswing which was changing the prosperity of Keighley. Figures released suggested that unemployment in Keighley had fallen by 2,545 to 2,055 (The Textile Mercury, Nov, 1933, p. 7). This optimism could be seen in the town's machine tool engineering industry represented by Dean, Smith and Grace and key textile engineering works (The Textile Mercury, Nov, 1933,). When contacted by The Leeds Mercury, Mr. H. Giffard Smith, a director of Hattersley's and commented that the company had been in full employment and that their order books revealed that 80% of textile machines produced were for the home market (The Textile Mercury, Nov, 1933,).

Furthermore, Hattersley's had also expanded their business by extending their Greengate Shed which had been purchased twelve months previously from R.M.C. Textiles Limited., of Keighley. This now allowed Hattersley's to run their newly-acquired purchase of S. Clayton and Co., of Halifax, web manufacturers, from the Greengate Shed in Keighley. Moreover, after almost half a century as sitting tenants, Hattersley's were also able to run their tape manufacturing, which had been situated at Walk Mills in Keighley, from their newly-extended Greengate Shed (The Textile Mercury, Nov, 1933,).

At the beginning of 1933, Hattersley's tried to be optimistic when interviewed about the textile machine manufacturing industry. They summed up their optimistic response to the trade by remarking that "we are not at all apprehensive about the future" (The Leeds Mercury, Jan, 1933). During 1933, the workforce at Hattersley's comprising of over 700 employees, had been working full-time for four months (The Leeds Mercury, Nov, 1933), manufacturing a variety of Hattersley's looms. This situation was greatly assisted by the expansion of their site. With the extension of their Greengate Shed in progress, Hattersley's began to make plans to swell the size of their workforce with an additional fifty employees (The Textile Mercury, Dec, 1933). Hattersley's concluded that 1933 had 'not been so bad' but they had noticed that the year seemed to have fallen away in terms of new orders for weaving equipment. Other companies such as Prince-Smith and Stells considered their future as 'uncertain and somewhat difficult' (The Leeds Mercury, Dec, 1933). Despite the difficult situation facing Prince-Smith and Stells, it was Hattersley's who hoped that the following year would improve and the 'restrictions on foreign currency' would ease up and allow a healthier export trade (The Leeds Mercury, Jan, 1933).

Loom manufacturing in 1934 was significantly better than the previous year even though there had been a German embargo imposed on imports and that the price of wool had altered on so many occasions that year. Hattersley's success during year had been based on manufacturing improved models of their popular looms which wove artificial silk or rayon solely for the British home market. With the continual success of these looms, Hattersley's viewed their prospects for 1935 as being very good or promising (The Leeds Mercury, Jan, 1935). Unfortunately, there was a dip in their production which continued to fall until 1935.

On a fact-finding trip to the Far East, Australia and New Zealand, Alfred Stells, the director of Prince-Smith and Stells, was interviewed by the Yorkshire Evening Post for his impressions of Britain's new, perceived trade rival. In the report, Alfred Stells was very critical at the development of Japan and the lack of reaction by the British government and the absence of measures taken to counter Japan's systematic trade inroads into the British home textile market. Stells argued that the British government should encourage the British textile industry to increase the:

> "rate of depreciation on new machinery and encouraging employers to throw out their obsolete plant" (The Yorkshire Evening Post, May, 1934).

Hattersley's announced at the beginning of 1935 that they had 'no complaints'. An increase in orders for the home trade (The Leeds Mercury, Dec, 1935) and the introduction of an improved artificial silk or rayon weaving loom continued to fill up the order books of Hattersley's. Furthermore, Hattersley's continued with a full employment of its workforce (The Leeds Mercury, Jan, 1935). During 1935, Hattersley's continued to refine and improve their automatic self-shutting looms. On the 1st of March 1935, the company of David Sowden and Sons Limited., located in Shipley, was taken over by Hattersley's. The advantage of this purchase was that Hattersley's were now able to offer even more looms as well as expanding their site located in Keighley, Yorkshire.

Pressure on Hattersley and other textile machine manufacturers came from British Northrop Loom Company, Limited., who had introduced their 3-shuttle pick-and-pick loom both for worsted and woollen cloths (The Yorkshire Post, Jan, 1937). This automatic weft mixing loom was proving ideal for the weaving of mixed fabrics. Inroads into the Yorkshire textile market were already taking place and it was perceived that there would be a demand for these types of looms (The Yorkshire Post, Jan, 1937).

The year 1936 was considered by some textile machine manufacturers in Keighley to be a better year since 1924. Mr. W. Prince Smith, from commented that his company had worked at "full capacity and some of the departments had to work a considerable amount of overtime to cope with the volume of trade" (The Leeds Mercury, Jan, 1937, p. 7). As far as Prince-Smith and Stells were concerned, their main competition had come from state-subsidised German companies as well as from Japan.

The competition experienced by British manufacturers continued unabated so much so that the Leeds Chamber of Commerce were obliged to reiterate Japan's unfair competition advantage which was affecting the world's textile markets (The Nottingham Evening Post, April, 1936). Addressing the Leeds Chamber of Commerce, Mr. Bretherick, their representative, complained that the prices of Japanese products were still undermining British and Empire goods in both quality and prices. He noted that:

> "I have handled in Leeds, this week, beautifully made men's all-wool knitted outwear made from the very best yarn on the latest British Jacquard machines, at prices which would break your hearts" (The Nottingham Evening Post, April, 1936, p. 4).

He concluded pessimistically that the 'rapid industrial progress made by Japan year after year' needed a radical economic approach which would require:

> "Great Britain and the Empire to consolidate our trade within the Colonies and Dominions" (The Nottingham Evening Post, April, 1936, p. 4).

Hattersley's, on the other hand, indicated that most of the trade that year had been restricted to home trade and that export activities for 1937 had proved to be somewhat problematic. The company exports, as well as their intended export strategy, had been undermined by foreign tariffs, quotas, currency restrictions and the challenging socio-political situations (The Leeds Mercury, Jan, 1937). By the middle of 1937, The Textile Manufacturer noted, with some caution, that "machinery activity is still quite good in all sections, but a slack season is approaching" (The Textile Manufacturer, July 1937, p. 285). Towards the end of the year, Hattersley's found out that their export orders for looms, destined for the Far East, had also experienced difficulties although locally-based commissions for weaving looms were still coming in and honoured. Even though Hattersley's was recorded as being 'not at all apprehensive about the future' the reality was that their loom production figures seemed to fall until 1938 when they started to improve and rise in output (The Leeds Mercury, Dec, 1937). Like many industries located in Yorkshire, the beginning of 1938 continued to be a problematic year for textile machine manufacture, especially in Keighley. All the textile manufacturing industries there had experienced a period of industrial depression the previous year (The Leeds Mercury, 1938). Geopolitical factors were still affecting any attempt to sustain a steady trade hoped for by Yorkshire textile companies. At the end of December 1938, the Leeds Mercury reported that Hattersley's had "started the year with a full order book" but with the on-going geopolitical and economic turmoil which was taking place in Europe and the Far East had caused a "lack of confidence" in Hattersley's textile machine output. This "lack of confidence" resulted in a three-day week, less sales and reduced trade (The Leeds Mercury, 1938, p. 5). Despite the instability of international events, Mr. R. Hattersley Smith tried to remain optimistic. He hoped that that there would "be an improvement, but everything hangs on whether we get some settlement of the international situation" (The Leeds Mercury, 1938, p. 5). Hattersley's tried to meet and counter the competition from their many competitors who were exporting different types of looms into the British textile market. In January 1939, Hattersley's launched their new 4-box automatic bobbin changing loom for the woollen and worsted trade (West Yorkshire Archive Service, 32D83/59) and their automatic self-shuttling underpick silk loom (The Yorkshire Post, Jan, 1939, p. 30) which they hoped would rival the many imported looms, mainly from Switzerland and the United States of America, coming into the British textile market. Unfortunately, Hattersley's noted that although these two looms were proving very popular they were unable to match the interest and 'demand' which was expressed by their potential customer base (West Yorkshire Archive Service, 32D83/59).

Hattersley's continued producing textile equipment up to the declaration of war in 1939 and in the period afterwards. At the onset of the war, the company found it difficult to adapt as they were switching from a domestic-based industry to a war-time industrial production. Subsequently, Hattersley's was engaged in resolving the shortage in webbing equipment (used in the manufacture of belts, packing and military belts). For the next few years, over 700 employees were engaged in trying to redress this shortage. What was more impressive was this was achieved when the demand for labour was at a premium. After 1940, this arrangement was to change when Hattersley's received the Machinery, Plant and Appliance (Control) Order which instructed them to switch to the construction of 'machine tools, turning out milling machines and in 1941 to aircraft work' (The Yorkshire Observer, March, 1945). The engineering skills and adaptability which Hattersley's had developed over a number of years allowed them to continue playing an important role in the war effort. Some of the items they were to work on were:

> "… inter-communication wireless sets, steering and balance gear assemblies for the 2-pounder, 6-pounder guns, 5.5 howitzer gun … as well as for the Bofors gun and the Bren gun…" (The Yorkshire Observer, March, 1945).

7.8 Summary

The main emphasis of this chapter has been to discuss the key determinants which supported Hattersley's as a key, industrial leader in loom production during the period 1890 to 1939 and examine the external factors which challenged the firm's primacy.

These determinants were instrumental in prompting the company's ability to reassess and adapt to the ever-changing market forces and economic situations. Indeed, these external factors also influenced Hattersley's loom production, trade and subsequent sales.

The British government's fiscal policies from 1925 onwards caused the British economy to suffer many economic shocks. Joining the gold standard [a country's monetary system which was directly associated with an agreed amount or fixed price of gold] had caused an adverse effect on the country's fortunes as well as prolonging the duration and intensity of the *Great Depression* [1929-1939] (Eichengreen, 1992). Arguably, the fault of the economic downturn lay in the fact that not all the countries who were integrated into the gold standard system shared similar economies, same problems or a similar economic structural landscape. Consequently, during the membership to the gold standard, adjustments or reactions to economic and fiscal problems by the British government were seen to be sluggish which caused trade markets to subsequently struggle (Kitson, 2012). From the 1920s and into the 1930s, British trade and services experienced a collapse in the demand for goods and rising unemployment (Feinstein *et al.,* 1997). Furthermore, 40% of British trade which had gone overseas was compromised by countries which could not purchase these goods because credit, previously provided by the USA, had been halted (Crafts and Fearon, 2010). Similarly, countries which had adopted the gold standard tried to retain their investors by raising the interest rates. In the meantime, the sales of goods were proving problematic for many manufacturers. By the beginning of the 1930s, Britain decided to opt out from the gold standard which encouraged economic growth as well as a slow recovery (Kitson, 2012).

Tariffs proved to be a major barrier or stumbling block for downturn. Any potential expansion was now hampered by the reaction of countries which began to impose tariffs. This was contrary to the fiscal approach taken by Britain which had been pro-active in advocating Free Trade which did not restrict the importation of goods or conversely the volume of exports. It was the American market which imposed the McKinley Tariff in 1890 to protect and nurture their 'infant industries'. Much later, the McKinley Tariff was followed by a succession of protective tariffs. By 1929, imports from Europe to the U.S.A fell from $1,334 to $390 million in 1932. Conversely, American exports declined from $2,3241 in 1929 and this reduction continued through to 1932 when exports amounted to $784 million (Irwin, 1998). As a consequence of these American import tariffs, the sale prices for Hattersley's looms became more expensive which forced them to restrict the sale of their looms to British and Empire markets. One researcher reflected the importance of the Empire to British industrialist and noted that:

> "The Empire share of British exports rose from 25% in the 1870s to 38% in 1902 and 35% in 1911-13" (Kindleberger, 1974, p. 39)

Hattersley's had many competitors to contend with in the manufacture of textile machines. Companies such as Sowden, Hodgson, Northrop and Dobcross had evolved into their main rivals. To hold their premier position in textile machine manufacture, Hattersley's had to continue to be versatile, forward-thinking and pioneering in their innovative designs of weaving looms.

One example of Hattersley's versatility was not textile-based, was manufacturing an automatic machine for cigarette production. This invention was in direct response to a similar German-based cigarette machine. Hattersley's engineers produced a cigarette machine which could produce '100,000 cigarettes per day, oval or round' (Cigar and Tobacco World, 1914). They also brought out a cigarette-stripping machine which also proved to be very useful and economical in the tobacco industry.

Despite being innovative, adaptable and arguably excellent manufacturers, Hattersley's continued to concentrate on manufacturing an array of different textile machinery. Instead of concentrating on one, such as the automatic loom or a selected number of looms, this decision of manufacturing many different types of looms may have arguably prevented them from becoming the premier textile machine manufacturer in the world. Furthermore, it was the local home market which seemed to attract their attention. This approach continued throughout 1890 to 1939 and beyond. The Cotton Industry (Working Party Report of 1946), headed by Sir Raymond Evershed's Committee, recorded and confirmed that:

> "…George Hattersley … manufacture a very wide range of different types of looms, and their automatic looms represent only one among many products…Moreover, their interest lies principally with looms for the woollen and worsted trades, silk and the finer end of the rayon industry…" (Yorkshire Observer, November, 28th, 1947).

Hattersley's continued to invent, innovate and market their array of looms and ancillary machines after the Second World War [1939-1945]. Their contribution to the history of loom manufacture was already established which continued into the 1980s despite the ever-changing economic markets and their many manufacturing rivals or competitors.

7.9 *PEST* (*&G*) (Political, Economic, Social, Technological and Geographical)

In this section, the expansion and challenges of the firm's loom production will be framed against the *individual* determinants of the *PEST* (*&G*) diagnostic tool.

7.9.1 Political (P)

One very important determinant which affected the textile trade was the imposition of tariffs on imported goods which became a great concern to the Yorkshire wool processors and machine manufacturers alike.

These American tariffs affected different categories of merchants which comprised of "wool merchants (wool staplers), mohair and alpaca merchants, top and noil merchants, yarn merchants and piece merchants" (Holme, 1988, p. 4) as well as machine manufacturers. To counter the financial and mercantile challenges that hit the export business market, the Leeds Mercury put forward a possible solution to the problem by hoping that:

> "…English enterprise, skill and industry will be able, as in the past, to overcome the difficulties created by Protectionist measure abroad" (The Leeds Mercury, December, 27th 1890).

During the 1890s, one of the newspapers local to Keighley claimed that the town was also losing its status as a textile weaving centre, the reason for this decline attributed to a continual conflict between retaining textile weavers and other workers due to the demands of the local iron trade for manpower (The Leeds Mercury, Dec, 1890). This challenge to the market share of the available labour was perceived as a threat by Hattersley's for whom, ironically:

> "It had been a tradition that members of the family [Messrs., George Hattersley and Sons Limited., when] entering the business should serve an apprenticeship in the foundry" (The Yorkshire Observer, March, 1945).

Metallurgy and metal production had assumed a greater importance in the field of technology, not least in refining and establishing practices and procedures useful in mechanical engineering. Working in iron or steel required a specialist knowledge of metal working, precision and strength. Consequently, working with the properties of metal seemed an essential acquisition of added skills and knowledge. Grosberg pointed out that the:

> "…traditional role of the textile engineer was to design machines for manipulating textile materials" (Grosberg, 1963, p. 1)

This factor became important when Hattersley's continued their progress of inventing, designing and innovating looms. Having acquired a working knowledge of metallurgical and metal working skill over a number of years facilitated Hattersley's ability were able to develop their all-metal innovative looms into the twentieth century.

7. 9. 2 Economic (E)

Looms made by Hattersley's became very important to the woollen cloth production and economy situated in the Outer Hebrides, Scotland. Harris Tweed or in Gaelic the "*Clo Mhor - the big cloth*" (Harper and McDougall, 2012, p. 78) was a traditional cloth woven by crofter/weavers who were localised in the Outer Hebrides in Scotland. Tweed has been described as "a woven cloth in a twill weave" (Anderson, 2021, p. 7). The weaving of this fabric, used initially for the local domestic market, was a well- established cloth which could be traced as far back as the 1800s (Bremner, 2013, p. 2).

Over the decades, the production of Harris Tweed together with its economy had remained mainly limited or "handwoven by the islanders" located in the Outer Hebrides (HMSO, 1993, p. 7; Hunter, 2001). The weaving of Harris Tweed cloth was dependent on one type of hand loom which was locally-named '*Bearst Bheag'* or small loom much used in the nineteenth century (Ennew, 1980, p. 43). The shuttle (carrying the weft thread) was thrown by hand from one end of the warp threads to the opposite side of the warp threads. By 1900, the Outer Hebrides crofter/weaver had introduced the '*Bearst-Mhòr'* a larger wooden loom which used a fly shuttle mechanism into their domestic industry. Contrary to the technology found on the '*Bearst Bheag'* wooden loom, the '*Bearst-Mhòr'* had a shuttle box situated on the side of the loom (Ennew, 1980,

p. 43). Production of cloth was slow and patchy as it depended on when the crofter could undertake weaving.

Hattersley's can be attributed to spearheading the economy and expanding the work practices found in the Outer Hebrides, Scotland. It was Lord Leverhulme who, on acquiring certain island in the Outer Hebrides, decided to *upgrade* the rudimentary weaving industry which was already established. Lord Leverhulme believed very strongly that a tweed industry had the potential to fit "into the life of the villages scattered throughout Lewis and Harris" (Stornoway Gazette, March, 14th, 1919).

He chose the Hattersley's semi-automatic treadle powered loom as it had the ability to not only weave a selection of weave patterns, but was also speedier than the heavy wooden looms used by the crofters/weavers had been using. Although weaving had traditionally been carried out on wooden hand looms, it was not until the Hattersley's semi-automatic treadle powered loom was introduced in the 1920s when productivity was seen to increase. It had been Lord Leverhulme's ambition to set up weaving sheds on the island and employ the crofter/weavers on a fixed, weekly contract but his plan did not come to fruition. Although the crofter/weavers continued to weave tweed cloth, they preferred to weave it when their crofting work allowed them to do so. Notwithstanding, the popularity, reliability and reputation of the Hattersley's single-width loom continued to be used and promoted in the Outer Hebrides well into the late twentieth century.

7. 9. 3 Social (S)

Bourdieu and Wacquant (1992) proposed that a firm that a firm, based in one locality, provides an ownership of that district's geography as well as portraying a uniqueness of its growth and much later the establishment of a competence skill level. The bringing together of a technically-able workforce ensured that Hattersley's developed a means of producing a channel for any technical information exchange. Bourdieu and Wacquant have noted that it is the:

> "Sum of resources that accrue to a firm by virtue of possessing a durable network of inter-firm relationships" (Bourdieu and Wacquant, 1992, p. 119).

The social contribution of Hattersley's within the network of 'inter-firm relationships' that it had forged in its geo-specific industrial cluster allowed it to create, patent and develop machinery and subsequently present new technical skills and knowledge. This highly-structured model of industrial dynamism allowed new, innovative machinery to diffuse faster into other areas and countries who were receptive to utilising reliability or uniqueness as well as increasing productivity in loom design. Maillat called this feature an "innovative milieu" (Maillat, 1998).

Firms which operate within an industrial district continue to promote the potential to demonstrate an environment for education or learning as well as the development of technical skills. This does not exclude the additional possibilities of promoting or diffusing any technical education and knowledge through individual contacts. Lundvall and Johnson have argued that networks, formed by successful companies, provide an access into relevant knowledge which would be of great benefit to future generations of technologists (Lundvall and Johnson, 1994).

Lundvall also posited that knowledge becomes a crucial component of any economy whilst learning located in an industrial district was an important process for acquiring new knowledge (Lundvall. 1992). Notwithstanding, learning becomes very important to a firm and its workers. Different forms of knowledge ranging from tacit knowledge (gained through experience) to contextual/practical knowledge (information for specific needs) proved to be very useful in the workplace. Mainwaring and Wood have put forward their interpretation of tacit skills as being:

> "The performance of 'routine' tasks involve a process of learning by which skills are acquired through experience… The second dimension of our concern with tacit skills is that there are different degrees of awareness required to perform certain activities… The third dimension of tacit skills relates to the collective nature of the labour process and the necessity for workers to develop co-operative skills. There are many such skills required in the production process, including congeniality, 'mucking in', timekeeping and obedience" (Mainwaring and Wood, 1985, pp. 172-3).

'Industrial districts', according to Marshall, guaranteed the availability of a number of key, supporting factors such as a ready source of hereditary work skills and the knowledge needed to operate new (Marshall, 1898). Furthermore, Marshall has put forward the idea that within an 'industrial district' the workforce continues to produce an endless supply of appropriately skilled operatives and because of this outcome, technical knowledge becomes widely available and easily diffused (Marshall, 1920). The arrangement of such an integrated industry of skills ensures that the commercial market will always attract an able workforce and similarly, industry will always be receptive to an appropriately skilled workforce (Krugman, 1991). In addition, Marshall discussed that within an industrial district, certain firms will also branch out into ancillary firms capable of supplying and refining all manner of equipment for the existing market (Marshall, 1920).

Technological change had become a very important determinant in economic growth. Bartel and Lictenberg (1987) concluded that when technological change takes place, it also has the ability to regulate or control the characteristics of industrial skills found in the workforce. Technical work skills have always been the foundation of manufacturing, technology and industry. Moreover, skills can, and do historically change over a period of time. The more common the skills are the easier they can become debased. Paradoxically, the acquisition of skills can create a division between different groups of workers and the work each group is undertaken. One such group of workers, who were generally employed in unskilled jobs, such as operating the weaving looms were women.

In researches undertaken by Phillips and Taylor, they point out the following observations:

> “Wherever women workers are, whatever jobs they do, they nearly always find themselves occupying the lowest rung on the skill ladder … Skill definitions are saturated with sexual bias. The work of women is often deemed inferior simply because it is women who do it” (Phillips and Taylor, 1980, p. 79).

Busfield (1988) has also confirmed Phillips and Taylor’s view that the status of women in the mills was not a question of women acquiring new knowledge or technical awareness. Rather, it was more likely that women did routine, monotonous jobs which required fewer skills. A male occupation in a mill, on the other hand, was regarded as a traditional skilled job which often required a certain degree of physical strength and technical know-how.

Gospel has articulated the notion that a:

> “trained labour force has a comparative advantage in developing, adopting and implementing new technologies” (Gospel, 1991, p. 2).

The skill factor was always very important to the firm of Hattersley’s over and above manufacturing textile machines. The skills-base of the workforce became the foundation of the company’s success. It was the chairman, Hattersley Smith, who stressed the continual importance of skill. He confirmed that:

> “We have always held that Keighley engineers can do as good a job as anybody” (The Yorkshire Observer, 1945, p. 2).

The Yorkshire Observer (1945, p. 2) went on to comment that Hattersley’s strength lay in the assurance that:

> “Confidence in the skill and workmanship of workers trained on the spot has engendered goodwill. The firm has never needed to import workers from other towns” (The Yorkshire Observer, 1945, p. 2).

Transferable skills developed at Hattersley’s became very important later on in their history. For instance, during the Second World War (1939-1945), they were able to transfer their manufacturing or machining skills to undertake the:

> “making of machine tools, turning out milling machines, drill etc., [and by 1941] aircraft work was fairly extensively undertaken …in addition to the manufacture of eyeleting machines for inter-communication wireless. Steering and balance gear assemblies for the 2-pounder, 6-pounder guns and 5.5-gun howitzer were supplied as well as the Bofors gun and the Bren gun… the manufacturer of the P. I. A. T - *Projector Infantry Anti-Tank* gun” (The Yorkshire Observer, 1945, p. 2).

The versatility of Hattersley's technical output continued adapting itself to the different requirements of the war effort and taking into account the mobilisation of the country's industrial resources. Hattersley's were soon engaged in machining and repairing:

> "damaged guns of this type, of which about 250 are being dealt with every week … parts for tanks, gun mountings, armoured vehicles for the Bailey bridges and gearing for bull-dozers and excavators. At present the firm is engaged in reconditioned shell lathes… mine-sweeping devices are included in the list of products" (The Yorkshire Observer*,* 1945, p. 2).

One major problem confronting Yorkshire machine manufacturers at the time was an unwillingness by mill owners to replace existing textile machines with more up-to date machines which could run at faster speeds. Some of these mill owners had machines which dated from the turn of the century (The Leeds Mercury, 1930, p. 5). The local newspaper also highlighted this reluctance to modernise a year later when they noted:

> "The difficulty experienced by manufacturers of such machinery is that [textile] manufacturers and reluctant to put capital into new equipment and even where refitting is done many use second-hand machinery of which there is a fair quantity available. Some concerns are still using equipment that gives only 70 picks an hour, although modern looms will do 100" (The Leeds Mercury, April, 1931).

Foreign competition, together with up-to-date machinery, proving to be formidable competitors even though Hattersley's were continually innovating and expanding their selection of weaving looms (which were) tailor-made for different fibres.

7.9.4 Technological (T)

Coccia (2005) has surmised that when attempts are made to investigate technical change within an industry, great emphasis is placed on measuring or calculating the pioneering technological developments and advancement. From 1789 to the early 1980s, the firm of Hattersley's was able to demonstrate a planned programme of continual machine development and innovative textile weaving loom designs which secured its primacy in the textile machine manufacturing industry. There were notable key milestones in the firm's history.

In 1834, Hattersley's became the first company to manufacture a power loom. Twenty-four years later, they built the revolving box loom and in 1858 introduced the revolving skip box. Nine years later in 1867, Hattersley's patented their "dobby or heald machine" (The Textile Weekly, 1951, p. 1342). They continued to develop and innovate their looms, introducing many types of loom into the textile market. Table 25. shows that year's output for innovations and inventions together with their various applications. At the beginning of the twentieth century Hattersley's introduced the smallware loom, their unique design of the automatic loom which was a rival to the American

Draper or Northrop loom. The Yorkshire Post mentioned the cachet that Hattersley's had achieved in that:

> "… the bulk of the manufacture of automatic looms is in the hands of two firms - British Northrop Loom Company of Blackburn who employ fewer than 2,000 operatives, and George Hattersley and Sons, of Keighley, who employ 600" (The Yorkshire Post, November, 1947).

By the 1920s, the Hattersley Standard loom was introduced into the textile market. After many improvements the design features and reliability greatly enhanced the company's reputation.

Hattersley looms	Used for weaving	Attachment Fitting(s)
Plain one-shuttle coating loom	Worsteds, blankets	40-shaft positive heald m/c
Circular box loom (6-shuttles)	Checked goods	
Handkerchief loom (6-shuttles)	Checked goods	
Plain loom (1-shuttle)	Light dress, twills etc.,	Heald m/c, non-positive
Revolving box loom (6x6 shuttles)	Dress goods	
Underpick, rising box loom	Heavy or light goods	
Overpick, rising box loom	Tweeds, meltons, etc.,	
Patent loom	Carpets, tweeds, worsteds	
Patent revolving skipping box loom	Gingham, tartans, checks	
Patent heald machine (non-positive)	Dress goods, skirtings	Narrow loom (47 ins width)
Patent automatic border motion		Automatic motion (border)
Patent loom	Lasting, serge de berrie	28-120 ins reed width
Power beaming machine	Wind warp from ball to beam	

Source: (The Century's Progress - Yorkshire 1893)

Table 25. Messrs., George Hattersley & Sons Limited., looms in 1893

Two key outcomes become evident with the patenting and introduction of new machinery. It is important to record that neither all inventions nor innovations are:

> "… selected for development, we cannot assume that the initial choice is a unique and obvious one dictated by the nature of the artefact. Each invention offers a spectrum of opportunities…" (Basalla, 1988, p. 141).

One opportunity revolved around the notion of a worker's skill. As old skills in weaving disappeared, new machine skills were introduced. Braverman (1974), have argued that with the introduction of new inventions, old skills or *deskilling* in workers or working practices takes place. *Deskilling* represents the removal of workers' existing skills, knowledge as well as removing their ability to manufacture an agreed product. Moreover, *deskilling* is often experienced by workers in many different ways. Equally, not all *deskilled* workers are subjected to the same pressures caused by new machinery and the acquisition of new skills. The retention of workplace skills continued to be a problem throughout the history of Hattersley's. In a report by The Yorkshire Observer one member of the staff commented that:

> "Our difficulty is lack of skilled workers" (The Yorkshire Observer, Oct. 1949).

Maillat has described some of the important factors where the fertile, inventive environment ensured that innovations were diffused and the development of technical knowledge and learning was advanced which he termed the *innovative milieu* (Maillat, 1998).

During their long involvement in inventing, innovating and playing a major role in the production of looms, Hattersley's became periodically embroiled in litigation over patent infringements. Weatherall *et al.,* (2007) have examined how patent infringements may affect a firm and have classified their possible outcomes:

1 Potential sales affected by patent infringements because of litigation
2 A disadvantage in competition caused by patent infringements
3 A loss of prestige and reputation caused by imitations or patent infringements
4 Unnecessary expenditure incurred because of patent infringements and litigation

Often, the reasons behind a patent infringement may be two-fold. The infringement of the patent may be due to a deliberate action of the firm without the agreement of the inventor or firm. The second reason is where the technology is developed without prior knowledge of a similar or identical patent (Webster, and Weatherall (2021).

An example of the aforementioned patent infringements was the litigation between Hattersley's and Hodgson's. Hattersley's became locked in litigation regarding improvements to their dobbies with Hodgson's. This patent litigation case was to span [1902-06] during the beginning of the twentieth century. The ruling went against Hattersley's who had "failed to properly describe their machine" (Times and Express, March, 1906). The unexpected ruling prompted them to appeal against the judgement. In the interim period, Hodgson's altered their dobbie and claimed that Hattersley's had infringed the patent on their dobbie. Eventually, after having taken professional and technical advice from independent experts, the Court of Appeal judged in favour of Hattersley's and labelling the Hodgson's dobbie as a "colourable imitation" (Times and Express, 1906).

This lengthy, legal case and its subsequent victory was a costly exercise. Bessen and Meurer have argued that a company in litigation of patent infringements causes indirect costs which were not part of the initial costings of the project. Some of these indirect factors include:

1 A key procedural disruption to the company requiring additional work in legal work, presentation, research and presence in court and then repeating the whole procedure in a higher court
2 Potential lost sales and confusion caused to buyers

3 Possible delay of product by rightful inventor or innovator

4 Additional costs in fighting the patent infringement (Bessen and Meurer, 2008).

7. 9. 5 Geographical (G)

The inclusion and importance of geography as a key factor to the original *PEST* analysis framework cannot be underestimated. Shin has described geography as the:

> "study of the nature that shapes and is shaped by human activities, and of the built environment that results from and circumscribes human intervention in nature" (Shin, 2017, p. 1).

This fact was also highlighted by Bowden and Higgins who recorded that:

> "This pattern of geographic and product specialisation, which existed in Lancashire's cotton industry, was mirrored in the Yorkshire woollen industry…Both industries were also remarkably similar in terms of industrial concentration" (cited in Bowden and Higgins, 2017, p. 94).

Shin went onto to explain that geography possessed the added advantage of covering a number of academic areas which become useful when investigating urban geography. These important subjects which were suitable for an investigation included:

> "distribution of population, resources, and social, political, economic, [and] cultural activities" (cited in Bowden and Higgins, 2017, p. 1).

A development of the study of geography, which is important to the foundation and security of an industry, is 'urban' geography. Pacione describes it as "the study of cities as systems within a system of cities" (Pacione, 2009, p. 18).

Historical development of firms, founded at the onset of the so-called 'Industrial Revolution,' have had to confront and adapt to the many macro challenges during the period when the nation's whole economic and social landscape changed forever (Piore and Sabel, 1984).

The inclusion of the geographical factor in the original *PEST* analysis framework emphasises the importance this determinant has in a clearer understanding of the industrial growth or development of any localised urban, cluster. Pyke, Becattini and Sengenberger have labelled an industrial district as a "geographically defined productive system" (Pyke, Becattini and Sengenberger, 1992, p. 2). Consequently, the connection between clusters and industrial districts reveal a close-business relationship and interaction between the various firms and subsidiary firms (Axelsson and Easton, 1992).

Renner has argued that industries located in a geographical area could be re-classified into four key factors or headings (Renner, 1947). He also made it clear from the onset that industries do not behave in a uniform manner and do vary with their choice of locations. The key factors which he outlined are as follows:

i) Extractive - The movement and removal of natural resources located on the land. To achieve this, a combination of factors would have to be brought to bear such as capital, power, workforce and transport.

ii) Reproductive - Industries such as agriculture, fishing timber management and farming is implied here.

iii) Fabricative - This involves an industry which receives raw materials and then processes it. Industries which fall into this class represent iron and steel-making, engineering, refining of metals and assembly of manufactured components and textile production.

iv) Facilitative - This component involves the provision of accompanying services created to assist in trade, transport of finished goods, the financing of finished goods and trade communication *(*Renner, 1947).

Renner went further and surmised that nascent industries required six crucial determinants. These important determinants which were fundamental in establishing a firm in a particular locality were:

i) Types of raw materials required
ii) The financial business environment
iii) An available pool of skilled or unskilled workers
iv) Different sources of power transmission
v) Sources of funding
vi) Different modes of transportation (Renner, 1947)

Notwithstanding, not all the towns, during and after the so-called ‘Industrial Revolution’, were to undergo geographical and spatial industrial expansion or urbanisation. (Clark, 1995). Some towns remained the same, whereas others were absorbed by other towns or simply ‘disappeared’ from the burgeoning, urban industrial landscape (Clark, 1995, p. 119). It could also be argued that the criteria for the geographical determinant in the *PEST(&G*) analysis framework has altered over the decades and that the factors which are applied today are not the factors which can be applied during and after the so-called ‘Industrial Revolution’. The key determinants examined in this section will only apply to the time period under consideration.

During the eighteenth and early part of the nineteenth century, the location and establishment of many industries became crucially important as a basis for long-term strategic production plans (Enright, 1990). Within these ‘industrial districts’, a multitude of firms would evolve with the sole purpose of processing the same wool staple. Furthermore, these industrial districts also encouraged a network of supporting specialised firms, such as Hattersley’s, able to provide new or up-to-date worsted machinery, reconditioned worsted machinery, spares etc., (Marshall, 1898).

Some commentators have assumed that the location of industrial districts was determined by destiny. St. John and Pouder pointed out that, on the whole, “there is an element of chance [or destiny] in the origin of a particular geographical cluster of firms” (St. John and Pouder, 2006, p. 146). It was Barrett (2005) who declared, that in the past, destiny, which was seen as integral to geographical location, had now been surpassed by the notion that opportunity, and not destiny, was more important to location. Marshall argued that a localised industry was “an industry concentrated in certain localities” (Marshall, 1920, p. 268). Weber, on the other hand, took the view that an industrial location was based on the geography of one venue e.g. one town to another and the prospective costs of transporting finished goods.

The prominence of a geographical location was further highlighted by Marshall who concluded that firms would be found in close proximity to physical resources. Marshall also considered accessibility to natural resources as important. These valuable natural resources could range from mines, quarries, type of weather, land, water to minerals. Certain manufacturing industries grew on the strength of a ready availability of natural resources. Belussi and Caldari (2009) gave examples of districts which based their industries around these raw materials. They cited southern geographical areas in England such as Bedfordshire, Buckinghamshire and Staffordshire renowned for certain products such as ceramics, brickmaking and potteries (Belussi and Caldari, 2009, p. 336). Marshall duly apportioned this relationship or dependence to certain geographical areas labelling it as the ’patronage of a court’ (Marshall, 1920, p. 269).

According to Ellinger, firms which established themselves in particular localities based their decisions on the “least-cost or maximum profit location” (Ellinger, 1977, p. 295). This view has been challenged by a number of researchers. Tiebout, has posited that firms establish their industrial sites on the basis of two key criteria. These were that any sales, purchases or distribution of goods had to conform to the particular social environment they were in and that the firm’s economic behaviour was accepted by the social environment in which they were placed (Tiebout, 1957).

7. 9. 6 Findings of the *PEST(&G)* analysis: a summary

Although the *PEST(&*G) analysis framework continues to be useful to policy makers and management and is easy to use, it does have some limitations. One of the main criticisms of the *PEST(&*G) analysis framework is that the user may look at the data from only one perspective and then generalise a conclusion from the findings. Any assumptions made from one view of the data is likely to produce a distorted view.

For a very effective overview, data needs to be extracted from many perspectives and specialisms and where possible, updated on a regular basis. Careful attention must be taken when gathering appropriate data to avoid the criticism of '*Paralysis by Analysis'*. This phrase is often used to describe a situation where a considerable amount of data is collected but the object of the exercise is forgotten or clarified (Rastogi and Trivedi, 2016).

In the course of researching the impact of the geographical determinant against the background of Hattersley's subsequent economic success/performance., what is incontrovertibly evident from the numerous primary/secondary sources consulted and evaluated is the importance of location in the evolution and development of the textile machine manufacturing industry in Keighley.

The factors which underline this point can be seen to include availability of local natural resources, a good transport and power network, an adaptable workforce, good workplace skills, a body of creative inventors and a neighbouring wool processing industry.

Power transmission was crucial to the development of working textile mills as well as providing a valuable source of power. As the size of mills grew, different configurations of power transmissions were installed to accommodate the increased size of machines that were being used. The height of machines such as dobbies and Jacquard looms required a substantial height for installation compared to the space which could accommodate a normal weaving loom (Mellor, 2005).

West Yorkshire mill owners also invested in locally-made stationary steam engines which were built to last. One typical example of the longevity of such a stationary mill engine's working life was the Myers and Robinson mill engine which ceased its working life as late as 1961. This mill engine, based in Crossflatts, near Bingley, had been providing power to the mill for approximately 50 years (Keighley, 2007, p. 107). Consequently, mill owners seemed somewhat reluctant to replace these engines for more up-to-date improved methods of generating power. Moreover, mill owners did not take in fully the deficiencies of the power transmissions in their sheds. Some of the unexpected effects were dark shadows being cast down from the belting onto the loom and oil stains dripping down from overhead line shafting or bearings which would often soil a piece of cloth being woven. The environmental atmosphere within the weaving mill sheds could also cause belting slippage which would cause the loom to come to an abrupt stop (Fawthrop, 1946). As a consequence of these deficiencies, productivity and time would be lost. According to Keighley:

> "most companies agreed that the electrical method of transmitting power was more efficient than any other method" (Keighley, 2007, p. 106).

Even so, there was a handful of enlightened mill owners, such as Ward and Holroyd, Bankfoot, Bradford, who became the first weaving firm to electrify their looms in 1911. The next firm to electrify their looms was Arthur Robertshaw of Bull Royd, Girlington who applied individual drives with their own motors to their looms (Keighley, 2007, p. 106).

In conclusion, the history of Hattersley's is undoubtedly a story of success for one of the major British textile loom manufacturing companies during the nineteenth and twentieth century as well as securing a prominent role in the forefront of loom innovations and inventions. Mechanised weaving, patents and loom construction had always demonstrated the need to understand and construct looms which could cope with of producing a complexity of woven cloths made from an array of different fibres. Consequently, different machine mechanisms were patented "such as dobbies, Jacquards and multiple shuttle boxes" which were essential for these tasks (Holden, 2014, p. 156).

The economic fortunes of any textile or loom manufacturing firm cannot be underestimated. Parsonage makes the point that having

> "the right machine at the right time make good profits …. a profit in one year is quickly turned into a loss the next and many companies have found themselves in this position in recent years" (Parsonage, 1973, p. 119).

During their long history, Hattersley's encountered many challenges which they had to confront and overcome. In the 1930s, Hattersley's managed to take over two of their main rivals - George Hodgson & Sons and later on David Sowden & Sons of Shipley. David Sowden & Sons was particularly important as they had:

> "built up a large export business before and after the First World War gaining valuable business in India, Egypt and Belgium" (Keighley, 2007, pp. 73-74).

The main challenge, however, continued to be trade. Throughout their existence there was continual uncertainty in global trade, especially from the Far East. This fear was reflected by the

Nottingham Evening Post who recorded the views of a representative from the Leeds Chamber of Commerce. He prophesised that:

> "Japan is making plans for a world-wide attack on the woollen trade. What Lancashire is suffering today, Yorkshire will suffer tomorrow" (Nottingham Evening Post, April, 1937, p. 4).

The loom trade seemed to fluctuate between the local market, European mainland, the Dominions and the Far East. International turmoil, internal events, monetary fluctuations seemed to have little effect (Shipley Times & Express, Jan, 1937). Instead, short-time working became the critical feature which affected the whole of the textile industry (Shipley Times & Express, Jan, 1937).

In spite of all these challenges, in the main, Hattersley's was able to overcome them and continue well into the 1980s. They continued to respond to the ever-changing requirements imposed by a volatile market. Notwithstanding, more sophisticated machinery was developed and placed into the textile market with the intention of competing with Italian, Swiss and German competitors. The declaration of war [1939-1945] put any development on hold as many local loom makers had joined the war effort.

The focus of this chapter was to investigate the *expansion* and *challenges* affecting the loom machinery production of Messrs., George Hattersley and Sons Limited., in the period 1890-1939 and to gain a deeper understanding of how the inter-relationships between the key determinants of the *PEST(&G)* analysis framework impacted on the firm during this period**.**

More importantly, the main objective of this particular subject-area would allow the researcher to evaluate whether the events and outcomes which exercised a significant influence on both the firm of Hattersley's and the textile worsted industry as a whole were determined by a single, dominant variable or a number of key variables.

As the primary purpose of this section was to closely examine the key factors which affected the *expansion* and *challenges* of the firm's loom production, of the five *PEST(&G)* determinants, the economic and the technological variables were critically significant to understanding the firm's managerial decisions and commercial activities during this period.

However, the overriding importance of the 'actions' of the political variable as the key driving force influencing the 'reactions' of the aforementioned determinants is incontestable. This key variable clearly shows how the ever-changing political environment in this 49-year period continued to make a significant impact on the nature and direction of Hattersley' loom production, technological innovations and commercial markets.

Though this period is seemingly a relatively short time span, the clearly defined timeframe of this study (1890-1939) was an intentional choice as it allowed the researcher to mine a rich source of historical information from which to analyse the firm and the textile industry against the five *PEST(&G)* determinants, not least the interaction of politics, economic and technological developments during the turbulent events at the end of the Victorian period, the unsettled periods up to and including the First World War and the difficult inter-war years leading up to the start of the Second World War.

Time and again, the findings gleaned from examining the course of events through the lens of the political determinant highlighted the *supremacy* of politics, not least in how the political events abroad had the *power* to change the dynamics of international trade and influence government policies and decisions on the nature of economic and commercial activities at national, regional and local level. The close interconnectivity of the economic and political variables showed at many different stages in this period how the vicissitudes of one determinant affected the other.

In *all* cases, the volatility in the political climate would necessarily challenge the economic environment which would in turn inevitably compromise the rates of progress in technological developments. Political events beyond the immediate cluster networks of the Yorkshire worsted industry compromised the commercial activities of the entrepreneurial class, the financial stability of the textile industry as a whole and the innovative technological developments of individual firms therein like Hattersley's.

Despite the many challenges in its eventful history, Hattersley's well-established skills and knowledge-base and its flexible approach to embracing change enabled it to adapt, exploit and supply the different needs which would arise in both domestic markets and foreign textile markets. This chapter has demonstrated unequivocally how the synchronicity of the economic and technology variables in the firm's loom development and expansion is directly influenced by and indelibly linked to the overarching events in the political environment. While this fact is undoubtedly true, it would be remiss to understate how, in many ways, Hattersley's own foresight and business acumen in countering change by exploiting all potential commercial possibilities, not least in securing patent copyrights for their innovative machinery and the marketing strategies used to promote their products in the volatile political landscape, account for both the firm's survival and its success.

Chapter 8 Conclusion

8.1 The Legacy of Messrs., Hattersley and Sons Limited., Keighley: A New Appraisal

Many of the conclusions to be drawn from this thesis have already been evidenced throughout the preceding chapters. Consequently, the purpose here is not to offer a comprehensive analysis of the methodology framework and findings which have been extensively covered previously but to reflect on them and how they have been understood and interpreted, and how they may be used in future studies.

The main aim of this thesis was to draw attention to and build on past scholarly studies on the Yorkshire textile industry by such writers as James, Cudworth, Clapham, Heaton, Sigsworth, Jenkins, Ponting, Keighley, Blaszczyk and Hahn in order to extend the research in the understanding of loom innovation, diffusion and technological change which took place in the Yorkshire worsted industry between 1890 and 1939.

The first step in such a research thesis is being able to visualise the inherent complexities in undertaking an historical study and work towards designing the best research paradigm around the key research questions, the constituent tools of which will be then be utilised to analyse and evaluate the key information sought in answer to these questions and attempt to present the findings in a new context, and in doing so, contributes new knowledge to the existing area of research which has previously only had limited coverage.

The original premise of this thesis was, first and foremost, to validate the assertion made by Hattersley and Sons Limited of Keighley as being the 'world's oldest loom makers' by undertaking an in-depth examination of the firm's history in order to examine closely the contributory factors which account for its long existence during which time, it reputedly became one of the leading worsted loom manufacturers in Great Britain and one of the internationally-renowned loom manufacturers in the world.

The overriding objective in all the chapters of this thesis was to better understand how this small, family firm, from very humble beginnings, came to dominate the loom-making market. Bailey commented that:

> "At the beginning of industrialisation, family firms [such as Hattersley's] provided kinship networks and personal connections which offered mutual trust, and helped to offset the uncertainties and risks of their developing markets" (Bailey, 1999, p. 14).

As a starting point, Hattersley's location in Keighley needed to be examined to understand how significant the choice of its original site in the late eighteenth century was as a contributory factor.

Richard Hattersley, the founder of the firm, was mindful of the importance of the geographical location in which to site his enterprise, and the benefits this location would provide for his commercial enterprise, one in which he would be able to supply the local engineering and textiles industries with integral machine components. Typically, in this period, mills were often built near fast-flowing rivers and streams to harness the driving force of flowing water which would in turn, power the machines in the mill. Often, these rivers were key to moving the final products to the market place. These early mills were also situated on or near to waterways as these locations provided a convenient place to discard any waste.

Stubbins Mill in Aireworth, Keighley was located very close to a canal which itself was a tributary of the River Aire. Richard Hattersley's choice was undoubtedly influenced by his own experience of working at his previous employment in Leeds where the machines were also powered by the River Aire.

As well as being conveniently situated near to a river, the choice of site in this small market town offered easy access to raw materials, not least for the iron ore needed for the smelting plants and ironworks.

Another deciding factor in selecting this plot was the close proximity to an existing 'network' of roads and pathways between neighbouring villages and towns, rudimentary to begin with but developed and upgraded over time as the area became more industrialised and a much-improved transportation network could accommodate the gradual increase in the production and distribution of goods.

Hattersley's origins at the beginning of the so-called 'Industrial Revolution' was an unsettling period of transformation in Great Britain, a period of time which led to large-scale socio-economic upheavals, the rapid growth of an industrial-based worsted textile industry, mechanisation to the region's industry and urban change.

As Hattersley's became more successful, the firm realised the emergence of a changing 'geographic footprint' which was gradually becoming an industrial landscape, one in which Hattersley's would be offered new opportunities. Within a short space of time, Hattersley's began to re-focus and diversify his business.

At this time, one of the more prominent industrial towns was the neighbouring town of Bradford which was beginning to transform itself into the worsted textile capital of Great Britain and an international centre for worsted wool processing. This dramatic change very soon attracted the interest, as well as the migration, of many individuals and firms into the area.

Industrialisation is recognised as a period of significant socio-economic change which transforms an agrarian society into an industrial society. This transformative process typically involves the radical re-organisation towards a manufacturing economy in which mass production and assembly lines replace manual and specialised labourers (UNIDO, 2020).

Economic growth created by this process has historically led to urbanisation. The siting of a factory or multiple factories in a geographical region creates job opportunities which draw people to these urban centres as well as other subsidiary businesses, to meet the product demands of the factories and the living needs of the workers and increasing populations in those areas (Koditschek, 2009).

During the period of rapid industrialisation and urbanisation in the nineteenth century, the rate of demographic expansion in Bradford was unprecedented. The township become a beacon for migrant workers from many towns and rural communities far and wide. In the first fifty years since the first census taken in 1801, the total population of Bradford increased almost tenfold to a population high of 103,778 (Richardson, 1976).

While the main focus of this study was the period 1890-1939, the dissertation set out, in the first instance, to contextualise the area of study by examining briefly some of the landmark textile developments in the late eighteenth and early nineteenth centuries. This was achieved by carefully reviewing some of the key academic literature related to this earlier period.

In the preliminary chapters of this thesis, it was necessary to briefly explore the phenomenon of migrant workers relocating to this region from other areas of the country. One particularly interesting study in this field, which merits a special mention as it explores the rural-to-urban migration caused by the 'de-industrialisation' of an *established worsted centre* by an emergent industrial, worsted '*loci*', is 'Clapham revisited: the decline of the Norwich worsted industry (c.1700–1820)', (Sugden, 2018).

In this study, Sugden examines the claim made in 1919 by the economic historian Sir John Clapham (1873-1946) that the transference of the worsted industry from Norfolk to the West Riding did not see a significant decline in the Norwich industry until after 1818. Sugden's review of a number of studies written by other historians on the de-industrialisation of worsted manufacturing in this area of southern England highlighted the fact that there was little general consensus on an agreed date for such an exodus. In view of the fact that the historiography of the transfer to the West Riding was complex and variable, Sugden researched this phenomenon utilising several sources of data of male occupations abstracted from wills, freemen lists, poll books, quarter sessions records, 1813–1820 baptism registers, and the 1851 census and able to track the decline of the industry between c1700 and 1820.

He shows that from being the main centre of the English worsted manufacture in 1700, over the course of a century or so, the Norwich industry collapsed and that in the West Riding rose to prominence, not least in the parishes of Halifax and Bradford. In his meticulously researched study, Sugden (2018) suggests that the decline of Norwich in both absolute and relative terms was becoming evident in around 1760, at least several decades before spinning and weaving were mechanised in the West Riding. This study provides a useful reference point in a better understanding of the transference of skills needed in a nascent industry; the details of the demographic changes in the early years of the nineteenth century support the findings of this thesis. Sugden (2018, p. 215) notes:

> "Norwich weaving was in significant decline, in both absolute and relative terms, after 1761–1780. By as early as 1813, there were tenfold as many adult male weavers in Halifax, Bradford, and Manchester as there were in Norwich. By this time, the bulk of the textile manufacture of England and Wales was located on or near a coal field in the north and the Norwich industry was of little national significance."

As was mentioned earlier, this population displacement is a direct consequence of de-industrialisation, the success of one economic development superseding another. The increased rates of productivity in manufacturing and patterns of trade specialisation were concomitant with both *positive* and *negative externalities*, a phenomenon investigated in the work by Dahmén (1991) on 'industrial clusters' in which he demonstrated the dynamism between these 'positive' and 'negative' transformations in an industry.

Interestingly, one of the negative externalities of the collapse of the Norwich industry was attributed to impact of the availability of relatively cheap coal found in the West Riding area, and as Sugden's research shows, this occurred well before steam power became important in spinning and weaving in this industrial economy.

Technology is perhaps one of the most prominent examples of a positive externality, though it is not the only one. The Research and Development (R&D) conducted by a company can be classed as a positive externality. R&D increases the private profits of a company but also has the added benefit of increasing the general level of knowledge within a society.

As this thesis attempted to show, the *benefits* or profits that Hattersley's received from the investments it made in the new technology are only a small portion of the overall benefits at a wider level. For example, the *social benefits* of the research and development in loom design and innovation conducted by the teams of inventors at Hattersley's also take into account the value of *all* the positive externalities of these new idea or products which benefit other companies within the cluster group as well as society as a whole.

Conversely, while these new methods and machinery simplified work and increased output, industrialisation also introduced unforeseen problems. The negative externalities brought about by environmental pollution in the air, water and soil also led to a significant deterioration in both the quality of life and life expectancy in these urban centres.

As this thesis showed with particular reference to Marx's pronouncements, industrialisation and technological change also heightened the division of labour and capital, the result of which led to a wider income inequality between the workers and those who owned the means of production.

As both Sugden's (2018) paper and this thesis demonstrate, the negative externalities of industrialisation impacted society in other ways. The migrants who once worked in the Norwich worsted industry were forced leave their families and migrate to urban areas in search of new jobs where they laboured long hours, and lived in overcrowded, insalubrious conditions which impacted on their health and well-being. Moreover, the machine operatives were obliged to perform repetitive tasks and under constant pressure to keep up production.

Unlike their previous work as craftsmen in rural towns which allowed for the possibility of moving around freely in their course of their daily work, as machine operatives in textile mills, the intense rate of machine production precluded these liberties.

In Hahn's (2020) book - *Technology in the Industrial Revolution* - she offers a new perspective on technology during this period. She examines closely the key historiographical narratives of the rise of the British textile industry in the period between the 1760s and the 1840s, and challenges the many established ideas and beliefs that have gained common currency over time.

The central premise of her study is that machines do not in themselves engender change – rather, their function is determined by the establishment of both the appropriate institutions and the markets in which they are set up to operate productively. Hahn rejects the traditional structure of a linear process proposed by scholars as a way of explaining the progression and impact of industrial development. Her study of a number of specific mills in Yorkshire and Lancashire, allows her to not only highlight the randomness and complex dynamics which underpin industrialisation, one in which new technologies do not necessarily supersede old, established work practices and forms of production but at the same time as being able to show how each mill was subject to local and overseas influences.

To illustrate this dynamic co-existence of the two systems, Hahn undertakes a brief study of the entrepreneurial accomplishments of Samuel Oldknow (1756-1828) the chief architect and driving force in the development and industrialisation of cotton manufacturing in and around the area of

Marple and Mellor in Lancashire. She shows how gradual the change was from the domestic system to the factory system, and how during the period of industrialisation, the knowledge and skills needed to operate the new machines were heavily reliant on the knowledge and skills of traditional, established practices.

Though the time period (1760s-1840s) which forms the basis of Hahn's study precedes the timeframe of this thesis (1890-1939) by over a century, there is nevertheless much to praise in the content she examines which supports the material explored briefly in the introductory chapters of this thesis. For example, she reviews John Kay's flying shuttle and its so-called spinning revolution, explores Richard Arkwright (1731-92) and his 'creation' of the technological system now called a 'factory' and evaluates Samuel Crompton (1753-1827) and his 'spinning mule.' Hahn's work covers a broader scope of early, key developments in the cotton and wool industries across both Yorkshire and Lancashire. The original, revisionist approach she has adopted in challenging established views, not least in the linear model of technological progression in this period of industrial evolution is an interesting development which is still being assessed and will continue to stimulate further academic discussions.

Where this thesis differs from Hahn's investigation is that it is specifically focused on loom innovation, diffusion and technological change in the Yorkshire worsted industry during a shorter time span (1890 -1939). Hahn's 'revisionist' approach posits how the coexistence of the domestic and factory system over a period of time supported the introduction and use of new machinery in the cotton and wool industry during the Industrial revolution rather than a technological change brought about by 'genius inventors.'

While this may be true of the emerging textile industry during this earlier period covered by Hahn, the focus of this thesis was to understand how technical innovations in weaving influenced the development of the Yorkshire loom manufacturing industry. In this respect, this study counters Hahn's assertion as it clearly identifies the ingenious approaches undertaken by individual inventors to improve different mechanisms on the loom.

While the thesis acknowledges many of the points raised in Hahn's discourse, the assertion that Hahn's makes on the misconception of the role of 'genius', skilled inventors in bringing about technological change is too broad a statement and does not sufficiently recognise how different the opportunities were for the forefathers of the inventors in late eighteenth century England, nor those of the inventors in the nineteenth and twentieth centuries.

As a point of interest, in *'The Hand Loom Weaver and the Power Loom: A Schumpeterian Perspective',* Allen (2018) researches the same period explored in Hahn's book but takes a different viewpoint to Hahn's pronouncement by claiming that as power looms expanded after

1780, the cottage approach to producing cloth was effectively replaced by an increased demand for sector-specific skills.

In his paper, Allen (2018) argues is that the fragmentation of the traditional manual weaving tasks provided the incentive for inventors to develop a power technology to replace it. The positive externalities brought about by advances in power loom technology were counterbalanced by the negative externalities brought about by a devaluation of old skills, or, in Allen's estimation, "poverty accompanied progress." (2018, p. i)

Allen (2018) also puts forward the idea that the fundamental character of eighteenth-century invention was not primarily about novel ideas; instead, it consisted of the practical engineering that converted often banal ideas into reliable machines that were cost effective in production.

Bradford and Keighley's rapid technological advances in worsted machinery, built on the strength of early mechanical engineering was spearheaded by a group of pioneering, textile entrepreneurs and inventors who were instrumental in ushering in improvements and designing new types of worsted textile machinery. The thesis presented some of the noteworthy inventors who were instrumental in the continual success of Hattersley's, their involvement in the development of looms, dobbies and loom mechanisms and the important role they played in the British and foreign machine manufacturing industry.

While it could be argued that the rise and decline of the veneration of British inventors coincided with the rise and decline of British competitiveness in technological innovations, what remains incontestable is the prominence of patents registered by these inventors as an indication of their enhanced status during this time. Allen's study (2018) again reinforces this point as the Schumpeterian perspective used in his research emphasises how the evolution of markets created the incentives that inventors faced and can explain the timing of their efforts more precisely than other approaches.

Hattersley's, along with other local firms, recognised that trading with Bradford would offer profitable business advantages and seized the opportunity to participate in this emerging 'industrial cluster'. Quite soon, other firms began to integrate themselves in this new 'industrial cluster' which Defoe had referred to as "a noble scene of industry" (Defoe, 1971, p. 500)

At this time, Hattersley's engineering reputation had also been steadily growing and quite soon the firm began to diversify further still in the production of textile looms.

As more firms were drawn to this industrial area, Hattersley's became the largest employer or 'dominator' in Keighley, a towering influence in this new, 'industrial cluster'. These clusters generated an 'entrepreneurial dynamism' which supported the developmental needs of the cluster and promoted the production of innovative designs. The formation of subsidiary firms within the cluster which could supply Hattersley's with the necessary implements and materials and the transference of skills allowed this firm to develop a highly-skilled workforce able to manufacture cutting-edge weaving looms.

Having acquired a working knowledge of metallurgical and engineering skills ensured that Hattersley's were able to continue to develop their all-metal, innovative looms into the twentieth century. The introduction of any new technology will inevitably bring about incremental transformations in how work is organised and controlled. Innovative technological machines change the way in which various work processes are carried out and transforms both the organisation and the practical labour aspects on which it impacts.

The appearance of these looms became more advanced in their mechanisms as well as in their production and these looms became almost independent thereby reducing constant human activity Hattersley were at the forefront in recognising the potential in developing its technological presence with these all-metal framed looms. In a competitive economic market, a failure to harness the potential would be detrimental to the firm's development.

The introduction of this new technology redefined the relationship between the weaver and the loom. One noticeable difference was that the old-fashioned method of weaving using a heavy box loom was now replaced by a faster, more complicated and efficient loom which could only be operated by a highly-skilled weaver. Habakkuk commented that the aim of 'new' technology, when it was being introduced, was to:

> "… substitute correct and effective operations of machinery for the skill of the artist which is acquired only by long practice and experience; a species of skill which is not possessed…[in] any considerable extent." (Habakkuk, 1962, p. 22)

As mentioned previously, as Hattersley's began to introduce their innovative looms and the factory system became better, larger and more established, weavers found that their weaving tasks became more specialised and the skills which they may have had as artisan weavers were obsolete in the main, and no longer needed.

It was Nelson who commented that:

> " . . . specific designs and practices" and as "generic knowledge ... that provides understanding of how [and why] things work … and what are the most promising approaches to further advances including . . . the nature of currently binding constraints." (Nelson, 1992, p. 350)

The new, improved looms, which were purchased and installed into weaving mills required additional or upgraded weaving skills. Hattersley's innovative looms demonstrated a continuous stream of inventiveness and originality which required the weavers to increase and improve both their weaving skills and knowledge. One alternative point of view comes from Polanyi (1958) who insisted that the terminology of *knowledge* should be replaced with the word *knowing,* which he considered to be the correct definition, as it clearly described a self-motivated action, personal to the worker who was undertaking the activity (Molander, 1996, p. 35).

One key factor which assisted the introduction of Hattersley's looms in mills was the addition of motive power, and much later electrification, which secured greater productivity (Atack *et al.,* 2008). These levels of higher productivity provided by new innovative Hattersley's looms also offered extended trading opportunities beyond local markets into international markets.

The importance of training new skills to the workforce was a high priority for Hattersley's. The firm's economic growth and expansion in this industrial landscape was dependent on a ready supply of appropriately skilled workers. A transition from old- fashioned practices and attitudes into the adoption of new methods and procedures.

Paradoxically, over time, the advances in the firm's loom technology led to a de-skilling in the workforce. There is a duality in this process - on the one hand, technology reduces the competencies and labour needed, on the other, humans have the capacity to enhance their knowledge and skills to exploit technology.

Brugger and Gehrke's (2018) comprehensive rreview of the literature on skilling and de-skilling brings together two literatures: the classical political economists' views on the skilling or de-skilling nature of technological change in England, during the eighteenth and nineteenth centuries and the empirical evidence about the skill effects of technological change that emerges from studies of economic historians. In the review of these materials, their findings uncover a number of interesting interpretations of these concepts. In the eighteenth century, economist and philosopher, Adam Smith (1723-1790) considered de-skilling to be the *unintended* corollary of technological change whereas a century or so later, Marx argued that under certain circumstances de-skilling was the *intended* goal of entrepreneurs to search for innovations with a de-skilling bias, as a means of breaking the bargaining power of skilled workers.

The mathematician, philosopher, inventor and mechanical engineer, Charles Babbage (1791-1871) argued that labelling the technological changes in the nineteenth-century as just 'de-skilling' as an oversimplification, the demise of some traditional skills but also recognising the emergence of newly-needed skills.

In The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle, Schumpeter (1934) proclaims that capitalist economics is a natural, self-regulating system in which a *circular flow* of the supply and demand between producer and consumer in these economic markets creates a general equilibrium or steady state flow. He further suggests that where entrepreneurs see the possibility of increasing their financial returns on new products, such as technology, these 'disruptive' innovations destabilise these market forces. He argues that this entrepreneurial profit is crucial in a developing economy where an innovation prompts a new business to replace the old, claiming that this phenomenon, which he called 'creative destruction' is unavoidable and cannot be removed or amended without jeopardising the mechanism of creating new wealth through innovation.

Schumpeter's 'disruptive' entrepreneurship should not be regarded uniquely as a negative externality in which industries decline and are replaced with new ones but as a positive externality bringing change and new opportunities to the market.

The findings of Brugger and Gehrke's (2018) research generally supports Babbage's view. In their conclusions, the authors point out that having analysed all the relevant literature on skilling and de-skilling from the two camps, with regards to the nineteenth century, there was:

> "no evidence that technical change was on average predominantly deskilling in this period… In fact, nineteenth-century technical change came with an extensive transformation of demanded skills and a change in the skew of the skill distribution, rather than with a deskilling bias alone." (Brugger and Gehrke, 2018, p. 686)

The continual introduction of innovations and the diffusion of relevant technical information was a cornerstone of Hattersley's early success in the industry.

Throughout their long history, Hattersley's was always receptive to the unpredictability of market forces, and ready to act on and respond to outside influences in order to improve their products and satisfy the needs of their customers. The technical skills-base at the heart of Hattersley's operation was staffed with an experienced, well-qualified team who actively sought, by modern standards, 'feedback' on the firm's products, seeking suggestions from manufacturers and overlookers on the improvements needed to further improve the efficiency of the machine.

The technical 'tacit knowledge' and personal experience in the Hattersley's workforce proved to be invaluable when working on the next generations of looms. Polanyi (1958) noted that this type of 'tacit' knowledge is not knowledge that can be written down or passed on. Instead, the only way to share it is through personal interaction and experience. This point is further developed by Shapin (1994) who argues that:

> "it does not stand outside of practical activity: it is made and sustained through, situated practical activity" (Shapin, 1994, p. xix).

The experiences and expectations of the client-base would be channelled back to the firm's design workshop allowing the skilled technicians to make into making the necessary adjustments and improvements to the loom or textile machines. This ability to make these continual improvements assisted not only in the promotion, manufacture and effectiveness of the textile machine, but also being able to provide the workforce at Hattersley's with a programme of continual development of their knowledge base and manufacturing skills.

Hattersley's was always adept at responding to unexpected changes as well as ensuring that any response to these changes was advantageous for the future of the firm's overall business strategy. The firm was also well aware how important invention and innovation were as a means of not only engendering technological change but also as the key drivers of the firm's economic growth.

At the heart of Hattersley's operation was a team of very talented, professional inventors whose innovative designs continued to maintaining a competitive edge over their competitors. Keighley (2010) recognised the emergence of this new *cadre*, describing the nineteenth century as a period where a considerable amount of professionalism could be located in the society at large.

The firm was very versatile, able to react to ever-changing market forces by innovating developing and expanding as major overseas exporters of looms, warping and ancillary machines for many different fibres such as cotton, wool, alpaca, silk, mohair and cashmere and much later man-made fibres (artificial silk/rayon).

Over the course of three historical time spans; the Victorian [1837-1901], Edwardian [1901-1914] and the Georgian period [1910-1936], textile mills in Yorkshire and elsewhere were expanding and becoming more specialised. They required particular weaving looms to process only one particular type of fibre. The success of Hattersley's as a leading, industrial powerhouse stems from the fact that they were one of only a handful of successful Yorkshire machine makers who were able to adapt and supply the different needs and develop both the domestic market of Bradford as well as the foreign textile markets with their innovative machinery. Unlike certain loom makers such as William Fairbairn and Sons of Manchester and Millwall, (London) who seemed to manufacture looms for the silk trade as a 'sideline,' Hattersley's guiding principles was to maintain a steadfast dedication to its client-base and a flexible approach to providing it with different looms for a multitude of processes.

Hattersley's was sometimes faced with an unexpected outcome. One such issue was that whenever Yorkshire textile manufacturers were confronted with a problem, such as in the area of loom production, distribution or pricing arrangements, overseas competitors would often capitalise on this opportune moment to intervene and resolve the issues at the expense of Yorkshire firms. Furthermore, Hattersley's had the added problem that competitors in some European countries were also copying their looms, which posed a problem of patent infringement. Patent infringements and successive legal actions also affected the development and publicity of Hattersley's looms, the consequences of which compromised future foreign exports, resulted in a loss of revenue and undermined the status of the firm.

Hattersley's was successful, in the main, in producing and promoting their looms to many buyers in Great Britain and overseas. It is unfortunate that, on occasions, Hattersley's business plans faltered. One market in which their efforts failed to secure a commercially-successful contract was in India. Although this 'technology risk' proved to be a setback, Hattersley's simply re-focused their production and commercial trading to the domestic markets and treated this experience as a missed or lost opportunity. Hattersley's had a long, entrepreneurial tradition of being able to re-focus and re-configure their commercial venture if such business sales did not yield a favourable outcome for the firm.

During the 1890s, Hattersley's was confronted with problems with their work-based skills. The many technical skills which had been honed at Hattersley's were displaced because a proportion of their skilled workforce were migrating to the worsted textile American town of Lawrence often labelled as the "Bradford of America" (Jowitt, 1991, p. 3). Hattersley's were fortunate that they were able to retain the remaining skilled workforce which allowed them to progress with the production of their innovative looms. In a rapidly changing technologically-driven economy. the longstanding workforce became an issue as Hattersley's found it difficult to recruit new members of staff to replace the aged workforce.

One approach taken to retain a skills-base was instigated by the B. D. A. [Bradford Dyers Group] in 1898. They took a holistic approach of establishing a combine [an amalgamation of over 20 Bradford firms who had a sizeable monopoly of the piece dyeing trade] which in turn would enable the:

> "Various firms unitedly to meet the more severe trading conditions which were appearing, by effecting economies and improvements in production through the pooling of technical skill and the experience and the centralisation of administration, purchasing, distribution and accountancy" (Jenkins and Ponting, 1982, p. 180).

Hattersley's also had to confront the socio-economic problems caused by the outbreak of the First World War [1914-1918] which had far-reaching consequences on the British textile market. Foreign markets were compromised and there was a drain of skills and labour in numerous mills as the male workforce was conscripted for military service. Furthermore, the fixed assets, such as mill machinery and plant, began to depreciate in net value.

Following the end of hostilities in 1918, many mill processors, not least Hattersley's loom production, were challenged by the changing styles in fashion style. Women's fashion, both in Europe and the United States of America, began to be heavily influenced by post-war Paris fashion. The French-inspired cut of fabric now gave American and European women the opportunity of purchasing, what Vogue (1917, p. 25) referred to at the time, as a "barrel-shaped figure [or a] pre-pubescent girl or the adolescent boy physique" (Johnson, 2018, p. 7). This new and influential Parisian trend in fashion required less woven cloth to make the garments which caused a reduction in mill spinning and mill weaving (Jenkins and Ponting, 1982). In the immediate post-war period, fashion seemed to have moved away from the more stylish trends to a more functional usage which encouraged the use of new or replacement fabrics such as rayon [a cheaper alternative to silk]. This encouraged loom manufacturers, such as Hattersley's, to bring out and market their up-to-date looms which could weave the new type of fabrics promoted in womens' fashion magazines.

Blaszczyk's (2017) book - *Fashionability: Abraham Moon and the creation of British cloth for the global market* - has made a major contribution to the field of textile studies in recent years, and has provided an interesting context for considering the relationship between British manufacture, empire and trade. In the book, Blaszczyk undertakes a thorough examination of the history of a textile mill in Yorkshire and their clients over the course of nearly two centuries.

In terms of the overall motivation for writing this book, Blaszczyk's well-researched study has many points of similarity and parallels to the overarching aims and objectives of this thesis and in this respect, merits a more comprehensive, comparative evaluation.

In the early chapters of the book, Blaszczyk argues that one of the limitations of traditional approaches to British textile industrial histories is a tendency for these studies to focus almost exclusively on major mills, management-labour conflicts and the subsequent industrial decline in these areas and suggests that very little historical research on the textile industries on the nineteenth and twentieth century has examined a particular area of interest - the multi-faceted processes of design, production and distribution combined with the history of retailing, fashion and consumer culture.

Blaszczyk makes the point that the "few histories of design and fashion consider the relationship among trade policies, technology and product innovation" (2017, p. 277). This book is the first study to connect Yorkshire to the fashion system and arguably, to address the under-representation of fashion in mainstream academic study. The same sentiment is true with regards to an under-representation in the academic textile histories on the impact *technology* made on the Yorkshire textile industry by similar small, family firms, such as Hattersley's. In this respect, Blaszczyk's study is very similar to the motivation to undertake this investigation which was to redress the under-representation of Hattersley as a subject of academic scholarship, not least in the pivotal role the firm played in the innovation, diffusion and technological changes in loom manufacturing in the Yorkshire worsted industry between 1890-1939.

In much the same way as this thesis, Blaszczyk's book traces the history of a single family-owned mill in Yorkshire. This textile firm, founded in 1837 by two clothiers, Abraham Moon and his brother in Guiseley (Leeds), is still in operation today. The impressive longevity of this firm offers Blaszczyk the opportunity to undertake a longitudinal in-depth study of an inter-generational family firm in which Blaszczyk is able to frame the mill's activities against the backdrop of external factors influencing design and innovation in the British woollen industry from the 1830s to the era of fashion globalisation in more recent times.

There are many similarities in the entrepreneurial skills and business acumen of both Abraham Moon and George Hattersley, and in the trajectories of their fortunes and challenges over the course of their long existence. The comparable levels of success of both these industrial leaders can, in many ways, be credited to their resilience and fierce competitiveness, both skilled in exploiting all opportunities of self-promotion in their marketing strategies and never losing sight of the need to secure the copyright of their innovative products.

The aim of this thesis from the outset was to highlight how significant the 'geographical' advantages of the Yorkshire region were to the development of the textile industry as a whole, not least in terms of the availability of raw materials, navigable waterways and rudimentary road networks connecting local villages and townships. These factors persuaded Hattersley to site his mill in Keighley, from which he was able to use coal and water to power the machinery and establish profitable economic trading routes along water and road networks.

Fifty years later, Abraham Moon began weaving shawls in a cottage in Guiseley. In 1845, he decided to join twenty clothiers at Springhead mill, a 'public' or 'company' mill, sited on the town springs which were replenished by a tributary of the River Aire. In much the same way as Hattersley, Abraham Moon recognised the importance of this source of fresh water needed for the various industrial processes in the mill.

In 1868, the foundation stone was laid down for the new three-storey building, Netherfield Mill, also in Guiseley. The siting of the 'vertical' mill, in this particular locality, will undoubtedly have been influenced by the knowledge he had of the waterways nearby, and in particular the underground water in close proximity to the mill which would provide an abundant source of 'soft' water ideal for scouring and dyeing the wool. Moreover, the new railway line connecting Leeds to Ilkley, which had recently been built very near to the mill, would not have gone unnoticed by Abraham Moon who would have been keen to capitalise on the economic advantages that this link would bring.

There is a close congruity with the monograph studies of both these firms, not least in their respective beginnings – Hattersley was founded in 1789; Abraham Moon was founded in 1837. Both firms were located in the Aire valley and situated approximately10 miles apart from one another. Each operated in an inter-connected network of businesses within the same industrial cluster and yet Blaszczyk makes no reference to Hattersley's or how they were instrumental in providing Abraham Moon with looms needed for their operations at this time.

One of the aims of this thesis was to show how the success of Hattersley's was to a large extent due to the technical knowledge and expertise of the inventors and design team at the firm who were pro-active in seeking feedback from customers in order to effect the necessary changes required by their customer base. As Blaszczyk is very much interested in exploring all the constituent elements to understanding the history of Abraham Moon's, Blaszczyk's unintended omission is probably as a result of a dearth of relevant materials in the company archives. Blaszczyk clarifies this point and explains some of difficulties encountered in acquiring the relevant primary sources. Even though Blaszczyk had access to a large collection of design sample books, in the preparatory stages of the study, Blaszczyk's research was hindered by the lack of business records preceding the 1920s which will undoubtedly have recorded these inter-firm commercial transactions. The genesis of this thesis was not without its own, similar challenges brought about by the absence of minute books which would have made it easier to understand the managerial direction and subsequent decisions taken by Hattersley's.

Another point of similarity with the approach taken in this thesis and the work of Blaszczyk is the value given to the power of storytelling as a means of organising the narrative history of a firm. Blaszczyk is enthusiastic in praising the validity of adopting this narrative approach when highlighting the fact that, at heart, the stories in the book are about "*a mill, a town, a region, an industry"* (2017, p. 6)

Blaszczyk is very keen to explore what is referred to as a "web of connections that linked the British woollen industry to the fashion system and the wider world" (2017, p. 7) with a particular focus on understanding how these 'connections' impacted on the firm of Abraham Moon over time. In this respect this research approach mirrors the methodology adopted in this thesis. Blaszczyk also advocates the single case study methodology. As Blaszczyk explains:

> “The beauty of a case study is that it allows the author to explore the many cultural, social and economic interactions within the fashion-industrial complex” (Blaszczyk, 2017, p. 8).

The significance of this research thesis is that it is among one of the first to consider using the case study format as the chosen methodology in seeking to understand how *one* loom manufacturer at the heart of the Yorkshire worsted industry played a leading role in the innovative design and manufacture of successive looms. Though Hattersley’s did not succeed in surviving in the textile trade as long as Abraham Moon, the findings of this thesis clearly show that their assertion in being the oldest loom manufacturers in the world holds true.

The single case study methodology investigates a real-life phenomenon through a detailed contextual analysis, a format ideally suited to examining a small geographical area or a very limited number of individuals as the subjects of study. As well as focusing attention to context, this longitudinal perspective provides a systematic way of observing the events, identify trends or patterns and develop hypotheses that can be further explored. The depth of analysis drawn from this rich, qualitative information and the impact of external factors at different points in its history provide an holistic understanding of a firm or a nascent industry.

Unlike Blaszczyk, who undertakes an all-embracing study of Abraham Moon’s over an extended period of almost 200 years to show how the firm’s activities were inexorably linked to the international political economy and interdependent, global fashion networks, this comprehensive thesis concentrates on Hattersley’s ever-changing challenges within a shorter temporal framework (1890-1939).

As both studies focus on the achievements of inter-generational family firms in the textile industry, this thesis endorses fully the approach adopted by Blaszczyk in which recognition is made to the importance of narrative history and champions the value of the case study format.

Coincidently, Hancock *et al.,* (2021), the authors of the recently-published manual for researchers and academics subscribe unreservedly to Hahn’s endorsement of the inherent merits of the case study format and are unequivocal in their support for adopting this qualitative approach where a deeper knowledge and understanding of the subject-area is sought:

> “Case study research is richly descriptive because it is grounded in deep and varied sources of information. It employs quotes from key participants, anecdotes, narratives composed from original interviews, and other literary techniques to create mental images that bring to life the complexity of the many variables inherent in the phenomenon being studied.” (Hancock *et al.,* 2021, p. 16)

With regards to the relatively short timeframe of this study, it was imperative to support the single-case study methodology with a rigorous and robust analytical framework which would allow the researcher to examine closely the key determining variables influencing the firm's commercial activities and secure a better understanding of the industry overall.

The *PEST* analysis framework offered an ideal solution to securing the best approach needed to ensure a comprehensive, in-depth study of the firm's activities during this period. This thesis is the *first* to use a *modified* version of the well-established diagnostic tool in conjunction with the single case study format in order to explore systematically and with attention to detail all the factors impacting on the firm over the course of their commercial history.

This approach has been utilised extensively as the focus of the key chapters in this thesis and in the summative conclusions – it is worth highlighting the fact that that this *PEST* analysis tool is very rarely used to evaluate events from long ago within a particular historical context; it is generally a diagnostic tool used in *real-time* (but with reference to recent events) to help businesses strategise, evaluate and deal with a whole host of issues in their day-to-day operations. The *PEST framework analysis* helps the company collect and collate all the necessary information to understand the needs of their consumers and enable them to make informed decisions on how to remain competitive in the economic markets.

The classic *PEST* framework analysis offers a clarity of purpose and direction in enabling researchers to navigate their way through the myriad of contextual factors impacting on their subject area. A comparison with Blaszczyk's most recent study on the textile industry, the focus of which is similar to this thesis, clearly shows how the constituent elements of the *PEST* framework feature in her research approach, but that these factors are not addressed as explicitly or reflected on with the same detailed analysis as the approach used here.

In a well-documented paper on the future of academic libraries, Cox *et al.,* use this methodology, which they claim has "not featured strongly in previous library literature" (2021, p. 1), to undertake a close analysis of the *previous twenty years* in order to better understand the "political, economic, social and technological factors influencing higher education and their implications for libraries" (2021, p. 9). Their findings clearly highlight how "trends across each of these four dimensions have wrought major changes in higher education" (2021, p. 9) and the paper goes on to outline the future trends that are likely to impact on academic libraries includes, most notably the changing higher education climate. In the final analysis, the authors recommend that the closely monitoring the higher education environment will remain vital for libraries, and impress the need for these institutions to remain vigilant in, "understanding the political, economic, social and technological factors shaping their immediate operations and future strategies". (2021, p. 10)

The flexibility that the classic *PEST* diagnostic tool offers the researcher, as Cox's paper, and this thesis have endeavoured to show, a versatile, well-structured, methodical approach when utilising this framework in their own investigations.

The first step in such a research thesis is being able to visualise the inherent complexities in undertaking an historical study and work towards designing the best research paradigm around the key research questions, the constituent tools of which will be then be utilised to analyse and evaluate the key information sought in answer to these questions and attempt to present the findings in a new context, and in doing so, make important contributions in an area which has previously only had limited coverage.

This newly-combined investigative approach incorporating a modified *PEST* (*&G*) and the single-case study format in this thesis allowed the researcher to gain a much clearer understanding as to the reasons why the worsted industry chose to locate itself in Yorkshire, how this choice of locality led to the establishment of 'industrial clusters', and how the industry reacted to the dynamic interplay of the many external influences and transformative events which took place in this region from 1890 to 1939.

Bradford and its immediate area, including Keighley from which Hattersley operated his loom manufacturing enterprise is now a classic 'post-industrial' city, once seen as an epitome of the textile industry, now known for continuing legacy of industrial decline.

In the post-war period, the area exhibited many of the signs of the effects of de-industrialisation, with high levels of urban deprivation, unemployment, and poor scores on the 'Index of Multiple Deprivation. In '*Indices of Deprivation 2019'* published by Understanding Bradford District, Bradford was ranked the 13th most deprived local authority in England, its position having worsened by six places since the 2015 report. Bradford was reported as having the 5th most income deprived and 6th most employment-deprived local authority in England (the same as in 2015 and 2010).

The socio-political upheavals in post-war Britain have stimulated much interest in the concept of de-industrialisation and the impact this has had on urban centres. In reference to the increased importance of this interdisciplinary, transnational field of research, as a means of substantiating the methodology and the approach used in historical research of this thesis, there is much scope to undertake a close examination of the current interest in the concept of de-industrialisation by using the single case-study format in conjunction with the modified *PEST* (*&G*) diagnostic tool to better understand how the negative externalities brought about by increasingly fierce global competition advances in new technologies ultimately led to the decline of the Yorkshire textile industry in the period after 1939.

In his study, Tomlinson (2019), draws on the literature of de-industrialisation and suggests that it is not a negative phenomenon but a natural consequence of further growth in advanced economies.

> "De-industrialization is most dramatically evident in the process of closure of factories and mines. Understandably, the traumas of such closure, and the political fights that have been a common accompaniment, have dominated much of the literature on de-industrialization. But, of course, as a process de-industrialization is about the limited creation of new industrial jobs as much as the loss of the old" (Tomlinson, 2019, p. 6).

This notion of an 'urban divergence' mooted by some academic scholars in 'Divergent Cities In Post-Industrial Britain' Martin *et al.,* (2015) suggest that de-industrialisation does not necessarily produce a total decline in large cities but triggers a divergence in specialisation and differences in productive bases. Sugden (2018) and Blaszczyk (2017) have already explored this phenomenon in their respective studies; Sugden (2018) in reference to how Norwich manufacturers in the mid-nineteenth responded to the competitive threat of the West Riding worsted industry by switching to the use of silk in their cloths, adopting a niche position at the high end of the market.

Abraham Moon's also occupies a niche position in the industry for producing high-quality and innovative fabrics and accessories. Blaszczyk's (2017) study shows how Abraham Moon's meteoric success is due to a large extent on the firm's ability to embrace change and reinvent itself in the course of their history, adapting their traditional expertise and practices to meet the ever-changing consumer preferences and influences in a fast-paced fashion industry.

Evidently, while the divergences in the geographies, chronologies and effects of de-industrialisation in these two examples preclude the possibility of proposing an all-embracing, uniform definition of this concept – the renewed interest in this area offers scope for further research in this industry.

8.2 Limitations and further work

8.2.1 Limitations of the thesis

As in all academic studies, rigour must be the cornerstone of research design and as such, there is an obligation to the academic community to present a complete and honest account of the limitations of this study which are in four main areas and listed below (in no particular order of importance).

The timeframe of this thesis does not chart the company's business fortunes after 1939. The main aim of this thesis was to undertake an investigation of technological innovations and diffusion in textile loom production during is the period 1890 to1939 rather than a detailed examination of looms produced after this period.

The narrow focus of this thesis did not allow much scope for an in-depth investigation into such areas as the social-economic conditions of the workers, gender roles, child labour, health and nutrition, wage differentials, environmental pollution and local politics during this period. As for selectivity, in an attempt to frame this study within a definite temporal and geographical context, only the occasional brief mention is made to the substantial quantity of non-worsted ancillary machinery.

The research into the firm during the years 1890-1939 has been impeded by the absence of some of the primary sources, notably the company minute books from 1890 to 1939. It is unfortunate that the first economic Census of Production of 1907 (having been instigated by the 1906 Production Act) did not cover woollen or worsted machinery production. Consequently, this omission proved difficult to ascertain what type of worsted machinery was manufactured and which technological developments, if any, had been officially recorded.

The absence of minute books hindered the investigation and made it difficult to gauge the managerial direction taken and the progress made by Hattersley's in this period. Research had to be conducted using the primary sources still available. The firm's original records were not a complete, chronological record; very often, the paper and the writing in these surviving documents had succumbed to significant levels of deterioration, resulting in faded, illegible text. Nevertheless, being able to contextualise these extant, archival documents alongside other primary and secondary sources enabled the researcher to better understand and reconstitute the narrative of the firm's industrial development, managerial direction and innovative loom production.

8.2.2 Some suggested recommendations for future research

Aside from the limitations mentioned in this chapter, by adopting a similar methodological approach, further study can be undertaken to explore other key industries within a wider context. With regard to the focus area of this thesis, a further research investigation could be to explore other allied textile industries within a specific time-frame and a geographical locality.

The more extensive cross-section of case studies that such an approach would bring about is, not only a rich source of new qualitative data from which the researcher would not only be able to build up a more holistic overview of the industry, but also open up new opportunities for undertaking further detailed studies within a particular area or a particular focus in a comparative study framed against the background of the trends at the time of study.

A potential development of this thesis would be an investigation of Hattersley's loom sales to countries in the Empire, Europe and the Americas. A large quantity of looms was selected and sold abroad creating an important sales market as well as developing a revenue base during 1890 to 1939.

This study on Hattersley's highlighted how the rapid pace of technological change brought about by invention, innovation, and diffusion affected the economic activities and work patterns of the communities in the Yorkshire textile area and across the globe.

Technology continues to evolve. In the present age, one in which technological advances are also revolutionising markets, changing how goods and services are made, and reshaping consumers' behaviours, market analysts are keen to study how these new technologies connect with customers and how they have become integral elements of the consumer decision-making process.

An interesting investigation would be to undertake a consumer psychology case-study on the apparent unwillingness of the part of some British mill owners to buy up-to-date or innovative Hattersley's weaving looms and seek to identify the key factors of this consumer reluctance. Equally, it would be interesting to frame this research against an in-depth, marketing psychological case-study on Hattersley's marketing strategies at the time in order to determine how they failed to influence this target group.

An investigation of any differences and competitive 'inter-county rivalries' between the firm of Hattersley's in Yorkshire and a counterpart machine manufacturer from Lancashire would also add a new body of knowledge to the *corpus* of textile studies as would an examination of a similar scenario between Hattersley's and another country in the British Empire. Having had the opportunity to look briefly at the role of a foreign loom manufacturer, another rich seam to mine for a comparative research study could be an investigation of George Draper and Sons of Massachusetts - the American loom manufacturer - who had attracted and employed a number of ex-Hattersley workers who went on to invent the Northrop loom [the automatic power loom with the self-threading shuttle and shuttle spring jaws]. Any investigation into this particular field of research would provide a greater insight into Anglo-American competition and supplement the findings of this thesis.

Another fertile area to investigate would be an analysis of the structural/technological dynamics and financial streams which underpinned Hattersley's interactions with the successive governments (and their respective legislative measures) and the key potential loom purchasers in each different period of time. Individual examination and findings of each of these three areas would provide a greater overview, evaluation and understanding of these economic transactions.

Finally, it is hoped that future scholars will be encouraged to re-visit and re-appraise existing information in this area of study, to embrace the challenge of tracking down rare and scarce documentation whose poor condition and faded content may have dissuaded previous historians to carry out a fuller investigation, and to think critically on how best to synthesise these primary and secondary source materials as they consider studying other local, regional or national textile manufacturers.

As this research has attempted to show, adopting a similar flexible approach with the single case-study format and a modified *PEST* analysis framework will allow future researchers in different academic fields to visualise more easily the interrelationships between the themes of their particular field of interest and determine the strategies needed to collect and collate the relevant source material needed for their academic study.

References

Abdullah, M, N, and Shamsher, R., (2011), 'A Study on the Impact of *PEST* Analysis on the Pharmaceutical Sector: The Bangladesh Context', *Journal of Modern Accounting and Auditing*, Vol. 7, No. 12, pp. 1466 -1456.

Abercrombie, N, Hill, S., and Turner, B, S., (1984), *Dictionary of Sociology*, Harmondsworth, Penguin, 1984.

Acemoglu, D, Aghion, P, and Zilibotti, F., (2002), 'Distance to Frontier, Selection, and Economic Growth', *Working Paper 9066, NBER*, 1050 Massachusetts Avenue Cambridge, MA 02138, USA.

Acs, Z, J, Anselin, L, and Varga, A., (2002), 'Patents and Innovation Counts as Measures of Regional Production of New Knowledge', *Research Policy*, Vol. 31, No. 7, pp. 1069–1085.

Agar, M., (1986), *Speaking of ethnography*, Beverly Hills, CA, Sage.

Alderson, W, E., (1986), *Salts and Saltaire,* W. E. Alderson, Shipley, Yorkshire.

Allen, R, C., (2018), 'The hand-loom weaver and the power loom: a Schumpeterian perspective', *European Review of Economic History*, 22, 4, (2018), pp. 381- 402.

Amsden, A., (2001), *The Rise of the Rest, Challenges to the West from Late-Industrializing Economies,* Oxford and New York, Oxford University Press.

Anderson, F., (2017), *Tweed,* Bloomsbury Academic, London.

Anon, *Bradford Observer*, 1847, December, 2nd.

Anon, *Bradford Observer*, 1861, May, 16th.

Anon, *Keighley News,* 1890, August, 4th.

Anon., *Bradford Observer*, 1890, August.

Anon., *Bradford Observer,* 1890, Letter Correspondence from Historicus, Dec.

Anon., *Bradford Observer,* 1892, September 5th.

Anon., *Bradford Observer,* 1890, November, 7th.

Anon., *Bradford Observer,* 1890, December, 10th.

Anon., *The Leeds Mercury,* 1890, December 27th, p. 9.

Anon., The Textile Manufacturer., (1890), 'A Practical Journal for Millowners, Machinists, Dyers, Calico Printers, Bleachers,' (1890), Manchester, p. 470.

Anon., *The Leeds Mercury,* The Trade Review of 1890, December 29th, p. 9.

Anon., *Huddersfield Daily Examiner*, September, 1891.

Anon., 1891, 'The Popular Science Monthly', *edited W. J, Youmans, May-October 1891, Vol. XXXIX, Appleton and Company, New York, Bond Street, London.*

Anon., *Bradford Daily Telegraph*, 1891, October, p. 4.

Anon., The Yorkshire College, Leeds, (1899-1900), "Report of the Work of the Textile Industries Dyeing and Art Classes', *Textile Industries Classes,* (Twenty-Sixth Session), Leeds.

Anon., *The Keighley News,* 1900, Aug, 4th.

Anon., *Supplement to the Yorkshire Post*, 1900, December, 26th, p. 3.

Anon., *The Leeds and Yorkshire Mercury*, 1901, October, 21st, p. 7.

Anon., *The Leeds and Yorkshire Mercury,* (1901), Monday, October 21st.

Anon., *The Leeds and Yorkshire Mercury*, 1901, December, 8th.

Anon., Textile Recorder., (1902), 15th April 1902, p. 364.

Anon., *Geelong Advertiser,* 1902, May 27th, p. 4.

Anon., *The Textile Manufacturer,* 1902, May, 1902, 8th December, p. 146.

Anon., *The Factory Times,* 1902, (Another Automatic Power Loom), July 18th, p. 8.

Anon., *Todmorden & District News,* 1902, September 4th.

Anon., *The Textile Journal,* 1902, September 8th.

Anon., *Todmorden & District News,*1902*,* September p. 8.

Anon, The Daily Dispatch, 1902, November, 27th.

Anon., *The Textile Manufacturer,* 1903, No. 326, XXIX.

Anon., The Textile World., (1903), 'Mills and Mill Life in England', Vol. 24, No.1, Lord & Nagle, Boston, USA, pp. 1-640.

Anon., The Textile Manufacturer., (1903), 'A Practical Journal for Millowners, Machinists, Dyers, Calico Printers, Bleachers,' (March 15th), Manchester, p. 89.

Anon., Guardian. 1903, Friday, March 20th, 1903.

Anon., The Textile World combining The Textile World and Textile Record., (1903), 'Free Trade in England', Vol. 26 (New Series), October 1903, No. 1, Lord & Nagle, Boston, USA, p. 70.

Anon., *The Bradford Daily Telegraph*, 1904, Monday, May 2nd.

Anon., (c1906?), *Fortunes Made in Business: Life Struggles of Successful People,* Amalgamated Press Ltd, London.

Anon., *Times and Express,* 1906, March 23rd, p. 3.

Anon., *Bradford Daily Telegraph*, 1906, March, p. 2.

Anon., *The Manchester Courier,* 1906, September 5th, p. 5.

Anon., *Textile World Record,* Jan, 1907, January, Vol. 32, No. 4.

Anon., *Yorkshire Factory Times,* 22nd April, 1909.

Anon., *Bradford Daily Telegraph,* 1909, May, 14th.

Anon., *Bradford Daily Telegraph,* 1909, Nov, 9th.

Anon., *Yorkshire Post and Leeds Intelligencer,* 1910, October 8th, p. 7.

Anon., *The Belfast News-Letter*, 1911, September, 12th.

Anon., *Bradford Daily Telegraph,* 1911, November, 14th.

Anon., (1913), *The Wool Year Book and Diary*, compiled by the editor of the Textile Mercury, 5th edition, Manchester.

Anon., *Yorkshire Factory Times*, 1914, November, 19th.

Anon., (1914), *Manchester Evening News,* December, Tuesday 22nd, p. 5.

Anon., *The Manchester Courier*, 1914, December, 23rd.

Anon., *The Leeds Mercury,* 1915, May, 15th.

Anon., *Bradford Weekly Telegraph,* 1915*,* May, 21st.

Anon, Th*e Next Vogue,* (1917), Vogue, Volume 49, Number 4.

Anon., *Stornoway Gazette,* 1919, March, 14th.

Anon., *Textile Institute Proceeding and Abstracts.,* (1919), Vol. x, 1919, No. 12, Textile Institute, pp. 350.

Anon., (1923-24), 'Mule Spun Worsted Yarns' (J. H. Bates), *The Journal of the Bradford Textile Society*, William Byles & Sons. Bradford, pp. 1-188.

Anon., *The Shipley Times and Express,* 1924, January, 18th, p. 3.

Anon., *The Leeds and Yorkshire Mercury.,* 1924, February, 14th.

Anon., *The Nottingham Journal*, 1925, December, 9th.

Anon., *Textile Mercury.,* 1928, 'Notes on 'Change', LXXVIII, No. 2025, January, p. 20.

Anon, *The Leeds Mercury*, 1928, December, 29th, p.6.

Anon, (1928), 'Long Service on a Keighley Loom: Weaver's Record Old-Time Machines Still in Use', *Textile Journal of Australia,* Vol. III, No. 6, August 15, 1928, A. M. Publishing Company Proprietary Limited, Melbourne, Australia.

Anon., *The Leeds Mercury*, 1929, December, 28th, p. 6.

Anon., *The Shipley Times and Express,* 1930, May 10th, p. 8.

Anon., *Burnley News,* 1930, May, 17th.

Anon., *The Leeds Mercury,* 1930, January, 10th, p. 5.

Anon., *The Yorkshire Post,* 1930, February, 1930, p. 3.

Anon., *The Yorkshire Post,* 1930, 1930, June 5th, p. 16.

Anon., *The Leeds Mercury*, 1930, December, 31st, p. 8.

Anon., *The Yorkshire Post,* 1931, January 1st, 1931, p. 4.

Anon., *The Yorkshire Post,* 1931, January 5th, 1931, p. 16.

Anon., *The Leeds Mercury*, 1931, April, 25th, p. 3.

Anon., *The Leeds Mercury*, 1931, November 5th, p. 2.

Anon., *The Shipley Times and Express,* 1931, December, 5th, p. 8.

Anon., *The Leeds and Yorkshire Mercury,* (1931), December, 30th.

Anon., *The Nottingham Evening Post*, 1932, December, 1st, p. 4.

Anon., *The Textile Manufacturer.,* (1932), 'A Bradford Textile Machinery and Accessories Exhibition,' A Practical Journal for Millowners, Machinists, Dyers, Calico Printers, Bleachers, (1932), Manchester.

Anon., *The Textile Mercury*, 1933, January, 4th, p. 7.

Anon., *The Journal of the Textile Institute Proceedings*., (1933), p. 72.

Anon., *The Textile Mercury,* 1933, November 25th, p. 7.

Anon., *The Textile Manufacturer.,* (1933), ‘A Bradford Textile Machinery and Accessories Exhibition,’ A Practical Journal for Millowners, Machinists, Dyers, Calico Printers, Bleachers, (1933), Manchester.

Anon., *The Leeds Mercury,* 1933, December, 29th, p. 1.

Anon., *The Yorkshire Evening Post,* 1934, May, 9th, p. 3.

Anon, *The Keighley News*, 1934, July.

Anon., *The Yorkshire Post,* 1935, January.

Anon., *The Leeds Mercury*, 1935, January, 1st, p. 7.

Anon., *The Leeds Mercury*, 1935, January.

Anon., *The Textile Mercury*, 1935, December.

Anon., *Shipley Times and Express*, 1936, January, Saturday 25th, p. 8.

Anon., *The Nottingham Evening Post*, 1936, April 29th, p. 4.

Anon., *The Textile Mercury,* 1937, January, 5th, p. 7.

Anon., *The Textile Manufacturer.,* (1937), ‘Textile Commodities: Trade Position and Prospects’, A Practical Journal for Millowners, Machinists, Dyers, Calico Printers, Bleachers, (1937), Manchester.

Anon., *The Shipley Times and Express,* 1937, January16th, p. 2.

Anon., *The Yorkshire Post,* 1937, January, 21st, p. 22.

Anon., *The Leeds Mercury,* 1937, December, 29th, p. 7.

Anon., *The Yorkshire Post,* 1938, January, 20th p. 28.

Anon., *The Leeds Mercury,* 1938, December, 28th, p. 5.

Anon., *The Yorkshire Post,* 1939, January, 26th p. 30.

Anon., *The Yorkshire Observer,* 1945, March 7th.

Anon., *The Yorkshire Observer,* 1947, November 28th, p. 1.

Anon., *The Yorkshire Observer,* 1947, November 28th, p. 3.

Anon, (1933), *Journal of the Textile Institute Proceedings,* ‘History of the Northrop Loom’, Vol. 24:4, pp. 71-72.

Anon., (1951), ‘Famous British Loom Works’, *The Textile Weekly*, Blackfriars Street, Manchester, May 18th, 1951, p. 1342.

Anon., The Economic Times., (2009), ‘Importance of Trade Fairs’, Th*e Economic Times*, May 22, 2009.

Argyres, M, and McGahan, A, M., (2002), ’An Interview with Michael Porter’, *The Academy of Management Executive,* 16, 2, p. 44.

Arthur, W, B., (1989), ‘Competing technologies, increasing returns and lock-in by historical events’, *Economic Journal,* 99, pp. 116–31.

Ashenhurst, T, R., (1907), *Practical Weaving and Designing of Textile fabrics: with chapters on the principles of construction of the loom, calculations and colour*, J. Broadbent and Co, Huddersfield and London.

Ashton, T, S., (1955), *An Economic History of England: The Eighteenth Century*. London: Methuen, p. 42.

Atack, J, Bateman, F, and Margo, R, A., (2008), 'Steam power, establishment size, and labor productivity growth in nineteenth century American manufacturing', *Explorations in Economic History*, Vol. 45, No. 2, pp. 185–198.

Atkeson, A and Kehoe, P.J., (2001), 'The transition to a New Economy after the Second Industrial Revolution', *Working Paper 8676*, National Bureau of Economic Research, Cambridge, MA, December 2001.

Auerbach, J, A., (1999), *The Great Exhibition of 1851: A Nation on Display,* New Haven, Conn., Yale University Press.

Australian Research Council., (2015), 'State of Australian University Research 2015-2016': *Vol. 1, ERA, National Report,* Canberra: Commonwealth of Australia, www.arc.gov/era-reports.

Axelsson, B, and Easton, G., (1992), *Industrial networks: A new view from reality*, Routledge: London.

Babbie, E, R., (2002), *The basics of social research,* Belmont, CA, Wadsworth Thompson Learning.

Baines, E., (1835), *History of the Cotton Manufacture in Great Britain with a notice of its early history in the east, and in all the quarters of the globe, a description of the Great Mechanical Inventions which have caused its unexampled extension in Britain, and a view of the present state of the manufacture and the condition of the classes engaged in its several departments,* H. Fisher, R. Fisher and P. Jackson, London.

Baines, E., (1970), *Account of the Woollen Manufacture of England,* (intro by K.G. Ponting), David and Charles, Newton Abbot, Devon.

Bairoch, P., (1993), *Economics and World History: Myths and Paradoxes*, Chicago, University of Chicago Press.

Barfoot, P, and Wilkes, J., (1791-8), *The Universal British Directory of Trade, Commerce, and Manufacture,* Vols. 1-5, Champante and Whitrow, London.

Bargheh, A; Rowley, J, and Sambrook, S., (2009), 'Towards a Multidisciplinary Definition of Innovation', *Management Decision*, 47, pp. 1323-1339.

Barker, D., (2013), 'The Manningham Mills Strike, 1890-91: 'Low Wages, Good Water, and No Unions', *Northern History,* 50: 1, pp. 93-114.

Barrett, C., (2005), 'Keynote address at the second phase of analysis and the evolution of cities,' *Environment and WSIS (World Summit on the Information Society)*, Tunis, Planning A, 31, 2169-2188, (16 November 2005).

Bartel, A, P, and Lictenberg, F, R., (1987), 'The Comparative Advantage of Educated Workers in Implementing New Technology', *Review of Economics and Statistics,* Vol. 69, No. 1.

Batchelor, R., (1994), *Not Looking at Kettles,* In Interpreting Objects and Collections, edited by S. Pearce, London: Routledge, pp. 139–143.

Basalla, G., (1988), *The Evolution of Technology,* Cambridge University Press: Cambridge.

Bekar, C. and Lipsey, R., (2004), 'Science Institutions and the Industrial Revolution', *Journal of European Economic History*, 33 (3), Winter 2004, pp. 709-753.

Belussi, F, and Caldari, K., (2009), 'At the origin of the industrial district: Alfred Marshall and the Cambridge School,' *Cambridge Journal of Economics,* Vol. 33, No. 2, (March, 2009).

Bentley, P., (1970), *The Pennine Weaver From The Earliest Times To The Present Day*, Firecrest Publishing Limited, Bath.

Berg, M., (1985), *The Age of Manufactures, 1700-1820: Industry, Innovation and Work in Britain*, Totowa, NJ, Barnes and Noble.

Berg, M., (1994), *The Age of Manufactures: Industry, Innovation and Work in Britain 1700-1820,* Fontana, London.

Berg, M., (2002), 'From imitation to invention: creating commodities in eighteenth-century Britain', *Economic History Review*, LV, 1, pp. 1-30.

Bekele, G, W, and Jackson, R., (2006), 'Theoretical Perspectives on Industry Clusters', *Regional Research Institute Publications and Working Papers,* 92.

Berthoff, R., (1953), *British immigrants in industrial America, 1790-1950,* Cambridge, MA: Harvard University Press.

Bessen, J, and Meurer, M., (2005), 'The Patent Litigation Explosion,' *Boston University School of Law Working Paper,* No. 05-18.

Bessen, J, and Meurer, M, J., (2008), 'The Private Costs of Patent Litigation', *Law and Economics Working Paper, No. 07-08 (2008)*, Boston University School of Law.

Bhagwati, J, N, and Irwin, D., (1987), 'The Return of the Reciprocations - U.S. Trade Policy Today' *World Economy 10*, (June 1987), pp. 109-130.

Blandy, R., (2002), 'South Australian Business Vision 2010, Industry Clusters Program: A Review*', Adelaide, SA: Centre for Applied Economics*, University of South Australia.

Blaszczyk, R, L., (2017), *Fashionability: Abraham Moon and the Creation of British Cloth for the Global Market*, Manchester University Press.

Blewett, M., (2006) 'Diversities of Class and Gender Experience and the Shaping of Labor Politics: Yorkshire's Manningham Mills Strike, 1890–91 and the Independent Labour Party', *Labor History*, 47, 4, pp. 511-535.

Board of Trade., (1908-1913*), Report on an enquiry into working-class rents, housing and retail prices*, HMSO.

Board of Trade and Industries., (1946), 'The South African Blanket Manufacturing Industry', *Report 290,* September 11th 1946, Chapter III.

Bogart, D., (2005), 'Turnpike trusts and the transportation revolution in 18th century England', *Explorations in Economic History*, 42, (4), pp. 479-508.

Boldrin, M, and Levine, D, K., (2008), *Against Intellectual Monopoly*, Cambridge University Press.

Bond, T, G., (2003), Validity and assessment: a Rasch measurement perspective, *Metodogia de Las Ciencias del Comportamiento,* 5, (2), pp. 179-194.

Born, W., (1977), 'The Indian Hand Spinning Wheel', *CIBA,* (Society of Chemical Industry in Basle, Switzerland), 1939, (reprint Rawdon, 1977), p. 990.

Bourdieu, L, and Wacquant, J, D., (1992), *An Invitation to Reflexive Sociology,* University of Chicago Press, Chicago.

Bowden and Higgins., (2017), *Industrial Clusters and Regional Business Networks in England, 1750-1970,* (editors Popp, A and Wilson, J, F,), Routledge, London and New York.

Bownass, R, and M, K, Hogan., (1988), *Vegetable Matter in Wool*, International Wool Secretariat, Ilkley, West Yorkshire.

Bradford Chamber of Commerce, (1903), Minute Books, December 4th, 1903.

Bradford Industrial Museum., (1891), Lister Correspondence, 880/2, 13 Mar. 1891.

Braverman, H., (1974), 'Labour and Monopoly Capital: The Degradation of Work in the Twentieth Century', *Monthly Review Press,* New York.

Brearley, A, and Iredale, J, A., (1980), *The Worsted Industry,* WIRA, (2nd edition), WIRA House, Leeds.

Bremner, E., (2013), 'Surpassing Tradition: Investigating Design Innovation Possibilities for Harris Tweed,' *In Futurescan 2: Collective Voices,* (10 – 11 January, 2012), UK: Sheffield Hallam University.

Breschi, S, and Lissoni, F., (2001), 'Knowledge spillovers and local innovation systems: a critical survey', *Industrial and Corporate Change*, Vol. 10 No. 4, pp. 975-1005.

Brierley, S, and Carter, G. R., (1914), 'Fluctuations in the Woollen and Worsted Industries of the West Riding', *The Economic Journal* Vol. 24, Issue 95, 1st September 1914, pp. 377–384.

Brierley, A, and Iredale, J, A., (1980), *The Worsted Industry*, WIRA, Leeds, 2nd edition, pp. 1-198.

Briggs, J., (1905), *With a Note on the Process of Hand Combing* included in Killick, H, F., (1905), *The Story of Lord Masham's Combing Machine* reprinted from the Yorkshire Daily Observer, William Byles & Sons, Bradford.

Brink, P., (1991), 'Issues of reliability and validity', In: Morse, J. (ed), *Qualitative nursing research: a contemporary dialogue,* Sage, London, pp. 164–186.

Brink, H, I., (1993), 'Validity and reliability in qualitative research', *Curationis,* 16 (2), pp. 35-38.

Broadberry, S., (1997), *The Productivity Race: British Manufacturing in International Perspective, 1850-1990,* Cambridge, Cambridge University Press.

Brown, R., (1992), 'Managing the 'S' curves of innovation', *The Journal of Consumer Marketing, 9,* pp. 61-73.

Brugger, F, and Gehrke, C., (2018), 'Skilling and deskilling: technological change in classical economic theory and its empirical evidence,' *Theory and Society,*47, (5), pp. 663-389.

Buchanan, P, J., (1998), *The Great Betrayal: How American Sovereignty and Social Justice Are Being Sacrificed to the Gods of the Global Economy*, Boston, Little, Brown.

Buchanan, S, and Gibb, F., (1998), 'The information audit: an integrated strategic approach'. *International Journal of Information Management*, 18, (1), pp. 29-47.

Burnley, J., (1889), *The History of Wool and Wool Combing*, Low, Marston, Searle and Rivington, p. 392.

Busfield, D., (1988), 'Skill and the sexual division of labour in the West Riding Textile Industry, 1850-1914' in J.A. Jowitt and A.J. McIvor (eds.), *Employers and Labour in the English Textile Industries 1850-1939* (London: Routledge, 1988).

Bushnell, H., (1847), *Discourse for Home Missions, Barbarism the First Danger,* American Home Missionary Society, New York.

Bythell, D., (1983), Cottage industry and the factory system, *History Today*, 33, pp. 17-23.

Campbell, D, T., (1975), 'Degrees of freedom and the case study', C*omparative Political Studies,* 8, pp. 178-193.

Carduff, E; Murray, S, A, and Kendall, M., (2015), 'Methodological developments in qualitative longitudinal research: the advantages and challenges of regular telephone contact with participants in a qualitative longitudinal interview study', *BMC Research Notes,* (2015), 8,142, pp. 1-10.

Carr, E, H., (1961), *What is History?* Macmillan, London.

Carus-Wilson, E. M., (1941), 'An Industrial Revolution of the Thirteenth Century', *Economic History Review*, 11, pp. 39–60.

Cavana, R, Y; Delahaye, B, L, and Sekaran, U., (2001), *Applied Business Research: Qualitative and Quantitative Methods,* Brisbane: John Wiley and Sons.

Cbakravorty, S, Koo, J, and Lall, S., (2003), 'Metropolitan Industrial Clusters: Patterns and Processes', World Bank's Development Research Group, *Policy Research Paper*, No. 3073

Chandler Jnr, A, D., (1990), *Scale and Scope: The Dynamics of Industrial Capitalism,* (Cambridge, Mass, Harvard University Press, p. 274.

Chandy, R, K, and Tellis, G. J., (2000) 'The Incumbent's Curse? Incumbency, Radical Product Innovation'. *Journal of Marketing*, 64, pp. 1-17.

Charnock, G, F., (1933), *The Mechanical Transmission of Power,* Crosby Lockwood Ltd, Ludgate Hill, London.

Checkland, S. G., (1966), *The Rise of Industrial Society in England 1815-1885*, 3th edition, Longmans, Green and Co Ltd, London.

Childs, D. J., (1999), 'A Peripheral Weapon? The Production and Employment of British Tanks in the First World War, contributions in military studies, studies in the photographic arts', Greenwood Publishers, Issue 173, pp. 1-210.

Christensen, C, M., (1997), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Boston, MA Harvard Business School Press.

Christensen, C, M, and Bower, J, L., (1996), 'Customer power, strategic investment, and the failure of leading firms', *Strategic Management Journal*, 17, (3), pp. 197–218.

Christiansen, T., (2002), 'Summary of the SWOT panel's evaluation of the organization and financing of the Danish health care system', *Health Policy,* Vol. 59, pp. 173 - 180.

Christensen, C, M, and Raynor, M, E., (2003), *The Innovator's Solution: Creating and Sustaining Successful Growth*, Boston, MA: Harvard Business School Press.

Christensen, C, M, McDonald, R, Altman, E, and Palmer, J, E., (2018), 'Disruptive Innovation: An Intellectual History and Directions for Future Research', *Journal of Management*, 55, (2018), pp.1043-1078.

Cigar and Tobacco World, 1914.

CIPD., (2014), 'Pestle analysis Fact sheet,' *Chartered Institute of Personnel and Development,* (url address: http://www.cipd.co.uk/hr-resources/factsheets/pestle- analysis.aspx).

Clapham, J, H., (1906), 'Industrial Organization in the Woollen and Worsted Industries of Yorkshire', *The Economic Journal,* Vol. 16, No. 64 (Dec., 1906).

Clapham, J, H., (1907), *The Woollen and Worsted Industries*, Methuen, London.

Clapham, J, H., (1910), 'The Transference of the Worsted Industry from Norfolk to the West Riding', *The Economic Journal,* Vol. 20, No. 78.

Clark, P., (1995), *Small towns in England 1550-1850: National and Regional population trends,* in Clark, P, (ed), Small Towns in Eighteenth Century Europe, Cambridge, Cambridge University Press.

Clark, G., (2005), 'The British Industrial Revolution, 1760 – 1860', *Course notes ECN 110B,* Spring. Davis, CA, University of California.

Clarke, M., (2007), *The Leeds and Liverpool Canal: A History and Guide*, Carnegie Publishing Ltd, pp. 1-288.

Clulow, V., (2005), "Futures dilemmas for marketeers: can stakeholder analysis add value?", *European Journal of Marketing*, 39, (9/10), pp. 978-997.

Coccia, M., (2005a), 'Technometrics: Origins, historical evolution and new direction', *Technological Forecasting & Social Change*, Vol. 72, No. 8, pp. 944 - 979.

Cole, A, H., (1926), *The American Wool Manufacture*, Harvard University Press, ii, p. 82.

Coleman, D, C., (1992), *Myth, History and the Industrial Revolution,* Hambledon, London.

Committee on Industry and Trade., (1929), *Survey of the Textile Industries*, H.M.S.O.

Cook, T, D, and Campbell, D, T., (1979), *Quasi-Experimental: design and analysis issues for field setting*, Chicago, Rand McNally.

Cookson, G., (1994), *The Yorkshire Textile Engineering Industry 1780-1850,* DPhil thesis, University of York, York.

Cooper, D, R, and Schindler, P., (2006), *Business Research Methods*, 9th ed, New York: McGraw- Hill Irwin.

Cope, D., (2015), ‘Case study research methodology in nursing research’, *Oncology Nursing, 42,* (6), pp. 681-882.

Copeland, M.T., (1911), ‘Progress of the Automatic Loom,’ *The Quarterly Journal of Economics*, Vol. 25, No. 4, Oxford University Press, pp. 746-750.

Correspondence from José Reixach to Samuel Cunliffe Lister., 11th of November 1890, (transcriber by D. Barker), Bradford Industrial Museum, T2002-880/2.

Correspondence from José Reixach to Samuel Cunliffe Lister, 1st of December, 1890, (transcribed by D. Barker), Bradford Industrial Museum, T2002-880/2.

Cox, J, and Cox, O., (1999), ‘Naval Hospitals of Port Royal, Jamaica’, *Caribbean Architectural Monograph Series, No. 1,* Caribbean School of Architecture at the University of Technology, Jamaica.

Cox, J., (2021), The higher education environment driving academic library strategy: A political, economic, social and technological (PEST) analysis’, *The Journal of Academic Librarianship*, Elsevier, Vol. 47, Issue. 1, pp. 1-11.

Crabtree, B, and Miller, W., (1999), *Doing Qualitative Research*, (2nd edition), (Eds), Sage, London, pp. 1- 406.

Crafts, N, F, R., (1985), *British Economic Growth during the Industrial Revolution,* Oxford University Press.

Crafts, N, and Fearon, P., (2010), ‘Lessons from the 1930s Great Depression’, *Oxford Review of Economic Policy*, Volume 26, Number 3, 2010, pp. 285–317.

Creswell, J., (2002), *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*, Upper Saddle River, NJ, Merrill, Prentice Hall.

Creswell, J, W., (2003), *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, Thousand Oaks, California: Sage Publications.

Creswell, J, W., (2013), *Qualitative inquiry and research design: choosing among five approaches,* 3rd ed, Thousand Oaks, CA, Sage.

Cronin, B, P., (2001), *Technology, Industrial Conflict and the Development of Technical Education in 19th Century England*, Ashgate, Aldershot.

Crotty, M., (1998), *The foundations of social research: Meaning and perspective in the research process*, Thousand Oaks, CA, Sage.

Crouzet, F., (1985), *The First Industrialists: The Problems of Origins*, Cambridge 41 University Press, Cambridge.

Crowe, S; Cresswell, K; Robertson, A; Huby, G; Avery, A, and Sheikh, A., (2011), ‘The case study approach’, *BMC Medical Research Methodology,* 11:100, pp. 1-10.

Crump, W, B, and Ghorbal, G., (1978), *History of the Huddersfield Woollen Industry*, (Huddersfield, 1935; reprinted in 1967), p. 121.

Cudworth, W., (1888), *Worstedopolis, A Sketch History of the Town and Trade of Bradford (The Metropolis of the Worsted Industry),* W. Byles & Sons, Hall Ings, Bradford, (rpt. The Old Bradfordian Press, Bradford).

Daft, R, L, and Becker, S, W., (1978), *The innovative organization: innovation adoption in school organizations*. New York: Elsevier, USA.

Dahlin, K, B, and Behrens, D, M., (2005), 'When Is an Invention Really Radical? Defining and Measuring Technological Radicalness,' *Research Policy,* 34, pp. 717–37.

Dahmén, E., (1991), 'Development Blocks' in Carlsson, B and R Henriksson, *Industrial Economics in Development Blocks and Industrial Transformation,* The Industrial Institute for Economic and Social Research Report Series, pp. 126-151.

Dahmén, E., (1993), *Research on railways in an historical perspective,* In J. Whitelegg & S. Hultén & T. Flink (Eds.), High speed trains: Fast tracks to the future Hawes, North Yorkshire: Leading Edge Publishing Ltd, pp. 18 - 25.

Damanpour, F., (1991), 'Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators', *The Academy of Management Journal,* 34, (3), pp. 555-590.

Danneels, E., (2002), 'The Dynamics of Product Innovation and Firm Competences', *Strategic Management Journal* 23, (12), pp. 1095-1121.

David, P, A., (1994) "The Evolution of Intellectual Property Institutions." *In Economics in a Changing World,* Vol. 1: *System Transformation: Eastern and Western Assessments*, edited by A. Aganbegyan, O. Bogomolov, and M. Kaser. London, MacMillan.

De Vries, J., (1994), 'The Industrial Revolution and the Industrious Revolution', *The Journal of Economic History*, Vol. 54, No. 2, Papers presented at the Fifty-Third Annual Meeting of the Economic History Association, pp. 249-270.

Denzin, N, K, and Lincoln, Y, S., (1994), *Handbook of Qualitative Research*, Thousand Oaks, Sage.

Department of Commerce and Labor, Bureau of Manufactures., (1916), Supplement to Commerce Annual Series, No. 19g, Reports Daily Consular and Trade Reports issued by the Bureau of Foreign and Domestic Commerce Department of Commerce, Washington D.C. (June 5th, 1916).

Dewhirst, I., (1974), *A History of Keighley*, Keighley Corporation, Keighley.

Dickens, C., (1852) *The Great Yorkshire Llama*. (ed.), Household Words, A Weekly Journal 1850-1859, (6).

Dodgson, M, and Hinze, S., (2000), 'Measuring innovation indicators used to measure the innovation process: defects and possible remedies,' *Research Evaluation,* 19, (2), pp. 101-114.

Doeringer P. B, and Terkla, D, G., (1995), 'Business Strategy and Cross-Industry Clusters', Econom*ic Development Quarterly,* 9, pp. 225-37.

Drake, B., (1920), *Women in Trade Unions,* Labour Research Department, London, p. 127.

Draper, A, and Raper, G, F., (1955), 'Economic and Technical Problems Associated with the Development and Introduction of a Textile Invention', *Journal of the Textile Institute Proceedings,* 46, 8, pp. P516 - 533.
Druker, J, and Feser, E., (2012), 'Regional industrial structure and agglomeration economies: An analysis of productivity in three manufacturing industries', *Regional Science and Urban Economics*, Vol. 42, Issues 1-2, p. 1-14.
Duchesneau, T, D, Cohn, S, and Dutton, J., (1979), 'A Study of Innovation in Manufacturing: Determination, Processes and Methodological Issues'. Vol. I, *Social Science Research Institute*, University of Maine, Orono, USA.
Duckett, B, and Waddington-Feather, J., (2005), *Bradford: history and guide,* Tempus Publishing, Stroud.
Duke-Williams, O, W., (2017), *A History of Census-taking in the UK,* (In: Stillwell, J, (ed.), The Routledge Handbook of Census Resources, Methods and Applications Unlocking the UK 2011 Census, Routledge: London.
Durlauf, S, N, and Lawrence E. B., (2007), *The New Palgrave Dictionary of Economics,* (2007), second edition, editors. Steven N. Durlauf and Lawrence E. Blume, Palgrave Macmillan.
Duryea, M; Hochman, M, and Parfitt, A., (2007), 'Measuring the Impact of Research, Research Global*'*, 27, pp. 8-9 (Published online: http://www.atn. edu.au/docs).
Easterby-Smith, M; Thorpe, R, and Jackson, P, R., (2009), *Management Research*, 3rd edition, Sage, London.
Easton, G., (2010), 'Critical realism in case study research', *Industrial Marketing Management, 39, (1)*, pp. 118-128.
Eckes, A, E, Jr., (1995), *Opening America's Market: U.S. Foreign Trade Policy since 1776,* Chapel Hill, University of North Carolina Press.
Edgerton, D., (1996), *Science, Technology, and the British Industrial "Decline", 1870-1970*, Cambridge, Cambridge University Press, 1996.
Eichengreen, B., (1992), 'The Eternal Fiscal Question: Free Trade and Protection in Britain, 1860-1929', In *Protectionism and the World Economy*, edited by Forrest Capie, Cheltenham, Edward Elgar.
Eichengreen, B., (1992), *Golden Fetters: The Gold Standard and the Great Depression, 1919-1939,* New York: Oxford University Press.
Elbaum, B, and Lazonick, W., (1986), *The Decline of the British Economy,* New York, Oxford University Press.
Ellinger, R., (1977), 'Industrial Location Behaviour and Spatial Evolution,' *The Journal of Industrial Economics*, Volume XXV, No. 4, (June, 1977).
Ellis, P., (2013), *Understanding Research for Nursing Students* (2nd ed), Learning Matters, Exeter Feagin, J, Orum, A, and Sjoberg, G., (1991), *A Case for Case Study*, Chapel Hill, NC: University of North Carolina Press.

Engels, F., (1993), *The Condition of the Working Class in England*, Ed. with introduction, David McLellan, Oxford, p.18.

Ennew, J., (1980), *The Western Isles Today,* Cambridge University Press, London.

Enright, M, E., (1990), *Geographical Concentration and Industrial Organization,* PhD dissertation Harvard University, USA.

Enright M. J., (1993), *The Geographic Scope of Competitive Advantage, in* Dirven E, Groenewegen, J. and Van Hoof, S, *Stuck in the Region: Changing Scales of Regional Identity*, Netherlands Geographical Studies, Utrecht.

Ensor, R, C, K., (1992), *England 1870-1914*, The Oxford History of England, Clarendon Press, Oxford.

Enright, M, E., (1990), *Geographical Concentration and Industrial Organization,* Unpublished PhD dissertation, Harvard University.

Ettlie, J. E., (1983), 'Organizational Policy and Innovation Among Suppliers to the Food Processing Sector,' *Acad. Management Journal*, 26 (1983), pp. 27-44.

European IPR Helpdesk., (2015), 'Publishing v. patenting', Fact Sheet, pp. 1-12.

European IPR Helpdesk., (2018), 'IP enforcement: asserting your rights', Fact Sheet, pp. 1-18.

Fagerberg, J., (2004), *Innovation: A guide to the Literature,* in Fagerberg, J., Mowery, D., and Nelson, R (eds.), The Oxford Handbook of Innovation, Oxford University Press, Oxford, pp 1-26.

Fairbairn, W., (1861), *Treatise on Mills and Millwork, Part 1. On the Principles of Mechanism and on Prime Movers,* Spottiswood & Co, London.

Farnie, D, A., (1990), 'The Textile Machine-Making Industry and the World Market', 1870–1960, *Business History,* 32:4, pp. 150-170.

Fawthrop, E., (1946), The development of loom drives, Journal of the Textile Institute Proceedings, Vol. 37, Issue 11, pp. 526-528.

Feagin, J; Orum, A, and Sjoberg, G., (1991), *A case for case study,* Chapel Hill, NC: University of North Carolina Press.

Fecher, B; Friesike, S, and Hebing M., (2015), 'What drives academic data sharing?' *PLoS One,* 10, (2), pp. 1–25.

Feinstein, C, H, Temin, P, and Toniolo, G., (1997), *The European Economy Between the Wars,* Oxford, Oxford University Press.

Feldman, M, P., (1999), 'The new economics of innovation, spillovers and agglomeration: a review of empirical studies', *Economy Innovation New Technology,* Vol. 8, pp. 5-25.

Feller, I, (1966), 'The Draper Loom in New England Textiles, 1894-1914: A Study of Diffusion of an Innovation', *The Journal of Economic History,* Vol. 26, No. 3 (Sep., 1966), pp. 320-347.

Feng, H, Morgan, N, A, and Rego, L, L., (2015), 'Marketing department power and firm performance', *Journal of Marketing,* 79, (5), pp. 1–20.

Final Report on the First Census of Production of the United Kingdom, (1907), HMSO.

Firestone, W., (1987), 'Meaning in method: The rhetoric of quantitative and qualitative research,' *Educational Researcher,* 16, (7).
Fischer, M. M., (2006), *Innovation, networks, and knowledge spillovers: selected essays* (1st ed.), Berlin, New York: Springer.
Fleisher, C, S, and Bensoussan, B, E., (2003), *Chapter 17: Macro-environmental (STEEP) Analysis Strategic and Competitive Analysis: Methods and Techniques for Analyzing Business Competition*, Prentice Hall. Upper Saddle River, New Jersey, pp. 269-283.
Floud, R, C., (1976), *The British Machine Tool Industry 1850-1914*, Cambridge University Press, Cambridge, pp. 1-231.
Flyvbjerb, B., (2011), *Case study,* In N. K. Denzin and Y. S. Lincoln (eds), The Sage Handbook of Qualitative Research, 4th ed, Thousand Oaks, CA, Sage, pp. 301-316.
Fornell, C, Johnson, D, M, Anderson, W, E, Cha, J, and Bryant, E, B., (1996), 'The American Customer Satisfaction Index: Nature, purpose, and findings', *Journal of Marketing.*
Fox, T, W., (1894), *The Mechanisms of Weaving*, Macmillan and Company, pp. 1-472.
Freeman, C., (1974), *The Economics of Industrial Innovation,* (1st edition, Harmondsworth, Penguin, 2nd edition, 1982, London, Pinter ed.) Harmondsworth, Penguin.
Freeman, C., (1984), The Economics of Industrial Innovation, Pinter, London.
Freeman, C., (1992), *A Green techno-economic paradigm for the world economy: In the economics of hope: essays on technical change, economic growth and the environment, C. Freeman (ed),* Pinter Publishers, London.
Garcia, R, and Calantone, R., (2002), 'A Critical Look at Technological Innovation Typology and Innovativeness,' *The Journal of Product Innovation Management,* 19, No. 2, pp. 110–32.
Garrett, E, M., (1986), *Before their Time Employment and Family Formation in a Northern Textile Town, Keighley, 1851-81*, PhD thesis, University of Sheffield.
Gatignon, H, Tushman, M, L, Smith, W, and Anderson, P., (2002), 'A Structural Approach to Assessing Innovation: Construct Development of Innovation Locus, Type, and Characteristics', *Management Science,* 48, (9), pp. 1103-1122.
Geraghty, T, M., (2003), Technology, Organization and Complementarity: The Factory System in the British Industrial Revolution,' *The Journal of Economic History*, Vol. 63, No. 2, pp. 536-541.
Geroski, P, A., (1989), 'Entry, Innovation and Productivity Growth,' *The Review of Economics and Statistics,* 71, (4), pp. 572-578. Journal of the Textile Institute Proceedings, (1933), 'History of the Northrop Loom', *Journal of the Textile Institute Proceedings,* 24:4, p. 71-72.
Gerring, J., (2006), *Case Study Research: Principles and Practices*, Cambridge University Press, Cambridge.
Gibb, G, S., (1950), *The Saco-Lowell Shops,* Cambridge, Mass. I950, p. 260.
Giles, C, and Goodhall, I, H., (1992), *Yorkshire Textile Mills, The Buildings of the Yorkshire Textile Industry 1770-1930*, HMSO.

Gimpel, J., (1979), *The Medieval Machine*, Tutna Publications.
Glesne, C, and Peshkin, J, R., (1992), *Becoming qualitative researchers: An introduction.* White Plains, NY: Longman.
Goulding, C., (2002), *Grounded Theory: A practical guide for management, business and market researchers*, Sage, London.
Glover, F, G., (1959), *Dewsbury Mills: A history of Messrs., Wormalds and Walker, Blanket Manufacturers, of Dewsbury with an economic survey of the Yorkshire Woollen Cloth Industry in the Nineteenth Century,* PhD thesis, Department of Economics and Commerce, University of Leeds, Leeds.
Godin, B., (2008), 'Innovation: The History of a Category, Montreal: Project of the Intellectual History of Innovation', *Working Paper, No. 1*, p. 26.
Gold, B, Rosseger, G, and Boylan, M, Jr., (1980), *Evaluating Technological Innovations*, Lexington Books, USA.
Gopalakrishnan, S, and Damanpour, F., (1997), 'A review of innovation research in economics, sociology and technology management', *Omega,* Vol. 25, Issue 1, pp. 15-28.
Gospel, H, F., (1991), *Industrial Training and Technological Innovation: A Comparative and Historical Study*, (Editor Gospel, H, F,), Routledge, London.
Gospel, H., (1992), *Markets, Films and the Management of Labour in Modern Britain*, Cambridge University Press, Cambridge.
Gratton, C, and Jones, I., (2009), *Research Methods for Sports Studies*, 2nd edition, London, Routledge.
Green, A, H, Russell, R, Daykyns, J, R, Ward, J, C, Fox Strangeways, C, Dalton, W, H, and Holmes, T, V., (1878), *The Geology of the Yorkshire Coalfield - Memoirs of the Geological Survey*, HMSO.
Grosberg, P., (1963), *The Changing Role of The Textile Engineer, An Inaugural Lecture,* Leeds University Press, pp. 1-14.
Grossman, G, M., and Helpman, E., (1991), *Innovation and Growth in the Global Economy,* Cambridge, MA, The MIT Press.
Grübler, A., (2003), *Technology and Global Change,* Cambridge University Press, p. 40.
Guba, E, G., (1981), 'Criteria for assessing the trustworthiness of naturalistic inquiries', *Educational Communication and Technology Journal,* 29, (2), pp. 75-91.
Gupta, S, D., (2015), 'Comparative Advantage and Competitive Advantage: An Economics Perspective and a Synthesis', *Athens Journal of Business and Economics*, Vol. 1, Issue 1, pp. 9-22.
Gustafsson, J., (2017), *Single case studies vs. multiple case studies: a comparative study,* Halmstad University, Sweden, http://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf.

Habakkuk, H. J., (1962), American and British Technology in the Nineteenth Century: The Search for Labour-Saving Inventions. Cambridge University Press, Cambridge.

Hagiu, A, and Yoffie, D, B., (2013), 'The New Patent Intermediaries: Platforms, Defensive Aggregators, and Super-Aggregators,' *Journal of Economic Perspectives,* 27, (1), pp. 45-65.

Hahn, B., (2020), *Technology in the industrial revolution*, New approaches to the history of science and medicine, (Cambridge: Cambridge University Press, 2020).

Hall, R., (1962), 'The Technical Act, The Changing Technical Act', *Technology and Culture* 3, pp. 501-515.

Hall, P., (1994), *Innovation, economics and evolution: Theoretical perspectives on changing technology in economic systems*, New York: Harvester Wheatsheaf. pp. 1-418.

Hall, B, H., (2004), 'Innovation and Diffusion, Working Paper' 10212, *National Bureau of Economic Research,* Cambridge, USA.

Halton, M, J., (2010), *L. Gardener and Sons Limited: The History of a British Industrial Firm. A Study with Special Reference to Markets, Workplace Industrial Relations, and Manufacturing Engineering Technology, 1955 – 1986,* PhD dissertation, University of Bolton.

Hancock, D, R, Algozzine B, Lim J, H., (2021), Doing case study research: *A practical guide for beginning researches*, Teachers College Press; 4th edition (30 Oct. 2021)

Hann, M, A, and Jackson, K, C., (1981), 'The Economics of Technological Change', *Textile Progress,* Volume 11, Number 3.

Hansard, (1930), HC, Deb 03 December 1930, Vol. 245, cc2297-350, [Online], [Accessed 5th November 2021], available from: https://www.parliament.uk/.

Hanusch, H, and Pyka, A., (2007), Schumpeter, Joseph Alois (1883-1950) in H. Hanusch and A. Pyka (eds.). *Elgar companion to neo-Schumpeterian economics*, Cheltenham: Edward Elgar, pp. 19-26.

Hardill, I., (1990), 'The Recent Restructuring in the British Wool Textile Industry', *Geography*, Vol. 75, No. 3 (July 1990), pp. 203-210.

Harley, K., (2014), '*The legacy of the early start'*, in R. Floud, J. Humphries and P. Johnson, eds., The Cambridge economic history of modern Britain, Vol. II, 1870 to the present (Cambridge, 2014), pp. 1-25.

Harper, C, and McDougall, K., (2012), 'The Very Recent Fall and Rise of Harris Tweed,' (co-author Kirsty McDougall), *Textile: The* Journal *of Cloth and Culture, Volume 10, Issue 1,* 2012, pp. 78–99.

Hattersley and Sons Limited, George., (1908), Publicity material, (West Yorkshire Archives, Bradford).

Hattersley, George., (1934), Letter sent to Raceview Woollen Mill, Ballymena in Northern Ireland on the 9th August, 1934, (West Yorkshire Archives, Bradford).

Hattersley, George., (1936), one-page document, (West Yorkshire Archives, Bradford).

Hattersley Order Books 1900 -1910, (West Yorkshire Archives, Bradford).

Hattersley Order Books 1911-1920, (West Yorkshire Archives, Bradford).

Hattersley Order Books 1921-1929, (West Yorkshire Archives, Bradford).

Hattersley Order Books 1930 -1939, (West Yorkshire Archives, Bradford).

Hattersley, G., (1937), Letter to F.A. Lodge, Stone Bridge Mills, Wortley, Leeds, (April 22nd 1937), (West Yorkshire Archives, Bradford).

Havell, E, B., (1912), - *The Basis for Artistic and Industrial Revival in India*, The Theosophist Society, Adyar, India.

Heaton, H., (1920), *The Yorkshire Woollen and Worsted from the Earliest Times up to the Industrial Revolution*, Oxford, Clarendon Press, Vol. 10.

Helpman, E., (1998), *General Purpose Technologies and Economic Growth*, MIT Press, Cambridge.

Henderson, R. and Clark, K., (1990), 'Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms', Administr*ative Science Quarterly*, 35, pp. 9-30.

Hicks, J, R., (1932), *The Theory of Wages*, McMillan, London.

Hill, C, W, L, and Rothaermel, F, T., (2003), 'The Performance of Incumbent Firms in the Face of Radical Technological Innovation', *The Academy of Management Review,* 28, pp. 257-274.

Hird, W, G., (1876), *The Poetical Works of John Nicholson (the Airedale Poet); carefully from the original editions, with additional notes, and a sketch of his life and writings,* Simpkin, Marshall & Co, Thomas Brear, p. 265.

HMSO., (1993), The Harris Tweed Act 1993, [Internet], http://www.harristweed.org/downloads/HarrisTweedAct.pdf

Hoar, H, M., (1930), *The Coal Industry of the World with Special Reference to International Trade in Coal,* United States, Bureau of Foreign and Domestic Commerce, Trade Promotion Series, No. 105, Washington: U.S.A, pp. 1-328.

Hodgson, J., (1879), *Textile Manufacture and Other Industries,* A. Hey, Keighley, pp. 1 - 276.

Holahan, P, J, Sullivan, Z, Z, and Markham, S, K., (2013), 'Product development as core competence: How formal product development practices differ for radical, more innovative, and incremental product innovations', *Journal of Product Innovation Management*, 31, 2, pp. 329-345.

Holden-Illingworth Letters., (1927), (Isaac Holden to A. Maclaurin, 1832), *Lund Humphries & Company, The Country Press*, Bradford.

Holden, R, N., (2014), 'The Origins of the Power Loom Revisited', *The International Journal for the History of Engineering and Technology,* Vol. 84, No. 2, (July, 2014), pp. 135-159.

Holden, R, N., (2017), *Manufacturing the Cloth of the World Weaving Mills in Lancashire,* Stockport.

Hollings, S, B., (1904), The Wool Comb and the Wool Trade, Textile World Record, Volume XXVIII, October 1904 - March 1905, Lord and Nagle Company, New York, pp. 332-333.
Holme, I., (1988), *A Centenary History of the Dyeing and Finishing Industry West Riding Region,* (editors, C, W, Edwards and R, W, Richardson), The Society of Dyers and Colourists, Perkin House, Bradford.
Honeyman, K, and Goodman, J., (1986), *Technology and Enterprise: Isaac Holden and the Mechanization of Woolcombing in France, 1848-1914*, Pasold Studies in Textile History 6, Scolar Press, Aldershot.
Horsewood, N, Sen, S, Voicu, A., (2010), 'Beggar Thy Neighbour: British Imports During the Inter-War Years and the Effect of the 1932 Tariff,' (presented at the *66th International Atlantic Economic Conference,* Montreal, Canada 9th - 12th 2008 and to the University of Birmingham Economics Department seminar in 2009), Papers 10-31.
Horstmann, I, J, MacDonald, G, and Slivinski, A., (1985),'Patents as Information Transfer Mechanisms: To Patent or (Maybe) Not to Patent', *Journal of Political Economy,* 93, (5), pp. 837–858.
House of Lords, (2019), 'Tariffs: Theory and Practice', *Library Briefing,* (Smith), London.
Howes, A., (2017), *The Relevance of Skills to Innovation during the British Industrial Revolution, 1547-1851*, (unpublished, Brown University).
Hudson, P., (1986), *The Genesis of Industrial Capital: A Study of the West Riding Wool Textile Industry c.1750–1850*, Cambridge University Press, 1986, pp. 1-345.
Hudson, P., (1989), *Regions and Industries: A Perspective on the Industrial Revolution in Britain,* Cambridge University Press.
Hughes, T. E., (1987) 'The Evolution of Large Technological Systems,' in W. E. Bijlcer, T. E Hughes and T. J. Pinch (eds), *The Social Construction of Technological Systems, The MIT Press, Cambridge, MA.*
Hunter, J, (2001), The Islanders and the Orb: The History of the Harris Tweed Industry 1835-1995, Acair Ltd, (17, Nov, 2001)
Hyde, C, K., (1977), *Technological Change and the British Iron Industry, 1700 -1870*, Princeton University Press.
Hyett, N; Kenny, A, and Dickson-Swift, V., (2014), 'Methodology or method? A critical review of qualitative case study reports', *International Journal of Qualitative Studies on Health and Well-being,* 9, (1).
Iammarino, S, and McCann, P., (2016), *Network geographies and geographical networks. co-dependence and co-evolution of multinational enterprises and space,* The New Oxford Handbook of Economic Geography, Oxford University Press, Oxford.
Ibrahim, M., (2012,) *Technological Change***, (**edited by Aurora, A.C, Teixeira), Intech, p. 3.

Irwin, D, A., (1998), 'The Smoot-Hawley Tariff: A Quantitative Assessment', *The Review of Economics and Statistics,* May, 1998, Vol. 80, No. 2 (May, 1998), The MIT Press, pp. 326-334.

Irwin, D, A., (2000), 'Did Late-Nineteenth-Century U.S. Tariffs Promote Infant Industries? Evidence from the Tinplate Industry', *The Journal of Economic History*, Vol. 60, No.2, (June 2000).

Irwin, D, A., (2007), 'Tariff Incidence in America's Gilded Age', *The Journal of Economic History*, (Sept., 2007), Vol. 67, No. 3.

Jacobs, D, and A-P, De Man., (1996), 'Clusters, Industrial Policy and Firm Strategy: A Menu Approach,' *Technology Analysis and Strategic Management*, 8, (4), pp. 425-437.

James, J., (1857), *History of the Worsted Manufacture in England, from the earliest times: with introductory notices of the manufacture among the ancient nations, and during the Middle Ages*, Longman, Brown, Green, Longman & Roberts, London.

James, D, Jowitt, T, and Laybourn, K., (1992), '*The Centennial History of the Independent Labour Party'*, Ryburn Academic Publishing, Halifax, pp.1-376.

Jamison, A., (1989), 'Technology's Theorists: Conceptions of Innovation in Relation to Science and Technology Policy', *Technology and Culture* 30.

Jansen, J, J, P, Bosch, F, A, J, V, D, and Volberda, H, W., (2006), 'Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators', *Management Science,* 52, (11), p. 1661.

Jarvis, P, R., (1947), *A Practical Weaving Course*, Harlequin Press Co Limited, Manchester.

Jenkins, D., (1993), 'Factories and the Industrial Revolution', *Recent Findings of Research in Economics & Social History, (Refresh 16, Spring),* Economic History Society, York.

Jenkins, D., (2003), '*Wool Textiles in the Twentieth Century,*' in David Jenkins (ed.), The Cambridge History of Western Textiles (Cambridge, 2003), pp. 993-1023.

Jenkins, D, T, and Ponting, K. G., (1982), *The British Wool Textile Industry, 1770-1914,* Heinemann Educational Books: Pasold Research Fund, London.

Jewkes, J, Sawers, D, and Stillerman, R., (1958), *The Sources of Invention,* Macmillan, London.

Johnson, S, C., (1913), *A History of Emigration from the United Kingdom to North America 1763-1912*, Studies in Economics and Political Science (edit. Hon, W, Pember Reeves), No. 34 Series of Monographs, George Routledge & Sons Limited, London.

Johnson, G; Scholes, K, and Whittington, R., (2009), *Fundamentals of Strategy*, Prentice Hall, Harlow.

Johnson, S, and Rasulova, S., (2016), 'Qualitative impact evaluation: Incorporating authenticity into the assessment of rigour', *Bath Papers in International Development and Wellbeing, No. 45,* University of Bath, Centre for Development Studies (CDS), Bath.

Johnson, A., (2018), ‘The War to End All Wars on Ideal Female Figures: An Analysis of WWI and its Effects on U.S. Women's Fashion from 1917-1927’, *Ursidae: The Undergraduate Research Journal,* University of Northern Colorado, Volume 7, Number 3.

Jongbo, O, C., (2014), ‘The role of research design in a purpose driven enquiry’, *Review of Public Administration and Management*, Vol. 3, No. 6, December 2014.

Journal of the Textile Institute Proceedings, (1933), ‘History of the Northrop Loom’, *Journal of the Textile Institute Proceedings,* 24:4, P71-P72.

Jowitt, J, A., (1989), ‘A Town Built on Cloth: The Making of ‘Worstedopolis’, *Costume,* Vol. 23, 1, pp. 86-97.

Jowitt, J, A., (1991), ‘Textiles and Society in Bradford and Lawrence, USA, 1880-1920’, Volume 5, of the third series of *The Bradford Antiquary***,** The journal of the Bradford Historical and Antiquarian Society, pp. 3-24.

Jowitt, J, A, and McIvor, A, J., (1998), *Employers and Labour in the English Textile Industries 1850-1939*, Routledge, London.

Kaluzny, A. D, Veney, J, E, and Gentry, J, T., (1972), ‘Innovation in health services: A comparative study of Hospitals and Health Departments,’ *Paper presented at the University of North Carolina Health Services Symposium, Innovation in Health Care Organizations*, Chapel Hill, N.C., May 18-19, 1972.

Katz, M, L., and C. Shapiro (1987), ‘R&D rivalry with licensing and imitation’, *American Economic Review,* 77 (3).

Kaur, K, and Kaur, M., (2010), ‘Innovation Diffusion and Adoption Models: Foundation and Conceptual Framework’, *Management and Labour Studies,* Vol. 35, No. 2, May 2010.

Keighley, M., (1989), *A Fabric Huge: The Story of Listers,* James and James, London.

Keighley, M., (2007), *Wool City: A History of the Bradford Textile industry in the 20th Century,* Whitaker & Co, pp. 1-288.

Keighley, M., (2010), (personal correspondence to author, 30/ 11/ 2010).

Kent, M. L., (2007), *The British Enlightenment and the Spirit of the Industrial Revolution: The Society for the Encouragement of Arts, Manufactures and Commerce (1754-1815),* University of California, pp.1-576.

Kertemelidou, P., (2018), *Exhibiting an everyday industrial object in the museum: the case of Thonet No. 14 chair*, Museum Management and Curatorship, 2018, Vol. 33, No. 2., Routledge, pp. 136-145.

Ketels, C, H, M, and Memedovic, O., (2008), ‘From clusters to cluster-based economic development’, *Int. J. Technological Learning, Innovation and Development,* Vol. 1, No. 3, 2008.

Khadka, K, & Maharjan, S., (2017), *Customer Satisfaction and Customer Loyalty*, Centria University of Applied Sciences.

Killick, H, F., (1905), *The Story of Lord Masham's Combing Machine with a note on the processing of Hand Combing by Mr. J. Brigg M.P.*, reprinted from the Yorkshire Daily Observer, William Byles & Sons, Bradford.

Kim-Keung Ho, J., (2014), Formulation of a Systemic PEST Analysis for Strategic Analysis, *European academic research*, Vol. II, Issue 5, 2014, pp. 6478-6492.

Kim, Y, and Zhang, P., (2015), 'Understanding data sharing behaviours of STEM researchers: The roles of attitudes, norms, and data repositories', *Library Information Science Research,* (2015), 37, (3), pp. 189-200, Available from: http://dx. doi.org/10.1016/j.lisr.2015.04.006.

Kindleberger, C, P., (1951), 'Group behaviour and international trade' *Journal of Political Economy*, Vol. 59, No. 1 (February), pp. 30-46.

Kindleberger, C, P., (1974), 'An American Economic Climacteric?' *Challenge,* Vol. 16, No. 6, Taylor & Francis, Limited, pp. 35-44.

Kirk, J, and Miller, M., (1986), *Reliability and validity in qualitative research,* Beverly Hills, CA, Sage.

Kitson, M., (2012), *End of an Epoch: Britain's Withdrawal from the Gold Standard,* Judge Business School, University of Cambridge, (June 2012).

Kitson, M., (2013), *Britain's withdrawal from the gold standard: the end of an epoch,* in R. Parker and R Whaples (eds), Handbook of Major Events in Economic History, London, Palgrave.

Kitson, M, and Michie, J., (1993), 'Coordinated Deflation: The Tale of Two Recessions', *Full Employment Forum.*

Kitson, M and Michie, J., (2014), 'The De-Industrial Revolution: The Rise and Fall of UK Manufacturing, 1870-2010', *Centre for Business Research, University of Cambridge Working Paper, No. 459, (*This working paper forms part of the CBR research programme on Enterprise and Innovation).

Kivunja, C, and Kuyini, A, B., (2017), 'Understanding and Applying Research Paradigms in Educational Contexts', *International Journal of Higher Education,6,* (5).

Kline, S. J. and Rosenberg, N., (1986), *An overview of innovation. The Positive Sum Strategy: Harnessing Technology for Economic Growth*. R. Landau and N. R. (Eds), Washington, DC, National Academy Press, pp. 275-305.

Knight, G, A., (2001), 'Entrepreneurship and strategy in the international SMEs,' *Journal of International Management,* 7, pp. 155–171.

Koditschek, T., (2016), *Class Formation and Urban Industrial Society: Bradford, 1750-1850,* Cambridge University Press.

Kothari, C.R., (2004), *Research Methodology — Methods and Techniques*, 2nd Edition, New Age, New Delphi, India.

Kotler, P., (1998), *Marketing management - Analysis, planning, implementation, and control* (9th ed.), Englewood Cliffs, Prentice-Hall.

Kotter, P., (1994), *Marketing management,* (8th, ed.), Upper Saddle River, NJ, Prentice Hall.

Kravis, I, B., (1956), 'Availability' and Other Influences on the Commodity Composition of Trade, '*Journal of Political Economy*, February 1956, pp. 143-155.

Krugman, P., (1991), *Geography and Trade*, Leuven University Press and MIT Press.

Küegler, A., (2016), 'The Responsiveness of Inventing: Evidence from a Patent Fee Reform', *Cambridge University Working Paper*, Cambridge, pp. 1-46.

Kuznet, S., (1962), *The Rate and Direction of Inventive Activity* (Report of the National Bureau of Economic Research, New York), Princeton University Press, Princeton N.J, U.S.A.

Labour Leader., (1905), 'Automatic Loom', *A Weekly Journal of Socialism, Trade Unionism and Politics,* No. 42, Jan 20th, 1905, p. 1.

Lan, W, and Zhangliu, W., (2012), '*Lecture Notes in Electrical Engineering,* Vol. 144 Springer, Berlin, Heidelberg.

Landes, D, S., (1969), *The Unbound Prometheus Technological change and industrial development in Western Europe from 1750 to the present*, Cambridge University Press, p. 78.

Langley, A; Smallman, C; Tsoukas, H, and Ven, A. H. V. De., (2013), 'Process studies of change in organization and management: unveiling temporality, activity, and flow', *Academy of Management Journal*, *56,* (1), pp. 1–13.

Law, J., (2006), *Oxford Dictionary of Business and Management,* (ed. J. Law), 4th ed., Oxford University Press, New York.

Laybourn, K., (1976), 'The Manningham Mill Strike' *in The Bradford Antiquary New Series - Part XLVI October 1976, The Journal of the Bradford Historical and Antiquarian Society,* Bradford, pp. 1-64.

Lazonick, W., (1979), 'Industrial Relations and Technical Change: The Case of the Self-Acting Mule,' *Cambridge Journal of Economics,* 3, p. 257.

Le Moniteur Universel (1827), 15th August 1827, p. 1202.

Leedy, P, and Ormrod, J., (2001), *Practical research: Planning and design*, (7thed.), Upper Saddle River, NJ, Merrill Prentice Hall, Thousand Oaks, Sage.

Leibovitz, J, S., (2002), 'Inventing a Nonexclusive Patent System',
The Yale Law Journal, Vol. 111, No. 8, pp. 2251-2287.

Leifer, R, McDermott, C, M, O'Connor, G, C, Peters, L, S, Rice, M, P, and Veyzer, R, W., (2000), *Radical Innovation How Mature Companies Can Outsmart Upstarts*, Harvard Business School Press, Boston, Massachusetts.

Lerner, J., (2002), '150 Years of Patent Protection,' *American Economic Review Papers and Proceedings* 92, No. 2, pp. 221–225.

Letters patent specification, McFarland, P., (1857), Cop-Changing Pat. No. 1046, (13th April 1857), George E. Eyre and William Spottiswoode, London.

Letters patent specification., (1900), 'Messrs. Hattersley and Sons Limited., (1900), Weft-replenishing mechanism, Pat. No. 22, 523', *George E. Eyre and William Spottiswoode,* London.

Letters patent specification., (1834)., 'Reid, J, P, and Johnson, T., (1834), Shuttle-changing, Pat. No. 6579,' *George E. Eyre and William Spottiswoode,* London.

Lewis, W, A., (1957), 'International competition in manufactures', *American Economic Review*, Vol. 47, No. 2, pp. 578-587.

Lidchi, H., (1997), *The Poetics and the Politics of Exhibiting Other Cultures,* In Representation: Cultural Representations and Signifying Practices, edited by S. Hall, London: Sage Publications, pp. 151–222.

Lincoln, Y, S, and Guba, E, G., (1985), *Naturalistic Inquiry*, Beverly Hills, Sage.

Lind, M., (1994), 'The Op-Ed History of America,' *The National Interest 37,* (Fall 1994), pp. 16-28.

Lines, T, and Monypenny, R, (2006), Industrial Clustering, In Charters, K, and Prasser, S, (eds, '*Proceedings Sustainable Economic Growth for Regional Australia, National Conference SEGRA 2006*,' Launceston, August 28-30, 2006.

Lipson, E., (1921), *The History of the English Woollen and Worsted Industries*, A & C Black, London.

Lloyd Prichard, M, F., (1951), 'The Decline of Norwich', *The Economic History Review New Series*, Vol. 3, No. 3 (1951), pp. 371-377.

Lobban, M., (2014), 'Special issue the Great War and private law: Introduction,' *Comparative Legal History*, 2, (2), pp. 163-183.

Lund's Bradford Directory., (1856), J. And C. Lund, Bradford.

Lundvall, B. Å., (1992), *Introduction*, *in Lundvall, B.-Å, (ed.), National Systems of Innovation,* Pinter Publishers, London, pp. 1-19.

Lundvall, B, and Johnson, B., (1994), 'The Learning Economy' *Journal of Industry Studies*, Vol. 1, pp. 23-42.

MacDougall, D., (1957), *The World Dollar Problem,* London: Macmillan.

MacLeod, C., (1992), 'Strategies for Innovation: The Diffusion of New Technology in Nineteenth-Century British Industry', *The Economic History Review*, New Series, Vol. 45, No. 2.

MacLeod, C, and Nuvolari, A., (2010), 'An Historical Overview of the British Case, 1624-1907', *A Report to the Strategic Advisory Board for Intellectual Property Policy (SABIP),* SSRN Electronic Journal.

Magee, G. B., (2004), *Manufacturing and technological change*, in R. Floud and P. Johnson (eds), The Cambridge Economic History of Modern Britain. Volume II: Economic Maturity, Cambridge, Cambridge University Press, pp. 74-98.

Maillat, D., (1998), ``Innovative milieux and new generations of regional policies,'' *Entrepreneurship and Regional Development,* 10 pp. 1-16.

Mainwaring, T, and Wood, S., (1985), 'The Ghost in the Labour Process', in Knights, D, Willmott, H, and Collinson, D., *Job Redesign,* Gower, Aldershot.

Makani, J., (2015), ‘Knowledge management, research data management and university scholarship’, *Vine*, 45, (3), pp. 344-359.
Malerba, F, and Orsenigo, L., (1997), ‘Technological regimes and sectoral patterns of innovative activities’ *Industrial and corporate change,* 6, (1), pp. 83-118.
Manchlup, F., (1962), *The Production and Distribution of Knowledge in the United States,* Princeton, Princeton University Press.
Mandich, G., (1948),’Venetian Patents (1450-1550)’, *Journal of the Patent Office Society*, 30, 3.
Mansfield, E, Rapoport, J. Schnee, J, Wagner, S, and Hamburger, M., (1971), Research *and Innovation in the Modern Corporation,* 166, Norton & Co, New York.
Mansfield, E, Schwartz, M, and Wagner, S., (1981), ‘Imitation Costs and Patents: An Empirical Study.’ *Economic. Journal,* Vol. 91, No. 364, (December 1981), pp. 907-918.
Mansfield, E., (1972), ‘Contributions of R & D to Economic Growth in the United States’, *Science,* 166, pp. 477 – 486.
Mansfield, E., (1986), ‘Patents and Innovation: An outline of the beginnings of the modern factory system in England. Empirical Study,’ *Management Science*, Vol. 32, No. 2, pp. 173-181.
Maoz, Z., (2002), *Case study methodology in international studies: from storytelling to hypothesis testing. In F. P. Harvey and M. Brecher (eds), Evaluating Methodology in International Studies*, University of Michigan Press, Ann Arbor.
Mantoux, P., (1961), *The Industrial Revolution in the Eighteenth Century; an outline of the beginnings of the modern factory system in England*, Cape, pp.1-528.
Marks, G, C., (M.P)., (1919), ‘British Patent Law’, *Journal of the Textile Institute Proceedings and Abstracts,*10, 12, pp. 348-353.
Marshall, A., (1898), *Principles of Economics*, 8th edition, New York, Macmillan.
Marshall, A., (1919), *Industry and Trade,* MacMillan, London.
Marshall, A., (1920), *Principles of Economics*, MacMillan, London 8th edition.
Marshall, A., (1961), *Principles of Economics: An Introductory Volume,* 9th (variorum) ed., Macmillan, London.
Marshall, C, and Rossman, G, B., (1999), *Designing qualitative research,* (3rd ed.), Thousand Oaks, CA, Sage.
Martin, R, and Sunley, P., (2003), ‘Deconstructing clusters: chaotic concept or policy panacea? *Journal Economic Geography*, 3, (1), pp. 5–35.
Marx, K., (1976), *Capital*, Vol. 1. (translated Ben Fowkes), Penguin, London.
Mason, O, T., (1895), *The Origins of Invention: A Study of Industry Among Primitive People*, Cambridge (Mass), MIT Press.
Mass, W., (1933), ‘History of the Northrop Loom’, *Journal of the Textile Institute Proceedings*, 24:4, pp. 71-72.

Mass, W., (1990), ‘The Decline of a Technological leader: Capability, Strategy, and Shuttlelesss Weaving, 1945-1974’, *Business and Economic History*, Second Series, Vol. 19, I, pp. 234-244.

Mass, W. and Lazonick. W., (1990), ‘The British Cotton Industry and International Competitive Advantage: The State of the Debates', *Business History,* XXXII, pp. 9—65.

Mass, W., (1989), ‘Mechanical and Organizational Innovation: The Drapers and the Automatic Loom,’ *The Business History Review*, Vol. 63, No. 4 (Winter, 1989), pp. 876-929.

Mathias, P., (1969), *The First Industrial Nation: An Economic History of Britain 1700-1914*, Methuen, London.

Mayhall, J., (1860), *The Annals of Yorkshire from the Earliest Time to The Present Time,* Joseph Johnson, Leeds.

McManus, J, Li, M, and Moitra, D., (2007), *China and India: opportunities and threats forth global software industry*, Oxford: Chandos Publishing.

Mellor, I., (2005), *Society and the Textile Mill c. 1780-1939,* PhD thesis, Department of Archaeology, University of York, (Sept 2005).

Merriam, S. B., (1998), *Qualitative research and case study applications in education*, San Francisco, CA, Jossey-Bass.

Merton, R, K., (1935), ‘Fluctuations in the Rate of Industrial Invention’, *The Quarterly Journal of Economics,* Vol. 49, No. 3 (May, 1935), Oxford University Press.

Midgley, E., (1932), *Technical Terms in the Textile Trade: Vol. II General Terms,* Emmott & Co, Manchester & London, pp. 1-259.

Miles, M, B, and Huberman, A, M., (1984), *Qualitative Data Analysis: A source book of new methods,* Newbury Park and London: Sage.

Miles, M, B, and Huberman, A, M., (1994), *Qualitative data analysis: An expanded source book,* (2nd ed.), Thousand Oaks, CA, Sage.

Mintzberg, H., (2005), *Developing Theory about the Development of Theory,* Oxford, Oxford University Press.

Mishler, E, G., (1990), ‘Validation in inquiry-guided research: the role of exemplars in narrative studies’, *Harvard Education Review,* 60, pp. 415-442.

Molander, B., (1996), *Knowledge in action,* Gothenburg: Daidalos, pp. 1-286.

Morse, J, M; Barrett, Mayan, M, Olson, K, and Spiers, J., (2002), ‘Verification strategies for establishing reliability and validity in qualitative research’, *International Journal Qualitative Methods*, pp.13-22.

Moser, P., (2013) ‘Patents and Innovation: Evidence from Economic History,’ *Journal of Economic Perspectives,* Vol. 27, Number 1, Winter 2013, pp. 23–44.

Moser, P., (2016), ‘Patents and Innovation in Economic History’, *Leonard N. Stern School of Business - Department of Economics, National Bureau of Economic Research, (NBER).*

Moykr, J., (1990), *The Lever of Riches: Technological Creativity and Economic Progress,* Oxford: Oxford University Press, p. 13.

Moykr, J., (1998), *The Second Industrial Revolution, 1870-1914*, Parts of this chapter are based his book The Lever of Riches: Technological Creativity and Economic Progress (1990), Oxford University Press, p. 1.

Moykr, J., (1999), *The Second Industrial Revolution, 1870-1914,* based on his book *The Lever of Riches Technological Creativity and Economic Progress,* New York, Oxford University Press.

Mokyr, J., (2000), 'The Rise and Fall of the Factory System: Technology, firms, and households since the Industrial Revolution', *Prepared for the Carnegie-Rochester Conference on Macroeconomics,* Pittsburgh, Nov. 17-19, 2000.

Mokyr, J., (2002), *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton: Princeton University Press.

Mukherji, P, and Albon, D., (2015), *Research Methods in Early Childhood. An Introductory Guide,* (2nd ed.), Sage, London.

Mukoyama, T., (2003), 'A Theory of Technology Diffusion', Concordia University and CIREQ, Department of Economics, available at http://129.3.20.41/eps/mac/paper/0303/0303020.pdf. [26. 07. 2012].

Nasmith, F., (1928), 'Foreign Competition and New Machinery', *The Textile Manufacturer,* Oct 28th, 1928, p. 535.

Nelson, R, R., (1992), *National innovation systems: A retrospective on a study*, Industrial and Corporate Change 1, (2) pp. 347-374.

Niiniluoto, I., (1993), 'The aim and structure of applied research', *Erkenntnis,* 38, pp. 1–21.

Nwokah, N, G, Ahiauzu, A, I., (2008),'Managerial competencies and marketing effectiveness in corporate organizations in Nigeria', *Journal of Management Development*, Vol. 27, No. 8, pp. 858-878.

O'Bryan, M., (2016), 'Innovation: The Most Important and Overused Word in America', (Nov 2013), *Wired Magazine.*

OECD, (1992), *Technology and the economy: the key relationship*, Paris.

OECD., (2005), *Oslo Manual: guidelines for collecting and interpreting innovation data,* Paris: OECD and Eurostat.

Oldfield, T, H, B., (1792), *An Entire and Complete History, political and personal, of the boroughs of Great Britain to which is prefixed, an original sketch of constitutional rights, from the earliest period until the present time*, G Riley, ii, London.

O'Rouke, K, H., (2000), "Tariffs and Growth in the Late Century", *The Economic Journal,* Royal Economic Society, Blackwell, pp. 456-483.

Orsenigo, L, and Sterzi, V., (2010), 'Comparative Study of the Use of Patents in Different Industries', Kites 33 (Knowledge, Internationalization and Technology Studies, Università Bocconi, pp.1-31.

Oxtoby, R., (1987), *Spun Yarn Technology,* Butterworths & Co, Ltd, London.

Ozcan, P; Han, S, and Graebner, M, E., (2017), *Single Cases: The What, Why, and How*, In R. Mir and S. Jain (Eds), from The Routledge Companion to Qualitative Research in Organization Studies, Routledge, Abingdon, UK, pp. 92-112.

Pacione, M., (2009), *Urban geography: A global perspective*, New York: Routledge.

Palen, M-W., (2017), *The Conspiracy of Free Trade: The Anglo-American Struggle over Empire and Economic Globalization, 1846–1896* (Cambridge, UK: Cambridge University Press, 2017), xi, pp. 1-333.

Paliokaite, A., (2019), 'An innovation policy framework for upgrading firm absorptive capacities in the context of catching-up economies', *Journal of Entrepreneurship, Management and Innovation*, 15, (3), pp. 103-130.

Palmer, R, R, and Armitage, D., (2014), *The Age of the Democratic Revolution: A Political History of Europe and America, 1760-1800*, Princeton University Press.

Papadimitriou, D., (1996), *Stability in the Financial System,* James Levy Economics Institute, Springer, pp. 1-441.

Paris, J, A., (1831), *The life of Sir Humphrey Davy, Bart*, Colburn and Bently, Oxford University Press May 2006), pp. 1-547.

Parsonage, A, C., (1973), '*An Economic And Technological Study Of The Competition Between Knitting And Weaving In the United Kingdom Textile Industry,*' PhD thesis, University of Surrey.

Pawson, E., (1977), *Transport and Economy. The Turnpike Roads of Eighteenth Century Britain,* 76, New York: Academic Press, p. II8.

Penfield, T; Baker, M, J; Scoble, R, and Wykes, M, C., (2014), 'Assessment, evaluations, and definitions of research impact: A review', *Research Evaluation,* 23, pp. 21–32.

Peng, G, C, A, and Nunes, M, B., (2007), 'Using *PEST* analysis as a tool for refining and focusing Contexts for Information Systems Research', *In ECRM 2007, 6th European Conference on Research Methodology for Business and Management Studies*, 9th-10th July 2007, Academics Conference International, Portugal, pp. 229-236.

Phillips, M, and Taylor, B., (1980), 'Sex and Skill: Notes Towards a Feminist Economics', *Feminist Review*, No. 6, (1).

Pigou, A. C., (1924), *The Economics of Welfare,* Second Edition, McMillan, London.

Piore, M, Sabel, C., (1984), *The second industrial divide: Possibilities for prosperity*, Basic Books, New York.

Platt, D, C, M., (1993), *Trade competition in the regions of recent settlement,* in D. C. M, Platt, (ed), *Decline and recovery in Britain's overseas trade, 1873-1914, (*London), pp. 91-138.

Polanyi, M., (1958), *Personal Knowledge: Towards a Post-Critical Philosophy*, University of Chicago Press, Chicago.

Pollard, S., (1998), *Political competition and the British Industrial Revolution,* in: Bernholz, P., Streit, M.E., Vaubel, R., (eds), Political Competition, Innovation and Growth. Springer, Berlin, Heidelberg.

Ponzurick, T, G., (1996), 'International buyer's perspective toward trade shows and other promotional methods', *Journal of Marketing Theory & Practice,* Vol. 4, No. 1, pp. 9-19.

Porter, M, E., (1985), *Competitive advantage: creating and sustaining superior performance,* New York: Free Press.

Porter, M., (1990), *The Competitive Advantage of Nations*, Macmillan, London.

Porter, M, E., (1998), 'Clusters and the New Economics of Competition' *Harvard Business Review, Boston*, 76, No. 6 (November-December 1998), pp. 77-90.

Porter, M, E., (2000), 'Location, competition, and economic development: Local clusters in a global economy,' *Economic Development Quarterly,* 14, (1), pp. 15-34.

Porter, M, E., (2003), *Locations, Clusters and Company Strategy* in Clark, G, Feldman, M, and Gertler, M, (Eds), The Oxford Handbook of Economic Geography, Oxford University Press.

Porter, M, E., (2011), *The Competitive Advantage of Nations: Creating and sustaining Superior Performance*, Simon and Schuster, pp. 1 - 896.

Post Office Bradford Directory., (1912), *Comprising the City of Bradford,* W. Byles & Sons, Hall Ings, Bradford.

Pourdeyhimi, B, Jackson, K, C, and Hepworth, K., (1985), *The Development of Weaving Using Automatic Looms*, Ars Textrina, 4, pp. 107-204.

Pourdeyhimi, B, and Jackson, K, C., (1986), *A Note on the Diffusion of the Automatic Weaving within the British Cotton Industry*, Ars Textrina, 6, pp. 101-118.

Powell, Rev, L, F., (1971), *J, Boswell, The Life of Johnson,* ed. G, B, Hill, 6 Volumes, Oxford: Clarendon Press, 1934; rept. 1971, IV, p. 188.

Prince-Smith & Stells Limited, (1954), The Raper Drawing System and The Raper Autoleveller, Publication No. 104).

Puckey, W., (1960), 'Management in the Second Industrial Revolution', *The Jubilee Conference of the Textile Institute,* Vol. 51, No. 8, August 1960, Proceedings, P371-P543 London, Manchester, England.

Pyke, F, and Sengenberger, W., (1992), 'Introduction, in F. Pyke, G. Becattini and W. Sengenberger (eds.), Industrial Districts and Inter-Firm Co-Operation in Italy', *International Institute for Labour Studies*, Geneva, pp. 1-9.

Raistrick, A., (1893), *The Century's Progress: Yorkshire Industry and Commerce,* (Jan. 1971), Brenton Publishing, Reprint edition.

Rastogi, N and Trivedi, M, K., (2016), 'Pestle Technique - A Tool To Identify External Risks In Construction Projects', International Research Journal of Engineering and Technology (IRJET)', Volume: 03, Issue 01.

Raynor, M, E., (2011), *The Innovator's Manifesto: Deliberate Disruption for Transformational Growth*, New York, Crown Business, USA.

Rebolj, A. B., (2013), 'The case study as a type of qualitative research', *Journal of Contemporary Educational Studies*, pp. 28-43.

Reichmann, J, H., (1994), 'Legal Hybrids between the Patent and Copyright Paradigm', *Columbia Law Review,* 94.

Renner, G, T., (1947), 'Geography of Industrial Localization,' *Economic Geography*, Jul. 1947, Vol. 23, No. 3 (Jul. 1947).

Report of the Select Committee on Coal in the U.K., (1871), Vol. III, Appendix 27, Luke Hansard & Co, London, p. 211.

Report from the *Select Committee on the Arts and their Connections with Manufacturers* (1836), Luke Hansard & Co, London.

Ravenstein, E, G., (1985), 'The Laws of Migration', *Journal of the Statistical Society*, Volume 48, Issue 2, June 1885, pp. 167-227.

Reynolds, J, and Laybourn, K., (1975), 'The Emergence of the Independent Labour Party in Bradford', *International Review of Social History,* 20/3.

Rhodes, J., (1911), *Keighley Industrial Cooperative Society Limited, 1860-1910, Jubilee History,* Society by the Co-operative Wholesale Society Limited, Manchester.

Rice, G., (1992), 'Using the interaction approach to understand international trade shows', *International Marketing Review,* Vol. 9, No. 4, pp. 32-45.

Rice, G, and Almossawi, M., (2002), 'A study of exhibitor firms at an Arabian Gulf trade show: goals, selection criteria and perceived problems', *The Journal of Global Marketing,* Vol. 15, No. 3.

Richardson, C., (1968), 'Irish Settlement in Mid-Nineteenth Century Bradford', *Yorkshire Bulletin of Economic and Social Research*, Vol. 20, (1).

Richardson, C., (1976), *A Geography of Bradford*, University of Bradford, Bradford, pp.1–202.

Richardson, C., (2002), *The Bradford Region Studies in its Human Geography*, Bradford Libraries Archives and Information Services, Bradford, pp. 1-182.

Ridder, H-G., (2017), 'The theory contribution of case study research designs,' *Business Research*, 10, pp. 282-305.

Ritortus., (1899), 'The Imperialism of British Trade - 11', *Contemporary Review*, 76, pp. 282 - 304.

Roberts, T., (1936), *Tappet and Dobby Looms: Their Mechanism and Management,* Emmott & Co, Manchester, 3rd edition, pp. 1-220.

Roberts, B, H, and Enright, M, J., (2004), 'Industry Clusters in Australia: Recent Trends and Prospects,' *European Planning Studies,* Vol, 12, No. 1.

Robinson, J., (1938), 'The Classification of Inventions', *Review of Economic Studies,* February, pp. 139-142.

Rogers, E, M, and Kincaid, D, L., (1981), *Communication Networks. Toward a New Paradigm for Research*, Free Press New York/London.

Rogers, E, M., (1983), *Diffusion of Innovations*, 3th ed, Free Press, New York, NY, USA.

Rogers, E, M., (2003), *Diffusion of Innovations*, (5^{th} edition), Free Press, New York, USA.

Roland, A., (1977), 'Problems of Definition', *Technology and Culture*, Detroit, Mich, p. 509.

Romer, P, M., (1990), 'Endogenous Technological Change.' *Journal of Political Economy,* 98, No. 5, pp. 71-102.

Rooth, T., (1993), *British Protectionism and the International Economy: Overseas Commercial Policy in the 1930s,* Cambridge University Press, pp. 1-376.

Rose, M, B., (1991), *International Competition and Strategic Response in the Textile Industries Since 1870*, Routledge.

Rosegger, G., (1996), *The Economics of Production and Innovation: An Industrial Perspective,* 3rd Edition, Butterworth-Heinemann.

Rosenberg N., (1972), *Technology and American Economic Growth,* White Plains, NY, M. E. Sharpe, 1972.

Rosenberg, N., (1992), *Technology and the Wealth of Nations,* (Contributors: Ralph Landau and David C. Mowery), Stanford University, Stanford, CA.

Rosenberg, N., (1994), *Exploring the Black Box: Technology, Economics and History.* Cambridge: Cambridge University Press.

Ross, L, F., (2008), *So you want to be a strategic leader: Here are the essentials to get you started,* Xlibris Corporation.

Rostow, W, W., (1960), *The Stages of Economic Growth, A Non-Communist Manifesto,* Cambridge University Press, pp. 1-179.

Rothwell, R., (1992), 'Developments towards the fifth generation model of innovation', *Technology Analysis & Strategic Management*, 4:1, pp. 73-75.

Rothwell, R., (1994), 'Towards the fifth-generation innovation process', *International Marketing Review*, 11*,* (1), pp. 7–31.

Rule, J., (1987), *The Property of Skill in the Period of Manufacture*, in The Historical Meanings of Work, ed. Patrick Joyce, (Cambridge, 1987), p. 99.

Sahal, D., (1981), 'Alternative Conception of Technology', *Research Policy,* 10, pp.2-24.

Sako, M., (1998), *'Does trust improve business performance?' in Trust Within and Between Organizations,'* Editors L, Christel, R, Backmann, (Oxford University Press, Oxford).

Sammut-Bonnici, T, and Galea, D., (2015), *PEST analysis*, Wiley Encyclopedia of Management, Vol. 12, Strategic Management, John Wiley & Sons, Ltd.

Sandberg, B., (2011), *Managing and Marketing Radical Innovations*, New York, Routledge.

Sanderson, M., (1993), 'Education and the Economy 1870-1939'*, ReFresh, Autumn 17, (1993), Research in Economics and Social History.*

Sarkar, J., (1998), 'Technological Diffusion: Alternative Theories and Historical Evidence', *Journal of Economic Surveys*, Vol. 12, issue 2, pp. 131-
76.
Saunders, M; Lewis, P, and Thornhill, A., (2007), *Research Methods for Business Students*, 4th edition, Pearson Education Limited.
Saunders, M, Lewis, P, and Thornhill, A., (2009), Research Methods for Business (5th edition), Harlow. Pearson education, England.
Scandura, T, A, and Williams, E, A., (2000), 'Research methodology in management: current practices, trends, and implications for future research', *Academy of Management Journal*, 43, (6), pp. 1248-1264.
Scherer, F, M., (1984), *Innovation and Growth: Schumpeterian Perspectives*, Cambridge, MA, MIT Press.
Schiele, H., (2008), 'Location, location: The geography of industry clusters', *Journal of Business Strategy,* May 2008, Vol. 29, Issue 3.
Schlote, W., (1952), *British overseas trade from 1700 to the 1930s,* trans., W. O. Henderson and W. H., Chaloner, Oxford, 1952.
Schmookler, J., (1966), 'Invention and Economic Growth', *Harvard Business Review*, Cambridge, Massachusetts.
Schramm, W., (1971), 'Notes on case studies for instructional media projects', *Working paper for Academy of Educational Development,* Washington DC.
Schulze-Gaevernitz, von, G., (1893), *Social Peace: A Study of the Trade Union Movement in England*, London.
Schumpeter, J, A., (1934), *The theory of economic development – An inquiry into profits, capital, credit, interest, and the business cycle*, Cambridge, MA: Harvard University Press, (rpt, New Brunswick: Transaction, 1983).
Schumpeter, J, A., (1939), *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, Vol. 1, New York, McGrew-Hill.
Schumpeter, J.A., (1947), 'The creative response in economic history', *Journal of Economic History*, 7, pp. 149-159.
Scotch Tweed., (1925), February, No. 6. Vol. II, p.186.
Sechrest, L, and Sidani, S., (1995), 'Quantitative and qualitative methods: Is there an alternative?' *Evaluation and Program Planning, 18,* (1), pp. 77–87.
Sell, S., (2004), 'Intellectual Property and Public Policy in Historical Perspective: Contestation and Settlement', *Loyola of Los Angeles Law Review,* Vol. 38, Los Angles, USA, pp. 267-321.
Shafaeddin, M., (1998), 'How did developed Countries industrialize? The History of Trade and Industrial Policy: The Case of Great Britain and the USA', No. 139, *Development Studies Association Annual Conference,* September 1996, University of Reading, (December 1998), UK.

Shapin, S., (1994), *A Social History of Truth: Civility and Science in Seventeenth-Century England*, University of Chicago, Chicago, USA.

Sharp, K., (1998), 'The Case for Case Studies in Nursing Research: The Problem with Generalization', *Journal of Advanced Nursing,* 27, pp. 785-789.

Shin, H, B., (2017), *Geography: Rethinking the 'Urban' and Urbanization,* in: Iossifova, D, Doll, C. and Gasparatos, A., (eds.), Defining the Urban: Interdisciplinary and Professional Perspectives, London: Routledge.

Siggelkow, N., (2007), 'Persuasion with case studies', *Academy of Management Journal*, 50, (1), pp. 20-24.

Sigsworth, E, M., (1958), *Black Dyke Mills: A History,* Liverpool University Press.

Sigsworth, E, M, and Blackman, J, M., (1968), 'The Woollen and Worsted Industries', In *The Development of British Industry and Foreign Competition 1875 -1914*, *Studies in Industrial Enterprise* edited by Aldcroft, D, H., George Allen & Unwin, pp. 128 - 157.

Silverman, D., (2005), *Doing qualitative research*, Sage, London.

Silverman, D., (2006), *Interpreting qualitative data*, Sage, London.

Simmie. J., (2004), 'Innovation and Clustering in the Globalised International Economy', *Urban Studies,* Vol.41, Nos 5/6, pp. 1095-1112.

Simons, H., (2009), *Case study research in practice*, London SAGE.

Skrabec, Q, R., (2008), *William McKinley, Apostle of Protectionism,* Algora Publishing, pp. 1- 269.

Slocum, A, and Rubin, E, S., (2008), 'Understanding Radical Technology, Innovation and the Application to CO2 Capture R & D': *Interim Report, Volume 1: Interim Report - Literature Review*, Department of Engineering and Public Policy, Paper 66, Carnegie Mellon University, Pittsburgh, USA.

Smith, A., (1811), *An Inquiry into the Nature and Causes of the Wealth of Nations*, Book iv, v, James Decker, Paris, pp. 247–48.

Smith, W., (1953), 'The Location of Manufacturing Industry in Great Britain'*, The Town Planning Review, (April, 1950),* Vol. 21*,* No. 1.

Smith, W., (1953), *An Economic Geography of Great Britain,* Methuen, London, p. 78.

Snow, C, E., (1931), '*Emigration from Great Britain'*, (W. F. Willcox, editor) International Migrations, NBER.

Snowden, J, K., (1896), *The Web of an Old Weaver*, Sampson Low, Marston and Company, p. 66.

Soete, L., (1985), 'International diffusion of technology, industrial development and technological leapfrogging', *World Development*, 13, (13), pp. 409-422.

Solberg Søilen, K, and Huber, S., (2006), '20 Swedish case studies for small and medium-sized companies', *Pedagogy and scientific method,* Lund: Studentlitteratur.

Southern, J., (2016), *Cotton and the Community: Exploring Changing Concepts of Identity and Community on Lancashire's Cotton Frontier c1890-1950,* PhD thesis, School of Education and Social Science, University of Central Lancashire.
Souvenir of Low Moor Iron Works 1791 to 1906., (1906), Souvenir of Low Moor Iron Works 1791 to 1906*,* W.H. Brocklehurst, pp. 1-158.
St. John, C, H, and Pouder, R, W., (2006), 'Technology Clusters versus Industry Clusters: Resources', *Networks, and Regional Advantages*, Growth and Change, 37, pp. 141-171.
Stake, R. E., (1995), *The Art of Case Study Research*, Thousand Oaks, CA, Sage.
Stanwood, E., (1903), *American Tariff Controversies, Vol. 2,* Houghton Mifflin, Boston, USA.
Stark, W., (1952), *Jeremy Bentham's Economic Writings*, George Allen and Unwin, (alterations in original).
Stobart, J., (2000), 'In search of causality: a regional approach to urban growth in eighteenth-century England, *'Geografiska Annaler. Series B, Swedish Society for Anthropology and Geography*,' Vol. 82, No. 3, pp. 149-163.
Stoneman, P, L., (1985), 'Technological Diffusion: The Viewpoint of Economic Theory', *The Warwick Economic Research Paper Series (TWERPS),* No. 270, University of Warwick, Department of Economics, pp. 1-37.
Story, V, Daniels, K, Zolkiewski, J, and Dainty, A, R, J., (2014), 'The barriers and consequences of radical innovations: introduction to the issue', *Industrial Marketing Management,* 43 (8), pp. 1271 - 1277.
Strambach, S., (2002), 'Change in the Innovation Process: New Knowledge Production and Competitive Cities–The Case of Stuttgart', *European Planning Studies*, Vol. 10, No. 2, pp. 214– 231.
Subramaniam, M, and Youndt, M, A., (2005), 'The influence of intellectual capital on the types of innovative capabilities', *Academy of Management Journal* 48 (3), pp. 450-463.
Sugden, K., (2016), 'The Location of the Textile Industry in England and Wales, 1813–1820', *Textile History,* 47, (2), pp. 208–226.
Sugden, K., (2018), 'Clapham revisited: the decline of the Norwich worsted industry (c. 1700–1820)', *Continuity and Change*, 33, 2, (2018), pp. 203-224.
Sundbo, J., (1998), *The theory of innovation: Entrepreneurs, technology and strategy,* Cheltenham: Edward Elgar, Swedberg, 2007.
Supplement to Commerce Reports, (1916), *Daily Consular and Trade Reports issued by the Bureau of Foreign and Domestic Commerce,* Department of Commerce, Washington, D.C., Annual Series, No. 4a, March 29th, 1916.
Swann, G, and Prevezer, M., (1998), 'A comparison of the dynamics of industrial clustering in computing and biotechnology', *Research Policy,* 25, pp. 1139–1157.
Swedberg, R., (2007), 'Rebuilding Schumpeter's Theory of Entrepreneurship', *Conference on Marshall, Schumpeter and Social Science,* Hitotsubashi University, Japan.

Szymanski, D, M, Kroff, M, W, and Troy, L. C., (2007), 'Innovativeness and new product success: Insights from the cumulative evidence', *Journal of the Academy of Marketing Science*, 35, 1, pp. 35–52.

Tann, J., (2015), 'Borrowing Brilliance: Technology Transfer Across Sectors in the Early Industrial Revolution', *International Journal for the History of Engineering and Technology*, Vol. 85, No. 1, pp. 94–114.

Tarde, G., (1969), *The laws of imitation,* (Elsie Clews Parsons, Trans.), Chicago, University of Chicago Press, (Original work published 1903).

Taylor, I, and Walton, P., (1971), 'Industrial sabotage: motives and meanings' in S. Cohen (ed), *Images of Deviance*, Harmondsworth, Penguin.

Taylor, J, T., (1909), *Cotton Weaving and Designing,* (rev. F Wilkinson and H. Nisbet), Longmans, Green & Co, London, New York, Bombay and Calcutta, 6th edition, pp. 1-350.

Taylor, M., (2008), "The Albert Medal - RSA", (22 January 2008), *www.thersa.org*.

Teece, D, J., (1986), 'Profiting from technological innovation: its implications for integration, collaboration, licensing and public policy', *Research Policy,* 15, pp. 285-305.

Tellis, W, M., (1997), 'Application of a Case Study Methodology', *The Qualitative Report*, 3, (3), pp. 1-19.

Tellis, G, J., (2006), 'Disruptive technology or visionary leadership?' *Journal of Product Innovation Management*, 23, pp. 34–38.

Tenopir, C; Allard, S; Douglass, K; Aydinoglu, AU; Wu, L; Read, E; Manoff, M, and Frame, M., (2011), 'Data sharing by scientists: Practices and perceptions', *PLoS One,* 6, (6), pp. 1–21.

Tesar, J., (1988), 'Trade Shows: Opportunities to Sell: A Case Study of Hanover Fair CeBIT', *Trade Show Bureau,* East Orleans, MA.

Thomas, G., (2011), 'A Typology for the case study in social sciences following a review of definition, discourse and structure', *Qualitative Inquiry*, 17th, Issue 6, pp. 511-521.

Thompson, V. A., (1965), 'Bureaucracy and innovation', *Administrative Science Quarterly,* Vol. 10, pp. 1-20.

Thompson, J, and Martin, F., (2006), *Strategic Management: Awareness and Change,* Cengage Learning EMEA, 8th edition, (9 Mar 2017).

Tomlinson, J., (2019), 'De-industrialization: Strengths and weaknesses as a key concept for understanding post-war British history', *Urban History*.

Tiebout, C., (1957), 'Location Theory, Empirical Evidence, and Economic Evaluation', *Papers and Proceedings of the Regional Science Association,* 3, (1957).

Toynbee, A., (1969), *Toynbee's Industrial Revolution,* David & Charles, Newton Abbot, pp.1- 256.

Turok, I., (2003), 'Cities, Clusters and Creative Industries: The Case of Film and Television in Scotland' *European Planning Studies*, Vol.11, No. 5, pp. 549-565.

Tushman, M, and Nadler, D., (1986), 'Organizing for Innovation', *California Management Review* No. 28, No.3, (Spring 1986), pp. 74-92.

(UNIDO) United Nations Industrial Development Organization., (2016), *Industrial Development Report 2016, The Role of Technology and Innovation in Inclusive and Sustainable Industrial Development*, UNIDO, Vienna.

(UNIDO) United Nations Industrial Development Organization., (2016), *Industrialization as the driver of sustained prosperity,* UNIDO, Vienna.

United States Tariff Commission., (1920), *A Survey of the British Wool-Manufacturing Industry*, Committee on Ways and Means House of Representatives, Government Printing Office.

Usher, A, P., (1954), *A History of Mechanical Inventions*, New York, Dover Publications.

Utterback, J. M., (1971), 'The Process of Technological Innovation within the Firm', *Academy of Management Journal,* 10, pp. 75-88.

Van Manen, M., (1990), *Researching Lived Experience: Human Science for an Action Sensitive Pedagogy*, Albany, N. Y: State University of New York Press.

Van, Wynsberghe, R, and Khan, S., (2007), 'Redefining Case Study', *International Institute for Qualitative Methodology,6, (2),* pp. 1-10.

Vandenbempt, K, and Matthyssens, P., (1999), 'Barriers to strategic innovation: a network perspective', *Research paper/UFSIA, Faculty of Applied Economics,* Antwerp.

Varian, B, D., (2017), *The course and character of Late-Victorian British exports*, PhD thesis, London School of Economics and Political Science, London.

Vasudevan, P., (2005), *An investigation into the effect of Licker-in Design on Carding Performance*, PhD Thesis, University of Leeds.

Veblen, T., (1915), *Imperial Germany and the Industrial Revolution,* New York: McMillan.

Venkataraman, K, S., (1936), *Handloom industry in the Madras Presidency*, The Diocesan Press, Madras.

Voss, C; Tsikriktsis, N, and Frohlich, M., (2002), 'Case research in operations management', *International Journal of Operations and Production Management, 22,* (2), pp. 195-219.

Vugt, W, E Van., (1999), *A Nation of Peoples: A Sourcebook on America's Multicultural Heritage,* (editor Barkan, E, R.), Greenwood Press, Connecticut, London.

Walford, E., (1920), *County Families of the United Kingdom, or Royal Manual of the Title and Untitled Aristocracy of England, Wales, Scotland and Ireland*, Spottiswoode, Ballantine & Co, Limited., London.

Walton, W., (1841), *A memoir addressed to proprietors of mountains and other waste lands, and agriculturalists of the United Kingdom, on the naturalization of the alpaca*, London: Smith, Elder and Co.

Ward, D, and Rivani, E., (2005), 'An Overview of Strategy Development Models and the Ward-Rivani Model', *Economics Working Paper Archive.*

Waterhouse, D., (1935), ‘Textile Machinery for the Production of Worsted Yarn’, *Proceedings of the Institution of Mechanical Engineers Conference Proceedings*, Vol. 129, Issue. 1., London.

Weatherall, K; Webster, E, and Bently, L., (2009), ‘IP Enforcement in the UK and Beyond: A literature Review,’ *SABIP Report*, Number EC001.

Weber, A., (1909), *Theory of the Location of Industries,* translated by C. J. Friedrich, (Chicago, 1929), The University of Chicago Press.

Weber, M., (1961), *General Economic History,* New York, Collier Books, (translated from German edition, published in 1923).

Webster, E, and Weatherall, K., (2021), ‘Patent Enforcement: A Review of the literature,’ *SSRN Electronic Journal*, (January 2021).

Weerth, G., (1957), *Samtliche Werke*, Vol. III, Berlin, (translated by Alan Farmer), p.169, xeroxed copy in Bradford Central Library.

Wells, D, A., (1867), ‘Report of the Special Commissioner of the Revenue’, *Senate Executive Document, No. 2., 39th Congress, 2d Session,* Washington, DC: GPO, 1867.

Wells, H, G., (1914), *The War that will end war*, 3rd edition, F & C Palmer, pp.1-99.

West Yorkshire Archive Service, 32D83/59, Firm's History.

West Yorkshire Archive Hattersley Collection.

Whitaker, J, K., (1975), *The Early Economic Writings of Alfred Marshall, 1867-1890*, 2 vols., Macmillan.

Wiener, M., (1981), *English Culture and the Decline of the Industrial Spirit 1850-1990*, Cambridge University Press, Cambridge.

Wiener, N., (1996), *Invention*, MIT Press, Cambridge: Massachusetts, U.S.A.

Wiersma, W., (2000), *Research methods in education: An introduction*, Boston, MA, Allyn and Bacon.

Wild, M, T., (1972), *The Wool Textile Industry*, in Jenkins, J, G., ed., Routledge and Kegan Paul, London, pp. 1-309.

Wilkening, E. A., (1956), ‘Roles of Communicating Agents in Technological Change in Agriculture,’ *Social Force,* 34, pp. 361-367.

Wilkinson, W., (1915), *Practical Weaving: A Handbook of the Principles and Practice of Shedding (Tappets and Dobbies),* Coulton & Co, Ltd, Nelson, pp. 1-194.

Williamson, J.G., (1984), ‘Why Was British Growth So Slow During the Industrial Revolution?’ *The Journal of Economic History,* Vol. 44, No. 3 (Sep. 1984), pp. 687-712.

Wilson, C., (1958), *Technology and Industrial Organization*, in C. Singer et al, (Editors*),* A History of Technology*,* Oxford 1958, Vol. 5, pp. 799-800.

Woodbury, R, S., (1960), ‘The Legend of Eli Whitney and Interchangeable Parts,’ *Technology and Culture*, Vol. 1, No. 3, (Summer, 1960), pp. 235-253.

Woodside, A, G., (2010), *Case Study Research: Theory, Methods, Practice*, Bingley, Emerald, UK.
Wright, D, G., (1982), 'Mid-Victorian Bradford: 1850-1880', *The Bradford Antiquary, The Journal of the Bradford Historical and Antiquarian Society*, New Series - Part XLVII, October 1982, Bradford.
Wrigley, J., (1986), *Technical Education and industry in the Nineteenth Century*, in B Elbaum and W. Lazonick, (Eds), The Decline of the British Economy, Oxford, Clarendon Press.
Yazan, B., (2015), 'Three Approaches to Case Study Methods in Education: Yin, Merriam, Stake', *The Qualitative Report* 2015, Volume 20, Number 2, Teaching and Learning Article 1, pp. 134-152.
Yin, R, K., (1981), 'The case study crisis: some answers,' *Administrative Science Quarterly*, 26, (1), pp. 58-65.
Yin, R.K., (1984), *Case Study Research: Design and Methods*, Beverly Hills, California, Sage Publications.
Yin, R, K., (1989), *Case Study Research: Design and Methods*, Applied Social Research Series, Vol. 5, Sage, London.
Yin, R, K., (2002), *Case Study Research: Design and Methods*, 3rd ed., Sage, London.
Yin, R, K., (2009), *Case Study Research: Design and Methods*, 4th ed, e-book, Sage, CA.
Yin, R, K., (2014), *Case Study Research: Design and Methods*, (5th ed.), Thousand Oaks, CA, Sage.
Zainal, Z., (2007), 'Case Study as a Research Method', *Jurnal Kemanusiaan bil.9,* June 2007, pp.1-5.
Zebel, S, H., (1940), 'Fair Trade: An English Reaction to the Breakdown of the Cobden Treaty System', *The Journal of Modern History*, Vol. 12, No. 2, (Jun., 1940), pp. 161-185.
Zimmern, D, M., (1918), 'The Wool Trade in War Time', *The Economic Journal,* Vol. 28, No. 109, (Mar 1918), pp. 7-29.

Appendices

Appendix 1.

Highest Award and GOLD MEDALS have been awarded us at the following Exhibitions:—

LONDON	1862
PARIS	1867
MOSCOW	1872
LEEDS	1875
PARIS	1878
BRADFORD	1882
HUDDERSFIELD (4 Gold Medals)	1883
SALTAIRE (3 Gold Medals)	1887
GLASGOW	1888
BELFAST	1895
GLASGOW	1901
CORK	1902
BRADFORD	1904
ST. LOUIS, U.S.A.	1904
LIEGE	1905
MILAN (Grand Prix)	1906
CALCUTTA } For Hand-Power Machinery	1906
NAGPUR } For Hand-Power Machinery	1908
FRANCO-BRITISH, INDIAN SECTION (The only Grand Prix for Hand-Power Textile Machines)	1908
FRANCO-BRITISH (The only Grand Prix for Weaving Machinery)	1908
BRUSSELS } Special Awards in Collaboration with Bradford Chamber of Commerce	1910
TURIN } Special Awards in Collaboration with Bradford Chamber of Commerce	1911
ROUBAIX (The only Grand Prix for Weaving Machinery)	1911

And many other minor Exhibitions.

Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 1)

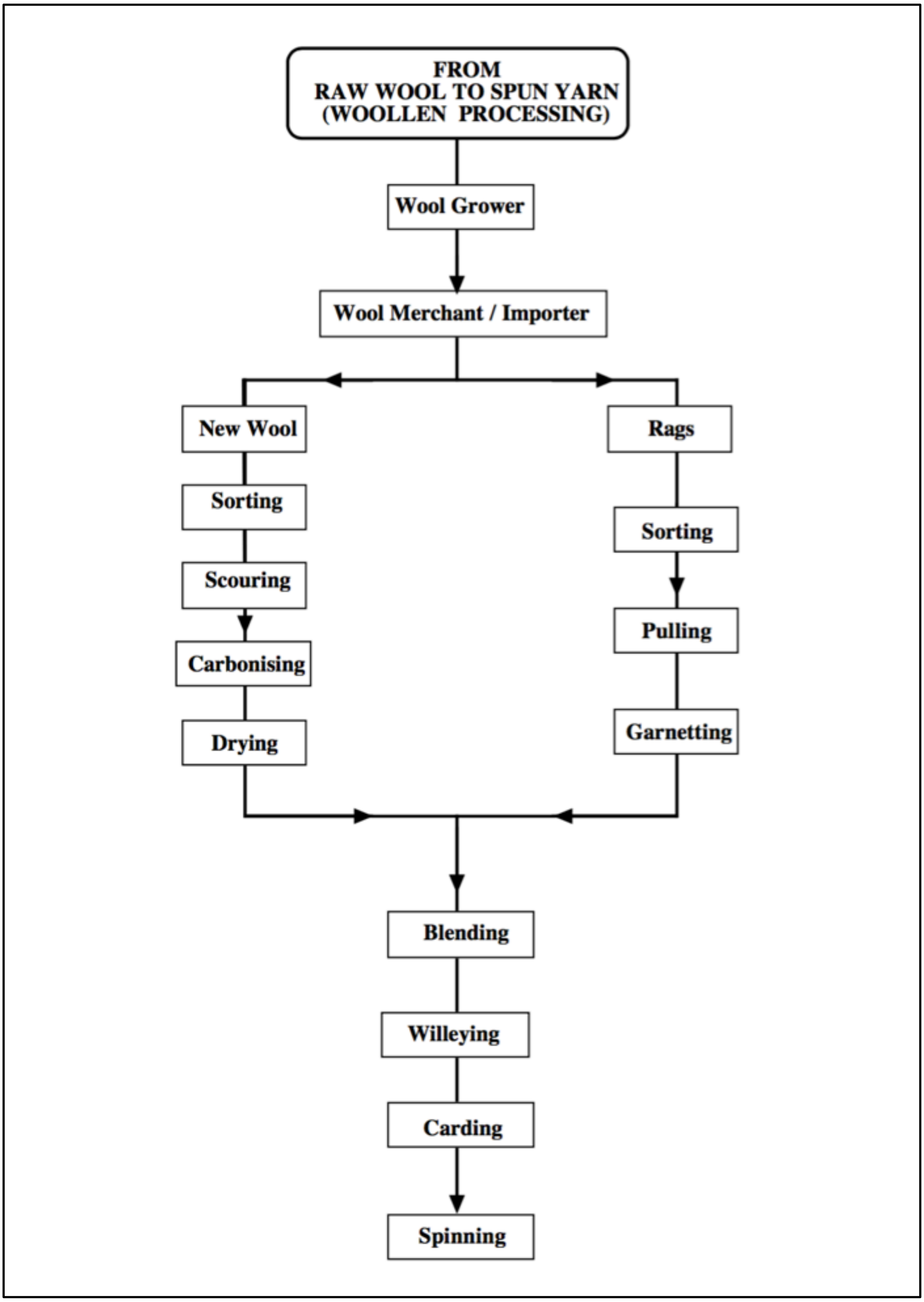
Exhibition Gold Medals and Awards given to Hattersley 1862-1911

Appendix 2

Source: (Keighley, 2007 p. 113)

Promotional Image of Standard Model Hattersley Loom

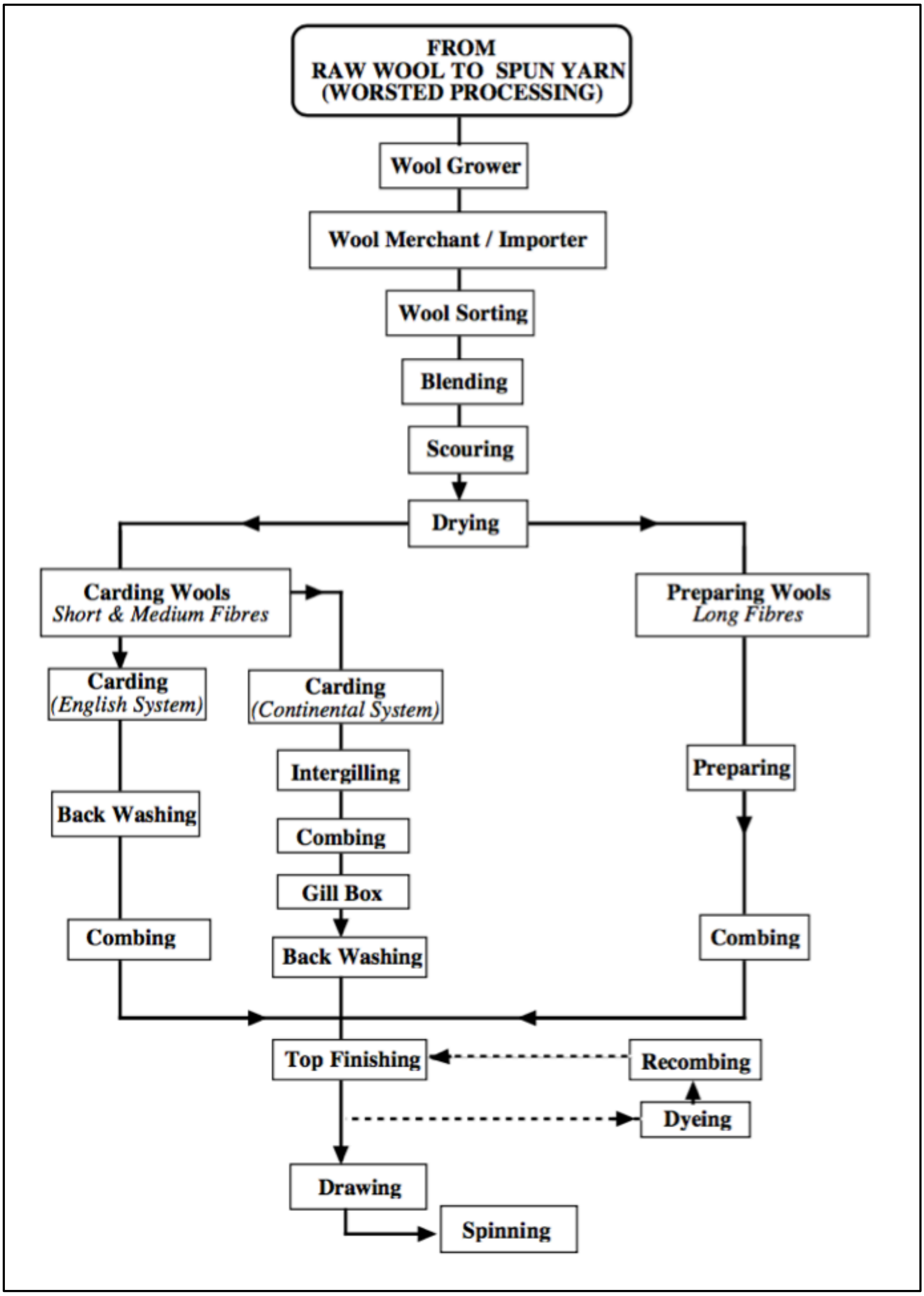
Appendix 3A



Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing woollen processing from raw wool to spun yarn

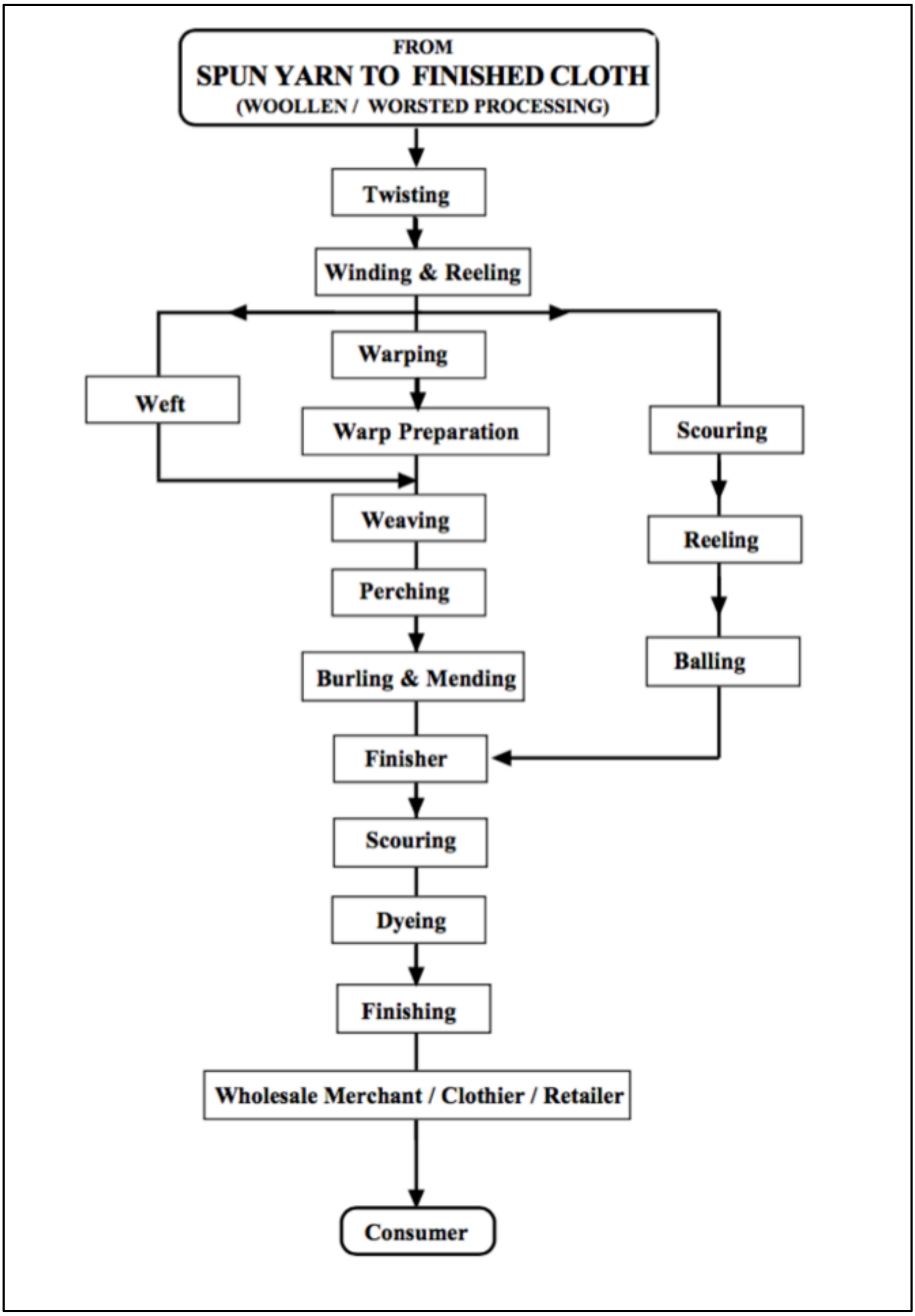
Appendix 3B



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing worsted processing from raw wool to spun yarn

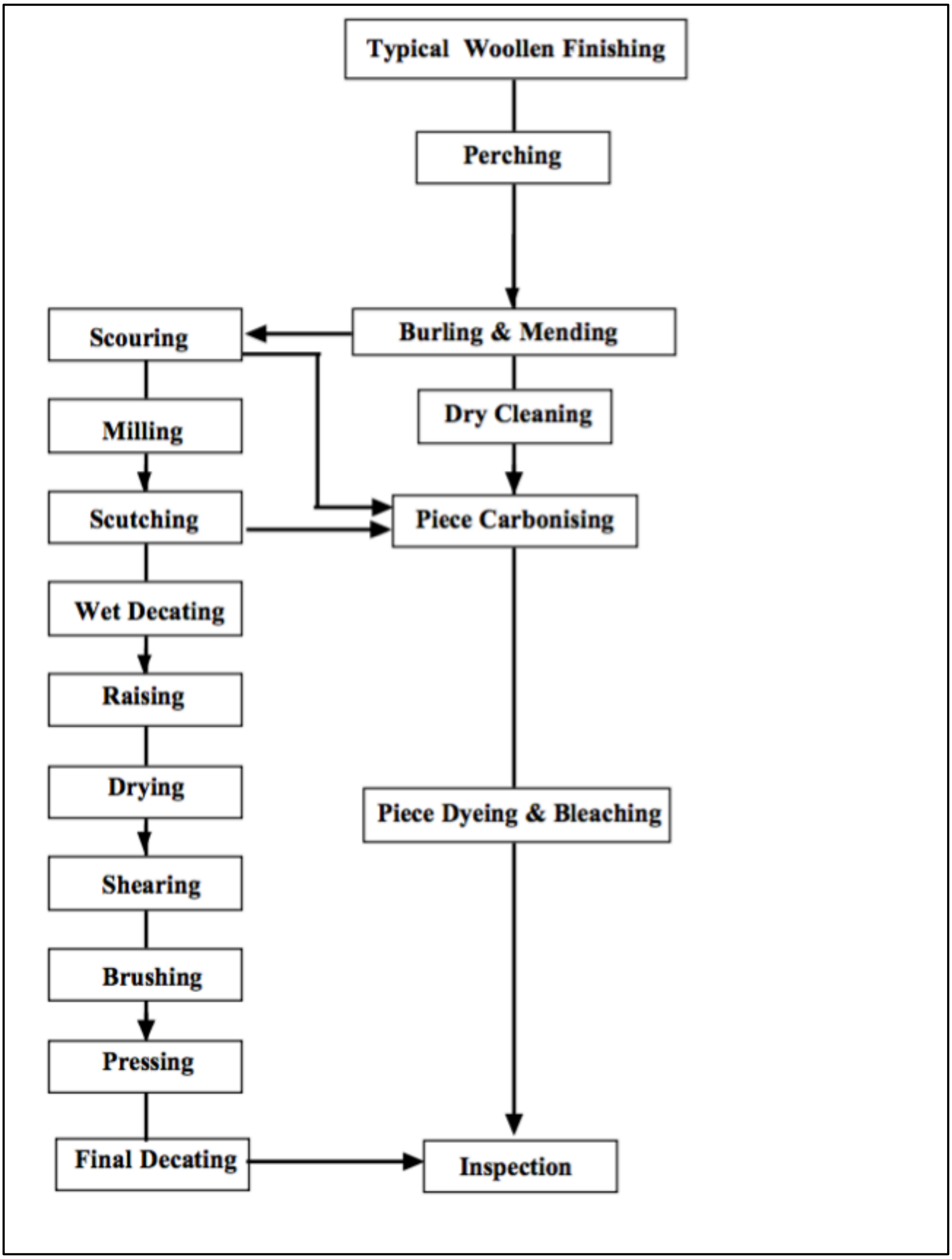
Appendix 3C



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing spun yarn processing to finished cloth

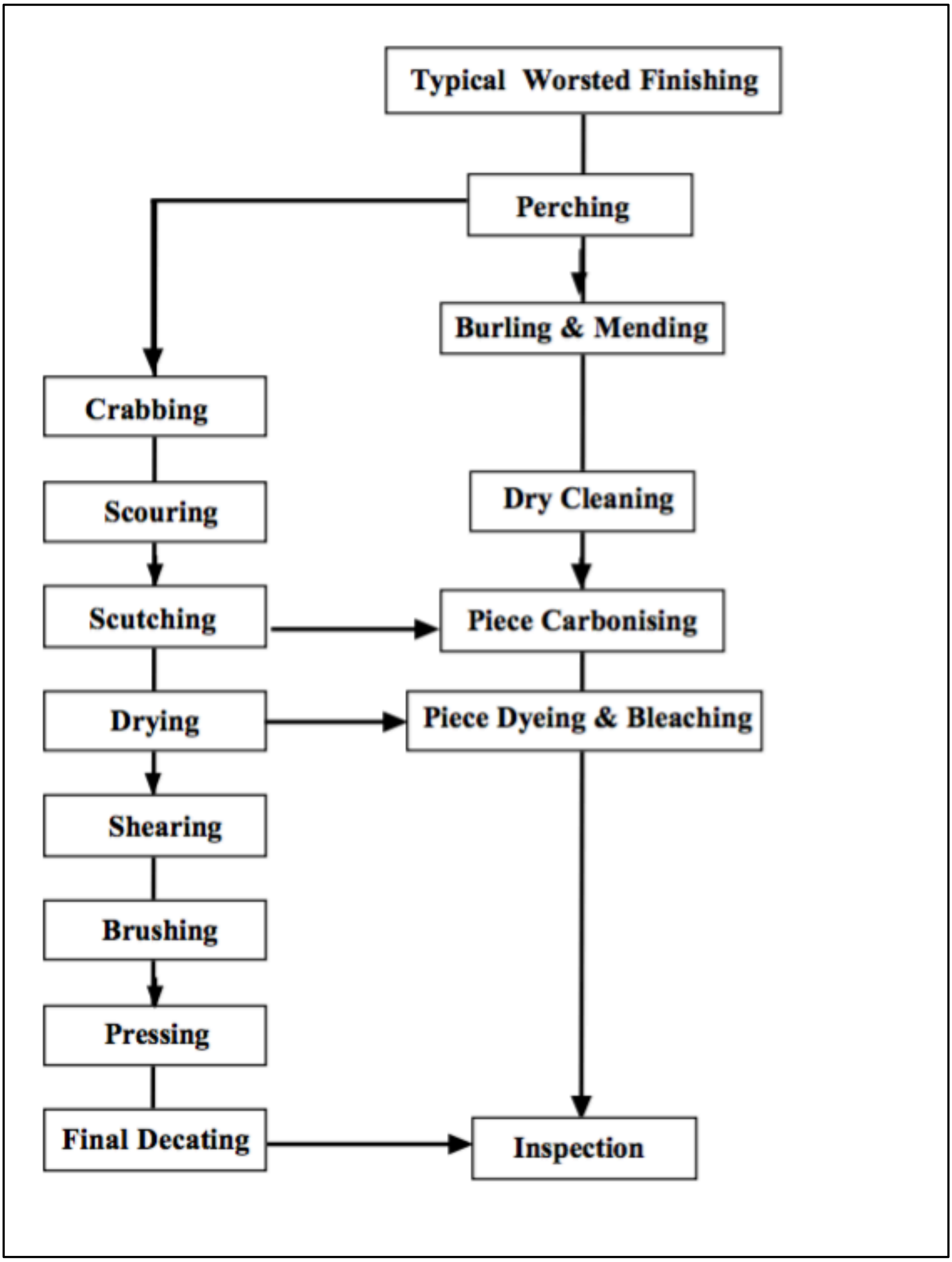
Appendix 3D



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing woollen finishing to inspection

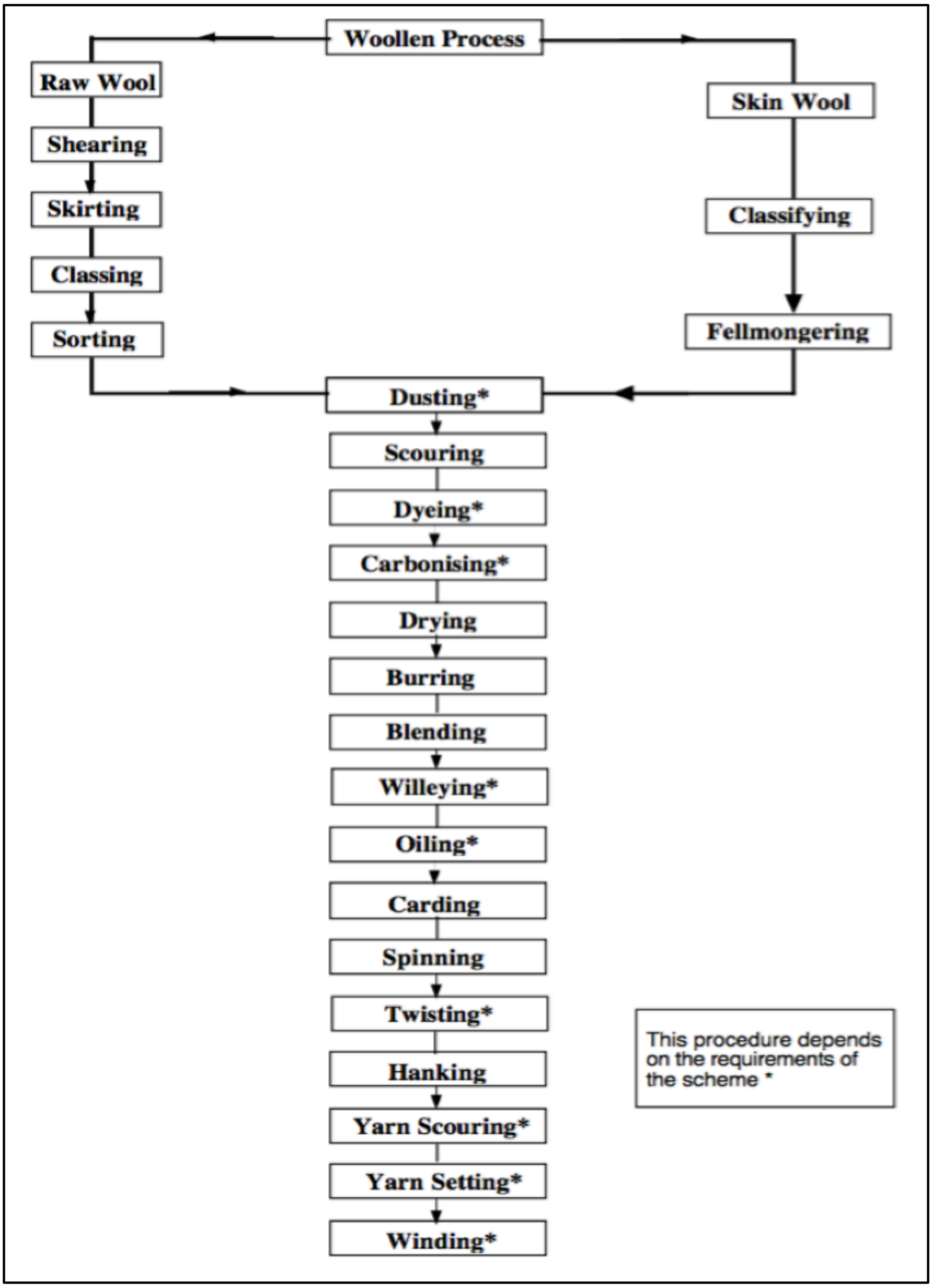
Appendix 3E



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing worsted processing from finishing to inspection

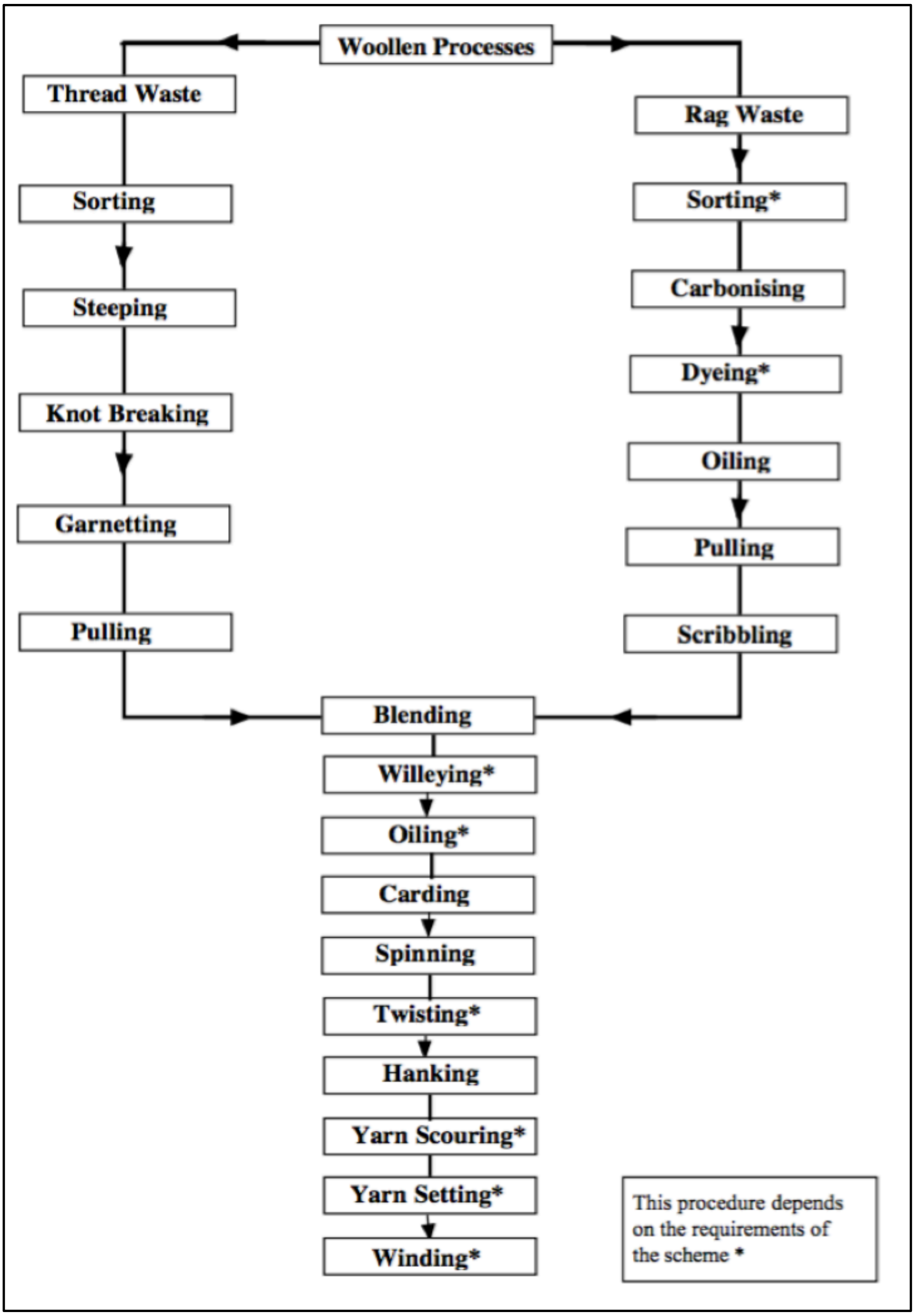
Appendix 3F



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing woollen processing from wool to yarn winding

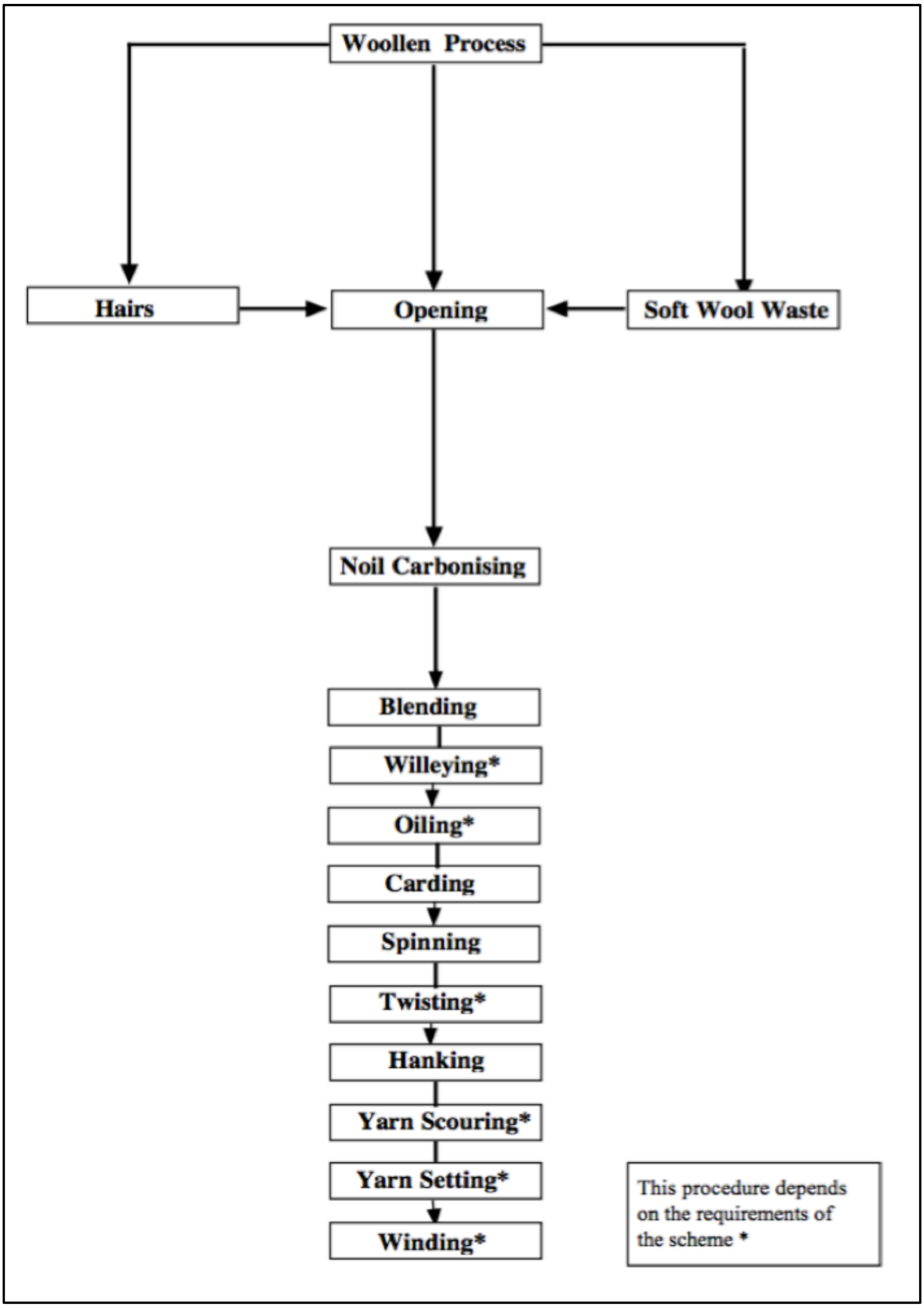
Appendix 3G



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing woollen processing from wool to winding yarn

Appendix 3H



Source: Source: (Adapted from McHugh, 1983, p. 5)

Flow chart showing woollen processing wool to spun winding yarn

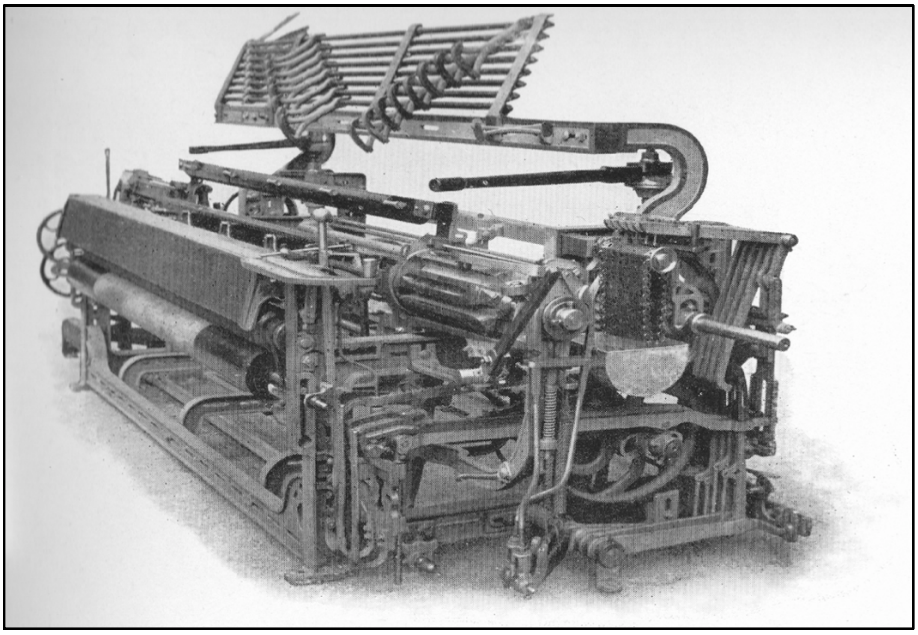
Appendix 4

	Single/Double	Take-Up	Let-Off	Reed Space	Dimensions
6 and 6 Revolving Box, "Dress Goods" Loom	Single	Positive	Friction	120	63 ½ ins
Automatic Self-Shuttling Coating Loom	Single	Positive	Rope or Friction	130	84 ins
Automatic Coating Loom for Weft Mixing	Double	Positive	Rope or Friction	118	84 ins
Automatic Self-Shuttling Loom	Single	Positive	Friction	130	84 ins
Overpick Tapestry Loom	Six	Positive	Friction	100	63 ½ ins
Underpick Centre Shed Dobby Woollen Loom	Six	Positive	Positive	100	84 ins
Coating Weft Mixing Loom	Double	Positive	Rope or Friction	125	76 ins
Heavy Woollen Loom	Single	Positive	Positive worm	90	110 ins
Light Coating Gabardine Loom	Single	Positive	Friction	150	71 ½ ins
Medium Light Weight Coating Loom	Six	Friction	Friction	110	80 ins
Overpick Rising Box Dress Goods Loom	Six	Positive	Positive	160	57 ½ ins
Revolving Box Dress Goods Loom	Six	Positive	Friction	170	40 ½ ins
Single Shuttle Tappet Coating Loom	Single	Positive	Friction	140	76 ins
Revolving Box Loom for Light and Medium Coatings	Six	Positive	Friction	130	76 ins
Single Shuttle Dress Goods Loom	Single	Positive	Friction	210	40 ½ ins

Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 1-96)

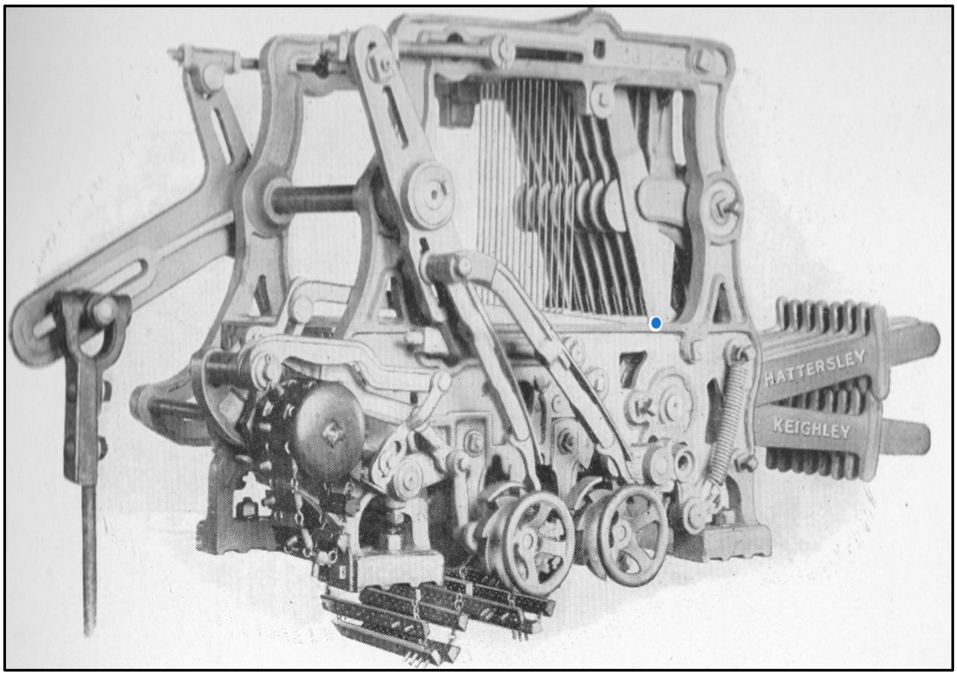
Selection of Hattersley loom specifications

Appendix 5



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 56)

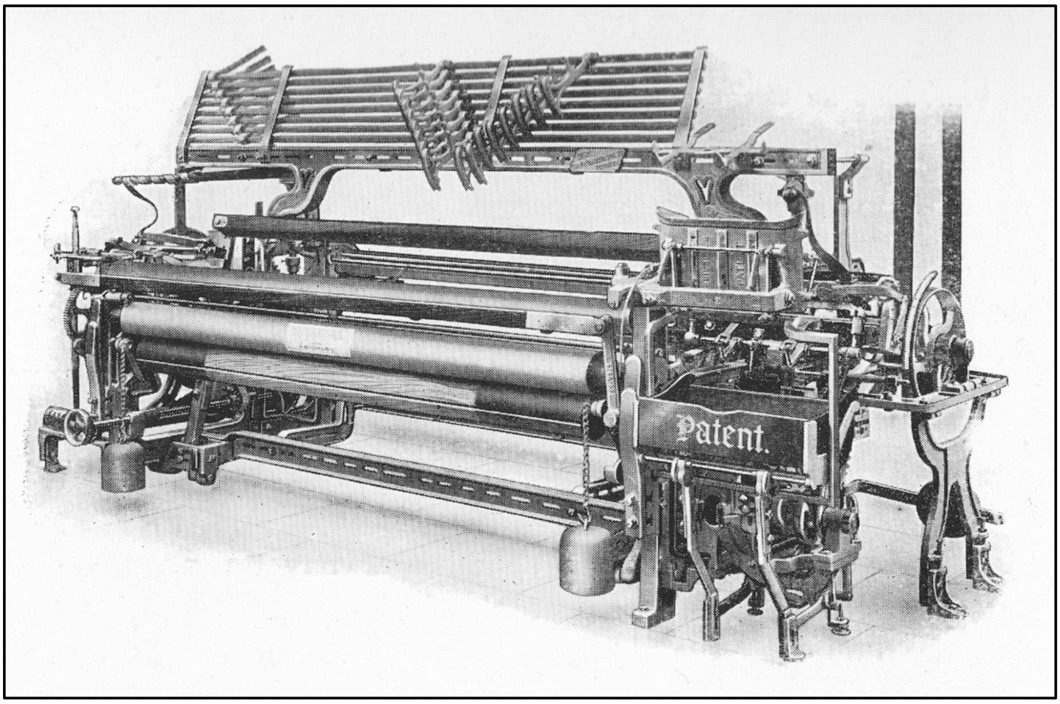
6 and 6 Revolving Box, 'Dress Goods' Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 88)

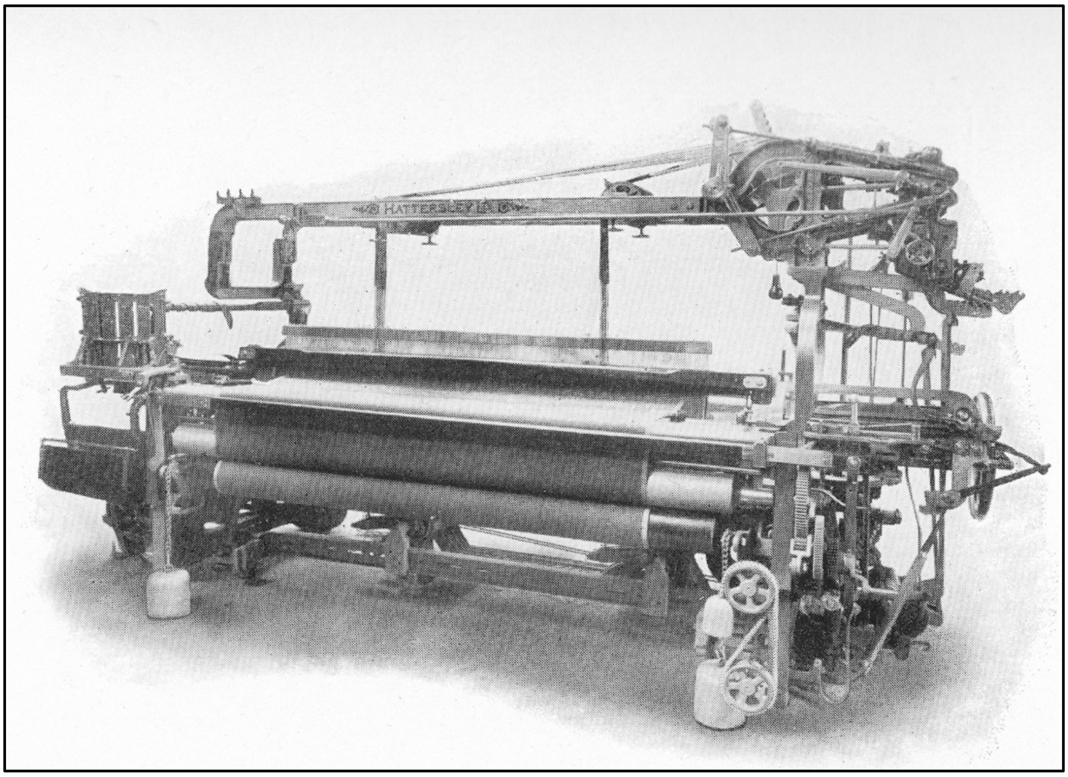
Automatic Border Motion Non-Positive Dobby Model No. 4

Appendix 6



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 41)

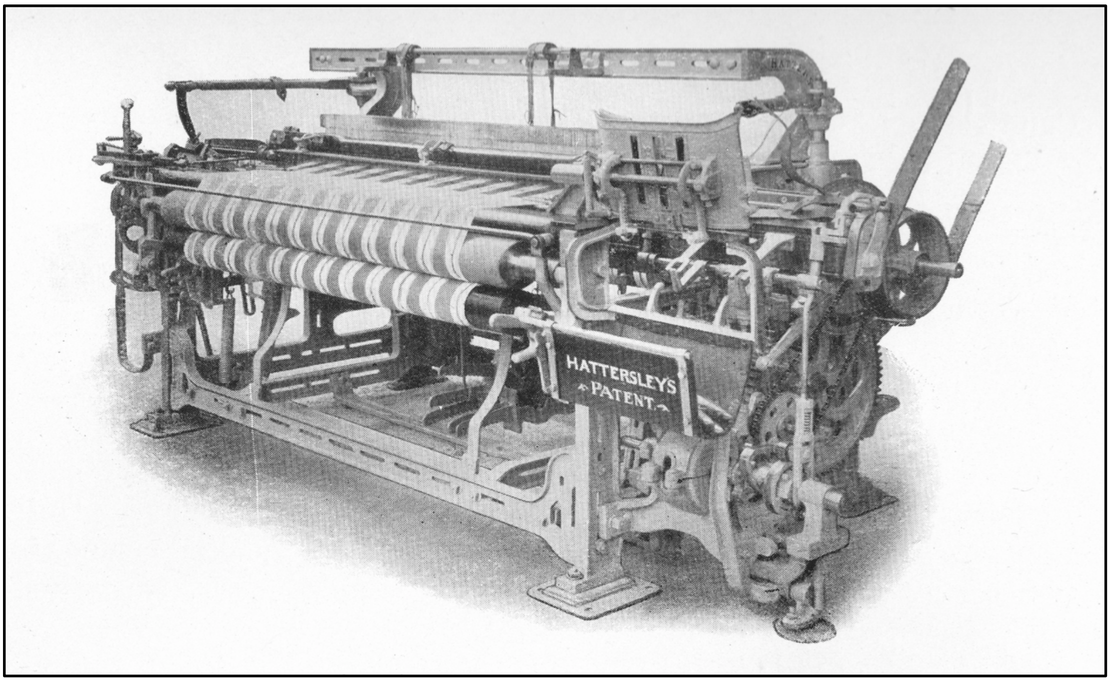
Automatic Self-Shuttling Coating Loom 1913 Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 43)

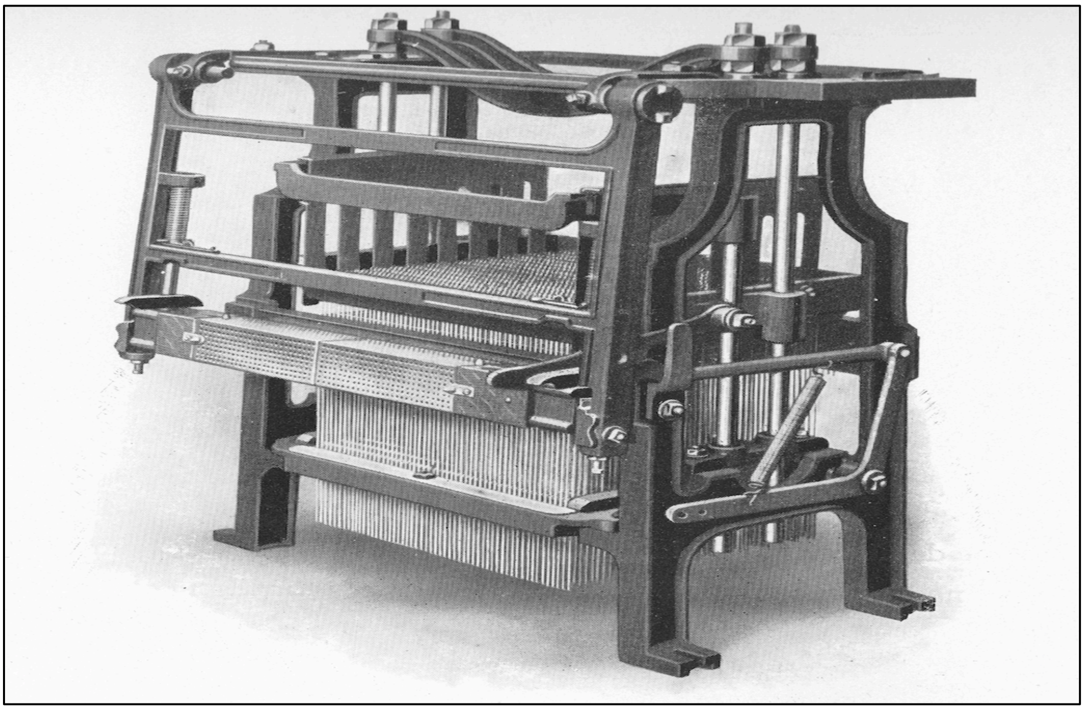
Automatic Coating Loom for Weft Mixing 1913 Model

Appendix 7



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 39)

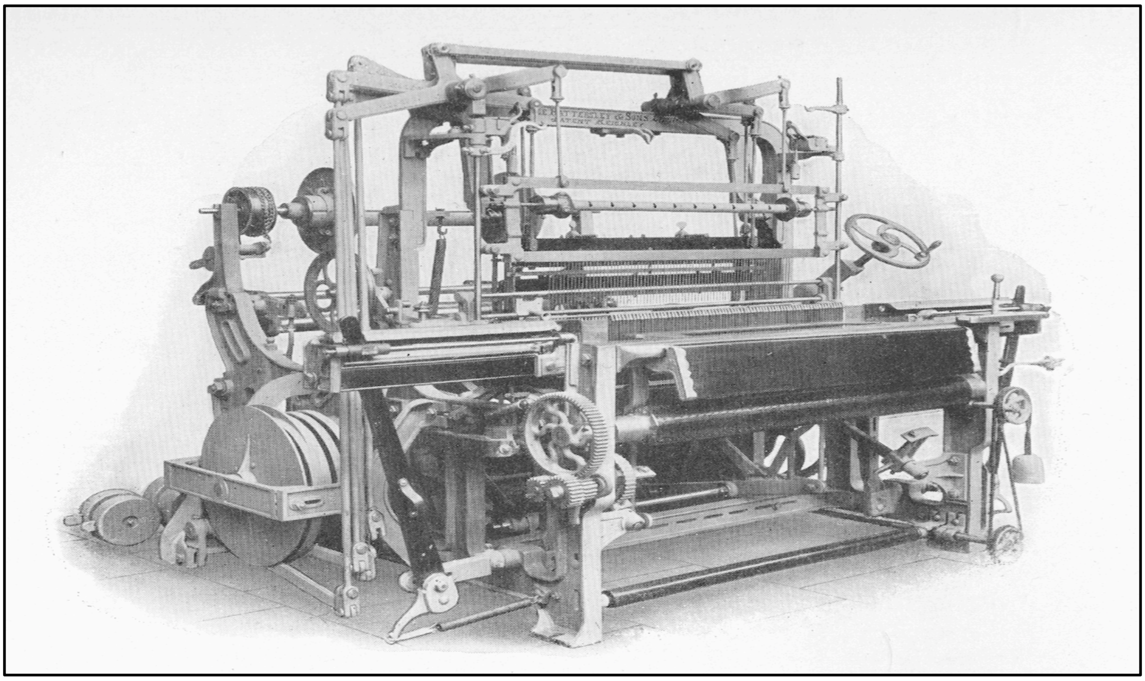
Automatic Self-Shuttling Loom 1913 Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 96)

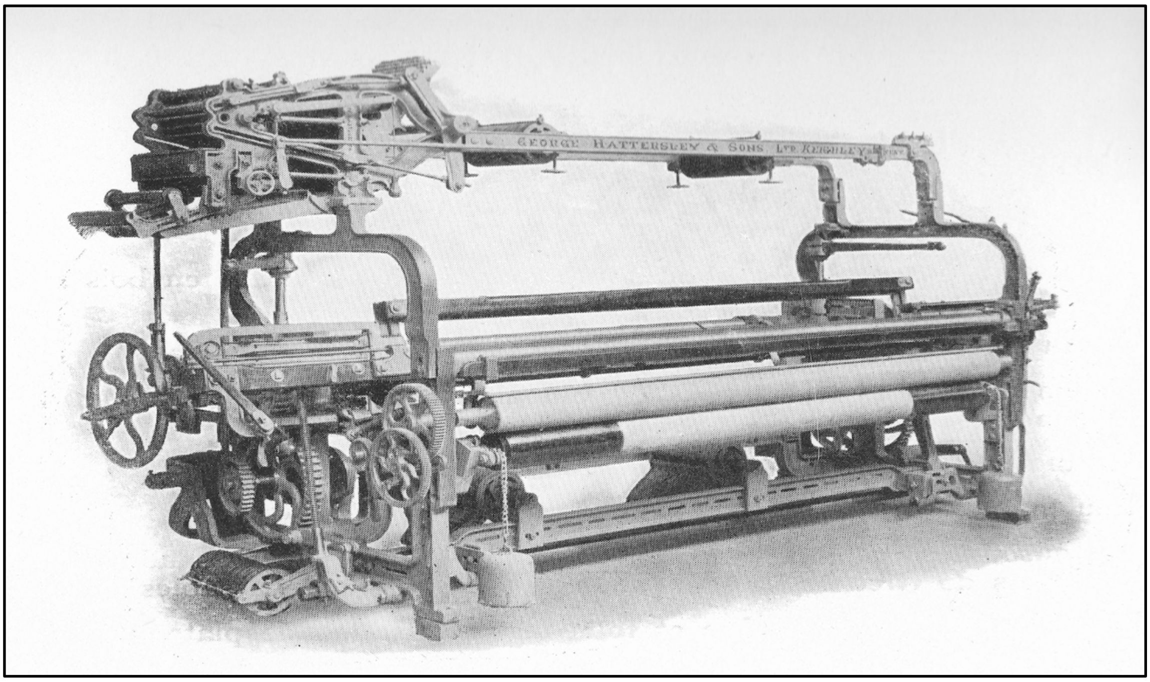
Double Lift Jacquard Engine

Appendix 8



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 29)

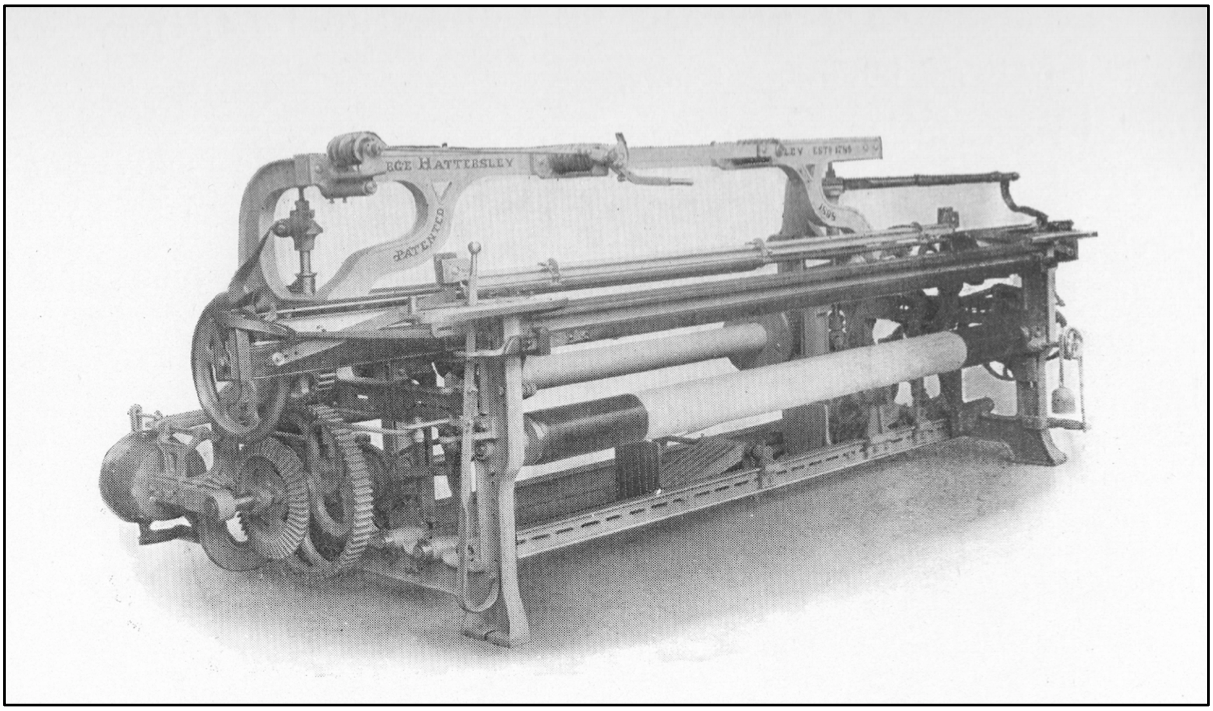
Chenille Setting Loom



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 69)

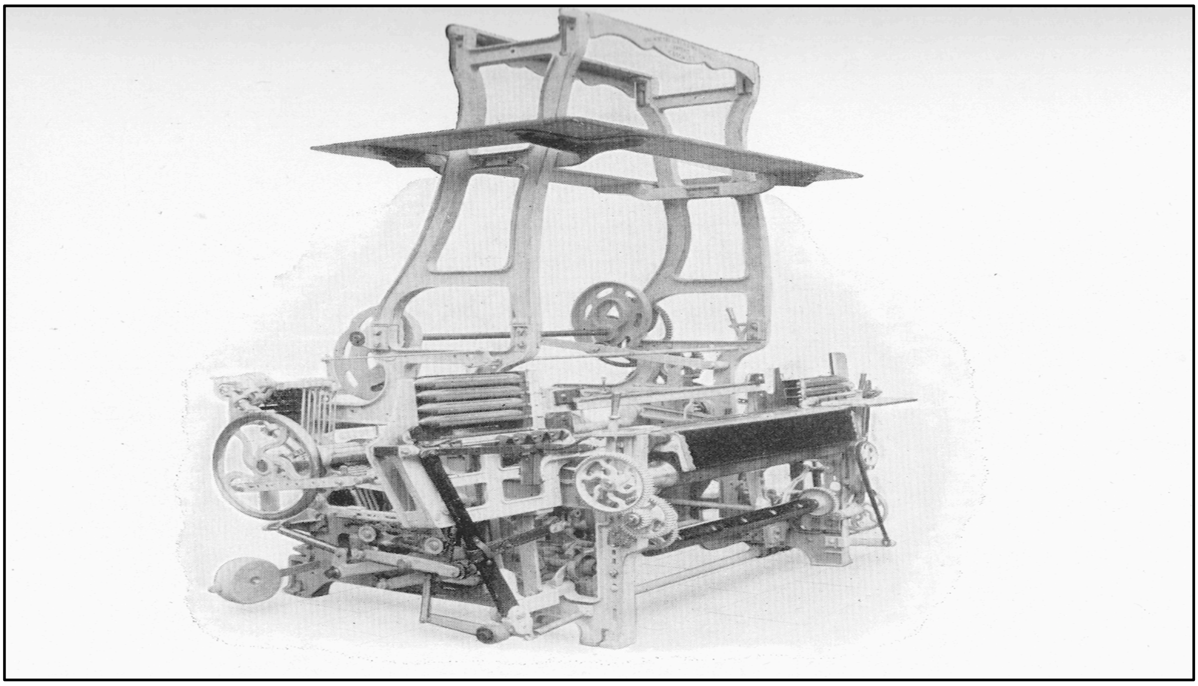
Coating Weft Mixing Model

Appendix 9



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 25)

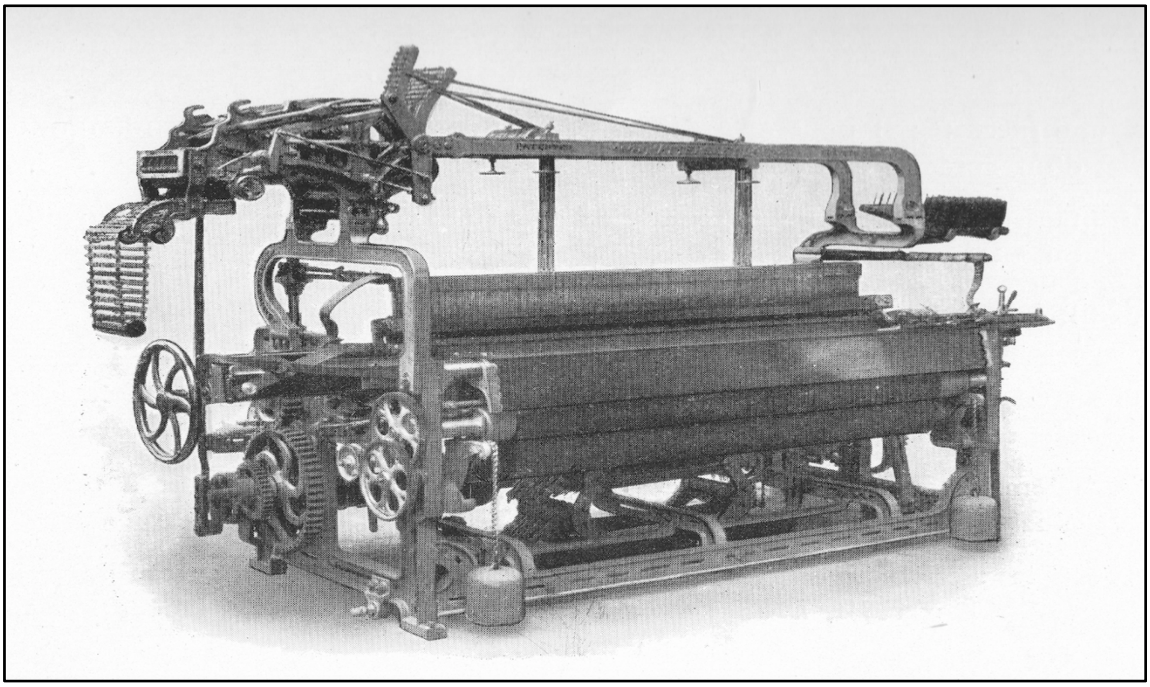
Heavy Woollen Loom



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 30)

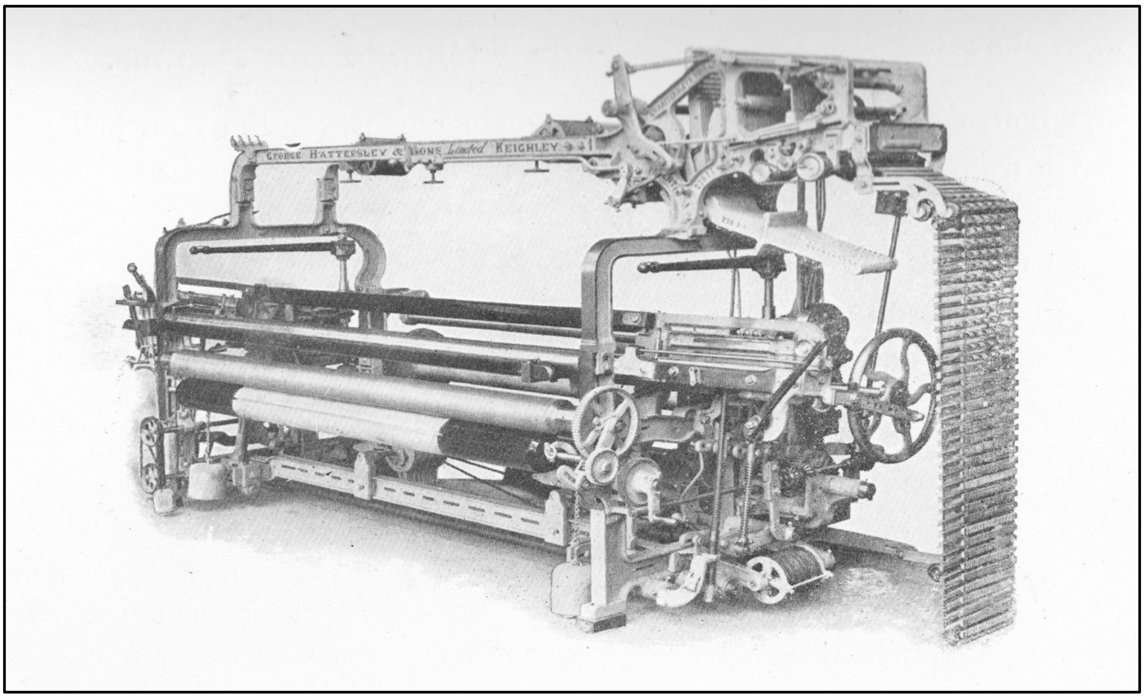
Ingrain or Scotch Loom

Appendix 10



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 13)

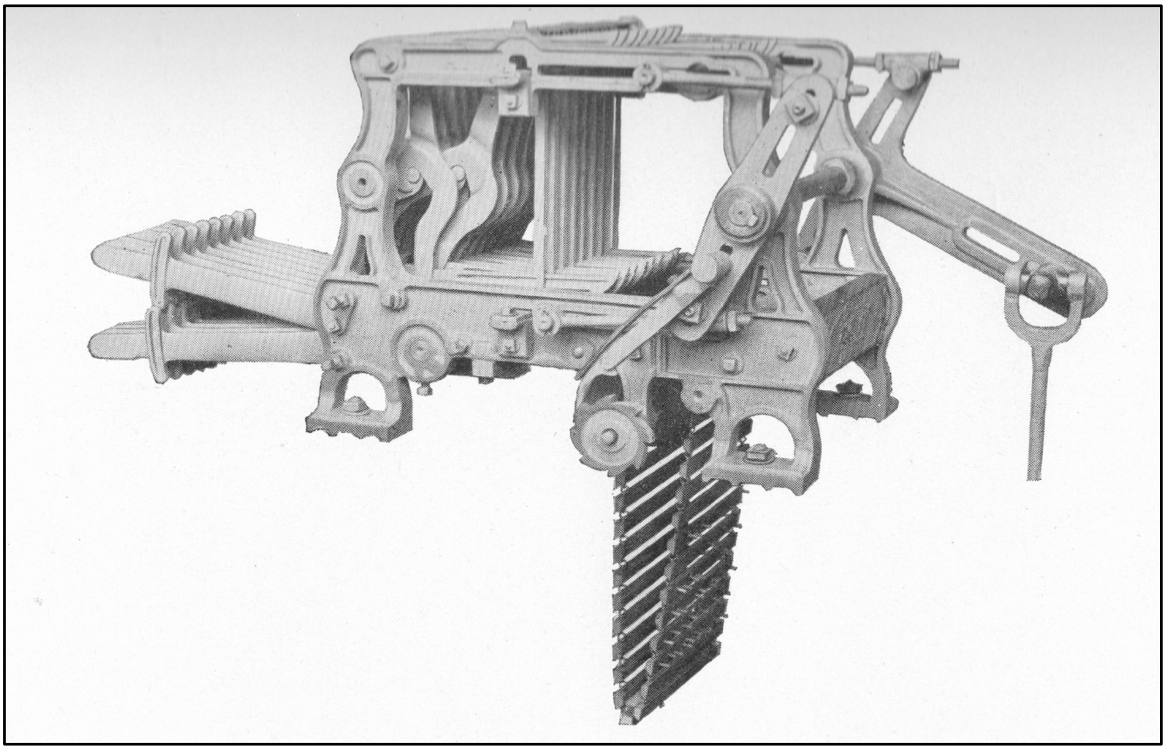
Light Coating Gabardine Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 71)

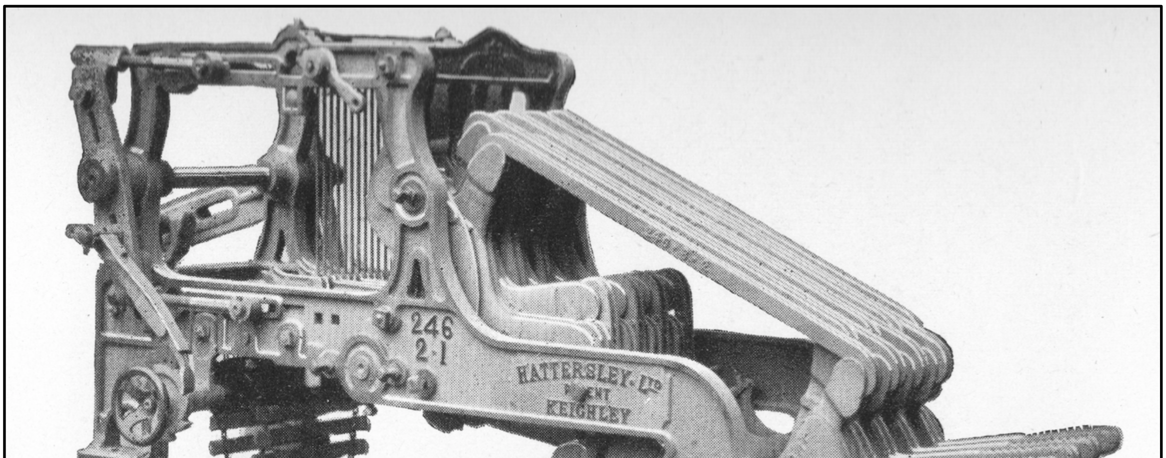
Medium Light Weight Coating Model

Appendix 11



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 83)

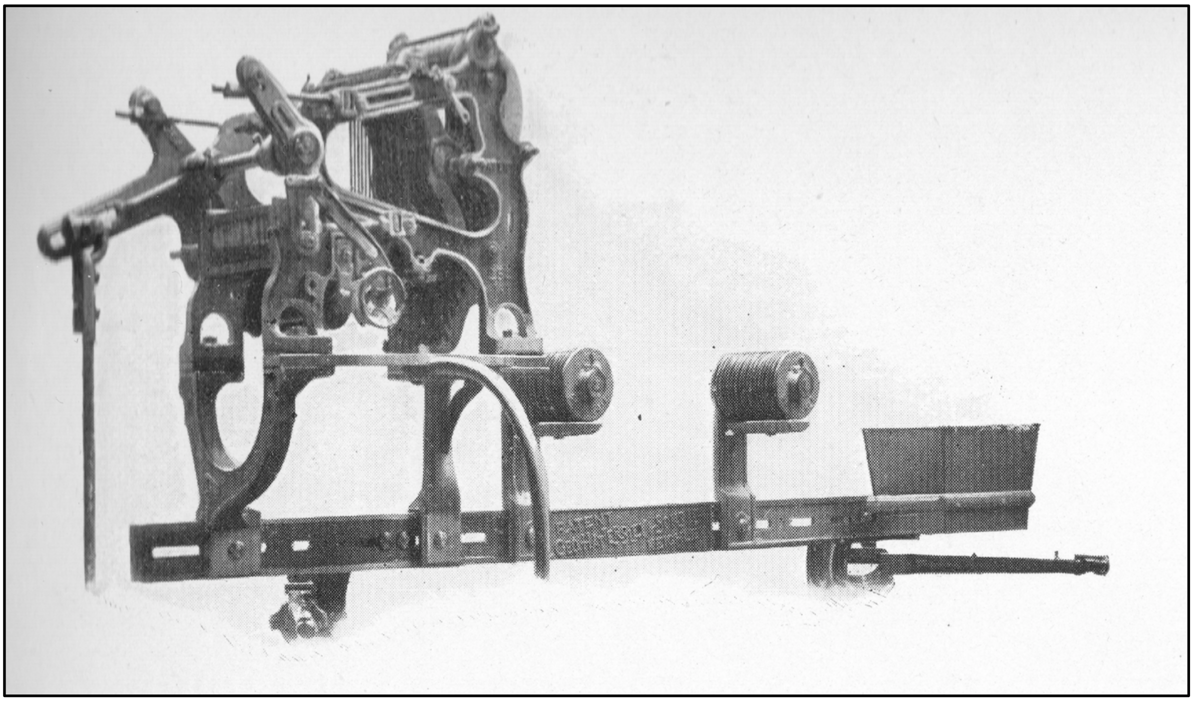
Non Positive Dobby Model No. 4



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 85)

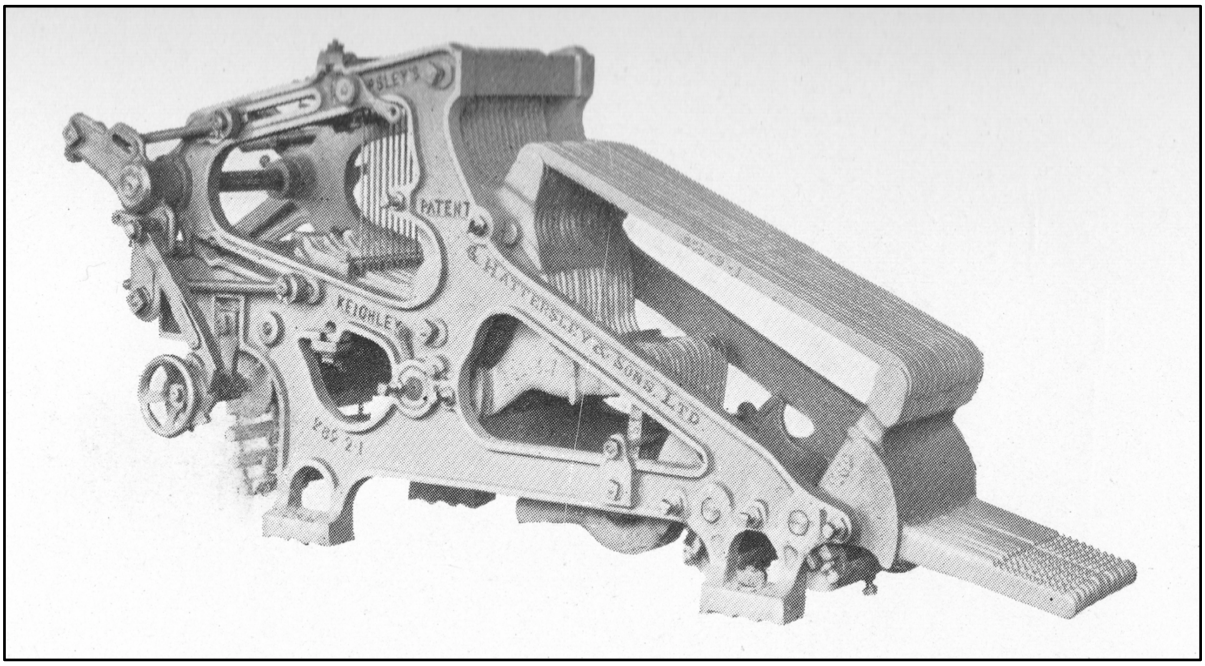
Non Positive Dobby Model No. 246

Appendix 12



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 86)

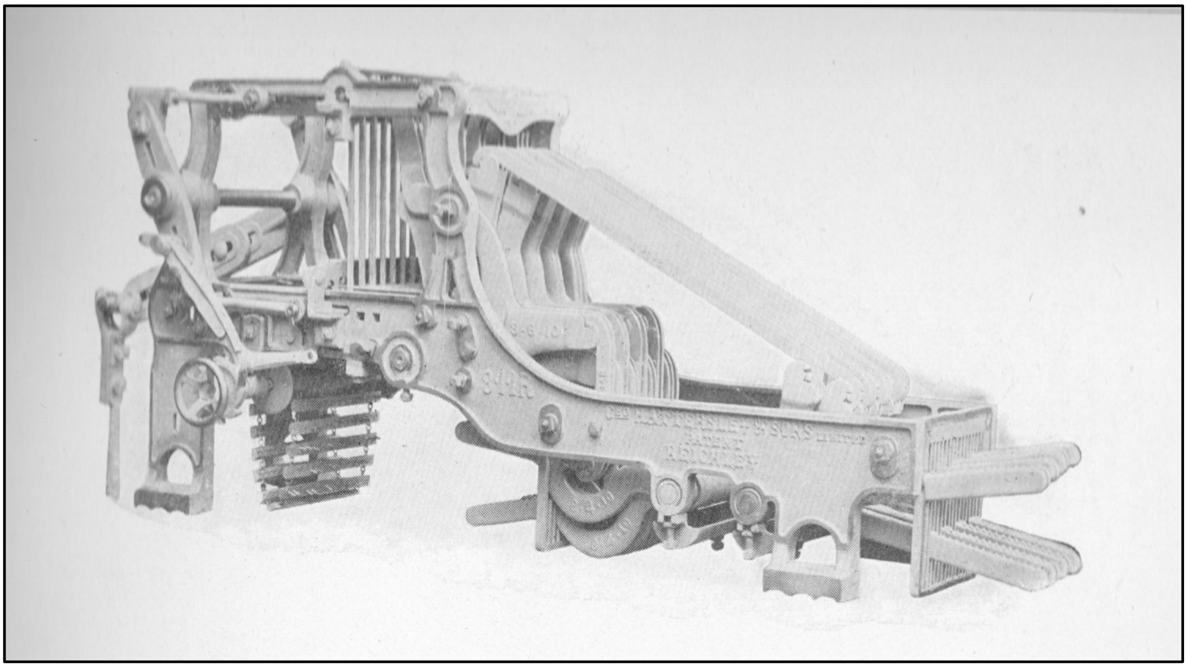
Non Positive Dobby Model No. 254



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 87)

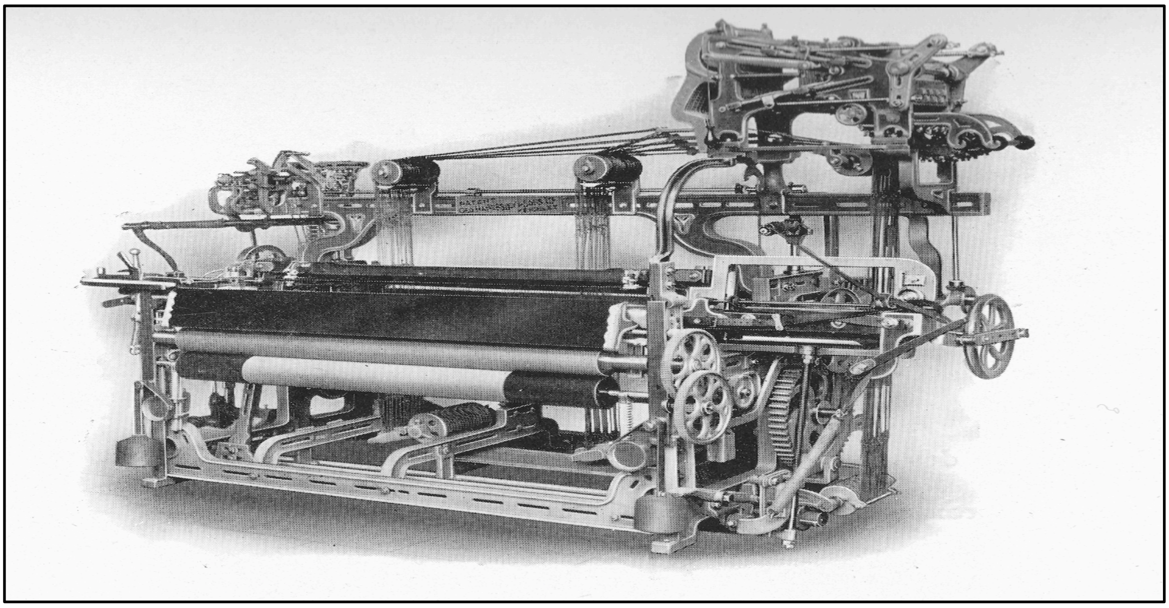
Non Positive Dobby Model No. 282

Appendix 13



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 84)

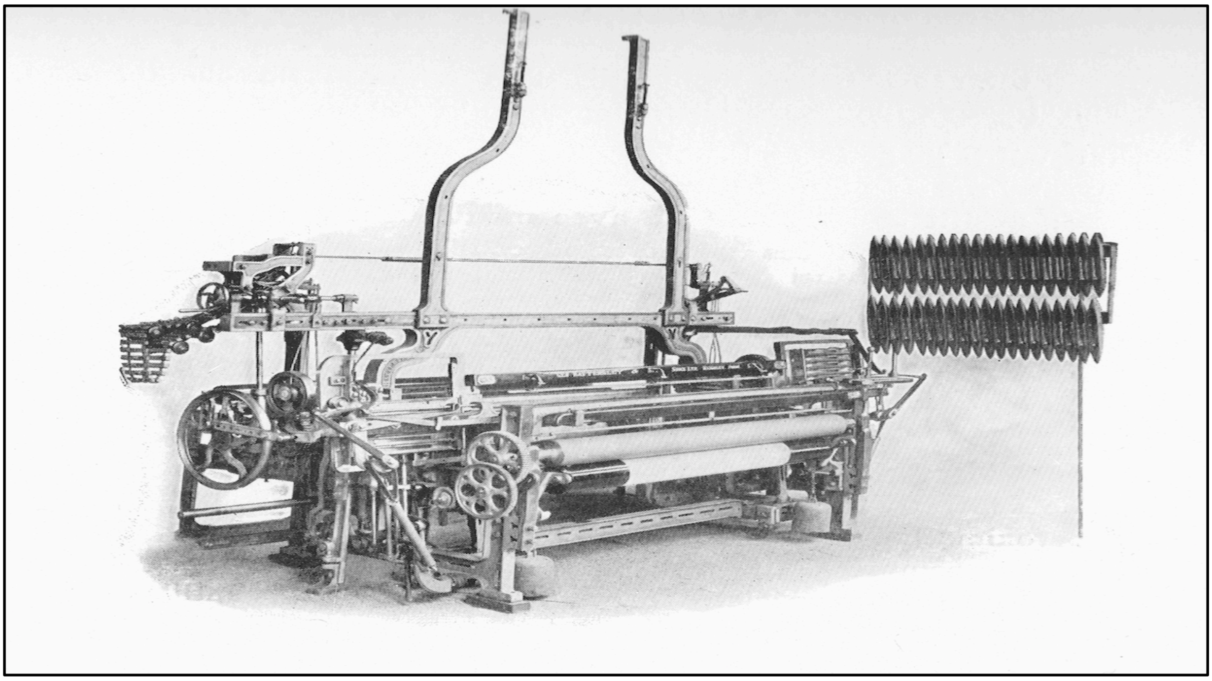
Non Positive Dobby Model No. 8



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 65)

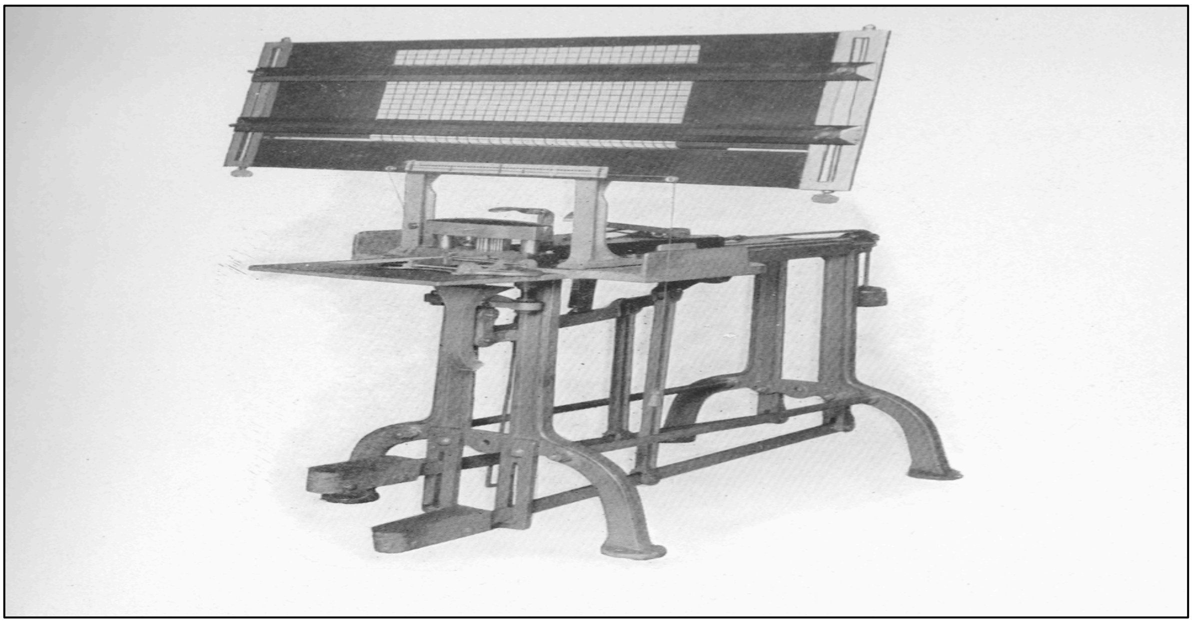
Overpick Rising Box Dress Goods Model Loom

Appendix 14



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 77)

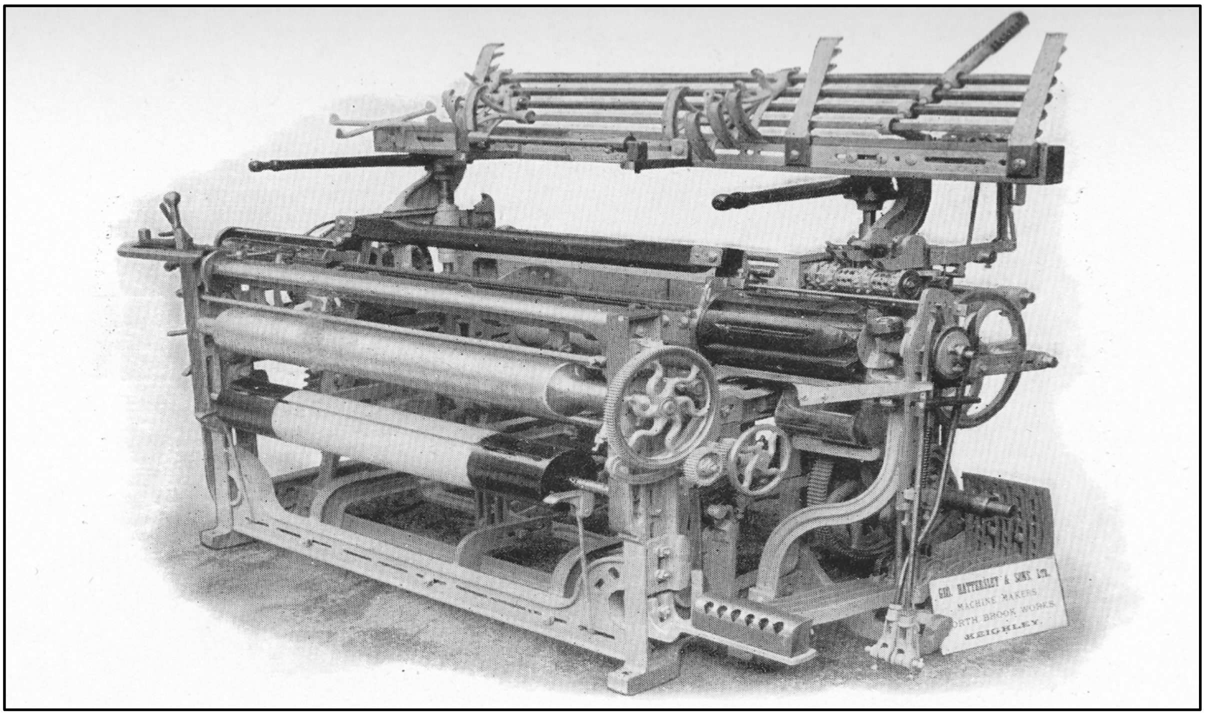
Overpick Tapestry Loom



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 9)

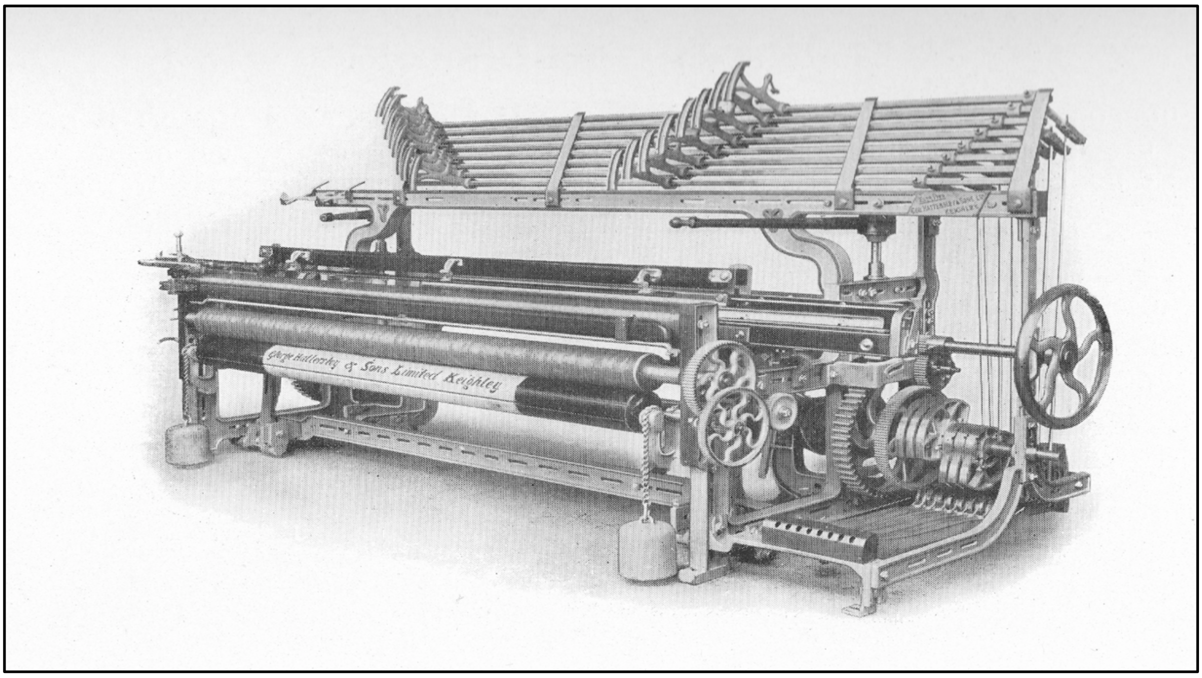
Piano Jacquard-card Stamping Machine

Appendix 15



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 55)

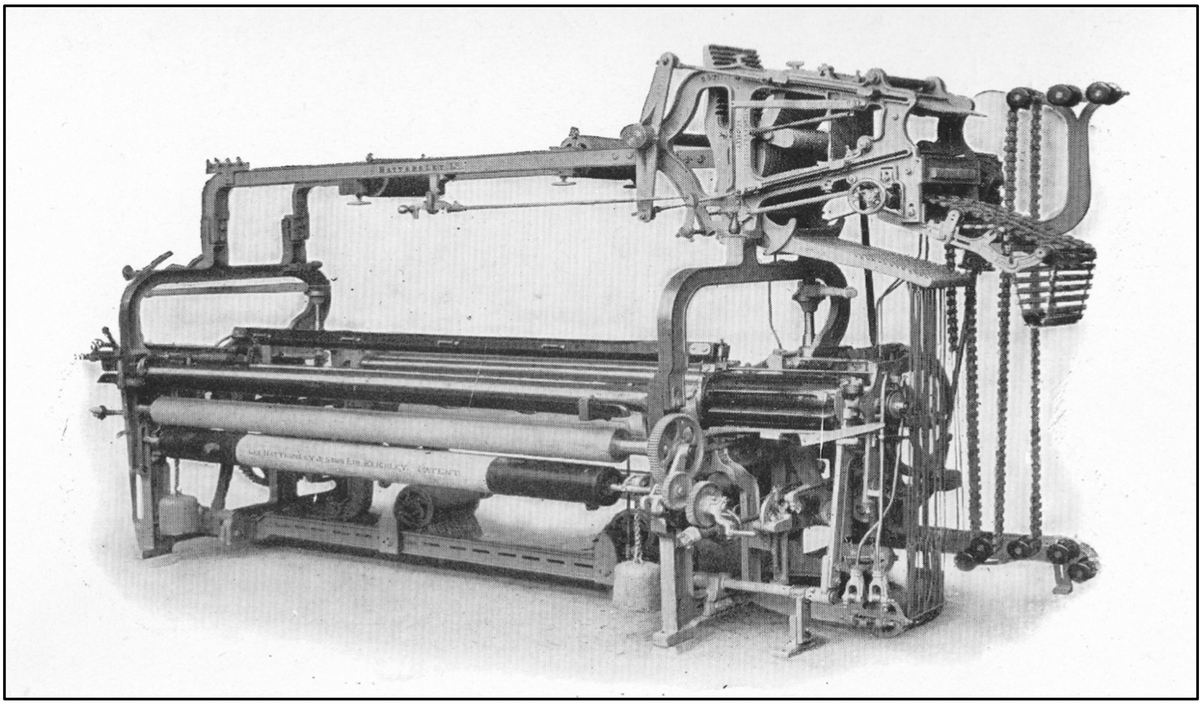
Revolving Box Dress Goods Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 15)

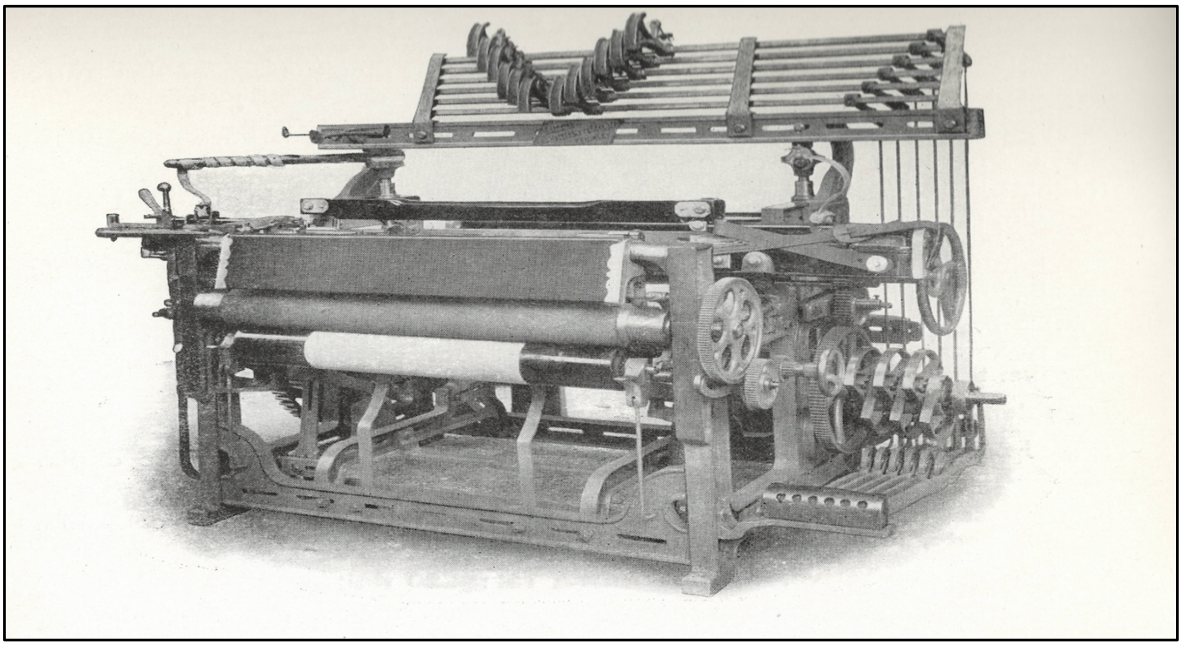
Single Shuttle Tappet Coating Loom

Appendix 16



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 57)

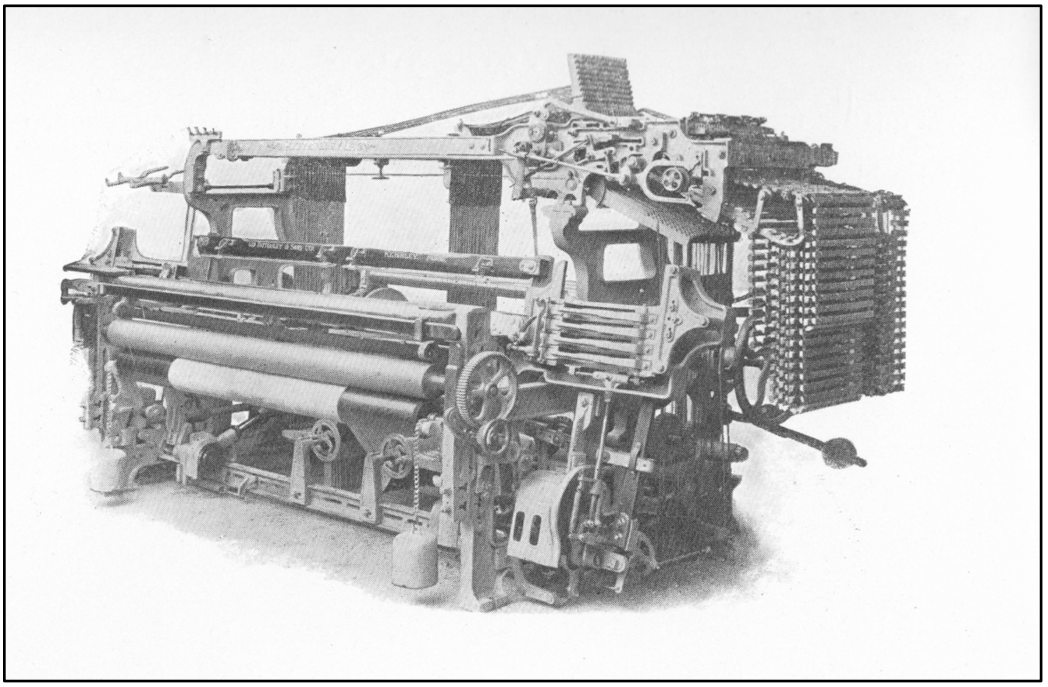
Revolving Box Loom for Light and Medium Coatings



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 5)

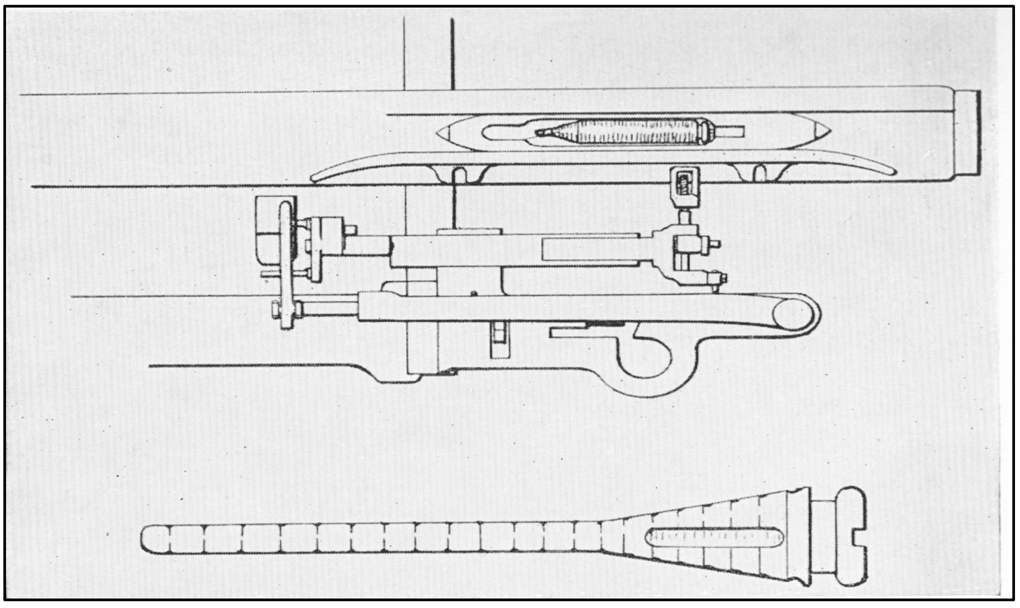
Single Shuttle Dress Goods Model

Appendix 17



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 75)

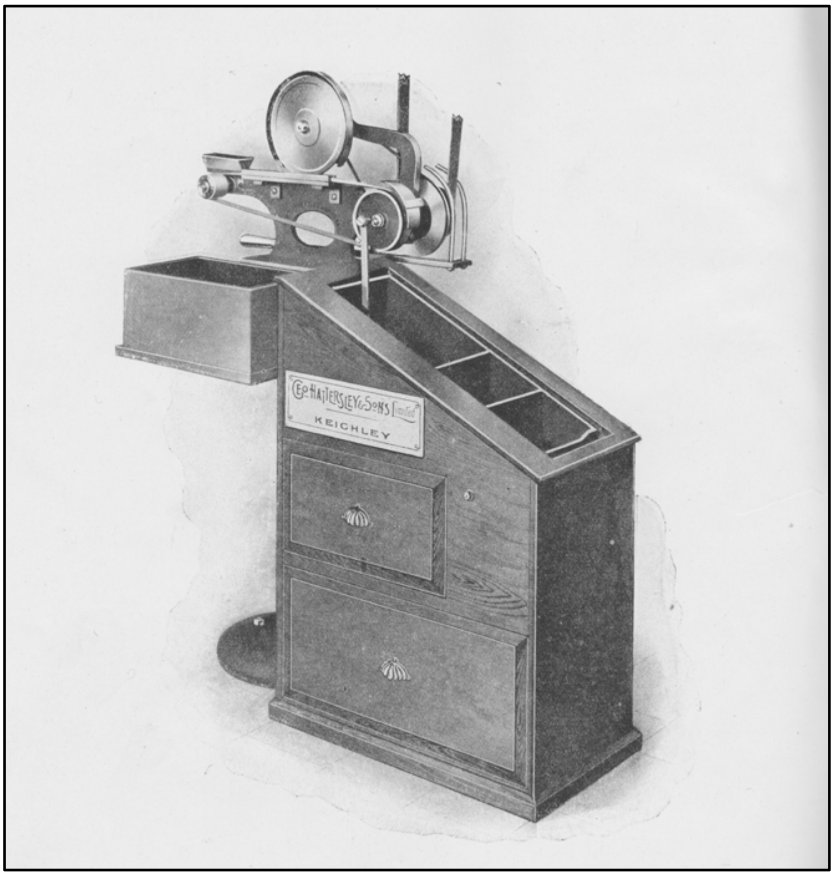
Underpick Centre Shed Dobby Woollen Loom



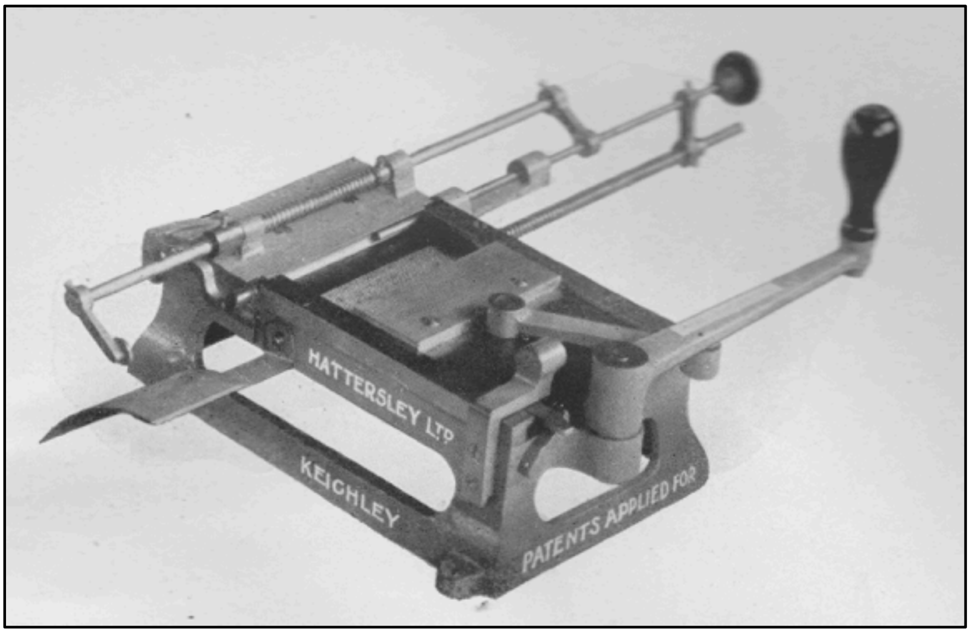
Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue, p. 51)

Weft Feeler Motion

Appendix 18

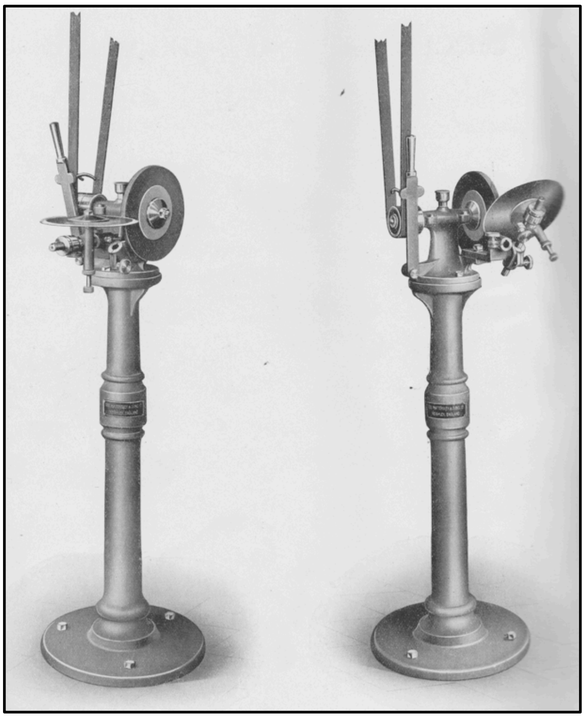


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Cigarette Stripping Machine No. 1/212. Model

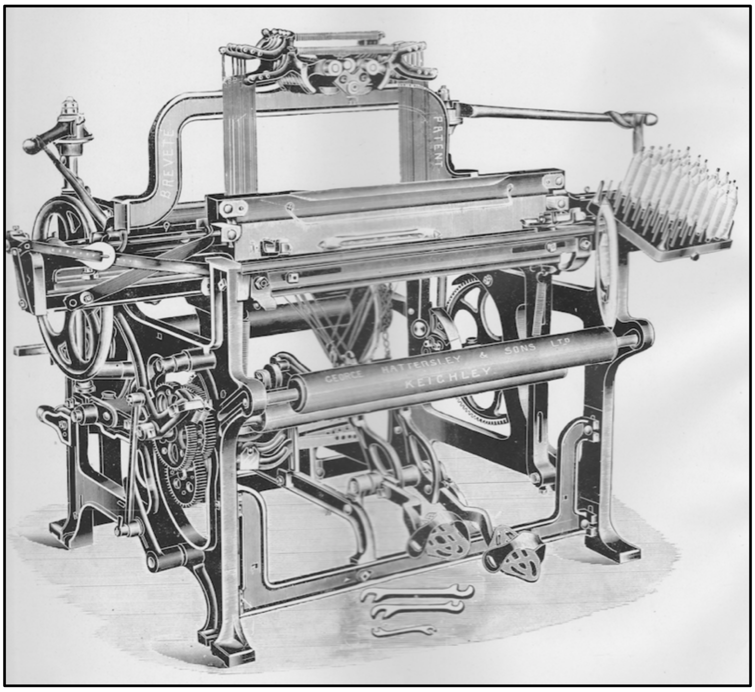


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Hand Cigarette Machine No. 3/212 Goods Model

Appendix 19

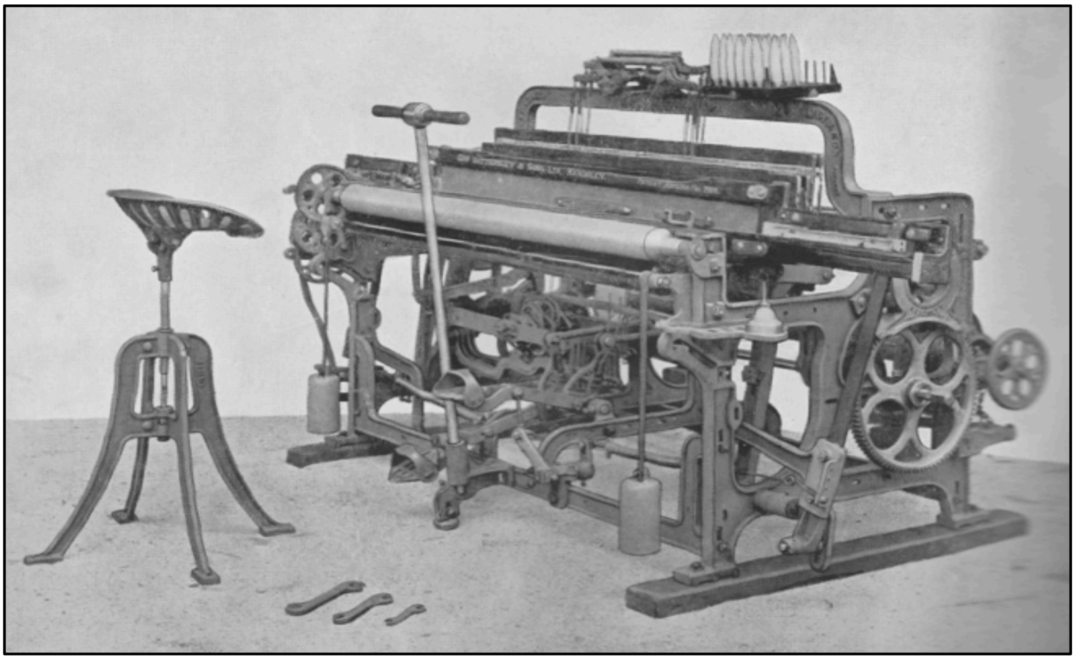


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Circular Knife Grinding Machine No. 2/212. Model

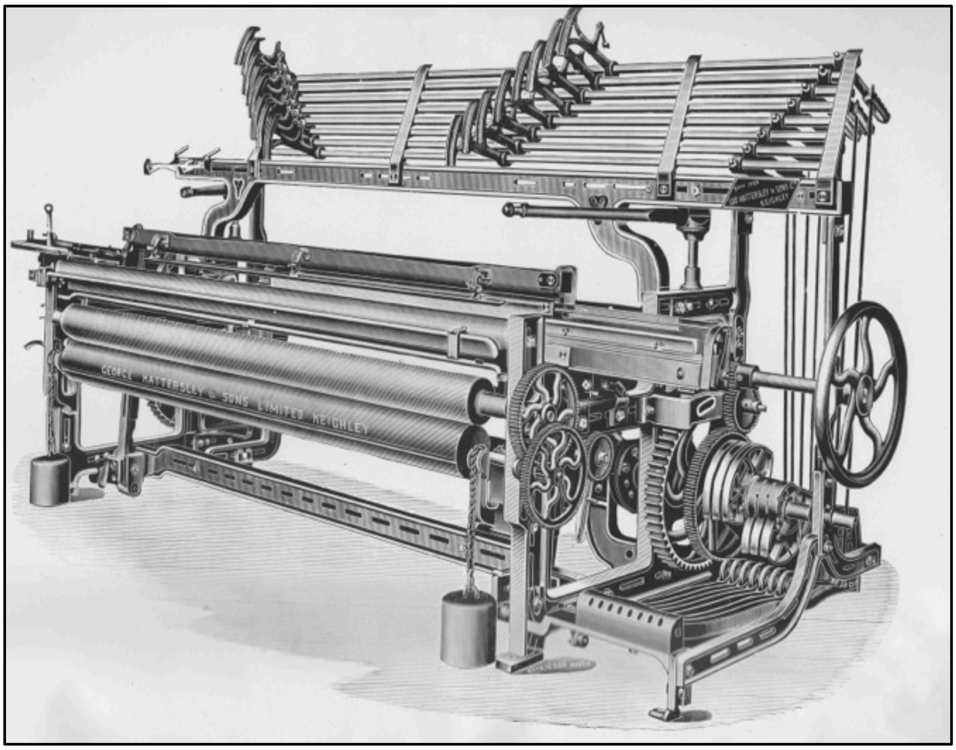


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Domestic Loom No. 65. Model

Appendix 20

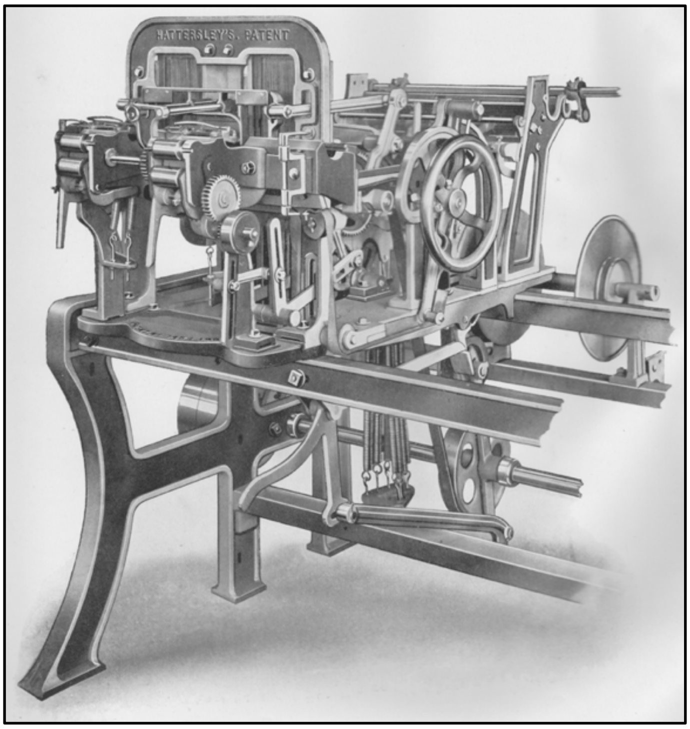


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue,)
Hattersley Patent Domestic Loom No. 113. Model

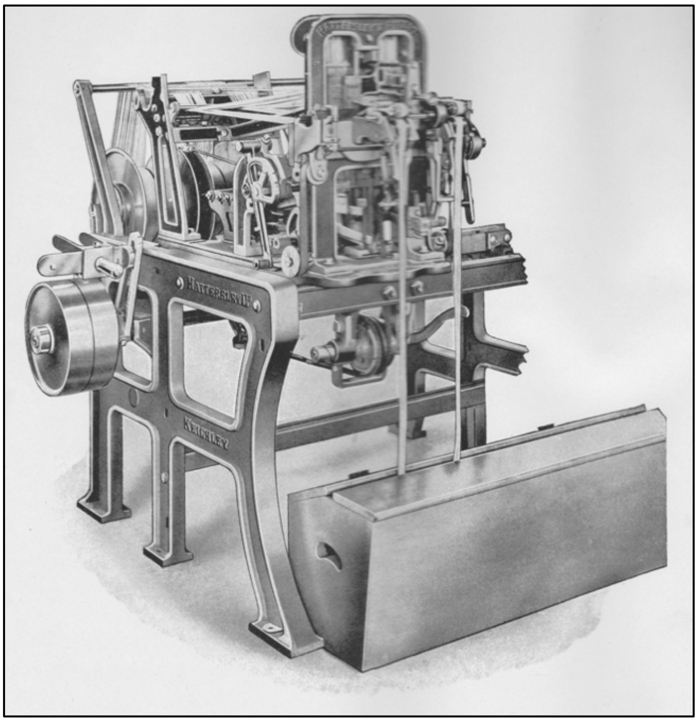


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue,)
Hattersley Single Shuttle Loom No. 33 Model

Appendix 21

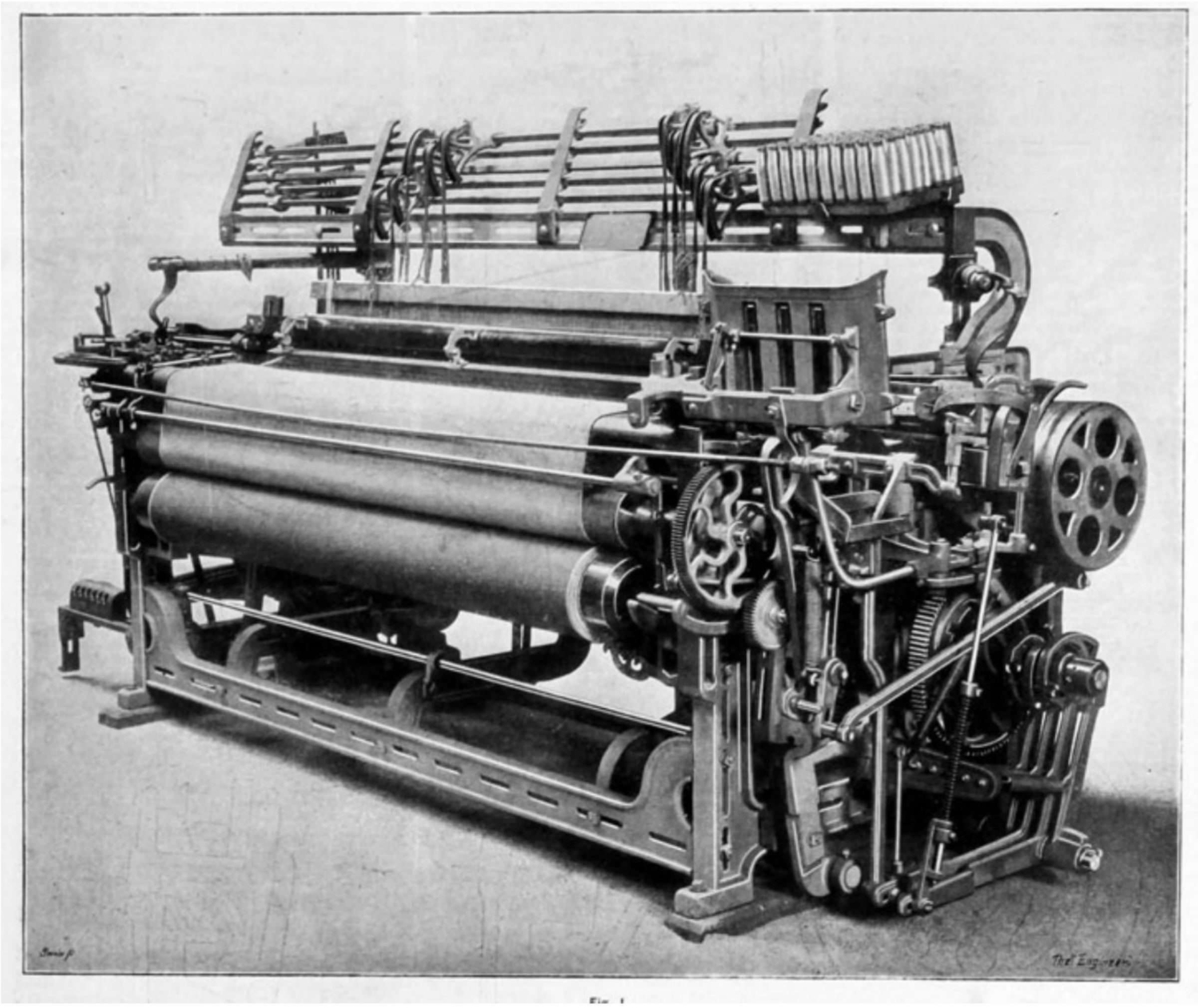


Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Smallware Loom 1909 No. 200 Model



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Smallware Loom No. 18 Model

Appendix 22



Source: (Messrs., George Hattersley and Sons. Ltd., 1914 catalogue)
Hattersley Automatic 1912 Loom No. 50 Model