A novel approach to combining scenario specification, visioning, and optimisation methods; a study from the Nigerian Petroleum Industry

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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. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The work attributable to the candidate comprises the literature review, planning and data collection, data analysis, writing, and creation of graphics.

The contributions of the co-authors consisted of supervision, critique and advice during the whole process, proof-reading and commenting.

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Abstract

The uncertainty in today's business environment threatens the efficacy of organisational strategies. In a bid to develop resilient strategies, planners require robust methods that address the complexities and complicatedness of long-term planning problems. Overtime, foresight methods such as visioning and exploratory scenario methods have evolved as suitable methods for addressing the complexities in long-term planning. While these methods are widely applied independently or in combined forms in diverse contexts, this research identifies two gaps in the visioning methodology that require attention. First, the research argues for the development of scenario-specific visions by stakeholder groups during visioning exercise as it supports the identification of unique features of stakeholder visions that can inform the strategy development processes. Second, the research argues that visioning can potentially provide useful inputs into optimisation models for the development of quantified visions. These quantified vision also inform strategic decision making. However, in the latter, the difference in the disciplinary foundations of visioning and optimisation creates a challenge for the integration of both methods. Consequently, this research attempts to bridge this gap by developing a multimethod approach that consistently integrates the exploratory scenario, visioning, and optimisation methods for the long-term planning of supply chain distribution networks.

The proposed multimethod was illustrated in the long-term planning for the Nigerian petroleum product distribution network for 2040. Four quantified external scenarios that are likely to occur in the Nigerian PPD network business environment by the 2040 were developed. The scenarios were used during a workshop and interviews to develop four scenario-specific visions for the Nigerian PPD network by 2040. The visioning outputs were translated from their qualitative forms into quantifiable forms, and finally optimised to identify their concrete implications for strategic decision making.

Findings from this research suggest that when a desk design is used for developing external scenarios, the scenarios must be revised with the stakeholders in order to gain a shared understanding of the scenarios prior to the development of visions. Also, the study confirmed that when stakeholder groups are encouraged to develop scenario- specific visions during visioning excercise, each group's vision is characterised by unique themes that suggest different options for implementation under different external scenarios. These distinct visions create an opportunity for the numerical assessment of the different scenario-specific visions that in turn provide concrete vision inputs into strategic decision making processes. While the risk of misrepresenting the stakeholder envisioned elements when translating visioning outputs into quantifiable elements was identified as a challenge of the OVAF, this limitation can be addressed by involving stakeholders during the framing of the optimisation model. However, users of the OVAF must note that the latter strategy depends on the knowledge of the stakeholders, and the time available for conducting the visioning exercise. Finally, the consistent link between the exploratory scenario, visioning and optimisation methods that led to the development of the OVAF bridges the gap between disciplinary foundations of qualitative and quantitative experts in the long-term planning domain.

List of Abbreviations

CA	Choices approach
CBN	Central Bank of Nigeria
CFLP	Capacitated facility location problem
CLD	Causal loop diagram
DRO	Distributional robust optimisation
ES	Exploratory scenario
IEO	International energy organisation
IMF	International monetary fund
LGA	Local government area
MILP	Mixed integer linear program
MOOP	Multi objective optimisation problem
MVCA	Modified visioning choices approach
NGN	Nigerian Naira
OVAF	Optimised visions of alternative futures
PD	Probability Distribution
PMS	Premium motor spirit
PSM	Problem structuring method
RO	Robust optimisation
SAST	Strategic assumption surfacing and testing
SCA	Strategy choice approach
SCND	Supply chain network design
SO	Stochastic optimisation
SP	Scenario planning
SSM	Soft systems methodology
TVA	Typical visioning approach
UFLP	Uncapacitated facility location problem
UN	United Nations
US IEA	United States International Energy Association
USD	United states dollar
VCA	Visioning choices approach
WLFR	Weighted location factor rating

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Chapter 1 - Introduction

1.1 Introduction

This thesis documents the development and evaluation of a multimethod for long-term planning within distribution network design contexts. The proposed multimethod consist of methodologies drawn from the foresight and the operational research (OR) domain. Specifically, the research seeks to integrate the exploratory scenario and visioning methods from the foresight field with facility location method from optimisation modelling field. The resultant multimethod will be labelled "Optimised Visions of Alternative Futures" (abbreviated to OVAF). The combination of the methods is inspired by the desire to provide a robust decision-support methodology that informs the long-term planning process for distribution network designs. Also, the underlying argument behind the developed approach is that every tool is useful for a particular job, but no single tool is suitable for all jobs. In some cases, more than one tool is needed to handle a job, and how they are used together impacts on the outcome. The individual methods have been widely used in the foresight and OR domain. However, the novel component of the research is to ascertain how the methods can be consistently combined and used to tackle complex real-world problems.

This research adopts a formative approach to the development and application of the OVAF in order to identify the strengths of the multimethod and aspects for improvement. Thus, the central argument presented in this research is that: "a viable multimethod approach for long-term planning of distribution network design contexts can be developed by consistently integrating exploratory scenario, visioning, and optimisation methods"**.** **T**he viability of the OVAF will be determined by evaluating the proposed multimethod approach through an illustration in a real-world, long-term planning case study within the distribution network design context. Based on the case study results, the viability of the approach can be assessed, and insights gained from the application will inform the modification of the multimethod.

The section 1.2 and 1.3 of this chapter provides the motivation for the research and a background to the key concepts that underpin the research. Subsequently, the research arguments central to the research design are discussed in section 1.4. The research aims and objectives, and questions are outlined in sections 1.5 and 1.6 respectively. The research contributions are provided in section 1.7. The framework that illustrates the focus of each chapters, and the relationship between the chapters is presented in section 1.8. Finally, the publications that evolved from this research are highlighted in section 1.9.

1.2 Motivation for research

This research is motivated by its practical relevance for long-term planning for the Nigerian Oil industry. It is motivated by the need for resilient strategies that ensure the efficient distribution of petroleum products in Nigeria by the year 2040. The quest has evolved due to the challenges faced by the oil industry as a result of unexpected and uncontrollable changes to the macro-forces (economic, political, social, technology, environmental and legal) in the Nigerian oil industry business environment. The industry planners have echoed the endless relevance of planning for the future of the oil industry in order to guarantee its continuous relevance to the Nigerian economy in the future.

The practical motivation described above has informed the review of literature to identify a method or methods for long-term planning under distribution network design contexts. The review revealed that long-term planning for the future involves different components. These include; i) the need for exploring the likely events that could occur in the oil industry macro-environment, and how these events can affect the operations of the industry; ii) the need for developing a vision or visions that would serve as a guide post which the industry aims to achieve. The vision intends to motivate the planners to develop resilient strategies that can reach the target pluralistic nature stakeholder perspectives when developing visions for the future; iii) the need for quantifying the visions in order to provide concrete implications of the visions for strategy development process, and iv) the need for developing pathways for achieving the visions for the future.

From the description of the elements for long-term planning described above, a single method cannot be used to address all the components as each component is underpinned by its underlying methodological assumption. For example, the exploration of the likely events that could occur in the oil industry macro-environment and the development visions for the industry require the use of qualitative methodologies such as exploratory scenario and visioning methods. The quantification of the visions can be addressed through quantitative modelling methods such as optimisation, and the pathway formation can be addressed either through qualitative or quantitative methods. Therefore, such long-term planning interventions would benefit from a consistent integration of the methodologies that address the different components of the long-term planning problem.

1.3 Background of study

Long-term planning is critical for maintaining the competitive edge in distribution network contexts. The design of such networks initiates with a strategic decision-making process that identifies the requirements for an ideal network design (Georgiadis and Athanasiou, 2013). Some of such strategic decisions include selecting the site and purpose of business facilities; creating a network of reliable suppliers, transporters, logistics handlers, and innovations that meet customer demand (Badri et al., 2013). These decisions must be robust and resilient in the face of unexpected uncertainty in the organisation's business environment. They aim at charting safe pathways to confront the uncertain events that are likely to unveil in the future. In the light of the latter issue, planners within the distribution planning contexts are always in search of suitable methodologies that address the complexity of long-term distribution planning problems.

Exploratory scenario and visioning methods have evolved as qualitative foresight methods for tackling long-term planning (Banister and Hickman, 2013). The boundary between these methods are sometimes unclear as they are both future-oriented and scenario-based. However, Timms et al. (2014) comments that a difference is that visioning scenarios focus on factors that are controllable by the organisation, while the exploratory scenarios concentrate on uncontrollable issues in the organisation’s business environment. Besides, the exploratory scenario method does not predict what will happen in the future. It embraces the existing societal trends as well as the uncertainties in the business environment to develop a variety of plausible alternative futures (Dator, 2012). On the other hand, visioning scenarios focus on organisational capabilities and other controllable drivers to craft desired future images (Rigby and Bilodeau, 2007). The visioning method can be used to create desired futures, which reflect the values, norms, and aspirations of actors within the system (Sheppard et al., 2011). Besides the highlighted differences, both methods have gained popularity in the climate change (Alcamo, 2009; Zhang et al., 2016), transport planning (Tight et al. 2011; Hickman et al. 2011), land-use planning (Mallampalli et al., 2016); water and environmental management (Booth et al. 2016; and Soria-Lara and Banister, 2017).

Govindan et al. (2017) identifies that long-term planning environments are characterised by certainty, risk, and uncertainty. Under "certainty" situations, all parameters are deterministic and known. Under “risk” situations, there are uncertain parameters whose values are governed by probability distributions that are known by the decision-maker. Under the “uncertainty” situations, most system parameters are subject to changes, and no information about their likelihood of occurrence is known. Planning problems under risk situations are also called stochastic optimisation problems. Whereas, problems under uncertainty are known as robust optimisation problems. Both stochastic and robust optimisation techniques can be used to plan for future systems under uncertainty (Dembo, 1991).

The combination of highlighted foresight (exploratory scenario and visioning) and optimisation (facility location models) methods has the potential to address the complexity and complicatedness of long-term planning problems for distribution networks. Visioning is credited for its ability to structure problem complexity by dealing with the plurality of stakeholder opinions (O’Brien and Meadows, 2007). On the other hand, the optimisation methods also referred to as the hard OR methods can be used to address the technical elements of planning problems. Therefore, there is a potential for the exploratory scenario and visioning structuring methods to be complemented by optimisation methods when planning for future systems. The foresight and optimisation methods are characterised by different epistemological assumptions. Exploratory scenarios and visioning scenario methods utilise qualitative data collection methods. While the optimisation methods rely on quantitative information for modelling complex problems. Consequently, one question comes to mind; can these methods drawn from different disciplinary backgrounds and underpinned by different epistemological assumptions be combined? If yes, then how?

1.4 Research arguments

The research arguments are presented in two levels. The first level, the argument for the methodological integration of the foresight methods (i.e., exploratory scenario and visioning) and quantitative modelling methods (optimisation). This argument align with the call by both researchers in OR domain for combining PSMs with hard OR methods. On the second level, one argument is provided on the need for a specific design for combining the two foresight methods (exploratory scenario and visioning). The design suggests how exploratory scenario outputs can be integrated into a participatory visioning exercises during a visioning workshop and interviews. Another argument echoes the need for the quantification of visioning outputs to support strategy development processes. The latter addresses how the classical visioning process can be improved through a consistent integration of visioning with optimisation methods. Details of these arguments are described in the following subsections.

1.4.1 The need for integrating PSMs (exploratory scenario, visioning), and optimisation method.

Overtime, researchers in the operational research domain have raised concern over the gradual drift of the operational research techniques away from the application of its techniques to solve real-world problems towards their contributions to mathematical theory (Kotiadis and Mingers, 2006). This drift has ignited concerns that the assumptions underpinning existing quantitative OR techniques were ill equipped to deal with the complex, messy problems faced by organisational managers (Prell et al., 2007). In response to the latter highlighted issue, problem structuring methods (PSMs) have evolved for structuring the messy and complex problem situations rather than solving well defined problems. Smith and Shaw (2019) highlight that PSMs explore the differing views and perspectives of the stakeholders in a situation and facilitate participation and engagement rather than analysing abstract data and models (Franco, 2009).

In addition, evidence from the OR literature suggest that industry planners and researchers have embraced the combination of the PSMs with quantitative modelling methods (Durbach and Stewart, 2003; Montibeller et al., 2006; Stewart et al., 2013; Kotiadis and Mingers, 2014, and Witt et al., 2020). This has materialised overtime through the following combinations: i) exploratory scenario with goal programming (Durbach and Stewart, 2003); exploratory scenario and multi-criteria decision analysis (Montibeller et al., 2006; Stewart et al., 2013; Witt et al., 2020); soft systems methodology and discrete event simulation (Kotiadis and Mingers, 2014; Tako and Kotiadis, 2015; Cardoso-Grillo et al., 2019), and exploratory scenarios with optimisation (Riddel et al., 2014)

In the combination proposed by Durbach and Stewart (2003), the scenario planning helped the decision-makers in the treatment of uncertainty and thinking about the possible future scenarios that could evolve due to the uncertainty while the goal programming method was used for the resolution of the conflicts among competing criteria. The combination proposed by Montibeller et al. (2006), the scenario planning performed the role as specified in the study of Durbach and Stewart, while the multi-criteria decision analysis provided an in-depth performance evaluation of each strategy as well as in the design of robust and better options. In terms of process and input translation between the SSM and Optimisation, the study of Cardoso-Grillo et al. (2019) combines the structuring of objectives and specificities of the medical training problem with the help of the SSM; the mathematical optimisation formulation tries to minimise the imbalance between demand and supply and the cost and maximising the equities across medical specialities.

While the researcher acknowledges the effort of researchers in the combination of exploratory scenarios with optimisation, to the researcher's knowledge, no study has explored the triple combination of exploratory scenarios, visioning, and optimisation methods. Each of the methodologies combined address different components of the long-term planning problems. The exploratory scenarios address the uncertainty in the organisation’s external environment; the visioning address the problem complexity associated with multiple stakeholder views on an ideal future, and the optimisation models address the specifics and complicatedness of the problems. The optimisation models will focus on the analysis of the scenario-specific visions to identify the quantified implications of the visions for strategy development. The link between the exploratory scenarios and the visions support the development of vision options that are consistent with different background contexts. Also, the link between the visioning and optimisation supports the quantification of visions that in turn provide concrete inputs for strategy development processes.

1.4.2 The need for developing multiple scenario-specific visions by stakeholders during visioning exercises.

The argument presented in this section draws from the linkage between the exploratory scenario and the visioning phase of the triple integration presented in section 1.4.1. Exploratory scenario or visioning methods have successfully been applied independently in different planning contexts (Heiko and Darkow, 2010; Blanco and Moudon, 2017; O'Brien and Meadows, 2007). However, some argue that combining both methods present complementary features that lead to an improvement in the strategy development process (Kok et al., 2011, and van Vliet and kok, 2015). While the relevance of external environment assessment during visioning cannot be overlooked, designs on how both methods are combined have not been adequately explored.

The discourse on how exploratory scenarios are combined with visioning expose rich methodological insights. Some authors argue for the development of exploratory scenarios prior the visioning process because the scenarios support the development of achievable visions (Wilson, 1992; Schoemaker, 1992; Jiménez et al., 1997; Tight et al. 2011; van Vliet and Kok, 2015). The importance of the latter design cannot be overemphasised as prior review of external scenarios provide stakeholders with the insights into the uncontrollable eventualities that can strongly influence the achievement of visions or the resilience of their strategies (O'Brien and Meadows, 2007; van Vliet and Kok, 2015). Besides, others argue that it is necessary for stakeholders to be involved in the development of the exploratory scenarios before developing the visions (kok et al., 2011; Schneider and Rist, 2014; van Vliet and Kok, 2015). Other opt for the external scenarios to be developed by experts and latter presented to the stakeholders to be used for the development of the visions (De Bruin et al., 2017; Tight et al., 2011; O'Brien and Meadows, 2007). Each highlighted approach present its unique challenge and call for deeper discussion on the implications of the methodological choices made when combining the methods.

This research lends its voice in furthering the argument on how both methods are combined. It provides insights into a new area for discussion that have been proposed by van Vliet and Kok, 2015 and not addressed by previous authors in the foresight domain. It argues on the potential for the development of multiple exploratory scenarios through a desk design and subsequently developing multiple stakeholder visions under the different exploratory scenarios. While some studies have proposed the development of such multiple visions (kok et al., 2011; Schneider and Rist, 2014; van Vliet and Kok, 2015), no study has provided an empirical evidence that exposes the rich issues associated with the proposed design. The research seeks to analyse the elements of scenario-specific visions developed by stakeholders when presented with exploratory scenarios developed through a researcher-led desk scenario approach. It explores the methodological insights associated with the development of multiple visions by different stakeholder groups that are consistent with different external scenario background contexts during a typical visioning workshop.

1.4.3 The need for developing quantified visions for strategy development.

Strategic decisions are basically long-term decisions, which affect the way the company moves forward. Hence, they are prerequisites for the success of every organisation. Kunc and O'Brien (2017) highlight the usefulness of scenario planning for strategy development. However, they note that problems associated with linking the scenarios developed to strategy development and implementation. The researcher posits that the latter challenge can be reduced if the outputs from exploratory and visioning scenario projects can be further analysed to add value to the strategy development process.

Visioning processes are qualitative and normative in nature due to its underlying paradigm foundation. Its interpretivist ontology is underpinned by the use of use multiple stakeholder participation for the creation of visions. While the latter is no doubt an ingredient for producing creative images of the future, the outputs from these processes are usually non-numerical and lack the technical details that support strategy development processes. Booth et al. (2016) argue that a reason for the later problem is that desirable future images originate from the imagination of complex systems by actors who may not possess the technical expertise. More so, where the technical knowledge of the systems exists, values which underpin stakeholder preference of an ideal state differ across participants. In addition, the practical constraints such as the short duration of visioning workshops may not allow such detailed quantification of visioning outputs by stakeholders during the exercise.

Regrettably, this unexplored field remains a challenge that limits the insights into the concrete implications of stakeholder vision options that in turn provide rich information for strategic decision making. Also, quantifying the visioning outputs bridges the gap between the underlying philosophical assumptions held by qualitative and quantitative experts and stakeholders about long-term planning procedures.

1.5 Research aims and objectives

The research aims to consistently integrate exploratory scenarios, visioning and optimisation methods into a multimethod approach that can be used for the long-term planning of distribution network design systems. The proposed approach will be termed "Optimised Visions of Alternative Futures Approach (abbreviated to OVAF)".

The objectives presented below are carried out to achieve the aim.

1. To develop an exploratory scenario approach that supports the development of quantitative scenario specifications for long-term planning;
2. To develop a visioning approach that supports the development scenario-specific visions by stakeholders during a visioning workshops;
3. To develop a visioning output translation framework that can be used to translate stakeholder visioning outputs into quantifiable optimisation elements;
4. To develop an optimisation method which quantifies vision defined variables for optimising the multiple visions options;
5. To evaluate the OVAF multimethod's usefulness for the long-term planning and strategy development for the Nigerian Petroleum Product Distribution (PPD) Network;

1.6 Research questions

In line with the aim and research objectives outlined in section 1.5, this research must address the following research questions:

RQ1: How can exploratory scenarios, visioning and optimisation be consistently combined to address long-term distribution network planning problems?

RQ1a: How useful is the development of multiple scenario-specific visions by stakeholders during a visioning exercise?

RQ1b: What are the issues associated with the quantification of stakeholder scenario-specific visions?

RQ1c: what are the issues associated with the optimisation of scenario specific visions?

RQ2: How can external scenario specifications be developed to support vision development and optimisation of the visions?

RQ2a: How many external scenarios are ideal to support the development of stakeholder scenario-specific visions?

RQ2b: How useful is a desk external scenario design compared to the participatory design?

RQ2c: How did the exploratory scenario stage address its purpose within the OVAF multimethod?

RQ3: What issues are associated with developing scenario-specific visions?

RQ3a: How does the participants characteristics during visioning exercise affect the visions developed?

RQ3b: How does visioning workshop schedules impact the quality of visions developed?

RQ3c: How does visioning interview schedule impact the quality of visions developed?

1.7 Research contributions

This research contributes to the methodological development in the foresight visioning and the OR field. In the former, the research improves on the state-of-the-art visioning procedure by quantifying the vague and qualitatively described visioning outputs, to a quantifiable form which can be used for numerical assessment purposes. In the OR domain, this research contributes to the call for mixing the PSMs and hard OR methods by proposing a multimethod that integrates exploratory scenario and visioning foresight methods with optimisation methods from the OR field. This proposed multimethod must be suitable for addressing the uncertainty, complexity, and complicatedness of long-term planning problems. This is the first study to propose such a combination of PSMs and hard OR methods with potential long-term distribution network design problems.

Another contribution of this research is the proposal for a unique design for integrating exploratory scenario within visioning exercises. While the researcher acknowledges that studies have combined these methods using different designs and rationales. The researcher's suggestion for the development of multiple visions under specific external scenarios (scenario-specific visions) provides the opportunity for exploration of the benefits of unique stakeholder vision options under different scenarios. While different studies have provided close designs as explained in the section 1.3.2, to the researcher's knowledge, the proposed design of developing scenario-specific visions by stakeholders during visioning workshop is new.

This research contributes to the existing scenario narrative translation methods described by Mallampalli et al. (2016). The proposed translation approach is a post-visioning expert-led procedure that consist of framing the optimisation problem and formulating the generic optimisation model. Finally, the research contributes to transdisciplinary research by bridging the philosophical gap between of the ontological assumptions held by positivists and interpretivist in the strategic planning domain.

1.8 Structure of the thesis

Below should help the readers to understand the sequence. The diagram shows the funnel shape flow of the argument between the chapters in the study.

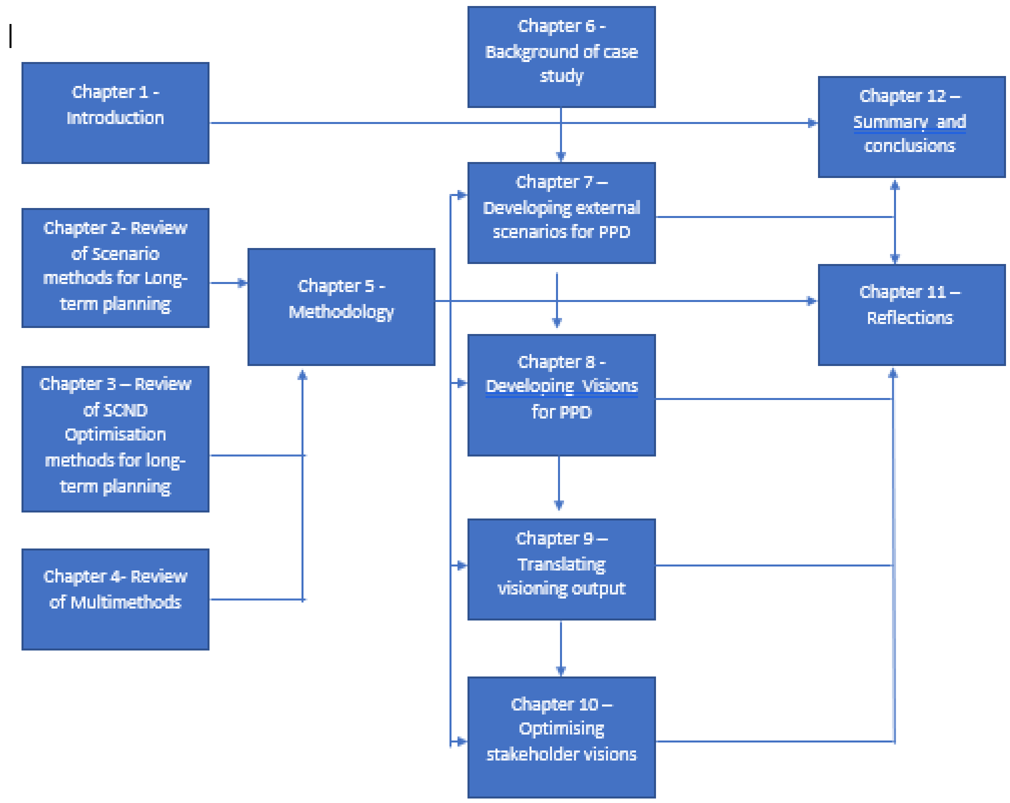


Figure 1.1 Conceptual structure of thesis chapters

Chapter 1 provides an overview of the focus of the research context, discusses the relevance of developing the OVAF multimethod for long-term planning for distribution network design contexts. It also presents the research questions, objectives, and potential contributions of the research to knowledge.

Chapter 2, and 3, present the literature review carried out to unravel the research gaps and the existing arguments in the foresight and optimisation domain that underpins the research. Chapter 2 specifically discusses the scenario planning and visioning methods and explores the current state of multimethod development involving scenario and Visioning methods. Chapter 3 deals with the quantitative methods for future decision making. It dives into the operational research domain to explore the state of multimethods involving hard operational research methods. Both chapters terminate with arguments for the combination of methods for the development of a more robust method.

Chapter 4 explores the literature on multimethod development, the underpinning philosophies, methodologies, tools, and features of these methods. It reviews the framework for mixing methods.

Chapter 5 draws insights from the chapter 2,3, and 4 to present the methodology for this Thesis following the literature research gaps and argument identified in chapter 2 and 3. It presents the selected philosophical standpoint of this research, the methodology selected to carry out the research that includes the development of OVAF method, the evaluation of the OVAF through the application in a case study, and the reflection on the method's application.

Chapter 6 provides a background of the Nigerian petroleum industry case study to be used for the evaluation of the OVAF. It provides a detailed description of the component of the Petroleum Industry, and the product distribution sector. It describes the existing network and elucidates the challenges faced by the sector in Nigeria.

Chapter 7,8,9 and 10 are the case study chapters. It consists of four interconnected studies that illustrate the four stages of the OVAF approach. These chapters draw on the decisions made in chapter five and the OVAF guidelines provided in chapter six.

Chapter 11 provides a high-level reflection on the results of the application of the OVAF in the case studies in chapter 7,8, 9, and 10. It also relates the results to alternative decisions that could have been made in chapter 5.

Chapter 12 presents a summary and conclusion chapter, which considers the results of all the evaluations presented in other chapters, presents the contribution of this Thesis, and offers recommendations for future investigation.

1.9 Journal / Conference publications arising from the thesis

Chikwendu D. (2017) Combining Foresight and Optimisation Methods for Long-term Planning; A case of the Nigerian oil industry. A paper presented at the Logistics and Supply Chain Conference Organised by the Sheffield University Management School and the British Academy of Management in March 2017

Chikwendu D. Timms, P. and Watling D. (2018) Future Scenarios for the Oil and Gas Downstream product Transportation; A case study from Southern Nigeria. A Paper Presented at the 50th UTSG Annual Conference held at University College London in January 2018.

Chikwendu D. Timms, P. and Watling D. (2019) Envisioning Petroleum Products Distribution Network Design in Nigeria; a Qual-Quant Visioning Approach. A paper presented at the Futures Conference Organised by the Future Institute of Finland and held at Turku, Finland in June 2019.

Chikwendu D. Timms, P. and Watling D. (2019). Improving Long Term Planning for Distribution Network Systems; and Optimisation – Visioning Approach; Presented at the UTSG 51st Annual Conference held at the University of Leeds in July 2019.

Chapter 2 - Review of scenario methods for long-term planning

2.1 Outline of review chapter

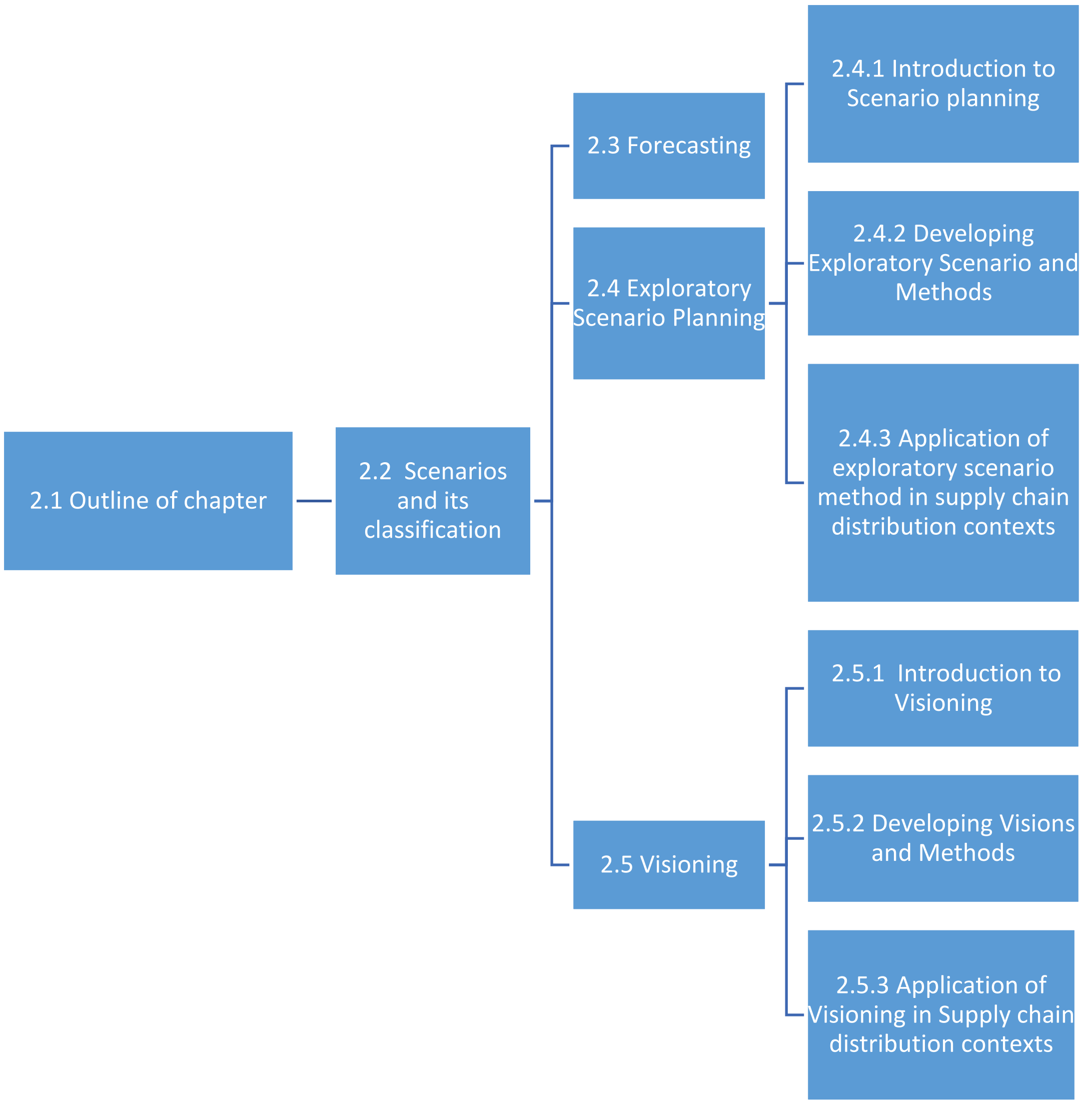


Figure 2. 1 Structure of the literature review

Figure 2.1 illustrates the structure of the literature review carried out in this chapter. The chapter initiates with the presentation of the outline of the chapter. In section 2.2, the concept of scenarios and its classifications are described. The widely adapted scenario classification proposed by Banister and Hickman's (2013) used to frame the structure of review. The sections of the review include forecasting (addressed in section 2.3), exploratory scenarios (addressed in section 2.4), and visioning (addressed in section 2.5). Each scenario class has been briefly described in section 2.2 to provide a brief definition of the concepts, and a detailed description of the types of scenarios, procedures and methods are provided in section 2.3, 2.4 and 2.5 respectively.

2.2 Scenarios and its classification

Scenarios can be defined as the representations of developments and possible future states (Borjeson et al., 2006). They are the different outcomes of the future that have been described in a coherent manner (Van Der Heijden et al., 2002). They help managers articulate their mental models about the future in order to make better decisions (Martelli, 2001). From these definitions, it can be deduced that scenarios generally represent future states. However, Banister and Hickman (2013) creates distinction among different types of scenarios by classifying scenarios into forecasting, exploratory scenarios, and normative scenario (visioning scenarios).

Banister and Hickman (2013) defines forecasting as a future oriented approach that is utilised where substantial changes to the macro-economic forces are not expected. Forecasts are developed on the assumption that existing conditions will remain the same over a specific planning period (Bornelind, 2019). Hence, their reliance on the extrapolation of past and present trends to predict what will happen in the future. On the other hand, exploratory scenarios are narratives of how various macro-elements in a firm's business environment might interact under certain conditions (Hiltunen, 2009; Banister and Hickman, 2013). They are worked out in order to span a broad scope of possible developments in the business environment of a focal firm (Svenfelt et al., 2019). They are elaborated with a long time-horizon to allow for more profound changes explicitly. Unlike forecasting that assumes a surprise-free future, exploratory scenarios embrace the uncertainties in the society to develop plausible long-term plots of events that could occur in the future (Schwartz, 1996). In the case of visioning, Wiek and Iwaniek (2014) defines it as “the process of creating a vision; a representation of a desirable future state”. It is a mental process in which images of a desired future are made intensely real and compelling to act as motivators for the prompt action (Banister and Hickman, 2013).

Besides Banister and Hickman’s (2013) scenario classification, other authors (Amara, 1981; Huss and Honton, 1987; Masini, 1993; Dreborg, 2004; Borjeson et al., 2006; Amer et al., 2013) have classified scenarios using different terminologies. Table 2.1 provides a summary of classifications of scenarios provided by different authors in the futures field and how these classifications differ from Banister and Hickman’s (2013) classification.

Table 2. 1 Scenario classifications

Author	Scenario Classification	Similarity to Banister and Hickman's Classification
Amara, 1981	"Possible", "Probable" and "Preferable"	Similar
Huss and Honton, 1987	"Intuitive logics", trend impact analysis", and "Cross-impact analysis".	Not Similar
Masini, 1993	"Extrapolation", "Utopian" and Vision"	Not similar
Dreborg, 2004	"Predictive", "Visioning", and "Eventualities"	Similar
Borjeson et al., 2006	"Predictive", "Explorative, "Normative"	Similar
Amer at al., 2013	"Intuitive", "Probabilistic trends", "La prospective"	Not similar

According to the table 2.1, the similarity implies the classifications that align with the definitions of the typologies provided by Banister and Hickman (2013) in section 2.2 above. The table indicates that there are similarities across the classifications provided by latter authors and classifications of other scenario developers. The similarity between the classification of Amara (1981); Dreborg (2004), and Borjesson et al. (2006) indicate that "the possible"," the eventualities" and "the explorative" align with the definition of the explorative provided by Banister and Hickman (2013). This scenario type depict the range of possibilities that can evolve in the future. It is premised on the fact that the future cannot be predicted. Instead, different plausible states of the future that suggest the likely occurrence can be created. Also, "the probable", "the extrapolative", and "the predictive" are similar to "the forecasting" of Banister and Hickman (2013). This class is premised on the notion that existing or past events will follow a similar trend into the future. This means that the future can be predicted through the extrapolation of past and existing trends. Furthermore, "the preferable", "the utopian" or "vision", "the Visioning" and "the normative" are similar to visioning of Banister and Hickman (2013). This class is based on a value, and desires of the actors in a system as regards the controllable forces in their organisation.

Among the typologies provided in table 2.1, the scenario classification provided by Masini (1993) and Amer et al. (2013) slightly differ from the reference scenario classification. While the "utopia" and “vision” class presented by Masini (2002) align with the visioning classification of Banister and Hickman (2013), it does not capture the exploratory component suggested by Banister and Hickman (2013). Masini explains that the utopia indicates either a positive or a negative future and differs from the probable. However, according to the Merriam -webster dictionary, utopia means “a place/state of ideal perfection”. Therefore, it is not clear if the utopia should correctly mean a positive or negative future as explained by Masini (1993). In essence, the utopia and the vision mean the same thing. This aligns with the definition of a vision as a desired future state. Consequently, both utopia and vision concepts suggest a desirable and positive image of the future. On the other hand, the intuitive classification of Amer et al. (2013) can be linked to the exploratory scenarios, while the probability modified trends relate to the forecasting. However, the La prospective relates to a form of exploratory scenario and forecasting. The latter is true because the probability modified scenario approach consist of elements of both forecasting and stakeholder judgement.

2.3 Forecasting scenarios

Forecasting scenarios provide insights into events that will happen in the near future and Banister and Hickman (2013) notes that the time horizon for forecasts are likely to be about 10 years. Forecasts are estimates of the actual, and the quality of a forecast is judged to be good when the difference between the predicted and the actual is minimal (Armstrong, 2001). In addition, the accuracy of forecasts are better when existing trends remain the same. This is not the case in long-term planning where existing trends discontinue and new events unfold (Dator, 2012). Hence, forecasts are not suitable for long-term planning horizon (Dator, 2012).

Forecasting has been criticised for its inability to provide accurate and reliable insights for long-term planning (Schnaars, 1989; Schwartz, 1996; Armstrong, 2001; Watling and Timms, 2014; Tartaglione et al., 2018, and Dator, 2012; 2019). Despite the evolution of complex forecasting techniques, Schnaars (1989) affirm that forecasting methods are not suitable for developing long-term planning scenarios because forecasting methods do not capture the complex issues that are uncertain and could evolve over longer periods. Watling and Timms (2014) comment on the level of uncertainty of the uncontrollable variables when predicting the future of transport systems for 20 years horizon. Therefore, relying on the extrapolation of past trends for long-term prediction without due consideration of uncertainty limits the accuracy and reliability of the forecasts.

In light of the described limitation of forecasting, researchers have considered alternative long-term suitable approaches such as the exploratory approach. Consequently, this review proceeds to the exploratory scenario class in the next section.

2.4 Exploratory scenarios

Exploratory scenarios were first developed by the United States Defence during the World war II for military planning (Khan, 1967). Exploratory scenarios respond to the question; what can happen in the future? They reflect the plausible outcomes of external factors outside the control of a particular organisation or sector (Timms et al., 2013). Exploratory scenarios are narratives of how various macro-elements in a firm's business environment might interact under certain conditions (Hiltunen, 2009). In this type of scenario, a set of scenarios are worked out in order to span a broad scope of possible developments (Svenfelt et al., 2019). They are elaborated with a long time-horizon to allow for more profound changes explicitly. Furthermore, the exploratory scenarios more often take their starting point in the future. Unlike the forecasting scenarios that assume a surprise-free future, exploratory scenarios embrace the uncertainties in the society to develop plausible long-term plots of events that could occur in the future.

Banister and Hickman (2013) echo the benefits of adopting exploratory scenarios for crafting robust strategies. These strategies are tested through external scenario frameworks to ascertain the resilience of policies in the face of several kinds of external environments (Kunc and O'Brien, 2017). They are used to provoke thoughts about future possibilities and inspire planners to invent robust responses to the surprises and uncertainties likely to erupt in the external business environment of the future (Inyatulah, 2009; Borjeson et al., 2006). To fully understand the future, scenarios developed should capture a wide range of options that can evoke the stakeholder reactions on how the future would evolve (Shoemaker, 1991; 1993). In light of the highlighted benefits of exploratory scenario for future planning, it is important to understand how these scenarios are developed using the scenario planning methodology.

2.4.1 Scenario planning (SP) methodology

The SP has evolved as an exploratory scenario methodology for the development of external scenarios; It does not predict what will happen in the future. Instead, it embraces uncertainties in the organisational business environment to develop a set of plausible scenarios that businesses may encounter in the future (Pillkhan, 2008; Raele et al., 2014). Lindgren and Bandhold (2003) add that the use of the SP methodology offers a connection between the future outcome and the strategies formulated. It helps managers explore the future related changes that may occur in their external environment, and testing their strategies against such futures (Burt and Van der Heijden, 2003). Martelli (2001) adds that the process helps managers to articulate their mental models about the future in order to make better decisions (Martelli, 2001).

Just like the concept of scenario has been widely applied differently in the futures field, Amer et al. (2013) categorised the SP method into three approaches. These include the probabilistic modified trend approach; the La prospective approach; and the intuitive logic school approach (Amer et al., 2013). Table 2 provides a comparison between the different scenario development approaches proposed by Amer at al. (2013).

2.4.1.1 Probabilistic modified trends (PMT) scenario approach

The probabilistic modified trends technique (PMT) have evolved due to the change in the futures research paradigm from a more quantitative approach (in the 1970s) toward a more qualitative and process-oriented one (Mietzner and Reger, 2005). This scenario approach to scenario development emerged from the work of Olaf Helmer, Ted Gordon, and others at the RAND Corporation in the USA (Bradfield et al., 2005; Bishop et al., 2007). Scenarios developed under the PMT school are developed analytically. Researchers combine elements of qualitative expert judgement with traditional forecasting such as time series analysis techniques. Models developed in this regard could either be conceptual or mathematically driven. These techniques involved include the trend impact analysis (TIA), and cross-impact analysis (CIA).

2.4.1.2 La prospective scenario approach

The La prospective uses a combination of qualitative and quantitative tools, and researchers describe it as a blend of both intuitive logics and PMT methodologies. The French philosopher Gaston Berger presented the “La prospective" which can be translated to prospective thinking (Durance, 2010). The rationale for this school is that the future is not part of a predetermined temporal continuity, and it can be deliberately created and modelled (Bradfield et al., 2005; Amer et al., 2013). A French governmental organisation known as DATAR (the Office for Regional Planning and Development) played a critical role in the development of this approach in the late 1960s and 1970s. This approach develops normative scenarios of the future and articulate idealistic future images so that scenarios can serve as a guiding vision to policymakers and provide a basis for future action (Amer et al., 2013).

Table 2. 2 Comparison of the scenario development approaches

Scenario characteristics	Intuitive logic methodology	La prospective methodology	Probabilistic modified trends (PMT) methodology
Purpose	Multiple, from a onetime activity to make sense of situations and developing strategy, to an ongoing learning activity	Usually, a onetime activity associated with developing more effective policy and strategic decisions	A onetime activity to make extrapolative prediction and policy evaluation
Scenario type/perspective	Descriptive or normative	Normative	Descriptive
Scope	Can be either broad or narrow, ranging from global, regional, country, industry to a specific issue	Generally, a narrow scope but examines a broad range of factors within that scope	The scope is narrowly focused on the probability and impact of specific events
Time frame	Varies: 3–20 years	Varies: 3–20 years	Varies: 3–20 years
Methodology type	Process-oriented approach, mostly subjective and qualitative	Outcome-oriented approach, which is directed, objective, quantitative and analytical relying on complex computer-based analysis and modelling	Outcome-oriented approach, very directed, objective, quantitative and analytical using computer-based extrapolative simulation models
Nature of the scenario team	Usually an internal team from the organisation for developing scenarios	Combination of some members from client organisation led by an expert (external consultant)	External teams, scenario developed by experts (external consultants)
Role of external experts	Experienced scenario practitioner to design and facilitate the process. External experts are used to obtaining their views for new ideas	The leading role of an external expert using an array of proprietary tools for comprehensive analysis	The leading role of an external expert using proprietary tools and expert judgments to identify high impact unprecedented events
Tools	Generic tools like brainstorming, STEEP analysis, and stakeholder analysis	Proprietary and structural tools like Micmac, SMIC and Mactor analysis etc.	Proprietary tools like trends impact and cross impact analysis etc.
Starting point	A management decision, issue, or general concern	A specific important phenomenon of concern	Decisions/issues for which detailed and reliable time series data exists
Identifying key driving forces	Intuition, STEEP analysis, research, brainstorming techniques, and expert opinion	Interviews with stakeholders and comprehensive structural analysis using sophisticated computer tools	Curve fitting to past time series data to identify trends and use expert judgment to create database of unprecedented events

Developing a scenario set	Defining the scenario logics as organising themes or principles	Matrices of sets of possible assumptions based on the key variables for future	Monte Carlo simulations to create an envelope of uncertainty around base forecasts
The output of scenario exercise	Qualitative set of equally plausible scenarios in narrative form with strategic options, implications, and early warning signals	Multiple quantitative and qualitative scenarios supported by comprehensive analysis, implications, and possible actions	Quantitative baseline case plus upper and lower quartiles of adjusted time series forecasts
Use of probabilities	No, all scenarios are equally probable	Yes, the probability of the evolution of variables under assumption sets of actors' behaviours	Yes, the conditional probability of occurrence of unprecedented and disruptive events
No. of scenarios	Generally, 2–4	Multiple	Usually, 3–6 depends on the no. of simulations
Evaluation criteria	Coherence, comprehensiveness, internal consistency, novelty, supported by rigorous structural analysis and logics	Coherence, comprehensiveness, internal consistency tested by rigorous analysis; plausible and verifiable in retrospect	Plausible and verifiable in retrospect

(Source: Adopted from Amer et al., 2013)

2.4.1.3 Intuitive logic scenario approach (ILS)

This ILS approach to scenario development is a widely applied approach to the development of scenarios (Bradfield et al., 2005; Amer et al., 2013). It was first used at the RAND Corporation in the 1960s, and it is attributed as the shell approach because Pierre Wack and his research team used the method to successfully anticipate OPEC's oil price rise in 1973 as well as *the* fall of the Soviet Union Circa in 1990. The ILS approach depend on understanding and viewpoints of experts for the development of scenarios (Pillkhan, 2008). It can be seen as an art since its creative techniques, such as storylines for the narration of the possible development of the future scenarios.

Unlike the PMT approach, the ILS does not rely on the mathematical algorithms for the development of scenarios (Pillkhan, 2008). Derbyshire and Wright (2017) explain that the ILS approach is qualitative, and it targets the development of alternative views of the future. The latter authors emphasise the difference between the ILS and the quantitative scenarios approach which focus on the development of point estimates for the future. They clarify that another difference between the ILS and the forecasting-based scenario methods is that the external scenarios from the ILS approach do not have any objective standard against which to adjust the validity of the intuitive judgements made by experts during a scenario process. These scenarios are suitable for the analysis of complex situations with extreme uncertainty where information cannot be entirely quantified (Ramirez and Wilkinson, 2014; Wright et al., 2013; Burt, 2010).

Amer et al. (2013) highlights that scenario developers have used different scenario development designs ranging from five to fifteen steps (Schwartz, 1996; Schoemaker, 1995; Keogh and Shanahan, 2008, and Riddle et al., 2018). Section 2.4.3 provides a description of the steps involved in the intuitive scenario development process.

2.4.2 Procedure for developing exploratory scenarios

It is generally recognised that there is no predominant procedure for developing scenarios. Ramirez & Wilkinson (2016) while agreeing to the absence of a formalised scenario approach notes that the non-uniformity of scenario procedures is due to issues and constraints such as time, budget, and stakeholder composition in the respective context. Amer et al. (2013) add that while scenarios are developed differently, their characteristics remain the same. Table 2.3 presents the steps involved in an exploratory scenario development process by different authors. The steps portray an "expanded" (Schoemaker, 1995; Schwartz, 1996), or a collapsed (Keogh and Shanahan, 2008; Riddle et al., 2018) scenario procedure.

Table 2. 3 Comparison of the scenario development steps

Shoemaker (1995) (10 steps)	**Schwartz (1996) (8 steps)**	**Keough and Shanahan (2008) (5 steps)**	**Riddell et al. (2018) (5 steps)**
Define the scope	Identify the focal issue or decision	Define focal issues	Identify the focal question
Identify the major stakeholders	Identify key factors in the local environment which influence decision	Identify key drivers, stakeholders, and trends	
Identify basic trends	Identify driving forces that influence the factors in the local environment		
Identify Key uncertainties	Rank key factors and driving trends	Rank drivers by importance and uncertainty	Identify key drivers and key policy responses
Construct initial scenario themes	Select Scenario Logics	Construct scenario snapshots	Determine scenario logic on uncertainty drivers and policy responses
Check for consistency and plausibility	Flesh Out Scenarios	Flesh out scenarios	Determine policy factors and scenario assumptions
Develop learning scenarios	Develop scenario implications		Assess scenario outcomes
Identify research needs	Select leading indicators		
Develop quantitative models			
Evolve towards decision scenarios			

For the expanded procedure, Schoemaker (1995) presents a scenario building model that consists of 10-steps. The author also recommends the creation of two extreme scenarios: an optimistic, and a pessimistic scenario under step five. Schwartz (1996) develops an eight-step procedure and suggests the plotting of scenario drivers for the development of the scenarios. Schwartz combined some steps in Shoemakers procedure into the other steps. For example, the "identification of stakeholder" step in Shoemaker's (1995) procedure is embedded as an activity within into the "identification of key factors in the local environment" of Schwartz (1996). Also, the "assess the internal consistency and plausibility" step suggested by Schoemaker was embedded within the "select scenario logics" step 5 of Schwartz (1996). Hence, it can be said that the formation of an 8-step scenario building procedure by Schwartz (1996) was drawn from the 10 steps scenario process earlier developed by Schoemaker.

Progressing to the collapsed exploratory scenario versions, Keogh and Shanahan (2008) and Riddle et al. (2018) presents a 5-step exploratory scenario development procedure that reflects a compressed model in relation to that of Schwartz and Schoemaker. From the table 2.3, the steps involved in the collapsed scenario procedures can be linked to selected steps in the earlier versions. Keogh and Shanahan (2008) still captures the following steps 2, 3, and 4: as a single step 2.

To further analyse the different procedures found in literature and presented in table 2.3, table 2.4 provides an account of the researcher's deductions on the generic steps found in scenario development processes. However, it must be said that the generic steps can be modified to suit the purpose of the scenario development process. For example, the steps adopted when the purpose of the scenarios are for awareness creation, is different from when the purpose is to provide inputs for strategy development. Also, in table 2.4, the researcher explains how the reviewed procedures fit with the generic steps to exploratory scenario creation.

Table 2.4 Comparison of exploratory scenario procedures

Steps	Shoemaker (1995)	Schwartz (1996)	Keogh and Shanahan (2008)	Riddel et al. (2018)
Step 1: Define the focal issue (s)	**Captured in Step 1**	**Captured in** Step 1	**Captured in** Step 1	**Captured in** Step 1
Step 2. Identify key stakeholders	**Captured in Step 2**	**Captured in** Step 1	**Captured in** Step 2	**Captured in** Step 1
Step 3: Identify driving forces of change	**Captured in** Step 3	**Captured in** Step 2 and 3	**Captured in** Step 2	**Captured in** Step 2
Step 4: Identify key uncertainties (critical uncertainties)	**Captured in** Step 4	**Captured in** Step 4	**Captured in** Step 3	**Captured in** Step 2
Step 5: Construct scenario	**Captured in** Step 5	**Captured in** Step 5	**Captured in** Step 4	**Captured in Step 3**
Step 6: Flesh out scenarios	**Captured in** Step 6,7 and 8	**Captured in** Step 6	**Captured in Step 5**	**Captured in Step 4**
Step 7: Communicate scenarios and implications	**Captured in** Step 9 and 10	**Captured in** Step 7	**Captured in Step 5**	**Captured in Step 5**
Step 8: Select leading indicators	Not captured	**Captured in Step 8**	**Not captured**	**No captured**

2.4.2.1 Step 1 - Define the focal issue (s)

The focal issue is a strategic query that is pivotal to the entire scenario process. They are issues that keep the planners and management awake at night (Global Business Network, 2010; Riddel et al., 2018). According to table 2.4, all the reviewed authors agree on initiating the scenario process by defining the focal issues. As observed in table 2.3, different authors (Schoemaker, 1995; Schwartz, 1996; Keough and Shanahan, 2008; and Riddle et al., 2018) use different titles for the step one of their exploratory scenario approach. However, the tasks carried out within the step is the same. Hence, the "definition of focal issue" has been selected as the first step in the generic scenario development process.

Activities carried out alongside the identification of the focal issue include: the determination of time horizon for the scenario project (Shoemaker, 1995; Pastor, 2009); the purpose of the scenario project (Pastor, 2009), and scope of analysis (Shoemaker, 1995) (i.e. what products, markets, technologies or geographic areas). In terms of the purpose, Pastor (2009) asserts that where a scenario study is focused on a new business, the scenario purpose should be used to generate new ideas or to work as filters to analyse new ideas. Alternatively, if it is focused on an old business, the purpose should be to evaluate existing strategies or products (Pastor, 2009). In terms of the time horizon, having a perspective of five years gives a different picture from having a view of twenty years (Pastor, 2009). Schwartz (1996) mentions that "the time horizon for scenarios must be short enough to create scenarios that probable, but long enough for us to imagine that important changes with an impact on the future business can take place". He reiterates that long-term scenario horizons range between 20-25 years.

The focal issue can be identified using different data collection methods, and the choice of methods is underpinned by the selected scenario design: participatory or desk design. Cornway (2006) explains that the focal issue can be determined using participatory methods. Here, a few stakeholders in the organisation of concern are interviewed to identify the specific issues that affect them the most. The use of such participatory method provides an opportunity to understand the assumptions held by the stakeholders about the focal issue of concern. Alternatively, the focal issue can be identified through an analysis of documents that report the issues and challenges facing the focal organisation of the sector. Frey (2018) posits that document analysis is a systematic procedure for analysis of literary evidence in order to provide answers to a specific research question. Ferganni and Jackson (2009) agree that document analysis for scenario development provides a quick and effective technique for identifying issues or scenario drivers without being exposed to the resource-intensive task of engaging stakeholders.

In light of the above discussion, the choice between adopting a document analysis or participatory method is dependent on context specific issues and the resources available for the project. Certain contexts present challenges where the stakeholder and expert participation are difficult to achieve. For example, an ethnographic research that involves the convergence of community stakeholders and experts to explore possible future challenges under a secured societal context would differ from a study that involved senior organisational professionals to discuss sensitive issues in an insecure environment. The likelihood of stakeholder participation in the former is higher as compared to the latter. Furthermore, where resource constraints such as the funds to organise multiple workshop events are limited, a non-participatory option may be an alternative. Where resources are available and stakeholders and experts are willing to take part in the process, a sequential design where the document analysis provides information to the participatory process should be encouraged.

2.4.2.2 Step 2 – Identify key stakeholders

In this step, the stakeholders and actors that may be affected by the events in the business environment are identified. Also, stakeholders that can influence the matters are identified and invited to take part in the scenario creation. Shoemaker (1995) highlights this step as the second step in his scenario development process. Schwartz (1996) does not explicitly account for this activity as a step in the eight-step scenario development procedure. However, the step 1-3 (i.e. identification of focal issue; identification of factors in the local environment; and the identification of driving forces) implicitly indicates that the actors and experts are involved in the process. Keough and Shanahan (2008) embeds this step as an activity in the second step. Riddel et al. (2018) does not explicitly account for this step in their enhanced scenario development procedure.

From the analysis of the position of above authors, it can be deduced that stakeholder involvement in scenario development is crucial, not all scenario projects require stakeholders. Non-participatory desk design could be used in the development of the scenarios. The choice of using either a participatory or a desk design depends on the contextual factors (Ferganni and Jackson, 2019). These factors could include time, the availability of actors and other issues associated with the focal organisation or sector.

2.4.2.3 Step 3- Identify driving forces of change

This step concerns the identification of driving forces of change in the organisation's external environment that will affect the focal issue (Cornway, 2006). This step is common to all the procedures presented in table 2.3. Shoemaker (1995) encourages users to identify a list of current trends or events that can be predetermined and affect the issues of interest. These trends should be explained with respect to its influence. Causal relationship diagrams can be used to show the interdependency between the forces. Schwartz (1996) notes that this step stretches the thoughts beyond the urgency of the existing system, to the uncontrollable external forces that may surprisingly impact the organisation in the future (GBN, 2010). For example, "One demographic certainty is that global population growth will continue and will put pressure on energy, food, and water resources — especially in the developing world" (GBN, 2010). Other drivers could be events whose occurrence remain unchanged or speculated, but not yet experienced.

Shoemaker (1995) outlines this step as the third step in his 10-step scenario procedure. Similarly, Schwartz's (1996) second and third steps are linked to the above step. Schwartz terms the second step as "the identification of the key factors in the firm's local environment". He presents another step that focuses on "the identification of the driving forces affecting the key factors". These steps differ in terms of the relationship between the factors and the driving forces. According to Schwartz, the key factors are those issues that revolve around the decision makers and the decisions that must be made to have a long-term influence. While the driving forces are those forces that influence the issues identified. Keough and Shanahan (2008) and Riddel et al. (2018) also capture this step in their five-step process.

The driving forces of change can be identified through continuous monitoring of the horizon or environmental scanning. Blanco and Moudon (2017) suggest that drivers of change are categorised by techniques such as DEGEST, PESTEL or STEEP, which are explained below.

- DEGEST: Demographic, Economic, Governance, Environmental, Societal, and Technological
- PESTEL: Political, Economic, Social, Technological, Ecological, and Legal
- STEEP: Societal, Technology, Economic, Environmental, and Political

Just as the methods for the identification focal issues in step 1 can be participatory or desk-based (document analysis), the methods for the identification of driving forces of change depend on the design for scenario development selected. Participatory methods used in this case include techniques such as in-depth interviews with acknowledged experts and brainstorming sessions during workshops (Ramirez et al., 2015; Svenfelt et al., 2019). Where a desk design is followed, a document analysis could be used to identify the driving forces which are likely to influence the focal sector in the future. The search for documents should include literature published over a time frame that captures contemporary events as well as events in the past. Search string should be set and used to identify documents (Heiko and Darkow, 2010; Blanco and Moudon, 2017; Fergnani and Jackson, 2019).

2.4.2.4 Step 4 - Identify key uncertainties (critical uncertainties)

Once the driving forces have been identified in the previous step, in this step, the driving forces are analysed with an aim to identify the critical drivers (Schwartz, 1996; Schoemaker, 1993:1995). The critical drivers are driving forces that possess a high level of uncertainty and impact on the case being explored. Shoemaker (1995) explains that events with a high uncertainty and impact will significantly affect the focal issue of concern. For example, when considering the PESTEL forces of change the following questions could be asked: will a specific piece of legislation be passed? will a new technology be developed?; will the insecurity in the sub-Saharan African countries degenerate into uncontrollable crisis?, will the price of oil crash to zero? These questions are critical to the focal issue and highly context specific because as such critical issues differ with respect to projects.

Shoemaker (1995) and Schwartz (1996) explicitly record this activity as step four, while Keogh and Shanahan (2008) map it on step 3 of their five-step process. Riddle et al. (2018) embed the activity within the step 2 of the five-step scenario development process. Avin (2007) combines this activity under the step three where driving forces shaping trends are identified. Irrespective of the position of this activity, it is clear that it precedes the creation of the scenarios across all the reviewed studies. It directs the outcome of the final scenarios as the two or three most impacting and uncertain drivers are used to define the divergent and relevant future conditions to be included in the scenario set.

A widely utilised approach for identifying the critical drivers is to employ expert or stakeholder judgement. In this case, the driving forces are ranked according to their degree of uncertainty and potential impact on the focal system being explored (Schwenker and Wulf, 2013). An impact/uncertainty grid (van der Heijden, 2005) is a tool for mapping the drivers to ascertain where each driver falls.

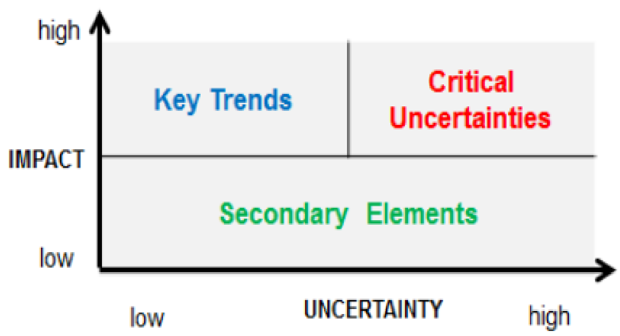


Figure 2.2 Illustration of Impact/ Uncertainty Grid (Source: Adapted from Dean, 2019)

As shown in Figure 2.2, the impact/uncertainty grid is structured into three sections (van der Heijden, 2005; Schwenker and Wulf, 2013). The factors that possess relatively minor impact on the future of the focal system are classed as “secondary elements” and are placed at the bottom section of the grid. The factors that possess a strong impact on the focal system but can easily be predicted are classed as the key trends and placed in the upper left section of the grid. Finally, the drivers that are highly impacting and difficult to predict are classed as the critical uncertainties and placed in the upper right section of the grid. In addition, Dean (2019) posits that when a researcher-led desk approach is adopted for the identification of the drivers, the position of the drivers in the grid is determined by the scenario-development team. Alternatively, when a participatory approach is utilised, the drivers within the different classes in the grid are developed through participatory techniques such as a Delphi exercise held by an expert panel or through a brainstorming workshop or focused group session held in collaboration between the experts and stakeholders (van’t Klooster and van Asselt, 2006; Schwenker and Wulf, 2013).

The number of critical drivers of change is influenced by the number of scenarios to be created. Different researchers have suggested the different number of scenarios ranging from three to six scenarios. However, Amer et al. (2013) encourages scenario developers to utilise two or three critical drivers in order to generate a manageable number of scenarios. The critical drivers must be combined in a logical manner such that the system dynamics are reflected, and core issues well communicated. The latter author adds that there is a positive correlation between the number of critical uncertainties and the number of scenarios developed. Therefore, to ensure a manageable number of scenarios, the researcher should seek to identify either two or three critical driving forces.

2.4.2.5 Step 5 - Construct scenarios

In this step, the critical uncertainties are used to construct alternative external scenarios that represent the likely states of the business (Schwartz, 1991; Schoemaker, 1995). Shoemaker (1995) explains that the driving forces and the critical uncertainties identified in step 3 and 4 above are the ingredients for the construction of the scenarios. Rounsevell and Metzger (2010) describe this step as the determination of the scenario logic, where the frameworks within which the scenarios developed are determined.

Scenarios can be constructed through different ways. One way is through the imagination of extreme worlds where one world consist of all positive elements, and another consist of the negative elements (Rounsevell and Metzger, 2010). The second is through the scenario-axes technique where two most critical uncertainty drivers are crossed on a four-quadrant matrix to create four different scenarios sets (van der Heijden, 2005; Schwenker and Wulf, 2013). The latter is one of the most popular scenario construction technique and illustrated in figure 2.3.

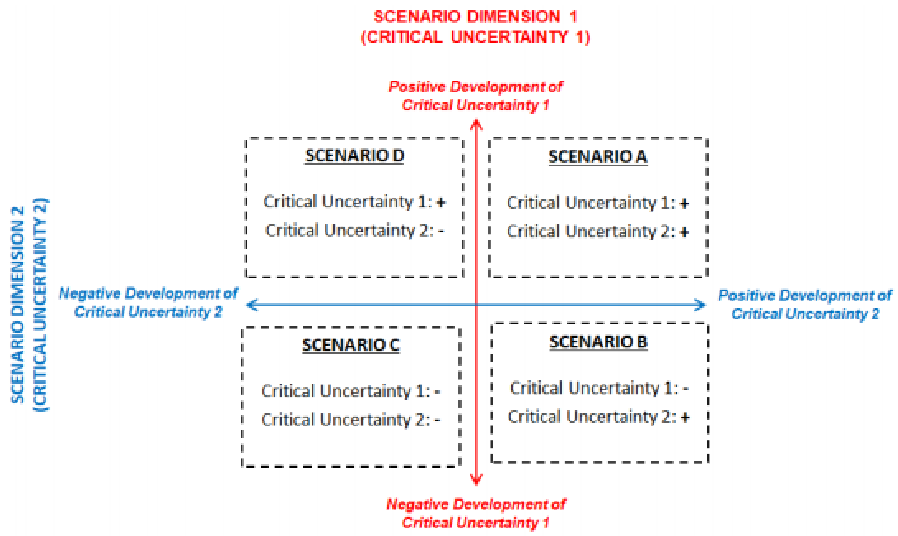


Figure 2. 3 Four quadrant matrix (FQM) technique

(Source: Adapted from Dean, 2019)

According to the figure 2.3, where two drivers are selected, the four-quadrant scenario matrix method (FQM) is used for creating four contrasted external scenarios (van der Heijden, 2005). Alternatively, where three critical drivers are selected, the maximal approach is used to develop six valid external scenario sets. For the two critical driver's scenario construction, the two critical drivers were placed on the biaxial polar extremes of a 2x2 matrix. The axes represent the continuums of plausible outcomes with uncertainty and impact on the focal issue. The endpoints of the axes are created by the analysis of trends and map out the scenario space and identify extreme outcomes.

The anticipated future changes of the uncertainties plotted on the axes of the 2x2 matrix, range from an extremely positive development to an extremely negative outlook. A scenario exists for every quadrant formed by the axes. Knowing that one axis creates two quadrants; two axes create four quadrants and three axes create nine quadrants, and so on. Using more axes runs the risk of making the results complex, hard to visualise and hard to interpret.

Amer et al. (2013) explain that there is no precise number of scenarios to be developed. Scenario developers have suggested the number of scenarios to range from three to six scenarios. Bezold (2010) echoed specifically for only three scenarios which consist of the most likely, challenging, and visionary. Schwartz (2009) echoed for four scenarios developed by ranking key factors on the basis of most impacting and uncertain. Pulver and Van Deever (2007) supports the creation of five scenarios that depict the business as usual, disaster, authoritarian control, hyper expansion, and human ecological. Amer et al. (2013) maintains that while the scenario developers are at liberty to develop the number of scenarios suitable for their scenarios processes, the key issue is to create a manageable number of scenarios in the most logical manner that reflects the system dynamics and communicate the issues within the system effectively. Durance and Godet (2010) suggest developing four to six scenarios to ensure that the description of the system dynamics is not overwhelming. The Global Business Network and the Stanford Research institute suggest that four scenarios should be developed. Amer et al. (2013) agree with Shoemaker (1995) on the connection between the number of scenarios created and the critical driving forces.

2.4.2.6 Step 6 - Flesh out scenarios

In this step, after the different scenarios have been constructed, each of the factors and driving forces identified in step three are revisited and given attention under each of the scenarios developed. Schwartz (1996) explains that each of drivers are linked together to form a story of how each scenario content will evolve. The combination of the drivers should indicate which events will occur and the end state would turn out. This step must answer questions such as What events are required to make the end state plausible? Are the states of the drivers of change and the factors being influenced within each scenario consistent with one another? Are the scenarios states plausible?

The fleshing out of the scenario is linked to the step 6,7, and 8 of Shoemaker's 10-step approach. Here, rather than using the title" fleshing out scenarios", Shoemakers has called this step a check for the internal consistency and plausibility of the individual scenarios created in step 5. Shoemaker assumes that after the scenarios are created, the painted worlds are full-fledged scenarios because they either have or lack internal consistencies that can provide a compelling storyline. He highlights that there are three tests on internal consistency, and these include i) dealing with the trends; ii) the outcome of combinations; iii) the reaction of the stakeholders.

First, the developer must check if the trends are compatible with the selected scenario time frame. Those found incompatible should be removed from the scenario storyline. Second, are the outcomes of the uncertainty under each scenario combined appropriately? For example, an extreme low-level unemployment and zero unemployment cannot go together. Third, are the stakeholders involved in the scenario placed in positions that they like? In addition to the consistency and the plausibility criteria for validating scenarios, others include the scenario relevance, novelty, and differentiation (Wilson, 1998). While scenarios must be consistent, relevant, original, and plausible, at least two of the scenarios must reflect uncertainty.

Amer et al. (2013) highlights that some of the methods for validating the scenarios include the minimal approach, Wilson matrix, morphological analysis, cross impact analysis and consistency analysis. Here, Pillkhan (2008) suggest that the minimal approach is appropriate when the elements in the environment indicate that two drivers can be used to construct the scenarios. The author also explains that the Wilson matrix can be used to evaluate the impact and influence by ranking all the scenario factors against the impact and uncertainty dimensions. Fritz Zwicky proposed the morphological analysis in the 1960's and this method has been employed in the futures field overtime to improve the selection and refining of scenarios (Ritchey, 1997; Börjeson et al., 2006; Durance and Godet, 2010). The method can be helpful in the elimination of any possible contradictions in the combinations. It also provides a visualisation of all possible combinations of the drivers to ensure the scenario plausibility.

2.4.2.7 Step 7 - Communicate scenarios and implications

Once the scenarios have been fleshed out, Schwartz (1996) suggest that the developer must recall the focal issue described in step one for rehearsing the future you have fleshed out. The team must explore the different vulnerabilities that the focal team can be exposed to if a particular scenario occurs in the future. It is also important to explore how the existing strategic decisions will cope in the face of the different scenarios. Shoemaker (1995) explains that it is important to retrace the activities to ensure that the scenarios created address the issue raised under the focal question. A decision that looks good in only one scenario is a better- company move, especially if you cannot control the likelihood of the scenario coming to pass.

This step is likened to the step 5 – "assess scenario outcomes" of the exploratory scenario approach proposed by Riddell et al. (2018). Also, it similar to the step 10- "evolve towards decision scenarios" of shoemaker's (1995) scenario approach. For Riddel et al., the impacts and implications of the scenarios must be discussed with participants. For example, in their application of their five-step approach to develop scenarios for disaster reduction, their discussions focussed on "how different natural hazard events would impact on the community and environment across each of the scenarios" (Riddel et al., 2018).

2.4.2.8 Step 8 - Select leading indicators

According to Schwartz (1996), the selection of the leading indicators is the final step in the 8-step scenario process. The purpose of this step is to ensure that the focal firm or future planner is informed on the possible changes that may occurs in the organisational environment. Schwartz explains that few indicators should be selected from the list forces and monitored as time progresses. Where the selection of drivers have been carefully and imaginatively carried out and monitored, such a firm will have a better idea of how future events may turn out and how likely such events will affect the organisations strategic decisions.

In addition, not all scenario studies consider the monitoring of leading indicators. As shown in table 2.4, the procedures of Shoemaker (1995); Keough and Shanahan (2008), and Riddel et al. (2018) does not capture this step in their scenario development process. One rationale for not considering the selection of any leading indicator for monitoring is on the basis that no indicator can in reality be predicted on the long run. These drivers are subject to changes as a result of several changes to other variables. Therefore, monitoring specific set of drivers could involve conducting an environmental scan at intervals to identify any new driver in the business environment or changes to the existing drivers. This will involve conducting step 3 (identify driving forces of change) from time to time.

2.4.3 Desk vs participatory scenario development designs

Based on the insights from Amer et al.'s (2013) classification of scenario planning methods in table 2.2, scenarios can be developed through participatory or desk-based designs. For example, in table 2.2, it was identified that the driving forces of change could be identified through a participatory or desk data collection method. Some of the methods in this step include; interviews held with stakeholders (participatory); a structural analysis using sophisticated computer tools (desk design), intuition by one experts (desk design) or multiple experts or stakeholders (participatory), STEEP analysis (desk or participatory), brainstorming techniques (desk or participatory), and expert opinion (desk or participatory) are different source of scenario related data which can either be carried out either ways. The subsection provide a review of participatory of desk scenario designs.

2.4.3.1 Participatory scenario development design

Ramirez et al. (2015) while developing scenarios for a retail format in India held three sets of scenario workshops with key stakeholders of the Indian retail development. The authors conducted interviews to identify the critical issues, driving forces and critical uncertainties. In another case study, the latter author developed scenarios for international migration futures in Europe and the Mediterranean by first embarking on online surveys and holding three workshops with stakeholders. Findings from these case studies revealed that the participatory design provides a structure for a process that can embrace many perspectives and create knowledge from multiple stakeholders through strategic conversations.

Kabak et al. (2018) proposed a new scenario analysis-based approach to investigate the relationship between logistics performance and exports at a country level. Different from the existing scenario analysis methods that contain subjectivity in measuring consistency, the proposed approach uses objective information rather than expert opinions. The authors proposed a binary integer program to select a significantly different, consistent, and small number of efficient scenarios. Based on the selected scenarios, they developed a new approach for evaluating the performance of strategies across a series of scenarios. The most important part of scenario analysis is generating a consistent, reliable, different, and small set of scenarios. In the literature, consistency checks have been performed using expert judgments, which are subjective in nature. Kabak et al. argue that the biases that may occur due to the subjectivity of the scenario analyst are eliminated by using the past data.

Boyonas et al. (2020), describes the benefits of scenario planning for future supply chains and demonstrates the effectiveness of the SP methodology on the supply chain of a Chemicals Company headquartered in Switzerland. Three scenarios were developed as sample representations of a whole range of plausible futures. These scenarios are differentiated by combinations of high and low conditions of the three critical uncertainties identified: (1) Emergence of trading blocks, (2) Changing consumer needs/behaviour, and (3) Changes in logistics infrastructure. The author affirms that the SP method provides an opportunity on which organisational learning can organically grow. The steps used in the methodology forces users of the scenarios to challenge existing mental models resulting in the broader perspective and appreciation of the dynamics that surround and impact an organisation in the future.

Svenfelt et al. (2019) developed scenarios for sustainable futures beyond GDP growth in 2050. The scenarios were developed through an interactive and participatory manner. Stakeholders involved in the research were the core scenario developers, project researchers, societal partners and other stakeholder groups were adequately represented throughout the process during workshops and interviews that took place at three municipalities. The authors note that the feedback from the workshops and interviews were diverse and extensive. They added that the scenarios developed stimulated discussions about sustainability and other pressing issues. Interestingly, the author notes that when focus groups, workshops and seminars are used for the development of scenarios, participants are always keen to question if the scenarios are realistic. They always stress that some additional drivers could have been included in the scenarios.

Chang et al. (2007) apply the scenario planning approach to develop a decision-making tool that can be used by government agencies in planning for flood emergency logistics. The study revealed that the application of scenarios was based on optimising the structure of rescue organisations, locations of rescue resource storehouses, allocations of rescue resources under capacity restrictions, and distributions of rescue resources. Still, in the logistics planning domain, Hu et al. (2015) applied the scenario planning approach for propositioning rescue centres for urban waterlog disasters (UWD. The study identifies that due to the limitation of the data collection methods, and the lack of published researches on scenario qualification, there is a need for sophisticated numerical assessment functions for a risk-induced penalty in future research.

2.4.3.2 Desk scenario development design

Van Notten (2006) posits that document analysis for scenario development may be less formalised and systematic when compared to the computer-driven model-based scenarios. However, the procedure is just as rigorous as the former. Scenarios developed through computer simulations are classed as techniques under the PMT school, they have been explained under section 2.4.1.1. Hence, this section focuses on the use of document analysis for scenario development.

Blanco and Moudon (2017) developed scenarios for the Havana transportation system. A STEEP technique was used to identify the driving forces that shape the future of the transport system in Havana. The authors reviewed the literature available on the Havana transport system. The study adopts literature review techniques in the determination of the drivers of change. Also, the study focused on the content of the scenarios for the case than the process for developing the scenarios.

Heiko and Darkow (2010) developed scenarios for the logistics service industry for the year 2025. In this study, a desk document analysis was first conducted using a PEST (political, economic, socio-cultural, and technological structure) analysis model to develop projections for the future of the logistics sector. The desk research was integrated into a Delphi approach which is classed as a semi-participatory approach. The author explains that the Delphi process is easy to integrate into the scenario process because it delivers, reliable, valid, and valuable data for scenario construction.

Fergnani and Jackson (2019) developed scenario archetypes through a quantitative text analysis of documents about the future. The scenario method proposed combined a quantitative text analysis with the creation of scenario narratives. The scenario extraction procedure aimed to extract many scenario archetypes of information from the document reviewed. 5600 English language online documents related to the issue of interest were first collected. These include, newspaper articles, scientific publications, books, private communication etc. were sourced from internets and transformed into a corpus for analysis. Findings from the study revealed that the approach successfully harnessed the views about the future succinctly without need for interviewing or conducting workshops for an inaccessible number of subjects on the focal issue. The method can be suited for developing scenarios for geographically broad macroscopic scenarios, for example, scenarios for the global economy, education, and capitalism.

Heiko and Darkow (2010) raises the awareness that some scenario planning studies have a quantitative focus by adopting the forecasts and trend extrapolations of past data (Stead and Banister, 2003, Sviden, 1988). The qualitative scenarios showcase the narrative description of the future. Such scenarios are meant to aid decision-makers in public policy develop scenarios based on a narrative description of the future (Institute for Mobility Research (ifmo), 2002, Institute for Mobility Research (ifmo), 2005). The intention of most of these studies has been to serve as a basis for decision-makers in public policy. Especially in logistics, scenario planning often focuses on macro-environmental aspects, such as infrastructure, roadwork, transportation markets, and policies (Piecyk and McKinnon, 2009, European Community, 2004, Stead and Banister, 2003).

Knowing that developing future scenarios within the logistic sector is an essential basis for long-term strategy development, Heiko and Darkow (2010) highlight the lack of awareness of future scenario planning among logistics researchers and practitioners. Hence, the author's application of scenario planning for the development of likely and unexpected scenarios of the future, which may provide a basis for strategy development in the logistics services industry by 2025. An exciting component of this study was the use of Delphi method as a basis for the scenario planning framework. The author draws attention to challenges of validity and reliability and proposes a rigorous methodology to develop scenarios based on a Delphi survey. He adds that when scenario studies are qualitatively driven, quantitative analysis (e.g. with respect to cost implications and industry growth rates) may be included in the analyses to provide a more tangible basis for strategic planning.

2.4.4 Application of exploratory scenario in distribution network design contexts

This section provides a review of studies that have applied exploratory scenario methods within the distribution network contexts. The aim of this review is to gain insights into the issues experienced by authors when applying exploratory scenario methods in distribution network contexts.

According to Heiko and Darkow (2010), the usefulness of the exploratory scenario approach has been proved through the consistent application in the distribution and transportation planning contexts (Chang et al. 2007; Heiko and Darkow, 2010; Phadnice et al. 2014; Mendes et al., 2014; Hu et al., 2015; Kabak et al., 2018; Boyonas et al., 2020). Heiko and Darkow (2010) posit that the logistics industry, is faced with complexity and uncertainty in its business environment. Some of the issues faced by these organisations include: the intense level of globalisation that compel businesses to move beyond their comfort zones; the stiff competition from new and existing entrants into the industry, the unpredictable behaviour of customers, and resource scarcity. These are just a few of the factors that lead to a more turbulent and uncertain environment for the logistics and distribution sectors within supply chains. Based on the potential opportunities or negative impacts of the forces outside the business environment, an analysis of future supply chain environments is essential to ensure innovation and resilience, and to maintain competitiveness.

Chang et al. (2007) applied the scenario planning approach to develop a decision-making tool that can be used by government agencies in planning for flood emergency logistics. The study revealed that the application of scenarios was based on optimising the structure of rescue organisations, locations of rescue resource storehouses, allocations of rescue resources under capacity restrictions, and distributions of rescue resources. Still, in the logistics planning domain, Hu et al. (2015) applied the scenario planning approach for positioning rescue centres for urban waterlog disasters. The study reveals that due to the limitation of the data collection methods, and the lack of published research on scenario quantification, there is a need for sophisticated numerical assessment functions for a risk-induced penalty in future research.

Heiko and Darkow (2010) opines that some scenario studies in supply chain context have assumed a quantitative focus by adopting the forecasts and trend extrapolations of past data (European Community, 2004, Stead and Banister, 2003, Sviden, 1988). However, Heiko and Darkow (2010) notes that qualitative exploratory scenarios showcase the rich content of the narrative description of the future. The scenarios aid decision-makers in public policy development (Institute for Mobility Research (ifmo), 2002, Institute for Mobility Research (ifmo), 2005). Especially in supply chain and distribution contexts, exploratory scenarios focus on aspects such as: transportation markets, environment, and transport policy formation (Piecyk and McKinnon, 2009, European Community, 2004, Stead and Banister, 2003).

Kabak et al. (2018) proposed a new scenario analysis-based approach to investigate the relationship between logistics performance and exports at a country level. Different from the existing scenario analysis methods that contain subjectivity in measuring consistency, the proposed approach uses objective information rather than expert opinions. The most important part of scenario analysis is generating a consistent, reliable, different, and small set of scenarios. In the literature, consistency checks have been performed using expert judgments, which are subjective in nature. The study also identified that biases may occur due to the subjectivity of the scenario analyst.

Boyonas et al. (2020), describes the benefits of scenario planning for future supply chains and demonstrates the effectiveness of the SP methodology on the supply chain of a Chemicals Company headquartered in Switzerland. Three scenarios were developed as sample representations of a whole range of plausible futures. These scenarios are differentiated by combinations of high and low conditions of the three critical uncertainties identified: (1) Emergence of trading blocks, (2) Changing consumer needs/behaviour, and (3) Changes in logistics infrastructure. The author affirms that the SP method provides an opportunity on which organisational learning can organically grow. The steps used in the methodology forces users of the scenarios to challenge existing mental models resulting in the broader perspective and appreciation of the dynamics that surround and impact an organisation in the future.

Heiko and Darkow (2010) applied the scenario planning for the development of likely and unexpected scenarios of the future, that may provide a basis for strategy development in the logistics services industry by 2025. An exciting component of this study was the use of Delphi method as a basis for the scenario planning framework. The author draws attention to challenges of validity and reliability and proposes a rigorous methodology to develop scenarios based on a Delphi survey. He concludes by highlighting that while most exploratory scenario techniques are useful for exploring the complexity of business environments, there is need for an inclusion of quantitative methods to provide a more tangible basis for strategic planning.

From the review conducted in this section, it can be deduced that scenario application within the supply chain distribution planning context forces users of the scenarios to challenge existing mental models resulting in the broader perspective and appreciation of the dynamics that surround and impact an organisation in the future. However, when objective opinions are used in developing scenarios for supply chain and distribution planning contexts, there is a risk of a bias due to the subjectivity of the scenario analyst. There is also a need for the inclusion of quantitative analysis within qualitative scenario frameworks to provide a more tangible basis for strategic planning.

2.5 Visioning

Most times, we imagine desirable images of our future, and the process of imagining these desirable future states is called "Visioning" (Blass et al., 2010). It is a mental process in which images of a desired future are made real and compelling to act as a motivator for the prompt action. Visioning is used to extract the imaginative and ingenuity of stakeholders when developing a vision for the future. Visions and visioning promote change, and a common motivation for developing visions is a dissatisfaction with the way things currently are, or the direction in which things are heading (Ziegler, 1991).

The concept of backcasting and visioning can sometimes be linked as they assume a normative view of a utopic future (Banister and Hickman, 2013). While visioning remains a process for developing the desirable images of the future, backcasting addresses the pathways for achieving the desired visions. Furthering from the latter definition, it is logical to believe that visioning precedes the backcasting activity (Banister and Hickman, 2013; Kok et al., 2011; van Vliet et al., 2015). However, not all visioning projects involve the pathway formation process (O'Brien and Meadows, 2007; Tight et al., 2011). Not minding how visioning has been deployed in practice, the researcher agrees that visioning must be carried out before any backcasting activity can occur. Therefore, it remains an initial phase in the backcasting process. The research focus is on the visioning component of the normative scenarios. Perhaps, subsequent research extension will involve the backcasting process.

The process of conducting the visioning exercise is not common across different applications. Different authors present procedures that suit their case (Collins and Porras, 1996; Jaminez et al. 1997; O'Brien and Meadows, 2001; 2017). While some of these procedures are similar under certain stages, they also differ on other occasions. Upon the observation of this unclear path in the visioning domain, O'Brien and Meadows (2001) investigated areas of harmony and discord in the procedures adopted by different visioning projects. They compare triads of articles to identify features shared by two of the articles that distinct it from the third. Result from the analysis revealed the following questions?

- Is it important to analyse the organisations current situation?
- Is it important to assess the external environment during Vision development? If yes, how and when should be done?
- Is it useful to create a desired future state or multiple desired future states?
- Should one connect the future to the present state during vision development?
- Is it important to test Visions?

In the case of analysing the organisations current situation, the purpose of such activity to is to understand the organisations current capability, how they achieved their strengths, and if their capability can cope with the dynamics in its business environment (Wilson, 1992). Shoemaker (1992) argues that the latter activity is important as it grounds the Visioning activity on realism which is prerequisite for a future. Ackoff (1993) argues against the latter, suggesting that Visions ought not be limited by the current capability of the focal firm. He reiterates that actors engaging the process should assume the organisation in a bad state and in turn envision a desirable state. While both arguments provide suitable justifications for each standpoint, the researcher aligns with Ackoff ideology of optimism of not being limited by the current state of the organisation. Robust Visions should be followed with well-crafted strategies to achieve the set goals.

In the case of assessing a firm's external environment during visioning, Collins and Porras (1994, 1996) and Ziegler (1991) argue that visions should be developed irrespective of the environmental trends, forces, and conditions. This opinion contradicts the role of exploratory scenarios for improving the quality of Vision and strategies echoed by authors (Van Vliet and Kok, 2015; Kunc and O' Brien, 2017). The latter authors stress that exploratory scenarios are used to test the resilience of strategies. Therefore, the researcher agrees with the latter that Visions cannot be developed without adequate attention to the varying macro-economic forces that can threaten the actualisation of the visions.

In addition, the point at which the exploratory scenarios are required becomes another issue of concern. Some posit that they should be carried out before the Vision development exercise (Wilson, 1992; Schoemaker, 1992; Jiminez et al., 1997; Tight et al. 2011; van Vliet and Kok, 2015). Others suggest that assumptions about possible unfolding events around the focal firm's environment should be made and tested after the visions have been developed (Kouzes and Posner, 1996). The researcher asserts that while the latter fosters the creativity of vision options by not looking at the external constraints prior to vision development. The awareness of possible and plausible eventualities in the firm's environment will evoke stakeholder thoughts to create Visions and strategies that can ensure the actualization of the desired future state.

The issue of developing either a single vision or multiple visions remains another contested topic among researchers in the Visioning domain. Most Visioning studies have focused on the development of single shared vision (Kok, 2011, van vliet, 2015). Others (O'Brien and Meadows, 2007; Tight et al., 2012) have stressed that the perspectives of multiple stakeholders during a Visioning exercise cannot be lumped into a single vision. Ziegler (1991) recommends that individuals with similar values should produce unique visions that are shared with other participants. Ziegler view is true because developing single vision will entail delineating some participants views over others to achieve a single vision. This limits the creativity and dynamism expected from the active participation of multiple stakeholders during a visioning practice.

Should a Vision be contrasted with the present is another contested dimension among Visioning researchers. Authors that recommend that a vision be contrasted with the current state, argue on the need for formulating the strategies and pathways required to progress in the desired goal. The latter has occasioned the need for backcasting processes from the future desired state to the present (Banister and Hickman, 2013). This indeed is highly recommended as it creates a sense of consciousness of the where they are and where they need to be. This internally enshrines an urgency to transform the status quo or dissatisfied state to the envisioned state. It creates opportunity for monitoring and evaluation of the progress towards the set goal, and latently drives the energy to meet the target.

In the final dimension, the argument on the testing of Visions is another issue of contention among authors. Also, among those that argue in favour of the testing of Visions (Shoemaker, 1992; Stewart, 1993; Raynor (1998), there is no agreement on how the Visions are to be tested. The resilience of Visions can be guaranteed through the testing of the Visions. Hence, Shoemaker uses a set of multiple scenarios to test the robustness of Visions. However, Stewart (1993) and Raynor (1998) suggest the use of a likely future scenario to test the visions. O'Brien and Meadows (2001) argues that the use of single scenarios for testing Visions may yield less robust visions because the single scenarios can be likened to single point forecasts which does not capture the dynamics of the firm's business environment. The researcher agrees with the latter echoing that multiple external scenarios present different forms of possibilities that may occur in the external environment, and the interrogating the Visions with such eventualities improves the suitability of Visions and strategies that will withstand any unplanned future occurrence.

2.5.1 Procedures for visioning - steps and methods

This section provides a review of the formalised procedures for developing visions in the visioning literature. The aim of this section is to analyse the different procedures a produce a generic procedure for vision development. The section draws on the typical visioning approach, the choices approach, and the visioning choices approach.

Figure 2.4 presents the activities involved in a typical visioning approach. O'Brien and Meadow's (2001) review of previous visioning methodologies identifies that a typical visioning procedure consist of the following elements presented in figure 2.4.

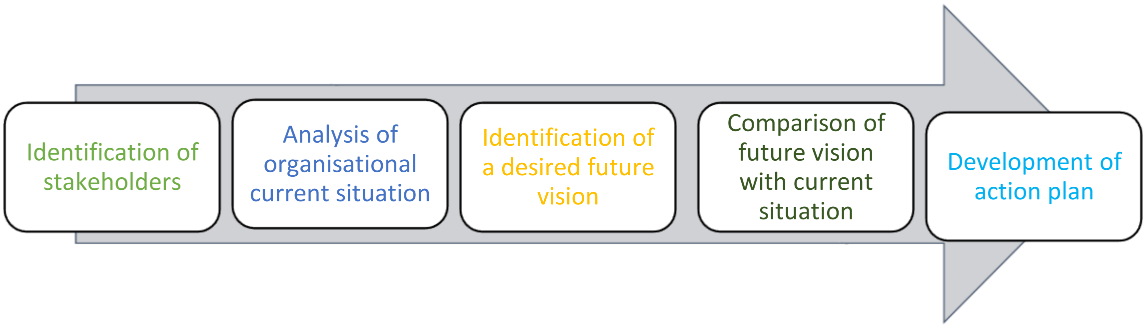


Figure 2. 4 Five-steps of a Typical Visioning Approach (TVA)

(Source: Adapted from O'Brien and Meadows, 2001)

The authors explain that every vision involves the identification of the relevant stakeholders that are worried about the current state of their organisations. These group of stakeholders tend to analyse their current situation and proceed to envisioning a desired future vision. Comparisons between the desired and the current is drawn to facilitate the formation of the actionable plans that can transit between the existing and the desired future state. These fundamental steps presented in figure 2.4 was used a foundation for improvement in the procedure for developing visions.

Due to the unclear procedure and details for the development of Visions, the choices approach (CA) and the visioning choices approach (VCA) were developed by O'Brien and Meadows in 2001 and 2007 respectively. Figure 2.5 and 2.6 illustrates the steps of the choices and the Visioning choices approach respectively.

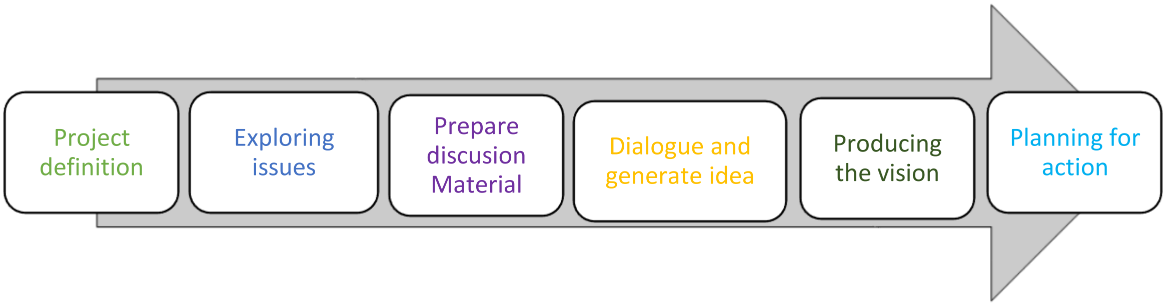


Figure 2. 5 Six-steps of the choices approach (CA)

(Source: Adapted from O'Brien and Meadows, 2001)

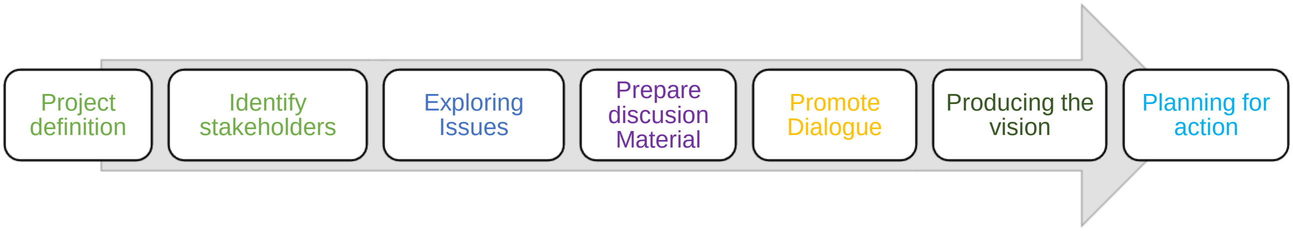


Figure 2. 6 Seven-steps of the visioning choices approach (VCA)

(Source: adapted from O' Brien and Meadows, 2007)

Based on the synthesis of the insights from the procedures highlighted in figures 2.4, 2.5, and 2.6, a question that comes to mind is: How have these procedures differed? A colour code adopted across the figures indicate that some steps though presented with a slightly different wording imply the same activity. Same colour indicate a similarity in activity. Drawing on the activities of the typical visioning approach, choices and visioning choices approach presented above, table 2.5 presents all the activities likely to take place in a Visioning process, and how they fit with the steps employed by other visioning projects (Tight et al. 2011; Iwaniec and Wiek, 2014; Soria-lara and Banister, 2017; Uwasu et al. 2020).

Table 2.5 Comparison of visioning procedures

Steps in a visioning process	TVA	CA O'Brien and Meadows (2001)	VCA O'Brien and Meadows (2007)	Soria-lara and Banister (2017)	Uwasu et al. 2020	Iwaniec and Wiek, 2014	Tight et al. 2011
Project definition	No	Yes	Yes	Yes	Yes	Yes	Yes
Identify stakeholders	Yes	No	Yes	Yes	Yes	Yes	Yes
Exploring issues	No	Yes	Yes	Yes	Yes	Yes	Yes
Prepare discussion material	No	Yes	Yes	No	No	Yes	Yes
Promote dialogue	No	Yes	Yes	Yes	Yes	Yes	Yes
Producing the vision	No	Yes	Yes	Yes	Yes	Yes	Yes
Planning for action	Yes	Yes	Yes	Yes	No	Yes	yes

Yes- means the step is captured in the author's process; No- means the step was not captured

The next section will address the individual activities presented in table 2.5 with a focus on how different visioning studies align to these activities. Furthermore, the section presents methods employed under the activities. In addition, the review presents the approaches and techniques applied under four broad vision development phases (Minowitz's, 2013). These include i) identification of the vision elements, ii) building agreement on visions; iii) drafting vision narratives, iv) visualising the vision contents. The list of techniques does not suggest any form of guidance to the specific choice of techniques to be adopted in practice, but a discussion on the merit and demerit of each method would serve as a pointer to users of such techniques.

2.5.1.1 Project definition (step 1)

According to O'Brien and Meadows (2007), the key tasks in this step involves the establishment of the project team and identification of need for change. Also, this activity is the first step of the choices approach (O'Brien and Meadows, 2001). The project definition is essential for every Visioning activity as most studies implicitly or explicitly define the project focus (Tight et al. 2011; Wiek and Iwaniek, 2014; Soria-Lara and Banister, 2017; Welch et al., 2018; Starricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020). In the projects of the latter authors, a team made up of the researchers within an organisation, external consultants or academics make up the project steering team.

According to figure 2.4 and table 2.5, the key elements of the TVA does not capture the project definition step. Does this imply that the formation of a project steering team when conducting a Visioning exercise is not considered? The answer is no. The project definition is implicitly defined and embedded within the stakeholder identification step. This is true as it can be argued that on one hand, the steering team must include all necessary stakeholders affected by the issue of concern. Alternatively, the stakeholders cannot be identified without the project steering team. The latter is more pronounced when the stakeholders are identified from within and external to organisation to make up the project steering team. Therefore, the project definition is a unique and compulsory activity which must be addressed in every visioning activity.

2.5.1.2 Stakeholder Identification (step 2)

In this step, the relevant stakeholder groups are identified. Also, their unique characteristics are explored and used to classify the stakeholders (O' Brien and Meadows, 2007). This activity is implicitly captured under the "issue exploration" step of the CA. Although the key task of this step under the choices approach involve the "identification of the concerns of the stakeholders". This supports the reason for identifying the stakeholders in the project definition stage of choices approach and exploring the issues in the second stage. Uniquely, the VCA identifies stakeholder identification as a critical step that informs the quality of participants involved in the Visioning exercise, hence the author documents this step as a separate phase in the process. Other studies reviewed (Tight et al., 2011; Iwaniec and Wiec, 2014; Soria-Lara and Banister, 2017; Welch et al., 2018; Starricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020) though not explicitly defined the stakeholder identification step still engage in the identification of the stakeholders.

A stakeholder analysis should be conducted to identify the different stakeholder groups. Taylor (2020) defines the stakeholder analysis as a process that assesses the factors that may impact on the people with underlying interests in or influence over the project or other stakeholders. The analysis of stakeholders help to find out the key stakeholders, and ascertain how their interests are addressed in the Visioning project.This has become important because the different stakeholders are attached to unique demand and interests, and defining how the these interests are managed to avoid conflicts across stakeholders improves the quality of the visioning process. Conducting this analysis at the initial point of the participatory project helps to identify potential challenges before the visioning exercise commences.

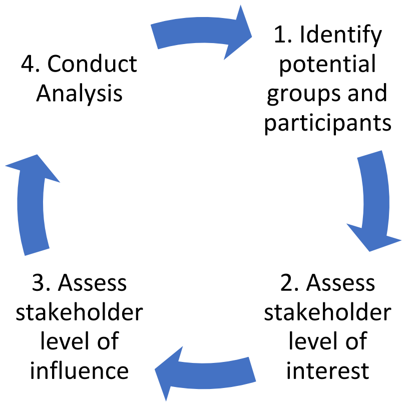


Figure 2.7 Stakeholder analysis cycle (Source: Adapted from Taylor, 2020)

By taking account of the interests and influences of the stakeholders, the success of the Visioning process is almost guaranteed. While the stakeholder engagement supports learning among participants during Visioning exercise, trust, quality decision creation, risk awareness and accountability (Taysom, 2020), other negative issues such as power imbalance, professional and personal affiliations, personality differences across stakeholders must be addressed in order to drive effective and active participation among participants during the visioning exercise.

The selection of participants remains a crucial aspect for consideration to reduce the visions from being overly focused on the expert opinion. Stakeholders must be adequately represented in the process. Finding from the study of Soria-lara and Banister (2017) revealed that younger participants tend to provide the most radical and creative visions, while the elder participants are less creative. The author reiterates that while the creativity must be encouraged during visioning, there is need to be realistic in the visions produced. Therefore, the author concludes that the use of different generations of participants is encouraged. In addition, the sample size is another issue for consideration during visioning projects. Soria-Lara and Banister (2017) notes that the decision on an acceptable sample size is not straightforward one because this decision is underpinned by several considerations. In the visioning and backcasting studies in transport, large samples (i.e. more than 40 participants) have not been frequently used (Zimmermann et al., 2012; Mattila and Antikainen, 2011;

Soria-Lara and Banister (2017). However, it is important to state that the use of large samples support the validation of tentative findings. While the choice of a sample size can be affected by time and cost constraints, it is important to select a sample that reflects the heterogeneity of the stakeholders.

2.5.1.3 Exploring issues (step 3)

The exploring issues step involves the identification of the pertinent issues affecting the focal organisation. The analysis of the organisation's current situation involves both exploring the current situation of the organisation in addition to the assessment of the organisation's capability. This implies that the wording "exploring issues" can be called the "analysis of the current state of the organisation" as mentioned in the TVA (O'Brien and Meadows, 2001) if the focus of the latter is limited to exploring the issues affecting the organisation at the moment.

Other reviewed studies (Tight et al. 2011; Iwaniec and Wiec, 2014; Soria-Lara and Banister, 2017; Welch et al., 2018; Starricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020) focused on exploring issues affecting the organisation captured by the CA and VCA as compared to the analysis of the current situation highlighted in the TVA. One reason for the latter revolves around the argument that the analysis of the current situation involves an exploration of the issues facing the organisation as well as evaluating the current capabilities of the organisation (see section 2.5). While it is argued that the latter grounds the visioning activity on realism (Schoemaker, 1992), Ackoff (1993) argues against, suggesting that visions ought not be limited by the current capability of the focal firm. In the light of the latter, it is believed that the authors that solely focus on exploring the issues align with the standpoint of Ackoff concerning organisational capability assessment.

O'Brien and Meadows (2007) add that primary and secondary data sources can be used for the collection of data related to the issues of concern. For example, focus groups and interviews can be conducted to with the relevant stakeholders to identify the issues of concern.

2.5.1.4 Prepare discussion materials (step 4)

This step stems naturally from the exploration of issue step. Here, the Visioning team constituted under the project definition stage analyse the result from their discussions with stakeholders or other secondary data sources on the issues of concern affecting the organisation. These issues are identified from the perspectives of the relevant stakeholder groups in order to capture the correct issues (O'Brien and Meadows, 2007). Other key tasks to be carried out include the development of an overview of the timescales that govern the Visioning exercise. Also, where external scenarios are considered as a tool for creating the visions, the plausible scenarios that demonstrate the likely futures that the organisation may encounter in the future are developed or summarised.

This step is explicitly captured under the CA and the VCA as a pre-vision development step. However, it was not explicitly defined as a step under the TVA. Also, the reviewed studies (Sora-Lara and Banister, 2017, Uwasu et al. 2019) implicitly defined the preparation of materials under their activities. They formally utilise participatory methods to carry out this step. Other studies (Iwaniek and wiek, 2020; Tigh et al; 2011) prepare their materials through the analysis of government or organisational documents. conduct the activities prescribed under this step. It is also important to add that other activities such as the recruitment and training of facilitators for the visioning exercise and the set-up of other logistics related activities are conducted during this stage.

2.5.1.5 Promote dialogue (step 5)

The dialogue and generation of ideas have been presented as the step where the vision elements of the visions are developed. This activity has been captured under the CA (see figure 2.5) and the VCA (see figure 2.6) developed by O'Brien and Meadows (2001, 2007). The dialogue stage does not differ from the identify desired Vision captured under the TVA in figure 2.4. The latter is true as O'Brien and Meadows assert that under this stage, the materials are disseminated to the stakeholder groups for them to brainstorms and identify actions that can move the organisation forward. These actions can also be called the vision elements as highlighted in the TVA and other visioning projects (Tigh et al., 2011; Iwaniek and Wiek, 2014; Soria-Lara and Banister, 2017; Welchet al., 2018; Starricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020). Therefore, this step can either be called the dialogue and generation of idea or identification of desired visions. They imply an activity where stakeholder discussions are guided by a set of discussion materials with an aim to identify the components of their visions (also known as the vision elements).

Minowitz (2013) explains that the tabula-rasa and responsive approach are two approaches used in the identification of vision elements. The former approach is used in a situation where the participants provide their vision elements without any pre-existing instructions. The responsive approach is applied where there is an existing vision, and stakeholder comments are used to reassess the suitability of feasibility of visions (Minowitz, 2013). Table 2.6 presents a description of the methods for identifying vision elements under the tabula-rasa approach. Also, table 2.7 presents the methods employed under the responsive approach. Minowitz reiterates that the methods are classed as either direct or indirect elicitation methods. Direct elicitation methods (e.g. focus groups, community meetings, or interviews) are applied where there is direct contact with participants (O'Brien and Meadows, 2007; Tigh et al, 2011; Uyesugi & Shipley, 2005; Staricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020). Indirect elicitation methods (e.g. public opinion surveys) are applied when there is no contact with the participants in the process (Shipley et al., 2004).

The exploration parcour and the multi-attribute analysis are methods that produce quantitative data (ranking, rating, and scoring) as outputs during the consensus building process. In the application of these methods, criteria for assessment are developed and stakeholders are asked to rank the different visions based on the criteria. These methods yield more unbiased results than the qualitative methods which produce desired through deliberations. However, the use of qualitative methods creates an avenue to understand justifications for preferences and could be a better option when considering consensus building.

Another task that take place at the latter part of the dialogue and generation of ideas step is the "building of agreement on Vision elements". Minowitz (2011) notes that this task aims at developing a representative or shared vision which reflects the overall opinion of the stakeholders. More so, the agreement can be developed through direct interface method (consensus conferences or collaborations) or indirect interface methods (Delphi surveys or online surveys). If the aim of the process is to build an agreement from the participants on the vision, it is recommended that a direct method which allows participants to interact and arrive at a consensus (Tight et al., 2011). However, if the aim involves extracting the stakeholder opinion concerning a pre-developed vision, the indirect approach (Delphi survey or validation mailer) can be utilized (Blass et al., 2010).

Generally, these participatory methods provide a significant source of qualitative evidence that can often not be accessed by other means. More importantly, this is a way of transferring the power in evaluation to the participant, making the participant be creative and engaged in the process. As a result, the participant is more likely to feel engaged and own the results.

Table 2.6 Methods for identifying vision elements under the tabula-rasa approach

Methods	Photo & Textual Diary	Public Opinion survey	Vision festival	Focus groups/Interviews	Kitchen table talks	Community table meetings
Description	This method involves asking the participants to present their desires in written or drawings. They are also at liberty to reflect the parts of the system they do not like as well. A categorisation of the drawings and write-ups are grouped into themes.	An indirect approach where participants and researchers are not in direct contact. The Surveys are designed with different attributes of the system and sent to participants through emails for them to react by filling the survey. Survey results are collated and analysed.	This is an informal direct method where an informal event is organised with games, entertainment, music, refreshments, and food, and participants are invited to provide and discuss vision statements.	A stakeholder is requested to discuss specific issues related to vision. This can be done in a workshop setting, or specific interview sessions are held with stakeholders. It is also applied during consensus building amongst participants.	A highly informal method whereby one of the organisers or volunteers' participants decides to invite others to her\his home to have discussions on the visions.	This is basically applied when conducting large public meetings. Members are brought together to discuss on one or more visions.
Expected results	Picture and short texts portraying future desires.	Preferred vision elements and extent of preference.	Desired future vision statements.	Vision statements	Vision statements	Vision statements
Setting	Individual activity during the workshop.	Survey using (Qualtrics or survey monkey)	Informal Workshop setting	Focus group/workshop	Public meeting	Public meeting
source	Elkins, 2009	Shipley, 2004	Uyesugi &Shipley, 2005,	Cuthill, 2004 & Shipley, 2012	Shipley, 2004	Shipley 2004

(Source: Adapted from Minowitz, 2013)

Table 2. 7 Methods of identifying vision elements under the responsive approach

Methods	**Exploration Parcour**	**Multi-attribute utility analysis**	**Alternative fairs**	**Focus groups**	**Visual preference survey**
Description	Participants are presented with some visions through audio and video formats after which they are asked to assess the pros and con of the visions. The assessment of the vision is measure on a scale of desirability of 1-100.	This method involves a process of measuring stakeholder's interests in the respective scenarios. Criteria upon which visions are evaluated are also identified. A pair wise comparison is conducted on each of the criteria in order to determine the best vision.	In this case the stakeholders are presented with all the different types of visions available and asked to review and modify the visions based on their new ideas.	Stakeholder are requested to discuss on specific issues related to vision. This can be done in workshop setting and also applied during consensus building amongst participants.	This is a situation where the different visions are visualised before the stakeholders for them to make their input based on the ideas they have generated.
Expected results	The score for each of the visions options which indicates the level of attractiveness of one vision and its criteria over another.	Satisfaction score which is based the evaluations and the importance of the weights given to the different scenario	Public assessment and favourites of visions or vision elements	To get an idea of the range of responses that exist	To explore desired alternatives to the existing visions.
Setting	Structured or semi structured Interview or workshop	Survey, focus group discussion	Focus group discussion	Workshops	Survey, focus group discussion
source	Loukopoulus, 2004	Loukopoulus, 2004	Loukopoulus, 2004	Cuthill, 2004 & Shipley, 2012	Loukopoulus, 2004

(Source: Adapted from Minowitz, 2013)

2.5.1.6 Producing the vision (step 6)

In producing visions, the team analyses and consolidates the vision elements generated from the dialogue step. The visions developed must be agreed upon by all stakeholders and expressed in actionable concepts (O'Brien and Meadows, 2007). This step is outrightly highlighted in the CA and VCA. However, in the TVA, this activity was not highlighted as a separate step, instead it was integrated into the identification of future desired vision step. The latter is the case for most visioning where the procedure for identification of the vision elements, analysis of stakeholder group visions and the consolidation of the outputs are carried out under a single visioning workshop (Uwasu et al., 2020; Hsu et al., 2020).

In addition, the drafting of the visions is an essential task when producing the final visions. It is done mainly through the community Visioning process which takes place in workshop session. The act of drafting of visions is not always mentioned during the Visioning process because it is the activity be either stakeholder participatory activity or conducted by the project team post visioning workshop event. This task is very important to be highlighted because it helps to communicate the visions to a wider audience.

Narrative or visualisation methods are employed to communicate the vision in full light. The ability to visually represent the vision is important as it helps make the visions more tangible and feasible. Visualisation methods include the use of Photorealistic visualisation PV to show how the visions will look like in maps. Images have also been created using computer-based renderings to give a picture of what a vision would look like in landscape (Tight et al., 2011). The activity location method plays a double function by pairing the visual elements with the existing structures in an area, thereby providing a pointer to where a vision should be suitably implemented

2.5.1.7 Planning for action (step 7)

The planning for action involves the stakeholders and participants making commitments to implementing the action points that have been developed from the Visioning exercise. O'Brien and Meadows (2007) highlight that in the planning for action phase of the Visioning process, the outputs from the visioning workshops are collated and analysed to develop reports to be sent to the decision-making bodies or institutions. The author explains that in some cases, the presentation of the report to the respective organisation marks the end of the Visioning process for the project steering team. In other cases, there could be a further analysis on the Visioning outputs where organisation develop "stretch goals" (O'Brien and Meadows, 2007).

Authors that argue that visioning is a part of the backcasting process extend beyond the development of the vision action plans. These authors include the development of pathways to achieving the visions (Banister and Hickman, 2013; Kok, 2011; tight et al., 2011; van Vliet and Kok, 2015). Also, Uwasu et al. (2020) extended their visioning activity by quantifying the four visions developed and developed road maps to achieving the Visions. In the case of the latter, the project team developed quantitative representations of their desired reduction in emission level under four energy visions.

This activity cuts across all the reviewed Visioning procedures (TVA, CA, and the VCA). It was also identified that most visioning projects (O'Brien and Meadows, 2007; Tigh et al, 2011; Uyesugi &Shipley, 2005, Stevenson, 2008; Welchet al., 2018; Starricco et al., 2019; Uwasu et al., 2020; Hsu et al., 2020) adopted the planning for action step in their process. Some of the studies termed it as the "development of action plans" as seen the typical visioning process.

2.5.2 Application of visioning in transport and distribution network design contexts

This section provides a review of visioning studies in the supply chain distribution network contexts. It aims to draw insight from the findings of visioning studies as these insights will guide the design of visioning approach. It is important to state that only few visioning studies focused on the application of visioning in supply chains. Consequently, the research added studies that focused on the visioning studies related to transportation in general.

Early research findings from the study of van Hoek et al. (1999) on the implementation of postponement strategies for European strategies identifies that the lack of supply chain visions constitutes a major challenge when managing change process. Soria-Lara and Banister (2017) conducted a participatory visioning and backcasting of the transport sector of Andalusia region in Spain. A delphi and semi-structured interviews were used for eliciting stakeholder opinions and findings revealed that the involvement of stakeholders in the developing visions as against the reliance on expert views is a democratic way of thinking about the desired futures. Also, the study revealed that when the sample size of stakeholders is large (above 40), there can be multiple endpoints from the conventional views. The study recommends a combination of methods during the vision development process because single methods can lead to outputs that are either too closed or open. However, the authors note that achieving the right sample size of participants for each method can be very challenging.

Tight et al. (2011) developed visions for a walking and cycling for a focused urban transport system. In this study, three visons for walking and cycling for the year 2030 were developed during a workshop setting. Each vision developed represent a desired walking- and cycling-focused transport system against a different external background contexts. The purpose of the visions was to evoke the debate on the plausibility and desirability of such alternative futures. This study raised the issue of the relevance of background context on visions. The authors note that vision developers can sometimes be drawn to the thought of a demarcation between the visions and the external environment. The authors conclude that for radical transformations to take place in the future, there must be significant changes to the exogenous background environment.

Starricco et al. (2019) developed three visions for the Italian city of Turin. The visions highlighted how "different forms of regulation of autonomous vehicles circulation and parking impact on the sustainability and livability of the city". A visioning validation was carried out by conducting focus groups and interviews with experts and stakeholders. The authors conclude that visioning is a first step in the backcasting process. Also, the authors affirm that the combination of experts and stakeholders is a good approach for elaboration of the visions and the selection of the most advisable one. They suggested that an interesting future study would be the use of quantitative models to determine the implications of the circulation of autonomous vehicles.

Musso and Corazza (2019) envisioned the bus system of the future. The aim of the visioning project was to develop a modern bus system that will increase the attractiveness of the bus transport mode. Since the study focused on the transferability of the vision options across European cities, the findings from the study revealed that innovative measures can be transferred across locations if the costs across locations do not differ. In addition, Esmaeilian et al. (2020) developed visions where blockchain and other industry 4.0 technologies support the actualisation of sustainable supply chains. The study adopted a four-step literature review method to; define the analysis unit; define the classification context based on method and problem context; literature collection and evaluating and interpreting the literature. The study revealed that while blockchain and industry 4.0 technologies can drive sustainable supply chains, the contextual facilitating conditions remain an important factor that either allows or disrupts the actualisation of the advanced supply chain technologies.

Abbasi (2017) explored the pattern and themes and challenges in developing future supply chains. This study was conducted through a systematic review of peer-reviewed literature to identify the theme documented in literature. Findings from the study revealed that the challenges limiting the achievement of sustainable supply chains include inadequate asymmetric knowledge; difficulty in the operations; and contextual difficulties faced by small and medium scale organisations.

2.6 Summary of chapter

This chapter provided a review of the scenario literature. It classified scenarios in the forecasting (see section 2.3), exploratory (see section 2.4) and the visioning (see section 2.5). Due to the limitation of the forecasting in producing single point forecast which in most cases are inaccurate in the long-term planning contexts, the researcher agreed that it was not a suitable methodology of focus. In the review of the exploratory scenario class it was identified that different scenario developers adopt between 5 and 12 steps while conducting exploratory scenarios. It was identified that while some authors compress the scenario procedure to few steps, other procedures are expanded. Also, some authors simply named some steps differently when the content meant the same. Furthermore, in the review, each of the steps employed in the exploratory scenario process was described, and methods employed adequately explained. This chapter also drew a comparison between the participatory and the desk exploratory scenario methods.

In the visioning section, the review critically focused on the methodological advancement in the Visioning field. The review drew on some of the key arguments in the visioning domain. Some of these include: i) Is it important to analyse the organisations current situation? ii) Is it important to assess the external environment during Vision development? If yes, how and when should be done? iii) Is it useful to create a desired future state or multiple desired future states? iv) Should one connect the future to the present state during vision development? and v) It is important to test visions? Furthermore, the typical visioning approach (TVA) was compared with the choices approach (CA) and the Visioning choices approach (VCA). Other visioning projects were compared with the above procedures and It identified that while these projects do not present any formalised procedure, they implicitly align with the activities under the phases of the CA and VCA proposed by O'Brien and Meadows (2001, 2007). It was identified that the number and the naming of the steps under the three approaches differed, the tasks engaged in the process were the same. Finally, the steps employed under the visioning exercise were presented, and methods to be used were described.

The next chapter will focus on the optimisation methods for long term planning of supply chain network designs.

Chapter 3 - Review of supply chain network design optimisation methods for long-term planning

3.1 Outline of review chapter

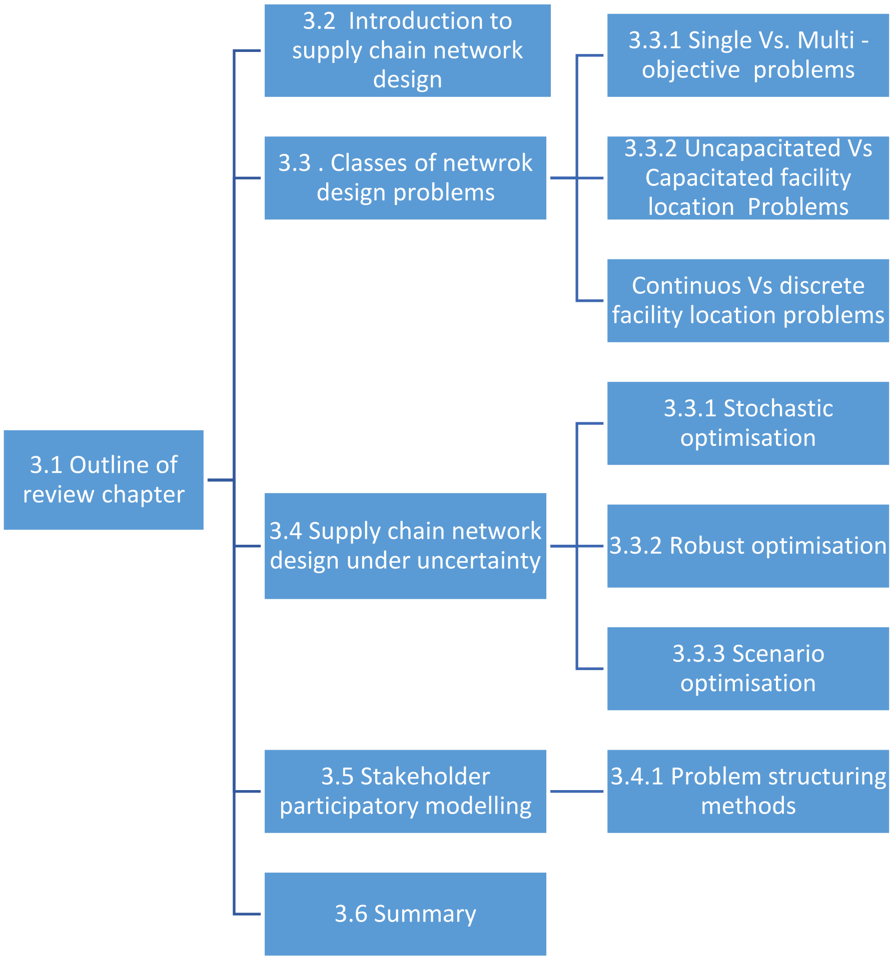


Figure 3. 1 Structure of the review chapter

Figure 3.1 illustrates the structure of the literature review carried out in this chapter. The purpose of this chapter is to review the techniques for optimising network designs under uncertainty. In section 3.2, the chapter provides an overview of supply chain network design problems. In section 3.3, the classes of facility location problems are presented. Section 3.4. addresses the network design problems uncertainty with specific attention to the different techniques for solving network design problems under uncertainty. Section 3.5 proceeds to a review of participatory stakeholder modelling with attention to problem structuring methods for long-term planning. The chapter is summarised in section 3.6.

3.2 Introduction to supply chain network design (SCND)

Supply chain network design is an integral element in every supply chain planning process. It determines the physical layout of infrastructure of a supply chain (Govindan et al., 2017). The network design of supply chains is synonymous with the term "strategic supply chain planning" (Chopra and Meindl, 2007). This is true because decisions made are capital intensive, difficult to reverse and can transform the entire business on the long run (Melo et al., 2008; Van Engeland et al., 2020; Doan, 2020). The common strategic decisions involve determining where facilities should be located; the number of facilities, the right capacities and sizes of facilities; technologies to be adopted; spatial allocation for production processes; and the selection of raw material suppliers (Klose and Drexl, 2005; Quintero-Araujo et al., 2019). These decisions are critical for supply chains because organisational operations such as manufacturing and marketing of products depend largely on the strategic location of facilities within supply chains.

Govindan et al. (2017) notes that the interest in network design optimisation stem from multiple sources. First, network design location decisions are ubiquitous because they are made by different entities such as individuals, households, firms, and government agencies. Second, they are strategic because they involve huge capital outlay, and the consequence of its decision cannot be easily reversed. Network design decisions made by private firms influence their ability to effectively compete in their business sphere. For public or government owned organisations, network design decisions influence the ability to provide services to the public. Third, network design problems are often difficult to solve, at least optimally. Fourth, in most cases, the network design problems are often uniquely defined by the problem context setting.

In addition, as individuals in public or private organisations strive to operate in their respective domains, uncontrollable forces in their environment such as market trends; the population; technology; consumer taste and preference continually evolve (Song and Sun, 2017). These dynamics require organisations to modify their existing network design decisions, and such changes are usually expensive and time-consuming (Simchi-Levi et al., 2004). In most cases, a redesign of the network to accommodate a new facility require scientific analysis to identify the best location that will yield the better return on investment (Song and Sun, 2017). Consequently, supply chain planners must strive to design networks that support the optimal allocation of resources to drive efficiency and productivity within their organisation.

3.3 Classes of facility location problems

Problems related to the location of facilities within supply chain networks can be classified into problem associated with either single or multiple objectives; uncapacitated or capacitated. This section will provide a description of the different categories of facility location problems.

3.3.1 Single Vs Multiple objective problems

Applications of facility location have been used in public sector domains such as recreation and leisure (Kaufman et al., 2019), or health centres (Meskarian et al., 2017; Mokrini et al., 2019), private sector such as supermarkets (Wang et al., 2017), distribution centres and factories (Trivedi and Singh, 2018) and in environmentally sensitive areas for production and disposal of obnoxious waste, chemicals (Gergin et al., 2019). These network design problems are characterised by either a single or multiple objective that are often considered for an optimisation (Heckmann et al., 2016). While some designs focus on a single objective (Afshar and Haghani, 2012 ; Akgun et al., 2015; Chen et al., 2013 ; Duran et al ., 2011; Hong et al., 2012), most real-world problems possess multiple conflicting objectives (Barzinpour and Esmaeil, 2014; Chanta and Sangsawang, 2012; Wichapa and khokhaikiat, 2017; karatas and Yakici., 2018).

For single objective problems, Akgun et al's (2015) model sought to minimise the risk faced by a demand point as a result on non-coverage by the located facilities. Afshar and Haghani (2012) proposed a model that monitors the flow of relief materials in order to minimise the unsatisfied demand at demand points; Chen et al. (2013) proposed a tri-level multi-echelon model that minimises the average distance of earthquake shelters from central support locations. Other authors such as Duran et al. (2011) and Hong et al. (2012) minimised the average response time and total logistics costs respectively. As regards the multi-objective problems, the objectives may conflict with one another. Barzinpour and Esmaeili (2014) developed a multi-objective location model that sought to maximise the coverage of population, minimise other costs such as the setup costs, transportation costs, equipment holding costs, shortage costs for urban disaster management. Chanta and Sangsawang (2012) tried to maximise the number of demand zones and minimise the weighted distance of between supply points and shelter-sites during flood disaster. (see Boonmee et al., 2017 for other single or multi-objective related studies)

Furthermore, Deb (2014) posits that it is misleading to assume that a single optimisation problem whose primary task is to determine that unique solution which optimizes the sole objective function is like a multi-objective optimisation problem (MOOP) where solutions to the respective objectives tend to differ significantly. Evidently, either class of optimisation problems differ on their underlying principles. Hence, they require different solution methods. Single objective problems have been solved using heuristics methods, the multi-objective problems have been solved by evolutionary algorithms. However, a unifying way to deal with single and multiple objectives is to refer to fix one objective as the main objective, and relax other objectives as soft constraints (Deb, 2014).

3.3.2Uncapacitated Vs Capacitated facility location problems (UFLP Vs CFLP)

The UFLP is often referred to as the warehouse location problem (ReVelle and Eiselt, 2005). They take a great variety of forms, depending on the nature of the objective function, the time horizon under consideration (static, dynamic), on the existence of hierarchical relationships between the facilities and on the inclusion or not of stochastic elements in their formulation (probabilistic, deterministic). The underlying assumption of UFLP is that facilities have enough supply or capacity to supply all their assigned customers. Hence, supply or capacity constraints are not considered under this class of problem (Barahona and Chudak, 2005), However, in practice, this may not be the case as facilities may only have a finite supply or capacity available. Thus, customers may be assigned to their nearest facility until the supply runs out, whilst some customers may be partially assigned to their nearest and/or nearest available facilities (Gendron et al., 2016; Glover et al., 2018). Therefore, facility location studies that consider of supply and capacity issues have been conducted.

The capacitated facility location problem (CFLP) is an extension to the uncapacitated facility location problem (UFLP) that consider the facilities in the network to have a finite supply/capacity constraint (Chauhan et al., 2019; Yang et al., 2019; Biajoli et al., 2019). The introduction of capacity constraints effectively makes these problems theoretically more difficult to solve and are generally NP-hard. Contributions to solving the CFLP are primarily metaheuristic and can be found in the following studies (Lorena and Senne, 2003, 2004; Scheuerer and Wendolsky; 2006; Osman and Ahmadi, 2007; Fleszar and Hindi, 2008).

3.4 Supply chain network design (SCND) under uncertainty

Long-term network design problems are complex and complicated as a result of the unexplainable nature of the forces in the business environment on the long-term basis. Hence, the objective of any SCND under uncertainty is to attain a configuration that can function effectively under the different realisation of the uncertain parameters (Govindan et al., 2017). The uncertainty surrounding design parameters are triggered by issues such as economic crisis or natural disasters and unexpected and unexplainable disease outbreaks. Evidently, the ability to detect the likelihood of occurrence of such events are low. However, their impact on the supply chain network designs could pose significant challenges to the functionality of distribution network designs.

The uncertainty in network design environments can be grouped into three broad categories (Rosenhead et al., 1972; Sahinidis, 2004; Govindan et al., 2017). First, the parameters influencing network design decisions can be stochastic in nature. In this case the likelihood of events occurring are known. Here, uncertain parameters such as customer demand are modelled through the normal distributions with known mean and variance. Synder et al. (2006) adds that other parameters can be described as stochastic parameters with diverse probability distributions (see section 3.4.1). Second, there is no prior information on the probability distribution of the uncertain parameters. Here, robust optimization models are used for optimising the worst-case performance of the distribution network (Kouvelis and Yu, 2013). Alternatively, the scenario approach or pre-specified intervals can be used to model discrete or continuous uncertain parameters with no prior probability distribution (Dembo, 1991) (see section 3.4.2 and 3.4.3).

Third, Govindan et al. (2017) highlights the fuzzy decision-making environment where uncertainties are underpinned by ambiguity and vagueness associated with the network design parameters. In this case, ambiguity denotes the conditions in which the choice among multiple alternatives is undetermined, and vagueness occurs when sharp and precise boundaries for some domains of interest are not delineated. For the latter, fuzzy mathematical programming handles the planner's expectations about the level of objective function, the uncertainty range of coefficients, and the satisfaction level of constraints (Inuiguchi and Ramık, 2000, Sahinidis, 2004).

3.4.1 Stochastic network design problems

Stochastic optimisation problems are modelled through a set of discrete scenarios with known probabilities. These network design stochastic problems are usually split into two-stages (Birge & Louveaux, 2011). In the first stage, there is a single moment for uncertain parameters to become known, and in the second stage, the uncertainty is realised progressively in more than one moment. This is often the case for most real-world problems and has led to the dual-stage stochastic program that is often applied. In solving these problems using the stochastic approach, some decisions have to be made before uncertainty realisation and some others are made afterwards.

The stochastic approach has been widely applied under uncertain contexts (Döyen et al., 2012; Golabi et al., 2017; Ortiz-Astorquiza et al., 2018; Yu et al., 2020; Zhou et al., 2013; Georgiadis et al., 2011, koltsaklis et al., 2015). Among other studies, Zhou et al. (2013) proposed a two-stage stochastic optimisation model for designing energy distribution systems. In this study, energy supply and demand parameters were the uncertain parameters. In the first stage a genetic algorithm was used for searching on the variables and a monte Carlo method was employed to deal with the uncertainty in the second stage. koltsaklis et al. (2015) proposed a multi-regional, multi-period mixed integer linear program (MILP) to address a "generation expansion planning (GEP) problem of a large-scale, central power system. This study combined the Monte Carlo and optimisation technique at both stages to deal with uncertainty in the electricity industry environment. Georgiadis et al, (2011) formulated a MILP to provide and optimal solution using the branch and bound algorithm. This study uniquely considered the number of possible scenarios that could evolve over the network lifetime. Döyen et al. (2012) developed a dual stage stochastic optimisation model where decisions were made for the prior and after disaster rescue facilities. Other decisions were related to the quantity of relief materials to be stockpiled at the initial disaster rescue facilities; the quantity of relief material owes at each stage in the network, and the quantity of shortage.

Synder et al. (2006) notes that the creation of scenarios and identification of parameters associated probabilities can be a cumbersome task when dealing with real-world design problems. Dembo (1991) adds that stochastic programming place a heavy data and computational burden on the user and as such are often intractable. Moreover, the models themselves are difficult to understand. This probably explains why one seldom sees a fundamentally stochastic model being solved using stochastic programming techniques. Instead, it is common practice to solve a deterministic model with different assumed scenarios for the random coefficients. For the above reasons, much attention will not be focused on the stochastic facility location methods.

3.4.2 Robust optimisation

Where the probability distributions of uncertain parameters are not known, it is not possible to use expected value criterion as applied for the stochastic problems. This has necessitated the use of robust facility location methods for dealing with uncertainty. Govindan et al. (2017) posits that the expected cost and associated objectives of stochastic problems are not relevant when the probabilities of uncertain parameters are not known. He reiterates that under the robust optimisation, the uncertain parameters can be modelled as either discrete or continuous. The discrete uncertain parameters are modelled using the scenario approach while the continuous parameters are generally assumed to lie within some pre-specified interval (Govindan et al., 2017).

3.4.2.1 Scenario optimisation

The scenario optimisation is a technique for obtaining solutions to robust optimization problems with discrete uncertain parameters (Govindan et al., 2017). It also relates to inductive reasoning in modelling and decision-making (Piplani and Saraswat, 2012). The technique has existed for decades as a heuristic approach that investigates how well feasible solutions perform in different scenarios and then tries to find the optimal solution. It attempts to draw representative scenarios that could happen. This form of optimisation is used where the parameters of a mathematical model are subject to randomness (Pickering and Choudhary, 2019).

Dembo (1991) explain that uncertainty can uniquely be represented conveniently using scenarios. Each scenario can be represented as a certain outcome of the uncertain data c_u , A_u , b_u represented by c_s , A_s , b_s . In this case, for every scenario s ϵ S {set of all scenarios}, the optimisation problem becomes a deterministic problem. Under the classical stochastic optimisation technique, it is assumed that each scenario is associated with a probability p_s. Also, it is assumed that the probability for p_s, for every scenario ss ϵ S are known in advance. This is not the case for most dynamic real-world problems where the parameter values change over time. In addition, Dembo argues that in some instances the behaviour of the stochastic processes may be known. However, in most real-world cases, neither the probabilities nor the parameter values will be known. Rather planners are expected to periodically review their policies as changes are observed about the parameter values.

Scenario-based optimisation has been used successfully in several cases to make decisions while taking into consideration possible future scenarios (Napolitano et al., 2016; Shavazipour and Stewart, 2019). Here, Napolitano et al., 2016 proposed an interesting combination between the scenario optimisation and the cost-risk balancing approach. Optimal decision rules were identified by balancing the risk of water shortages and the operating costs of pumping stations. Considering the multi-objective nature of the problem, a scenario optimisation model was developed to optimise the trade-off between the cost and risk associated with the system. Shavazipour and Stewart (2019) presents a scenario-based multi-objective structure to handle decision making problems under deep uncertainty (DMDU). This study provides as extension to the two-stage stochastic optimisation problems in order to address the potential for adopting scenario planning for handling deep uncertainty rather than statistical expectation. Scenarios were used chosen in preference to the stochastic options to avoid problems associated with the assessment and use of probabilities when confronted with deep uncertainty.

Mulvey et al. (1995) compared robust optimisation with stochastic optimisation and stated that stochastic optimisation is suitable for problems where solutions can be adjusted easily in response to changing conditions, while robust optimisation is for problems where once a solution is implemented, it is not changed for a considerable length of time. Also, if the problem has high uncertainty in data, then stochastic optimisation, with expected value minimisation as the objective, may not yield appropriate solutions.

3.4.2.2 Robust models with interval-uncertainty

Generally, robust optimisation (RO) models with interval-uncertain parameters has been applied in order to protect optimization problems against infeasibility due to perturbations of uncertain parameters, and to retain computational tractability. The primary step in RO with interval uncertain parameters was done by Soyster (1973). The general idea was to convert the uncertain optimization problems into a deterministic counterpart so that each feasible solution should be feasible for all realizations of uncertain parameters within their pre-defined uncertainty sets. However, Soyster's approach mostly achieves over-conservative solutions.

Ghaoui et al., (2003) addressed the issue of over-conservatism raised by Soyster (1973) by limiting over-conservatism of this robust optimisation problems to a fewer conservative solutions. Uniquely, Bertsimas and Sim (2003) showcased a different robust approach in which the conservatism level of robust solutions could be controlled and resulted in a linear optimization model. This approach is also applied for discrete optimization models. However, Ben-Tal et al. (2005) pointed out that in all above conventional RO approaches, all decisions have to be made before uncertainty realization. Nevertheless, most real-world problems, in particular the network design problem, have multi-stage nature, and hence some decisions have to be determined after realization of all or part of existing uncertainties. To this aim, they presented a multi-stage RO approach, called Affinely Adjustable Robust Counterpart (AARC). This idea allows for making adjustable decisions that are affinely contingent on the primitive uncertainties.

In practice, even though the exact distributions of uncertain parameters are often not known in advance, moment information or uncertainty about the distribution itself is usually known. To deal with this situation, Distributional Robust Optimization (DRO) was firstly proposed by Arow et al., (1958), and then extended by Delage and Ye (2010), Goh and Sim (2010), and Wiesemann et al. (2014). In DRO, an uncertain parameter follows a distribution which is itself subject to uncertainty. There are a few studies about robust supply chain network design with interval-uncertainty. Most of these reference papers used commercial solvers to solve the equivalent models for their robust counterparts. It is worth noting that in Keyvanshokooh et al. (2016) and Hatefi and Jolai (2014), some uncertain parameters have interval-uncertainty and some others are modeled by using discrete scenarios. This approach is applicable whenever we have different types of uncertainty.

3.4.2.3 Robustness measures for discrete uncertain parameters

Two common robustness measures used for modelling discrete uncertain parameters for scenario-based RO programs are minimax cost and minimax regret. While the minimax cost measure seeks to minimise the maximum cost across all possible scenarios, the minimax regret seeks to minimise the difference between the cost of a solution and the cost of the optimal solution for a scenario. The latter measure was applied by several authors; some of which include Realff et al. (2004) and Ramezani et al. (2013) to design a reverse logistics and a closed loop supply chain network respectively. Also, the AhmadiJavid and Seddighi (2013) and Govindan and Fattahi (2017) applied the minimax cost measure to examine a supply chain network design problem. In addition, Kouvelis et al. (1992) employed the p-robustness measure where constraints were introduced to ensure that the relative regret is not greater than a specified value p. Other studies (Hatefi and Jolai, 2014; Peng et al., 2011; Tian and Yue, 2014; and Salahi et al., 2016) applied the p-robustness approach. Govindan et al. (2017) identifies that the p-robustness measure shrinks the feasibility space and could lead to infeasibility for some values of p.

3.5 Participatory modelling

Researchers in the Operational research domain have expressed concern over the gradual drift of the operational research techniques away from the application of its techniques to solve real problems towards the use of its techniques for contributions to mathematical theory. This drift has ignited concerns that the assumptions underpinning existing quantitative OR techniques were ill equipped to deal with the complex, messy problems faced by organisational managers (Prell et al., 2007). In response to the highlighted issue, new approaches were developed with different methods of analysis, and viewing problems from a different philosophical position. This group of methods are classed a "problem structuring methods" (PSMs). The next section will provide a description of PSM.

3.5.1 Problem structuring methods

Problem structuring methods (PSMs) are a family of facilitated modelling approaches that support the work of groups of diverse composition in order to help them address complex problem situations in a variety of organizational domains. They emphasise: (i) structuring messy, complex problem situations rather than solving well-defined problems; (ii) exploring the differing views and perspectives of the stakeholders in a situation; and (iii) facilitating participation and engagement rather than analysing abstract data and models. The characteristics of problems that PSMs address have been called 'messy' and 'wicked' (Ackoff, 1979; Peters, 2017; Forrester et al., 2018). While these problems are varied, and it is difficult to exhaustively list their attributes, Churchman (1967) posits that these problems possess the following properties:

- They cannot be exhaustively formulated.
- Every formulation is a statement of a solution;
- There is no stopping rule;
- There is no true or false, and no exhaustive list of operations;
- There are many explanations for the same problem;
- Every problem is a symptom of another problem;
- There is no immediate or ultimate test;
- solutions are 'one shot' and every problem is unique;

Problem structuring methods offer an alternative to 'traditional hard OR' methods. OR methods are premised on the assumption that reality can be objectively modelled to identify efficient ways of achieving well-specified objectives (Rosenhead & Mingers, 2001). However, since some real-world problems often lack reliable data, and standard mathematical techniques are not applicable I am dealing with the complexity associated with such problems (Smith and Shaw, 2019). In contrast to the hard OR methods, PSMs take an interpretivist and social constructivist view that situations are constructed differently by different people. They are subjective and require the participation of actors (Rosenhead & Mingers, 2001a). PSMs sit within operational research (OR) but represent an alternative paradigm for problem-solving, distinct from 'traditional quantitative OR' (Rosenhead & Mingers, 2001b).

According to Smith and Shaw (2019), three PSM approaches were found to dominate the literature. These are i) Soft Systems Methodology (SSM) (Checkland and Scholes, 1999), ii) Strategic Choice Approach (SCA), and iii) Strategic Options Development and Analysis/Journey Making (SODA). Other PSMs found in literature include cognitive Mapping (Eden and Ackerman, 2004); Strategic Assumption Surfacing and Testing (SAST) (Mitroff and Mason, 1981), and Visioning Choices (O 'Brien and Meadows, 2007). While these PSMs have been used by practitioners, others have shown interest in the use of OR methods. However, there are potentials for PSMs to complement quantitative analysis (Kotiadis and Mingers, 2006; 2014), and questions arise such as which one should be used in which circumstances? And, can different methods be combined and, if so, how? (Mingers, 2000).

The PSM and optimisation methods present two dimensions; - one concerning the complexity of the problem domain (from simple to complex) and one concerning the relations between stakeholders (unitary - general agreement, pluralist – differing but reconcilable views, and coercive-differing and irreconcilable views). This typology could then be used to choose a method appropriate to a situation. These soft approaches have been highly successful in widening the range of problematic situations that operational research can tackle both as methods and as complements to more traditional quantitative analyses.

3.6 Summary of chapter

This chapter focused on the review of the optimisation of supply chain network designs under uncertainty. The chapter identified that stochastic optimisation methods can be used to model the uncertainty under two-stages. Stochastic models assume that the probabilities of uncertain parameters are known in advance. However, it was identified that this is not the case for real world problems. Also, the robust optimisation method was identified as another approach to modelling uncertainty when the probabilities of the uncertain parameters are not known in advance. Discrete and continuous parameters are modelled using scenario optimisation. Therefore, the scenario optimisation literature was also reviewed. The chapter reviewed the recent developments in the field of OR where stakeholder's participation is integrated within the modelling practice. On this premise, problem structuring method literature was reviewed. It was identified that recent developments in the OR domain call for combining the hard OR methods with the problem structuring methods. The latter will set the scene for the review of multimethod development in the next chapter.

Chapter 4 - Review of multimethodology

4.1 Outline of the chapter

This chapter provides a review of the multimethodology. Figure 4.1 presents the different aspects of the multimethod field covered in this review chapter.

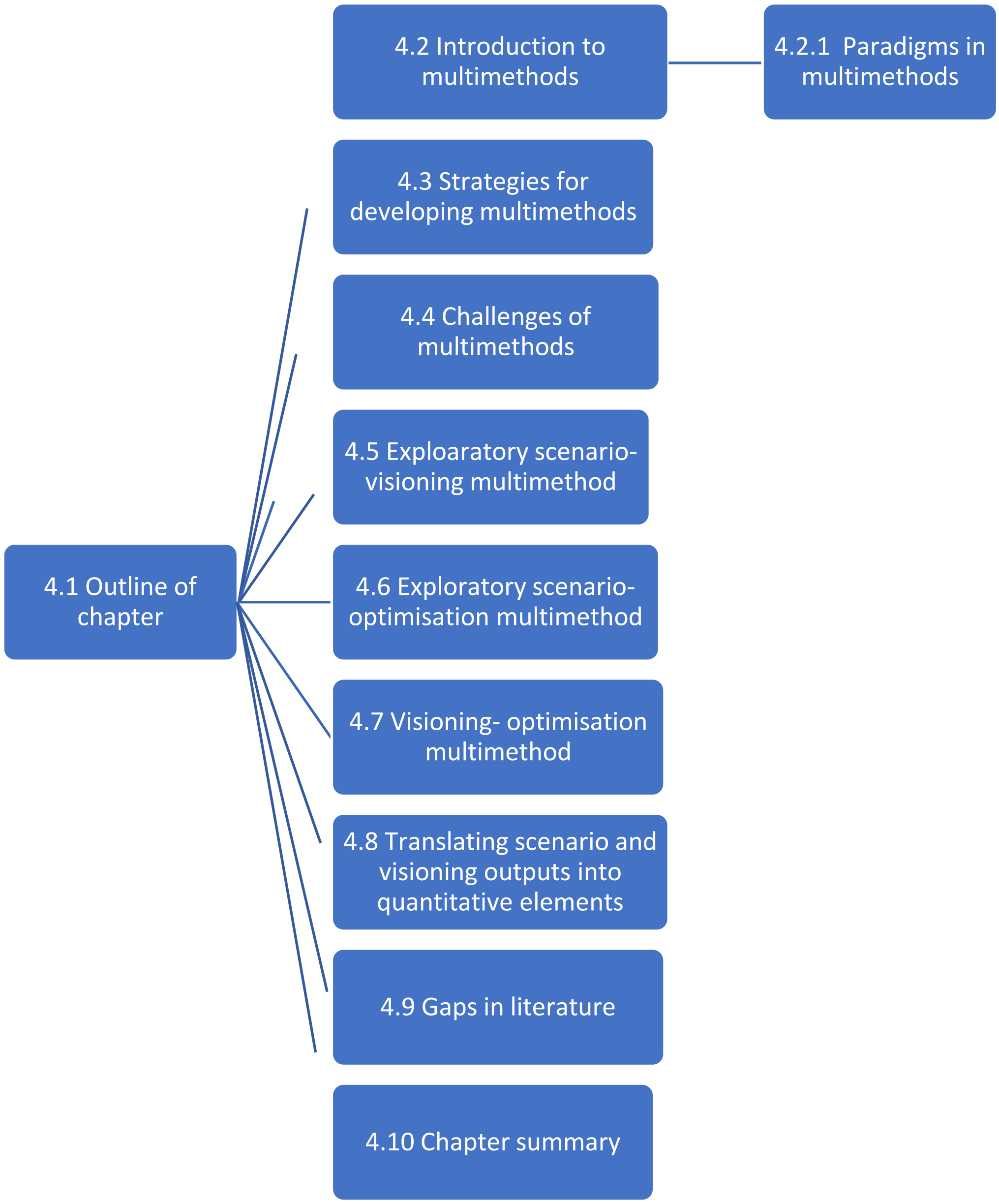


Figure 4.1 Structure of review chapter

The structure of this review chapter as presented in figure 4.1 depicts the elements relevant to the development of a multimethod that consist of two foresight methodologies (exploratory scenario and visioning) and the facility location optimisation method. The chapter is broadly structured into ten sections. In section 4.1, the chapter presents a road map into the review conducted in the chapter. In section 4.2, a review of the multimethod concept and the underlying philosophical paradigms are presented. The strategies for multimethod development are reviewed in section 4.3, and challenges associated with the development of a multimethod are described in section 4. 4. Section 4.5, 4.6, and 4.7 provides a review of different multimethods involving exploratory scenario, visioning, and optimisation. Attention will be given to the combination of exploratory scenarios and visioning in section 4; exploratory scenario and optimisation in section 4.6, and visioning and optimisation in section 4.7. The chapter also provides a review of the methods for translating qualitative scenario outputs into quantitative in section 4.8. The gaps identified from the related literature are presented in section 4.9. Finally, a chapter summary is provided in section 4.10.

4.2 Introduction to multimethods

"The essence of multimethods is to utilize more than one methodology, or part thereof, possibly from different paradigms, within a single intervention" (Mingers and Brocklesby, 1997). The term multimethod is sometimes confused with mixed method. As highlighted above, Mingers and Brocklesby (1997) explains that mmultimethods involve the combination of different methodologies. On the other hand, mixed methods consist of the combination of two different methods for data collection on a specific research study (Johnson and Onwuegbuzie, 2007). In addition, while the primary objective of a multimethod is to explore the complementarity of the different methodologies (Pidd, 2004; Brown et al., 2006), Johnson and Onwuegbuzie (2007) posits that the purpose of mixed methods includes, but not limited to the achievement of convergence of research findings from the use of the methods. Based on the description and the purpose of the multimethod and mixed method provided, it can be said that mixed methods designs are embedded within a broad multimethod framework. In this case, each methodology within the multimethod framework can adopt a mixed method approach for the data collection process.

4.2.1 Research paradigms in multimethods

Research paradigms are "a set of belief that offer a lens through which a research is viewed; a framework for thinking and determining how a research may be conducted" (Weaver and Olson, 2006 pp. 87). They provide insights into the methods and tools for data collection in the research; the types of problems that may be addressed, and the questions that may be posed (Weaver and Olson, 2006 pp. 87). When a research has been framed within a paradigm, a reader can view the work with an appreciation of the underlying beliefs, allowing the researcher to discuss the problem at hand without having to justify their belief system over.

Three important questions must be asked by every researcher before beginning an actual research: These include; the ontological inquiry; the epistemological inquiry, and the methodological inquiry (Makombe, 2017). These question form the basis of the research paradigm and they are described below.

4.2.1.1 Ontological assumptions

Ontology can be defined as "the science or study of being" (Blaikie, 2010). It refers to "the nature of our beliefs about reality" (Richards, 2003, p. 33). In other words, ontology is associated with a central question of whether social entities should be perceived as objective or subjective (Makombe, 2017). Accordingly, objectivism otherwise known as positivism and subjectivism are two important aspects of ontology. Objectivism is premised on the assumption that "social entities exist in reality independent of the social actors concerned with their existence" (Saunders et al., 2012). Subjectivism (also known as constructionism or interpretivism) on the contrary, assumes that the social phenomena evolve from the perceptions and consequent actions of the social actors concerned with its existence (Bryman, 2012, pp 45).

A third ontological standpoint is critical realism, also known as the "transformative paradigm". This ontology is premised on the assumption that an objective reality exist irrespective of human thoughts, but this reality can be interpreted through social conditioning (Saunders et al., 2012). The latter takes the view that reality is socially situated but not socially determined: a world exists out there that we seek to understand. (Al Riyami, 2015). This ontology emerged from critics to the positivist assumptions. Hence, it is also termed the post-positivism because it takes a middle position between the positivist and interpretivist paradigms" (Grix, 2004, p. 86). It differs from the interpretivism through the intention to appreciate the dynamics and insights drawn from stakeholder involvement within quantitative research designs. Accordingly, critical realists practice their research with consideration of social, economic, political, and cultural contexts for specific research interventions (Hammersely, 2013, p30). Creswell (2007) agrees that "research should contain an action agenda for reform that may change the lives of participants". This ontology is particularly suitable within the management science as it allows for a distinctive approach to be taken and supports the use of the multimethodology (Mingers, 2004; 2006).

4.2.1.2 Epistemological assumptions

Epistemology can be defined as that "branch of philosophy that studies the nature of knowledge and the process by which knowledge is acquired and validated" (Gall, Gall, & Borg, 2003, p. 13). It is concerned with how knowledge can be communicated to other human beings" (Cohen, Manion, & Morrison, 2007, p. 7). A researchers explicit or implicit ontological belief informs how the knowledge is pursued and acquired. For example, if a researcher assumes a positivist ontology that in underpinned by an objective reality that is singular and verifiable, then the researcher must be isolated from the process of discovery of the truth in order to ascertain 'how things really are' and 'how things really work'" (Guba & Lincoln, 1994, p. 108). Conversely, when an interpretivist ontology that supports the existence of multiple realities in addition to the belief that such realities are socially constructed by the perception of actors is followed, researchers are likely to reject the idea that people should be studied like objects of natural sciences. Instead, researchers are involved with the subject of concern and try and understand phenomena in their contexts.

Epistemological position of the positivist's researcher is that of objectivism and realism. Researchers come in as objective observers to study phenomena that exist independently of them and they do not affect or disturb what is being observed. They will use language and symbols to describe phenomena in their real form, as they exist, without any interference whatsoever. On the other hand, the epistemological position of the researcher with an interpretivist ontology relativism. The researcher immerses into the research because they are inextricably part of the social inquiry being researched. Here, one interpretation of the investigated phenomenon is not chosen or preferred over others as the "correct" one, but the multiple knowledges are welcomed with the acknowledgement that different researchers and participants can bring different useful perspectives to the same issue.

While the critical realists assume the existence of reality, they argue that realities are shaped by different socio-cultural, demographic, and political factors that interact with each other to create a social system. Epistemologically, the critical realist position is subjective in that it is assumed that no object can be researched without being affected by the researcher. Researchers in this domain are aware of their epistemological presuppositions and communicate them explicitly when conducting a research so "no one is confused concerning the epistemological and political baggage they bring with them to the research site" (Kincheloe & McLaren, 2005, pp. 305-306).

4.2.1.3 Methodological assumptions

The methodology can either be quantitative or qualitative and there are several research techniques under each methodology. The quantitative research methodology is commonly used in the natural science domain while the qualitative research methodology is more common in the social science domain. The quantitative research is underpinned by a positivist ontology and an objectivist epistemology. Researchers within the positivist domain use a large social sample data, and depend on numbers and numerical data (Creswell, 2013). Research projects underpinned by such positivist assumption understand the objects by empirical tests and methods as sampling, measurement, and questionnaire. This suggest that insights provided by positivist researchers may be of high-quality standard of validity and reliability and can be easily generalised to a larger population (Johnson & Onwuegbuzie, 2007). Findings from quantitative research are based on evidence and statistic, and the findings from a particular event can be transferable to different groups or subgroups of the population in social contexts. Such replication saves time and cost in the discovery of knowledge (Johnson & Onwuegbuzie, 2004).

Qualitative research is underpinned by the interpretivism paradigm. It argues that methods for gaining knowledge of the humanities and social sciences are not the same as those used in the physical sciences because humans interpret their world and act based on such an interpretation (Hammersley, 2013 p. 26). Consequently, qualitative research adopts a relativist epistemology in which a single phenomenon may have multiple interpretations rather than a truth that can be determined by process of measurement. Creswell (2007) posits that qualitative researchers gain a deeper understanding of a phenomenon and its complexity in its unique context instead of trying to generalise the base of understanding for the whole population. However, Hammersley (2013) notes that interpretivist researchers should seek to understand the world through different contexts and cultures. They should avoid the bias in studying the events and people with their own interpretations.

4.2.2 Multimethod paradigms

In a multimethod research, the methodologies of interest can be underpinned by a single paradigm or consist of methodologies with different ontological and epistemological assumptions (Morse, 2009). As described in section 4.2.1.1, 4.2.1.2, and 4.2.1.3, the positivism and interpretivism are two paradigms in the broad spectrum of quantitative and qualitative research (Hammersley, 2013). Pham (2018) adds that the critical realist paradigm is positioned between the two extreme positivist and interpretivist paradigms (Pham, 2018). Mingers (2006) opine that while positivist and interpretivist paradigms are useful and valid philosophical standpoints that produce quality research outputs, the critical realist ontology is particularly suitable within the management science as it allows for a distinctive approach to be taken and supports the use of the multimethodology (Mingers, 2004; 2006). He reiterates that quality of multimethods research can be improved and preserved by assuming a middle position that draws on the strength of both objectivist and relativist epistemologies in the pursuit of knowledge.

Adopting the critical realist position in multimethod research implies that the researcher agrees that rather than only assuming an objective reality that is independent of social actors or solely relying on the interpretation of social actors for the realisation of multiple realities, complex real world interventions can be addressed by assuming a middle position that certain elements of reality exist and can be modelled and they the perspective of social actors can be used to make sense of the realities. In addressing real-world problems, it is crucial to understand and incorporate the social structures without sacrificing the benefits of objectivity and reliability of data. While collecting and using quantitative data, it is important to understand that some of the real-world conditions are hard to quantify as they consist of tangible and intangible elements. Therefore, adopting a critical realist approach enables the researcher to combine both qualitative and quantitative methodologies to address the complexity and complicatedness of real-world problems.

The next section will address the strategies and challenges associated with combining similar and different methodologies.

4.3 Strategies for developing multimethods

Overtime, researchers agree on the benefit of combining different methodologies for solving complex problems. However, they differ in the approach to combining the methodologies. Some strategies for developing multimethods include the concepts of; "coherent pluralism" by Jackson (1999); "creative design of methods" by Midgley, (1997); "pragmatic pluralism" by White and Taket (1997); and 'complementarity' by Pidd (2004). Despite the highlighted strategies put forward by the authors, Shanon-Baker (2016) argues that multimethod development can be grouped into two categories. The first are those that propagate the development and use of multimethods consisting of methodologies from different paradigms. The second group are those that propagate the combination of methodologies while respecting their individual underpinning paradigms (Brown et al., 2006).

While the dual grouping provided by Shannon-Baker (2016) and Brown et al. (2006) suggest a difference between both class of users of the multimethod, It can be said that the central focus of multimethod development is the ability to effectively balance the use of the participating methodologies within the multimethod framework (Shannon-Baker, 2016). Therefore, coherently combining the methods (Shannon-Baker, 2016), and respecting the individual methodology assumptions during combination (Brown et al., 2006), points to a consistent multimethod development process.

Mingers and Brocklesby (1997) presents four arguments in support of multiparadigm multimethod. Firstly, the authors argue that the world is complex and multidimensional, and using different paradigms enables one to focus attention on different aspects of the situation. Second, a problem goes through different phases and more than one methodology might be required to tackle all phases. Thirdly, multi-paradigm multimethodology is common practice even if there are limited reports in the literature. Finally, triangulation on the situation using different methodologies can generate new insights, whilst enhancing confidence in the results through a reciprocal validation. These arguments encourage the fusion of methods from different paradigms.

Schultz and Hatch (1996) describes this fusion process as "paradigm crossing". The authors highlight that strategies for crossing paradigms in multimethod development include: (a) the sequential, (b) the parallel, (c) the bridging and (d) the interplay (Schultz and Hatch's strategy). In the sequential strategy, the relationship between paradigms is linear and movement from one paradigm to another is unidirectional. In the parallel strategy, different paradigms are all applied on an equal basis instead of sequentially. The sequential and parallel strategies leave the boundaries of each paradigm deployed intact but in the bridging strategy the boundaries are more permeable. In fact, Gioia and Pitre (1990) , who first articulated the bridging strategy, argued that paradigm boundaries are ill defined and blurred, and that it is 'difficult, if not impossible, to establish exactly where one paradigm leaves off and another begins' (p 592). Therefore, the boundaries are better conceived as transition zones.

The interplay strategy 'refers to the simultaneous recognition of both contrasts and connections between paradigms rather than differences' (p 534). Researchers using this strategy will transpose the findings from one paradigm in such a way that they inform the research conducted in a different paradigm. Therefore, the researcher can move back and forth between paradigms allowing cross-fertilization between the paradigms while maintaining diversity. The main difference of the interplay with the other strategies is 'in the nature of the relationship it constructs between the researcher and the multiple paradigms it specifies'. It is this approach that is closest to that advocated by Mingers (1997b) and appears to fit Pidd's (2004) multimethod development framework presented in (Figure 4.2d) .

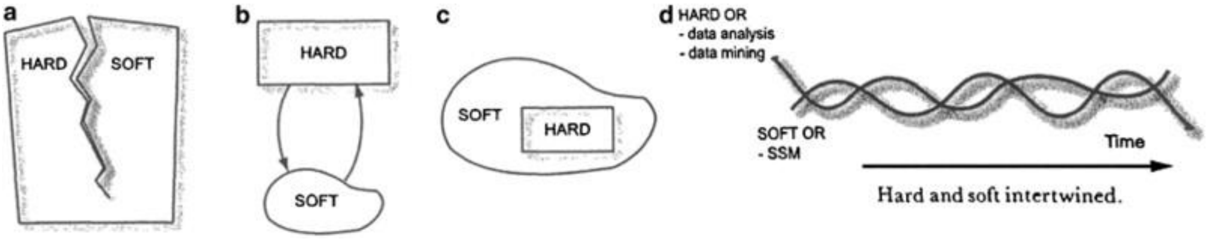


Figure 4.2 Interactions between soft and hard paradigm.

(Source: Adapted from Kotiadis and Mingers, 2017)

Kotiadis and Mingers (2017) while explaining the interaction between soft and hard paradigm argue that multimethods can be pursued through four frameworks. The first being the paradigm incommensurability as presented in figure 4.2a. The second is an eclectic and paradigmatic approach presented in figure 4.2b. in the third which is illustrated in 4.2c shows that the soft methods are seen to contain the hard methods, which means that 'understanding of meanings gained in soft OR enables a sensible attempt at hard OR/MS'. The fourth which is illustrated in figure 4.2d shows soft and hard OR being intertwined. The illustration (d) in Figure 4.2 visually seems closer to illustrating multiparadigm multimethodology than the other representations.

4.4 Challenges of multimethod development

Mingers (2001) explain that the challenges encountered with multimethods can be categorised into; (a) cultural issues associated with the degree to which organizational and academic cultures militate against multi-paradigm work, (b) cognitive issues associated with the difficulties experienced by users when transiting from one paradigm to another, (c) practical issues associated with lengthy time; lack of researcher's experience of several methods; innate conservatism—especially of funding bodies and journals; pressure to do something not 'risky' by organization/client, and (d) philosophical issues associated with paradigm incommensurability. Each of these will be explored in the following sections.

4.4.1 Cultural difficulties

Assumptions about the world and how to deal with its problems are to some extent a cultural issue that has resulted through socialization and education. There are communities that are perceived as more hard OR focused or to have a more balanced number of hard and soft OR specialists than others. However, the latter are thought to be fewer particularly as many working in the field of management science emerge from a variety of positivist disciplines, for example, mathematics, computer science, engineering, etc. Undoubtedly, this must affect both the type of research or projects undertaken in these departments as well as the student's experience and attitude to problem solving immediately after university. PSMs are probably not even considered by most management scientists in the first instance when considering a problematic situation and many will simply turn to the old familiar approaches. If they are considered for use either alone or with a traditional hard OR method, there is probably a degree of fear about being competent in their use.

On the other hand, Pidd (2004) makes some interesting points about the client's view about someone being able to shift from hard to soft work. The first one is that the client is not always convinced that someone can be competent enough to conduct a research from a quantitative and high-quality qualitative work. He reiterates that knowledge of either qualitative or quantitative methods are not simply gained by reading of books. Instead, being able to switch between such methodological domains require new skills that must be developed and practiced.

4.4.2 Cognitive difficulties

Ormerod and Kiossis (1997) believe that mixing methods is possible and that switching between paradigms was not an issue for them. However, the limitations of such paradigm interplay lie in the competence of the researcher and the participants rather than the methods themselves. Brocklesby (1995) adds that that shifts in paradigms can be a difficult experience for the individuals adopting such research designs. However, with sufficient detrmination, it is possible for a person to become multimethodology literate. Brocklesby (1995) highlights that for someone to be a multimethodology expert several obstacles must be overcome.

Firstly, the agent must become paradigm conscious. Secondly, the agent must believe that the new paradigm offers something worth having and fits with the agent's personality and beliefs. Thirdly, effective performance in a paradigm necessitates learning its propositional and commonsense knowledge. Varela et al's. (1991) identifies two types of knowledge: propositional and commonsense, needed to act effectively in a 'new paradigm'. He explains that while the knowledge required to create rich pictures, produce definitions can be extracted from textbooks, to be effective in soft OR, the user must engage with actors, and adjust to changing situations. To become proficient in a new paradigm researcher must be willing to learn and unlearn new and previously gained knowledge.

In the light of the above discussion is understandable why some researchers prefer to stick to a particular domain as it more difficult to move from one to domain to another (Pidd, 2004). Pidd notes insights from the different domains must be respected. It is therefore correct to assert that the integration between the hard and the soft methodology is less common as compared to the link between two hard or two soft methodologies. This finding may be an indication that researchers find it difficult to work across two paradigms and there is evidence that this may be related to particular personality types (Mingers and Brocklesby, 1997).

4.4.3 Practical problems - data requirement

Multimethod work requires the knowledge and experience of several methodologies. Indeed, this can be challenging, especially if there is one investigator. Societal problems related to energy supply, food, biodiversity and mobility are characterized by scientific uncertainties, and policy-makers must deal with situations in which different people (scientists and stakeholders) have different ideas about what exactly the problem is and how it should be solved. These types of policy problem have been labelled as wicked problems(kotiadis and Mingers, 2017). Stakeholder dialogue is geared towards learning about the diversity of perspectives on a problem and its potential solutions. This process of problem structuring needs to be supported by multimethod procedures. There are practical difficulties that constrain multimethod work (Mingers, 2001). It takes time to undertake such work, which means that many, particularly academics, might choose the clean-cut single methodology work, which is easier to explain and sell to funding bodies and journals.

One of the biggest challenges for stakeholder dialogues is to find methods that can be used to design and evaluate dialogues in a way that does clarify the dissimilarity between opinions. There is a challenge of opinion subjectivity where the stakeholders literally desire a single thing, but this means different things to them. This is a challenge for combination with scientific methods where numerically defined inputs are required. Cuppen (2013) opines that Q methodology is a useful method for selecting stakeholders who represent the diversity of perspectives and for evaluating the learning about perspectives that occurs in stakeholder dialogue. However, this methodology leaves the study within a qualitative domain methodology.

4.4.4 Philosophical challenges

The debate on paradigm incommensurability have been discussed in the organisational theory and management science domain (Schultz and Hatch, 1996). Central to the debate is Burrell and Morgan's (1979) position that some paradigms are incommensurable, mutually exclusive and unable to be combined because of the dissimilarity and incompatibility of their underpinning assumptions. However, Willmott (1993) argues that the outright polarisation of existing paradigms to either a "subjective or objective" approach is restrictive. Pidd (2004) mentions that the incommensurable characteristics of subjective or objective paradigms remain a limitation to the development of multimethods. Drawing on the arguments of Burrell and Morgan (1979); Willmott (1993) and Pidd (2004), it is evident that the authors acknowledge in agreement with Mingers and Brocklesby (1997) that multimethods are crucial for solving complex problems. So, instead of incommensurability being a limitation for multimethod application, its users should effectively deploy the right methodology to address specific problems within the broad intervention (Mingers and Brocklesby, 1997).

4.5 Exploratory scenario and visioning multimethod

This section provides a review of exploratory scenarios and visioning multimethod with specific attention to the strategies for integration, challenges encountered, and lessons learnt from the such combination.

Kok et al. (2011) combined the exploratory scenarios with visioning and backcasting in the SCENES project. The authors engaged stakeholders through series of stakeholder workshops to develop four exploratory scenarios. A group discussion was held with stakeholders to develop a vision for 2050**.** Later, the stakeholders constructed pathways under the different scenario contexts. Stakeholders were encouraged to use the four external scenarios as contextual scenarios that could not be controlled to construct pathways under the different scenario contexts to achieve the visions. While the stakeholders were satisfied with the process, the authors highlight a cognitive related challenge of choosing the right number of methods given the time for the study. As such, the authors agree on the feasibility of conducting small workshops where exploratory and backcasting approaches are combined.

Tight et al. (2011) integrated the outputs of an exploratory scenarios process for the development of visions. The authors evaluated three alternative visions for the year 2030 in which walking, and cycling play a substantially more central role in urban transportation than is currently the case. The visioning process developed through a participatory process where discussions were held amongst the research team with expertise in transport planning, computing sciences, mathematical modelling, urban design, and socio-cultural change. During the visioning scenarios, a single external scenario was presented to the participants during workshops. However, four visions were developed. Subsequently, different external scenarios were matched to suit the different stakeholder visions. The authors affirm that background contexts can have significant influence on the potential transformations of the visions. Other issues from the study relate to the stability or dynamism of vision contents; causality implications in visions; and the role of background contexts in Visioning analysis; and the relevance of scenario scale on the visions

Schneider and Rist (2014) proposed an approach that consistently combines the normative, explorative, and participatory scenario elements. The external scenarios were developed through a deliberative process between the stakeholders and the researchers during a brainstorming interview session. Similarly, three visions were developed through a collaborative discussion of the research team. The authors highlight the collaboration between the stakeholders and the researchers during the scenario and vision development was instrument towards formation of the visions. Results from the initial visioning discussion were not very innovative as most actors were inclined towards gradual changes from the current state. Time constraint was a critical issue during the development of the visioning as the stakeholders were not able to agree on the visions over the allotted time. Therefore, based on the discussions carried out, the researchers developed three visions and presented to the stakeholder groups. The intention to build a joint vision was welcomed by the researchers. However, it also posed new challenge as the stakeholders had to revise the visions over multiple iterations before arriving at a shared vision.

van Vliet and Kok (2015) combined exploratory scenarios, visioning and backcasting to develop robust water strategies in the face of uncertain futures. These authors presented a combined approach that engaged same stakeholders to develop multiple scenarios during two workshop events and subsequently developed a single desired vision that is agreed upon by all stakeholders. This single vision was used across all the different exploratory scenarios for the development pathways for achieving the visions. Results from the study revealed that the external scenarios developed influenced the content of the backcast, thus making the identification of robust strategies possible. Also, participants did not deviate from the exploratory scenarios when identifying the obstacles and opportunities. The level of experience of participants in using participatory methods supported the success of the process. However, during the exercise, time was a constraint and some group participants preferred to work with only a preferred scenario. Also, it was difficult to define one specific desired endpoint that made sense for all four scenarios. Some participants would have liked to use different endpoints, to better match the exploratory scenario. It was often difficult for participants to deal with a desired endpoint that did not easily fit the logic of the exploratory scenario

De Bruin et al. (2017) proposed a three-step multimethod approach where exploratory scenarios were combined with a visioning and backcasting process to develop robust strategies. The exploratory scenarios were first developed by experts and introduced to the Dutch forest sector stakeholders during participatory workshops. Subsequently, a desired Vision for 2044 was determined. Participants were later split into groups to generate backcasts on how to achieve the desired vision. The authors agree that the combined methodologies were highly complementary and useful for a better future exploration. It was also identified that the diversity of action plans and the participants were imperative for the success of the exercise. However, the authors argue that due to the complex nature of the system explored, the problem can only be addressed through a transdisciplinary research process.

Philline and Elna (2018) combined exploratory scenario development with elements from backcasting and a normative scenario to develop transformative transition pathways towards socially sustainable global value chains. The approach was applied in two scenario workshops, one focusing on smartphone production the other on the textile sector. Also, Mangnus et al. (2019) applied multiple, complementary futures methods to test how innovative urban food practices can be used as a basis for imagining new food futures. The method provides an innovative combination of visioning, back-casting, and simulation games methods. The multimethod was used and assessed in order to create multiple ways of experimenting and engaging with food system futures. Each method brings in its unique pathway elements: visioning to formulate the desired end goal, back-casting to create a step-by-step action plan, and gaming to practice with the future. Findings from the study revealed that the complementary use of methods, on the one hand, and new content on the other contributed to a variety of rich and diverse shared futures containing novel elements for participants, arguably leading to extended imaginaries. The study concludes that processes that combine visioning, planning, and experimentation can offer fundamentally new ways to both imagine and realize desired futures from the bottom up.

Star et al. (2016) combined the exploratory scenarios with the visioning component of a backcasting process. While the study echoed the emerging benefits of combining expert-driven exploratory scenario methods and participatory visioning processes, they highlight that this form of combination is in its infant stage. As scenarios and visioning processes progress from mere awareness raising to strategy development (Bradfield et al., 2005), both experienced scenario developers and practitioners new to scenario development have to develop, learn, or adapt novel designs and applications of combining exploratory scenario, visioning and backcasting methods.

Sarkki and Pihlajamaki (2019) presents a three-step approach that can be used to explore how normative recommendations work across exploratory scenarios. The author first organised a participatory backcasting workshop, then they defined the exploratory scenarios by research-driven strategy, and finally combined the two with a desk study. 11 stakeholders consisting of fishermen, producers, administration, and researchers were converged over a two-day workshop to develop a vision for the future of the Baltic herring, Subsequently, the team were split into groups to develop pathways to achieve the vision. In the next stage an exploratory desk approach was used to create four exploratory scenarios on general future states of Baltic Sea. The external scenarios were used to test how the recommendations will work under the four divergent worlds. Findings revealed that recommendation under a single vision can only be actualised under one or two of the scenarios. Therefore, detailed analysis can lead to finding alternative ways of achieving the normative target in other ways.

Table 4.1 Comparison between procedures for combining exploratory scenario- visioning

Authors	Develop multiple/single vision(s)	Develop multiple scenarios	Engage stakeholders in scenario development	Use same stakeholders for scenario and visioning	Stakeholders developed scenario specific visions
kok et al., 2011	Single (1)	Yes	Yes	Yes	No (only one vision was developed from four scenarios)
Tight et al., 2011	Multiple(3)	Yes (3)	No (research team)	No (experts developed external scenarios)	No (one scenario was discussed during workshop and other scenarios were latter retrofitted to visions).Visions were pre-created and evaluated during the exercise.
Schneider and Rist, 2014	Multiple	Yes	Yes(researcher and stakeholders)	No (Only experts for developing visions)	No (experts developed three visions and four scenarios by stakeholders)
Van vliet and Kok, 2015	Single	Yes	Yes	Yes (engaged same Stakeholders and researchers for vision development)	No (Developed only one vision and multiple external scenarios)
De Briun et al., 2017	Single	Yes	No	No (expert developed scenarios and presented to stakeholders)	No (stakeholders developed only a single vision)
Sarkki and Pihlajamaki (2019)	Single	Yes	No	No (stakeholder developed the visions and experts later developed the scenarios).	No (only a single vision was developed by stakeholders)

From the studies reviewed above, the researcher identifies that both methodologies are complementary and capable of dealing with complex problems. In this case, the exploratory scenario approach can handle the complex and uncertain business environment. However, they cannot be used to develop normative scenarios where the desires, values and ideals of the stakeholders are of utmost importance. Consequently, visioning is used for the development of the future desirable endpoints. Also, as drawn from the studies reviewed, the backcasting component is important in the creation of pathways for achieving the desired vision. Furthermore, the reviewed studies agree that visioning is a part of the backcasting process, and its outputs feeds into the backcasting process for strategy development (Kok et al., 2011: van Vliet and Kok, 2015). While the title of the latter studies were termed as “a combination between exploratory scenarios and backcasting”, these studies have actually combined the exploratory scenarios, visioning and backcasting.

The process for combining the exploratory scenarios with the visioning component of the backcasting process of the reviewed studies indicate a dualized process for combination. In some cases, it was identified that participants develop single vision for the future during the visioning exercise (Van Vliet and Kok, 2015; Kok et al., 2011), and later develop multiple backcast that are consistent with the different external scenario contexts. On the other hand, multiple visions are developed (Tight et al., 2011; Schneider and Rist, 2014) during the visioning workshop after critically assessing a single external scenario or retrofitting external scenarios to the different visions. In both cases, the essence of the process is to ensure that the scenarios provide a background context for the creation of the visions as well as a guiding framework for the construction of the pathways. However, the researcher argues as shown in table 4.1 that no study has explored the development of scenario specific visions. The later investigation would provide the opportunity to ascertain if the vision developed under each external scenario are likely to differ when same stakeholder groups are encouraged to develop the visions under the different scenarios during visioning workshops. The latter is an area for exploration in this research.

Another important insight from this review relate to the implication of adopting an expert-led scenario development process as compared to using the same stakeholders for the development of the external scenarios and the visions. The latter is born out of the different designs carried out in the reviewed studies. In one case, the participants within the Visioning exercise are presented with external scenarios for the creation of the visions. On the other hand, the participants are involved in the development of the external scenarios. In the latter case, the authors attest to a successful integration process where participants understood the scenarios and adhered to them during the creation of the vision. The latter reveal that that cognitive challenges are limited when participants with good knowledge of specific methods are exposed to similar methods compared to when they are exposed to methods from an entirely different paradigm. The users understood the use of qualitative and participatory data collection and analysis methods. Also, the data requirements were easily met since they were based on the opinion of the participants.

Other issues identified from the review relate to the role of the scenarios on the quality of visions; the impact of the workshop design on the Visioning process; the level of causality between the external scenario content and the visions, the extent to which vision developers adhere to external background contexts during vision development.

4.6 Exploratory scenario and optimisation multimethod

In recent times, industry planners and researchers are beginning to appreciate the relevance of combining problem structuring methods such as scenario methods with optimisation models (Kotiadis and Mingers, 2014). Such combination has the potential for addressing complex problems. In light of this, this section provides a review of multimethod studies involving exploratory scenario and quantitative methods such as optimisation. Since this combination involves methods from either a qualitative or quantitative domain, the researcher seeks to understand; the strategies for such multiparadigm combination, and the challenges encountered by researchers while developing multiparadigm multimethods.

Durbach and Stewart (2003) focused on the integration of exploratory scenario planning and goal programming as an aid to decision making under uncertainty. In their study, the goal programming resolved the problem complexity associated with conflicting objectives. However, it did not give a consideration for uncertainty. Therefore, it was combined with scenario planning method that can addresses the uncertainty in the business environment. The authors highlight the challenge of transition between the scenario methods used in structuring the complex problem and the goal programming used for evaluating the scenario related options. The researcher identifies that a paradigm crossing of this nature requires a transfer between the qualitative and quantitative methods. This portrays the cognitive, practical, and philosophical challenges described in section 4.4. The core of the multimethod was the problem structuring phase where some number of scenarios were first constructed before the structuring of goal programming within each of the scenarios. The study concludes that there is need for combination of such methodologies and application in real-world contexts to investigate and raise awareness of other issues around the use of other multimethod frameworks.

Montibeller et al. (2006) proposed the combination of scenario planning with multi-criteria decision analysis (MCDA) in exploring the future of two real-world case studies - the English provincial broker's future and the development of a warehouse at Casemurate, Italy. The authors highlight that while scenario planning helps decision-makers in thinking about possible future scenarios, it does not involve the evaluation of the strategic options. Hence, the combination with MCDA, a quantitative decision-making method for the evaluation of options. Their study revealed that the combination between scenario planning and multi-criteria decision analysis led to the achievement of objectives. However, it was observed that the decision makers struggled in the provision of quantitative information such as the criteria weights as a result of the complexity of analysis pairs of strategy scenario. It was also identified that organisational priorities are limited and a dominating option could reduce the quality of the process. Allocating the quantitative weights to these competing criteria posed a challenge to the participants. The authors conclude that despite a growing interest in the integration between SP and MCDA, there is limited real-world interventions that use both techniques in an integrated way.

Witt et al. (2020) proposed a combination of Energy System Analysis (ESA), Scenario planning and Multi-criteria decision analysis for the development and evaluation of energy scenarios. The scenario planning was used to describe the technical and organisation options of the energy system, while the MCDA focused on the transparent evaluation of the scenarios developed. The overall system objectives decision support problem was formulated through the energy system model. In line with the paradigm crossing Pidd (2004) described in 4.3, the scenario planning outputs enriched the ESA model by providing inputs of the external scenario parameters to the model. The authors posit that during such methodological combinations that involve scenario planning, the researcher must differentiate between the external and internal scenario elements. The sole consideration of internal scenario elements otherwise called the decision elements, delineates the investigation of external uncertainties, and this is inadequate for long-term planning for energy scenarios. Also, combining these methods requires adequate coordination of the process due to the numerous iterative steps between the model analysis and the scenario development component.

Stewart et al. (2013) also explored the combination of scenario planning and multi-criteria decision analysis in a coherent manner. Their motivation for integration was on the basis that each methodology provides value to the other, especially when the main focus is on creating preferences between and within scenarios. Also, the combination may enrich discussion by allowing the construction and evaluation of alternatives to include consideration of their advantages or disadvantages for different criteria under different scenarios. The synergies between scenario-planning and quantitative decision modelling can be exploited to considerable advantage in addressing complex decision contexts. Confining attention to well-structured scenarios which" take-out" gross uncertainties may allow tractable quantitative analyses which do not require, e.g. the elicitation of non-additive multiattribute utility functions and probability distributions over highly correlated variables. The authors illustrated their combination in the context of MCDA using multiattribute value functions but recognise that the same approach may be applied with Bayesian expected multiattribute utility analyses; and, indeed, with many other forms of quantitative decision analysis.

Kotiadis and Mingers (2014) proposed a multimethod framework that integrates Discrete Event Simulation (DES) with soft systems methodology. An interplay strategy for crossing paradigms described in 4.3 was adopted to connect both methods while respecting their underlying assumptions. The author's reflections on the integration are linked to the philosophical and cognitive barriers described in section 4.4. An initial challenge identified was the vagueness and subjectivity on what constitutes an ideal health care system or what is required for its utmost functionality. While on a generic level, the vagueness and subjectivity are not new, in the study context, the modelling team were not sure of the critical elements to optimise. On the other hand, the members of the research team did not have a good understanding of the health care system. An important lesson from this study is that a researcher's gender, previous experience, and personality affect the approach to multimethod research. They however do not limit the possibility of combining such methods in practice.

Riddel et al. (2017) proposed the combination between exploratory scenarios and simulation models in the multi-hazard mitigation conducted in Southern Australia. The proposed multimethod captures the uncontrollable elements such as population, economic, climate, policy and individual drivers using the exploratory scenario methodology. Five exploratory scenarios that focus on the possible environmental related changes that can occur between 2016 and 2050 were developed through the insights and knowledge of experts. A simulation modelling technique was connected with the scenario methodology to enable the translation between the qualitative and quantitative scenario elements into numerical risk assessment processes. The authors conclude that there is need for continued research that emphasises research collaboration with stakeholders so that their insights can be used to inform disaster risk reduction strategies.

Schmitt-Olabisi et al. (2010) combined the exploratory scenario, visioning with participatory system dynamics to explore the future of the Minnesota by 2050. The authors argue that while these methodologies complement each other, little or no research has been carried out to combine the methods. The multimethod demonstrates an example of a multi-paradigm multimethod since the scenario Visioning is underpinned by a qualitative research paradigm while the quantitative system dynamics is drawn from the positivist paradigm. The authors confirm that while the process was very useful for exploring the context, there were some creative tensions between the creative scenario Visioning and the quantitative system dynamics. The latter challenge aligns with the cultural, cognitive, or practical challenges experienced during the implementation of multi-paradigm multimethod study described in section 4.4. Another issue highlighted by the authors was that not all the scenario parameters were modelled. The authors focused on the parameters that provide information about the quantitative parameters. The latter issue also relates to the philosophical challenge of paradigms incommensurability described in 4.4.4. where the different methods cannot be judged on similar standards rather their underlying assumptions should be respected. It is also a practical data requirement challenge because not all aspects of the scenarios where fully represented in the models developed.

The integrated assessment studies come to play when considering the combination of scenarios and quantitative methods. Some of these projects include the IPCC Special Report on Emission Scenarios (Nakicenovic and Swart, 2000). This report describes how greenhouse gas emissions will evolve in the future. In this study, the scenarios were developed through a review of literature, development of the scenario narrative storylines, and the use of six integrated models for the quantification of the scenario’s contents. The study demonstrates a transition between the qualitative document analysis, narrative storyline development, and the model quantification of the scenarios.

Symstad et al. (2017) proposed the combination of exploratory scenario method with quantitative simulation methods for natural resource decision making. The authors posit that the use of exploratory scenarios methods to develop ecosystem responses to climate change possibilities is beneficial for managers when addressing climate change. However, the exploratory methods may not adequately resolve the responses of complex systems to changing climate conditions. Also, it is confronted with some cultural related changes as managers sometimes believe that developing scenario through participatory methods lacks scientific credibility. For the latter reason, the author integrates the quantitative simulation modelling methods to boast the credibility of the ecosystem response to climate change condition. The integrated exploratory scenario-simulation framework retains the qualitative component as the core element of the method because its participatory approach provides insights for both managers and scientists. Also, it initiates the foundation to focus quantitative simulations on crucial system dynamics.

This section has provided an array of studies that combine exploratory scenario with quantitative methods or other futures integrated assessment studies. The translation between the qualitative exploratory scenario and optimisation has led to different forms of cognitive, and practical and paradigm incommensurability challenges (see section 4.3 above). To date, the story and simulation (SAS) approach developed by Alcamo (2009) has been widely used in most integrated assessment studies to couple qualitative and quantitative scenarios (Alcamo et al., 2009; Houet et al., 2016). However, there is need for more robust multimethod approaches that consist of a clear and replicable translation technique (Voinov and Bosquest, 2010; Alcamo et al; 2009). In light of this challenge, Mallampalli et al. (2016) combines a list of methods for translating between qualitative scenario narratives to the quantifiable inputs for quantitative assessment scenario studies. These methods have been reviewed in section 4.7 of this chapter.

4.7 Translating scenario and visioning outputs into quantitative elements

The translation process is an important component when developing a multimethod that consists of qualitative foresight methods such as exploratory or visioning scenarios with a quantitative modelling method. In the case of exploratory scenarios, such scenarios are not developed using quantitative methods. Consequently, their outputs consist of intuitive and non-numerical descriptions of plausible future states (Mallampalli et al. 2016). On the other hand, visioning outputs are normative in nature, and the outputs are dependent on the perspectives of the stakeholders affected by the situation. Since these visions are developed by stakeholders during a workshop, their outputs are qualitatively described with little or no quantification or technical description. While these outputs are useful for strategy formulation, they do not support the numerical assessment and description of the implications of envisioned options that can provide better inputs for strategy development.

Since the foresight (exploratory and visioning scenario) and optimisation methods are characterised by a qualitative and quantitative methods respectively, there is need for a translation procedure that consistently link these qualitative outputs from exploratory and visioning scenarios with quantitative models such as the optimisation models. The latter can be achieved when qualitative outputs of the scenarios are coupled with the specificity of quantitative Modeling" (Mallampalli et al., 2016).

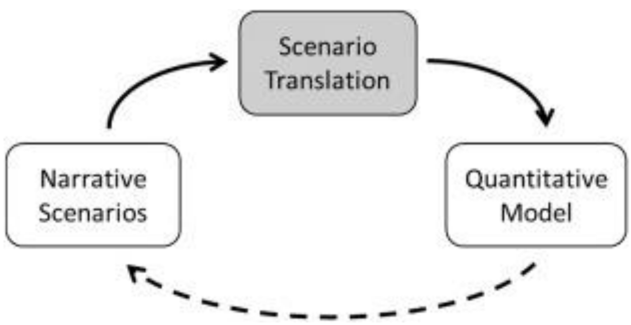


Figure 4. 3 The scenario-modelling cycle

(Source: Mallampalli et al., 2016)

Figure 4.3 presents a scenario-modelling cycle adapted from Mallampalli et al. (2016). The intermediate “scenario translation” step converts the non-technical and qualitatively described scenario outputs into suitable inputs for quantitative models.

The discourse on translating outputs from exploratory scenario analysis into model inputs has gained attention in literature (Booth et al., 2016). The later author argues that while exploratory scenarios can be used to unfold the plausible dynamics of the social and ecological systems (Raskin, 2005), they can be integrated with different models to explore the range of possible outcomes and consequences of different strategic actions (Carpenter et al., 2006; Lebel et al., 2005; Polasky et al., 2011). Furthermore, some scenario studies have also quantified the impacts of scenario drivers especially in the climate change and land use planning domain (Lawler et al., 2014; Byrd et al., 2015). This form of integration of qualitative and quantitative methods have been demonstrated in studies, such as the IPCC Special Report on Emission Scenarios (Nakicenovic and Swart, 2000) and the MEC report (Millennium Ecosystem Assessment, 2003). Other methods that tend to link the qualitative scenarios to the quantitative models is the story and simulation (SAS) approach proposed by Alcamo, (2009). In the SAS approach the qualitative scenarios are first developed by a group of stakeholders and subsequently translated into quantitative parameters that are used as inputs into simulation models (Alcamo et al., 2008, Houet et al., 2016).

Alcamo (2009) notes that the translation from scenario outputs into quantifiable forms can be complex if the scenario includes many interacting drivers of change (Alcamo, 2009). He adds that where the rules for translation are not clearly described, this procedure for converting these outputs are arbitrary and hard to replicate. Titeux et al. (2016) notes that sometimes the rich qualitatively described narratives are reduced to one-dimensional and straightforward representations during the translation to model inputs process (Titeux et al., 2016). However, Kok (2009) comments on the importance of preserving the assumptions and interactions contained in the qualitatively described scenarios. The latter problem is amplified in the translation of visioning outputs that are normative in nature.

Visioning is a process that focuses on the creation of desired futures; hence it is normative and relies on the opinion of stakeholders involved in the process. It is difficult for stakeholders who are not technically oriented to develop quantitative implications of their visions. Even when technical experts are involved in the visioning workshops, it is difficult for such quantification to be made over the short visioning exercise as this might lead to a complication of the exercise. The latter challenge resonates a practical and philosophical challenge highlighted in section 4.3 where the disciplinary foundations of the vision developers and the quantitative experts differ significantly. The latter issue opens up the challenge associated with the interpretation of stakeholder vision outputs by the quantitative experts. Morgan (2018) explains that data can be misinterpreted as essential variables may be omitted, oversimplified, or overcomplicated. This challenge has been observed in scenario translations where only a few drivers are quantified and others are ignored (Booth et al., 2016; Titeux et al., 2016). Titeux et al. (2016) adds that drivers under the social, political domains are ignored.

4.7.1 Translation methods

Some studies on scenario-modelling exist in water-sheds management (Carpenter et al., 2015) and the story and simulation approach (Alcamo, 2009). However, these authors attest to the weak connection between the scenario outputs and numerical assessment exercises. Different studies have presented examples of translating storylines into modelling inputs (Booth et al., 2016; Alcamo et al., 2008; Mallampalli et al., 2016), some of the methods for translating qualitative statements from scenario-based vision narratives into quantitative values are presented in table 4.2 .

Table 4. 2 Summary of scenario translation methods

Method	Techniques	Compatibility with simulation models	References
Causal loop diagrams	Suitable for stakeholder engagement and facilitated through workshops.	Causal loop diagrams are often used as a basis for building stock-flow models. Stand-alone CLDs can also be used to understand leverage points for policy intervention.	Schmitt Olabisi et al., 2010, Sterman, 2000)
Agent-based modelling	Suitable for stakeholder engagement and facilitated through workshops.	Agent-based causal diagrams are used as a basis for constructing agent-based models. Stand-alone causal diagrams can also be used to understand leverage points for policy intervention	(Janssen, 2005, Crooks and Heppenstall, 2012
Fuzzy cognitive maps	Suitable for stakeholder engagement and facilitated through workshops.	The FCM itself can be simulated after the strength of causal relationships is identified.	van Vliet et al., 2010)
Fuzzy sets	Very suitable for stakeholder engagement in multiple forms. It is a secure method to teach to stakeholders	The fuzzy numerical output can be used directly as inputs to stochastic models or defuzzified for non-stochastic models.	(Alcamo, 2009, Kok et al., 2015)
Pairwise comparison	Suitable for stakeholder engagement, with participation facilitated through workshops.	Provides direct input for a simulation model.	(Abildtrup et al., 2006, McDaniels et al., 2012)
Bayesian networks	This method is suitable for stakeholder engagement, but it requires stakeholders to understand the concept of conditional probabilities.	Influence diagrams and CPTs lead to functional Bayesian Networks, which themselves may lead to inputs for other models.	(Aalders, 2008, Marcot et al., 2006)
Role-playing games	Stakeholder engagement is essential for this method, whose participation is facilitated through workshops.	Stakeholders' decisions during the game can serve as inputs to simulation models.	(Castella et al., 2005,
Surveys or semi-structured interviews	This method can allow for stakeholder engagement.	Provides direct inputs to analytical and simulation models.	(McDaniels et al., 2012)
Literature review	Not generally applicable.	Provides direct input to a simulation model.	(Promper et al., 2014,

(Source: Adapted from Mallampalli et al., 2016)

4.8 Gaps in literature

This section presents the gaps identified from the review conducted.

4.8.1 The need for integrating PSMs (exploratory scenario, visioning), and optimisation method.

Overtime, researchers in the operational research domain have raised concern over the gradual drift of the operational research techniques away from the application of its techniques to solve real-world problems towards their contributions to mathematical theory (Kotiadis and Mingers, 2006). This drift has ignited concerns that the assumptions underpinning existing quantitative OR techniques were ill equipped to deal with the complex, messy problems faced by organisational managers (Prell et al., 2007). In response to the latter highlighted issue, problem structuring methods (PSMs) have evolved for structuring the messy and complex problem situations rather than solving well defined problems. Smith and Shaw (2019) highlight that PSMs explore the differing views and perspectives of the stakeholders in a situation and facilitate participation and engagement rather than analysing abstract data and models (Franco, 2009).

In addition, evidence from the OR literature suggest that industry planners and researchers have embraced the combination of the PSMs with quantitative modelling methods (Durbach and Stewart, 2003; Montibeller et al., 2006; Stewart et al., 2013; Kotiadis and Mingers, 2014, and Witt et al., 2020). This has materialised overtime through the following combinations: i) exploratory scenario with goal programming (Durbach and Stewart, 2003); exploratory scenario and multi-criteria decision analysis (Montibeller et al., 2006; Stewart et al., 2013; Witt et al., 2020); soft systems methodology and discrete event simulation (Kotiadis and Mingers, 2014; Tako and Kotiadis, 2015; Cardoso-Grillo et al., 2019), and exploratory scenarios with optimisation (Riddel et al., 2014)

In the combination proposed by Durbach and Stewart (2003), the scenario planning helped the decision-makers in the treatment of uncertainty and thinking about the possible future scenarios that could evolve due to the uncertainty while the goal programming method was used for the resolution of the conflicts among competing criteria. The combination proposed by Montibeller et al. (2006), the scenario planning performed the role as specified in the study of Durbach and Stewart, while the multi-criteria decision analysis provided an in-depth performance evaluation of each strategy as well as in the design of robust and better options. In terms of process and input translation between the SSM and Optimisation, the study of Cardoso-Grillo et al. (2019) combines the structuring of objectives and specificities of the medical training problem with the help of the SSM; the mathematical optimisation formulation tries to minimise the imbalance between demand and supply and the cost and maximising the equities across medical specialities.

While the researcher acknowledges the effort of researchers in the combination of exploratory scenarios with optimisation, to the researcher's knowledge, no study has explored the triple combination of exploratory scenarios, visioning, and optimisation methods. Each of the methodologies combined address different components of the long-term planning problems. The exploratory scenarios address the uncertainty in the organisation's external environment; the visioning address the problem complexity associated with multiple stakeholder views on an ideal future, and the optimisation models address the specifics and complicatedness of the problems. The optimisation models will focus on the analysis of the scenario-specific visions to identify the quantified implications of the visions for strategy development. The link between the exploratory scenarios and the visions support the development of vision options that are consistent with different background contexts. Also, the link between the visioning and optimisation supports the quantification of visions that in turn provide concrete inputs for strategy development processes. This gap has informed the research question 5 highlighted in section 1.6 of chapter one.

4.8.2 The need for developing multiple scenario-specific visions by stakeholders during visioning exercises.

The argument presented in this section draws from the linkage between the exploratory scenario and the visioning phase of the triple integration presented in section 1.4.1. Exploratory scenario or visioning methods have successfully been applied independently in different planning contexts (Heiko and Darkow, 2010; Blanco and Moudon, 2017; O'Brien and Meadows, 2007). However, some argue that combining both methods present complementary features that lead to an improvement in the strategy development process (Kok et al., 2011, and van Vliet and kok, 2015). While the relevance of external environment assessment during visioning cannot be overlooked, designs on how both methods are combined have not been adequately explored.

The discourse on how exploratory scenarios are combined with visioning expose rich methodological insights. Some authors argue for the development of exploratory scenarios prior the visioning process because the scenarios support the development of achievable visions (Wilson, 1992; Schoemaker, 1992; Jiménez et al., 1997; Tight et al. 2011; van Vliet and Kok, 2015). The importance of the latter design cannot be overemphasised as prior review of external scenarios provide stakeholders with the insights into the uncontrollable eventualities that can strongly influence the achievement of visions or the resilience of their strategies (O'Brien and Meadows, 2007; van Vliet and Kok, 2015). Besides, others argue that it is necessary for stakeholders to be involved in the development of the exploratory scenarios before developing the visions (kok et al., 2011; Schneider and Rist, 2014; van Vliet and Kok, 2015). Other opt for the external scenarios to be developed by experts and latter presented to the stakeholders to be used for the development of the visions (De Bruin et al., 2017; Tight et al., 2011; O'Brien and Meadows, 2007). Each highlighted approach present its unique challenge and call for deeper discussion on the implications of the methodological choices made when combining the methods.

This research lends its voice in furthering the argument on how both methods are combined. It provides insights into a new area for discussion that have been proposed by van Vliet and Kok, 2015 and not addressed by previous authors in the foresight domain. It argues on the potential for the development of multiple exploratory scenarios through a desk design and subsequently developing multiple stakeholder visions under the different exploratory scenarios. While some studies have proposed the development of such multiple visions (kok et al., 2011; Schneider and Rist, 2014; van Vliet and Kok, 2015), no study has provided an empirical evidence that exposes the rich issues associated with the proposed design. The research seeks to analyse the elements of scenario-specific visions developed by stakeholders when presented with exploratory scenarios developed through a researcher-led desk scenario approach. It explores the methodological insights associated with the development of multiple visions by different stakeholder groups that are consistent with different external scenario background contexts during a typical visioning workshop. This gap has informed the research question 2 highlighted in section 1.6 of chapter one.

4.8.3 The need for developing quantified visions for strategy development.

Strategic decisions are long-term decisions that affect the way a company moves forward. Hence, they are prerequisites for the success of every organisation. Kunc and O'Brien (2017) highlight the usefulness of scenario planning for strategy development. However, they highlight some problems associated with linking the scenarios developed to strategy development and implementation. The researcher posits that the latter challenge can be reduced if the outputs from exploratory and visioning scenario projects can be further analysed to add value to the strategy development process.

Visioning processes are qualitative and normative in nature due to its underlying paradigm foundation. Its interpretivist ontology is underpinned by the use of use multiple stakeholder participation for the creation of visions. While the latter is no doubt an ingredient for producing creative images of the future, the outputs from these processes are usually non-numerical and lack the technical details that support strategy development processes. Booth et al. (2016) argue that a reason for the later problem is that desirable future images originate from the imagination of complex systems by actors who may not possess the technical expertise. More so, where the technical knowledge of the systems exists, values which underpin stakeholder preference of an ideal state differ across participants. In addition, the practical constraints such as the short duration of visioning workshops may not allow such detailed quantification of visioning outputs by stakeholders during the exercise.

This unexplored field remains a challenge that limits the insights into the concrete implications of stakeholder vision options that in turn provide rich information for strategic decision making. Also, quantifying the visioning outputs bridges the gap between the underlying philosophical assumptions held by qualitative and quantitative experts and stakeholders about long-term planning procedures. This gap has informed the research question 3 highlighted in section 1.6 of chapter one.

4.9 Summary of chapter

This chapter has provided a review of the multimethod literature. It initiated with an overview of the multimethodology, the different paradigms within multimethod, strategies for the combination and the likely challenges faced when combining different methodologies. The chapter proceeded to a review of different multimethod involving exploratory scenario, visioning, and optimisation methods. The review exposed the strategies for integration by different authors. Also, it documents the challenges encountered when combining the methods. Having understood the challenge of linking the participating methods, this chapter addressed the techniques for translating scenarios narratives to quantitative dimensions. The gaps were highlighted in literature were presented. The next chapter will present the methodology for achieving the aim and objectives of this research.

Chapter 5 - Methodology

5.1 Introduction

Chapter 2 of this thesis provided a review of different scenario methods (forecasting, exploratory scenario, and visioning) for long-term planning. Chapter 3 focused on the supply chain network design optimisation methods that can be applied under uncertain conditions. Both chapters aimed at describing how both foresight and optimisation methods are applied for long term planning purposes. Chapter 4 advanced the review by introducing the concept of multimethods; strategies for its development; and the associated challenges associated with developing multimethods. Specifically, actions 4.5 and 4.6 of chapter 4 reviewed multimethods consisting of the following set of methods; i) exploratory scenario and visioning (see section 4.5); ii) exploratory scenario and optimisation (see section 4.6).

This chapter describes and justifies the researcher's choices that led to the development, application, and evaluation of the proposed multimethod. It enunciates the researcher's philosophical stance which links to the specifics of the research objectives, data requirements, and analysis. Lessons from the methodological choices made in the studies reviewed in section 4.5 and 4.6 informed the choices made in the proposed multimethod being developed in this chapter. The different stages of the proposed multimethod drew on the insights from the exploratory scenario; visioning and network design optimisation procedures presented in sections 2.4.2, 2.5.1 and 3.4 respectively. More so, the strategies for combining methods reviewed in section 4.3 informed the framework for linking the different methods into a robust multimethod suitable for addressing long-term distribution planning problems.

Furthermore, the gaps presented in section 4.8 influenced the unique design for the development of the multimethod. The first gap suggested a rare combination of two foresight methods (exploratory scenario and visioning) with an optimisation method. The second gap suggested the development of scenario-specific visions by stakeholders during a visioning exercise: a novel approach to integrating exploratory scenarios with visioning methods. The argument of the third gap suggested the quantification of scenario-specific visions for strategy development processes. The research stressed that the quantification of visions can improve the precision of visioning outputs, and this can be achieved through a consistent integration between visioning with quantitative modelling methods. Evidently, the challenge to achieving the latter dwells on the difficulty of linking qualitative visioning outputs with the required quantitative inputs for modelling processes. This has led to the development of a novel translation procedure that effectively translates the qualitative visioning outputs into quantifiable elements that are suitable quantitative analysis.

This chapter is structured according to the research objectives to provide a link between the choices made in the method development provided in this chapter and the underlying arguments around the choices as presented in the literature review chapters.

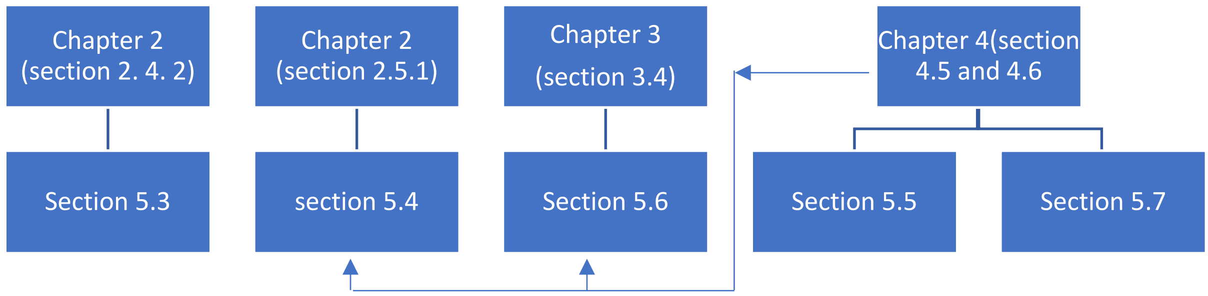


Figure 5.1 Linkage between researchers' choices and literature arguments

The figure 5.2 above is important as it provides the reader with a map indicating a linkage between the researcher's choices for the development of the multimethod and the corresponding arguments provided in literature. Specific references have also been provided under the respective sections of this methodology chapter.

5.2 Justification for the OVAF approach

This section elucidates the researcher's rationale for the choice of the OVAF multimethod approach as compared to other long-term planning approaches already reviewed in chapters 2, 3 and 4. Here, the research addresses two questions: i) why was the OVAF chosen over other methods such as the forecasting (predictive modelling)(section 2.3) or existing problem structuring methods (soft systems methodology (SSM); strategic choice approach (SCA)? (ii) why was the OVAF chosen against other integrations between multimethods (exploratory scenario and visioning; or exploratory scenario and optimisation)?

In the first case, the research argues in agreement with Kotiadis and Mingers (2014) that no single approach has the capacity to address the different component of long-term planning problems. While the forecasting has the capacity to provide estimations of what will happen in the future, it does not account for potential discontinuity of existing trends or the emergence of unexpected events in the business external environment. Hence, it is limited in its ability to accurately project future events on the long-term. Also, it does not address the desires of the actors within a specific organisation during strategy development process. This also limits the use of forecasting as a sole method for long-term planning. In addition, while problem structuring methods(e.g. SSM,SCA) are useful for structuring problems associated multiple stakeholder views during strategy development processes, it can be argued that these methods do not address the quantification of stakeholder opinions. This agrees with kemp-Benedict's (2006) position that complexity can be explored through human reasoning and brainstorming methods as seen in PSMs. However, they do not address issues of complicatedness in planning decisions .

Since the above argument suggest that single methods do not address all components of long-term planning problems, it is important to ascertain why the OVAF was preferred over multimethods consisting of exploratory scenario and visioning; or exploratory scenario and optimisation. In this regard, the review in section 4.5 of chapter 4 revealed that multimethods that consist of exploratory scenario and visioning exist in literature (Kok et al., 2011; Schneider and Rist, 2014; Van Vliet and Kok, 2015; De Briun et al., 2017; Star et al., 2016; Sarkki and Pihlajamaki, 2019). While these multimethods contribute to the strategy development process, none of these approaches have empirically explored if development of scenario-specific visions by stakeholders is useful.

On the other hand, the combination of exploratory scenario and optimisation methods as reviewed in section 4.6 has shown significant usefulness in planning, and these methods have prevailed in the quantitative modelling domain. Researchers in this field appreciate the relevance of linking the scenario planning with quantitative methods such as optimisation, simulation and multicriteria decision analytical MCDA methods (Durbach and Stewart, 2003; Montibellar et al., 2006, and Stewart. 2013; Witt et al. 2020; Kotiadis and Mingers, 2014, and Riddle et al., 2017). In this group of multimethod, the scenario planning methodology within the multimethod address the uncertainty by helping the decision makers reflect on the plausible futures that are beyond their control while the quantitative methods deal with the complicatedness of resolving the conflicts among competing criteria and finding an ideal solution that satisfies all conditions. However, this group of multimethod does not integrate the visioning component within their multimethod framework. Hence, alienating the opinion and desires of stakeholders in the planning process. The latter component can be addressed by the visioning methodology. For this reason, the combination of scenario planning, visioning and optimisation is worth exploring in this research.

5.2.1 Overview of the OVAF approach

The proposed multimethod approach was termed the Optimised Visions of Alternative Futures, abbreviated to OVAF. The OVAF is structured into four stages, and figure 5. 2 presents the four stages of the proposed OVAF multimethod approach.

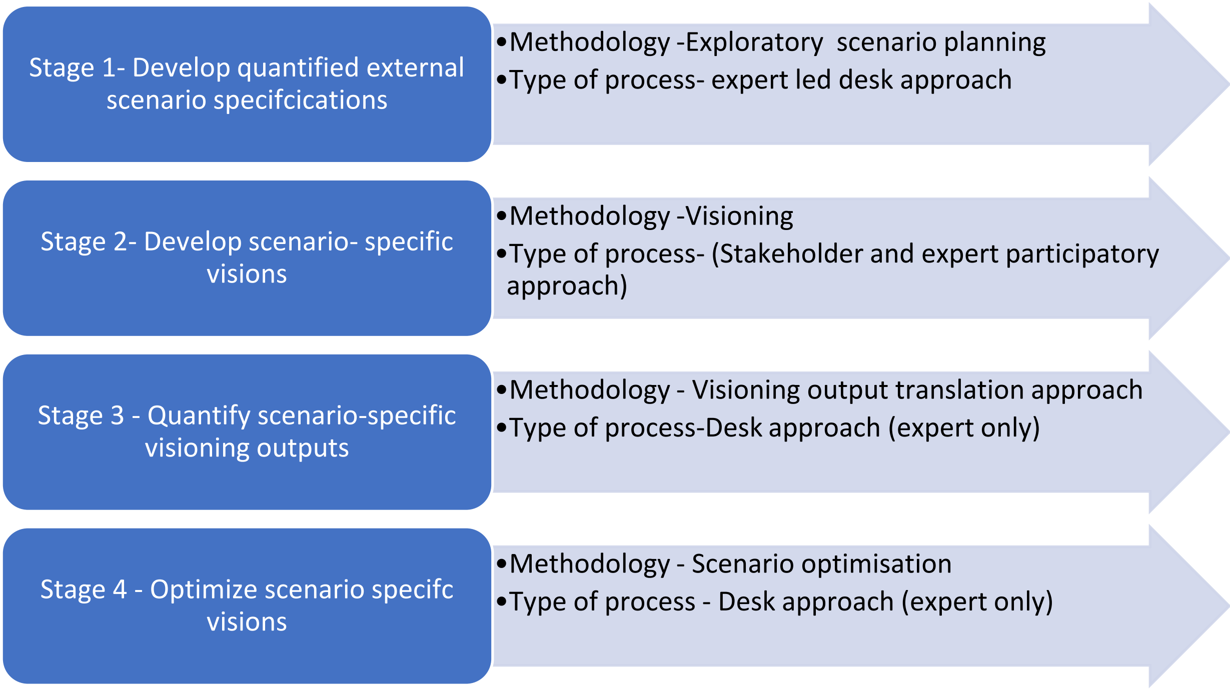


Figure 5.2 Stages of the proposed OVAF multimethod approach

As illustrated in figure 5.2, the OVAF multimethod consist of four stages. The question that comes to mind is why has the selected methods been embedded within the proposed long-term planning multimethod? As mentioned in section 2.4 of chapter two, the exploratory scenario approach in stage 1 play a critical role in long-term planning for distribution contexts because it is used for testing strategies in order to develop highly resilient strategies (Bannister and Hickman, 2013; Kunc and O'Brien, 2017). Exploratory scenarios planning helps to capture a wide range of options that can evoke the stakeholder reactions on how the future would evolve, and how the events will impact the business operations of the organisation under consideration (Shoemaker, 1991, 1993).

Based on Banister and Hickman's (2013) description of scenario typologies in section 2.3 of chapter two, forecasting remain a type of scenario method for future planning (Banister and Hickman, 2013). However, it was not considered for inclusion in the proposed multimethod. The arguments of Schwartz (1996) and Dator (2012) put forward in section 2.3 of chapter two suggest that while forecasting supports future decision making, they are mere estimates of the actual and cannot be relied upon as the actual representation of what will happen in the future. Also, its poor level of accuracy under long-term planning horizons limits its reliability (Armstrong, 2001). Despite the evolution of highly sophisticated forecasting techniques, its reliance on previous data limits its ability to project long-term plausibility where most events remain extremely uncertain (Shoemaker, 1996). Therefore, rather than focusing on what will happen in the future, a component of the proposed multimethod seeks to explore what could happen in the future.

The role of visioning within the OVAF multimethod framework ensures the development of desired future targets that can act as a guidepost that the organisation must work towards achieving in the future. As described in section 2.5 of chapter two, visions are created by stakeholders that are affected by a situation or dissatisfied with the current state. Hence, visioning is useful for eliciting their opinions about a system they desire to see in the future. Furthermore, the quantification of visions options can be highly useful for strategy development processes as they provide concrete inputs for the development of pathways for achieving the desired future. The quantification of these visioning outputs can only be possible if visioning outputs are translated from their qualitative forms into quantifiable forms that can be suitable inputs for quantitative analytical processes such as the optimisation of future systems. Therefore, in addition to the undeniable relevance of optimisation modelling technique within the OVAF, a translation approach that converts the qualitative visioning outputs into quantifiable forms is needed within the multimethod.

Therefore, this research aims to develop a multimethod approach termed "Optimised Visions of Alternative Futures Approach (abbreviated to OVAF)" that consistently combines the exploratory scenario planning, visioning, and optimisation methods into a robust long-term planning approach for distribution network design systems.

The subsequent subsection presents the researcher’s philosophical stance underlying the OVAF multimethod presented in this chapter.

5.2.2 Philosophical assumptions of the OVAF multimethod

The developed OVAF multimethod draws on the arguments of Mingers and Brocklesby’s (1997) for multi-paradigm multimethod described in section 4.2 of chapter four. Firstly, the world is complex and multidimensional and using different methodologies enables one to focus attention on different aspects of the situation. Secondly, a problem goes through different phases, and more than one methodology might be required to tackle all phases. Thirdly, multi-paradigm multimethod is common practice even if there are limited reports in the literature. Finally, triangulation on the situation using different methodologies can generate new insights, whilst enhancing confidence in the results through a reciprocal validation (Mingers, 2002).

Considering the above, the researcher assumes that there is an existence of an objective reality, and these realities can be sufficiently explained when shaped by the perception’s relevant stakeholders. Therefore, the latter position aligns with the critical realist epistemology described in section 4.2.1 of chapter 4. More so, the researcher believes that no single method can be adopted for all instances of a problem situation. Therefore, the OVAF multimethod is underpinned by a critical realist position and a mixed methodology that furthers the consistent integration of different qualitative and quantitative methods within a multimethod framework.

The critical realist position is suitable for practical, real-world problems that consist of both hard and soft components such as the long-term planning for distribution network design contexts. The mixed-method research methodology aligns with the nature of intervention where long-term strategies are developed for the Nigerian petroleum products distribution sector. It combines qualitative methodologies for addressing the complexity associated with qualitative data and the quantitative methodologies to handle the complicatedness of the long-term planning problem. The qualitative methodological design of visioning, scenario planning are used to tackle the wicked and unstructured nature of long-term planning. The quantitative methodological design tackles the quantitative analysis of the long-term planning problems.

To develop an appreciation of possible frameworks for the integrated use of scenario-based visioning and optimisation, the researcher intends to modify the known view held by positivists within the mathematical modelling field, proposing that long-term planning for distribution network designs transcends the single-use of existing quantitative data for optimising networks. It involves identifying the complexities inherent in the system, which can only be determined through active stakeholder involvement and translating their opinions into numerical inputs for modelling and optimisation purposes.

The research intervention is targeted at working in collaboration with stakeholders in the Nigerian oil industry. Overall, the impact this theoretical position/perspective has on the research question is that the research seeks to propose a framework for integrating exploratory scenario planning/visioning methods and the optimisation methods. Due to the limited work conducted in this field, adopting a critical realist position enables the framework to be developed in conjunction with organisations and the research design to be dynamic. The theoretical position and research methodology adopted recognises the need for the reflective attribute of the researcher that provides the opportunity for reasoning and learning. The optimisation requires quantitative parameters; however, some of the requirements of the network to optimised could contain personal information. This is particularly true because of the real-world consist of tangible and intangible elements. The critical realist position enables the researcher to adopt an involved, action research approach, working with stakeholders within an organisation to develop frameworks for integrating the methods.

5.3 External scenario development – OVAF stage 1

A six-step exploratory scenario approach has been proposed for the development of external scenario for the supply chain distribution network design contexts. The proposed procedure draws on the intuitive scenario approach presented by Amer et al. (2013) and described in subsection 2.4.1.3 of chapter two. The intuitive approach was considered because it captures the complex and broad range of issues in the business environment. Unlike the PMT approach that relies on the mathematical algorithms for the development of scenarios (Pillkhan, 2008) presented in 2.4.1.1, the intuitive approach is qualitative, and it targets the development of alternative views of the future (Derbyshire and Wright, 2017). The probability modified trend approach has not been followed due to its reliance on the extrapolation of past trends for the prediction of the future which in reality may be subject to discontinuity in the long run. The probability-based approach is more suitable in the short-term planning horizons where existing trends and events remain unchanged.

5.3.1 Justification for external scenario development steps (OVAF stage 1)

This section provides a justification for the choice of the six-steps of the external scenario development procedure presented in table 5.1. It provides a rationale for excluding the “identification of key stakeholders” and “selection of leading indicators” steps highlighted in the generic steps presented in table 2.4 of chapter 2 and highlighted in column 3 of table 5.1.

In addition to the influence of the scenario approaches proposed by Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008), and Riddel et al. (2018) on the design of proposed exploratory scenario approach, the six-steps were also influenced by the purpose of the exploratory scenario within the OVAF multimethod framework. Specifically, the purpose of the exploratory scenario approach is to provide a set of external scenarios that inform the diverse background contexts for the creation of future visions. Also, the exploratory scenarios are designed to provide quantified scenario specifications that will inform the optimisation modelling analysis stage.

Table 5.1 outlines the six steps of the proposed exploratory scenario approach, the link to the generic exploratory scenario planning steps presented in table 2.4, and the sources of influence.

Table 5.1 Adapted exploratory scenario steps, link to generic steps and sources of influence

Exploratory scenario steps (OVAF Stage 1)	Link to generic exploratory scenario steps in table 2.4	Generic exploratory scenario steps in table 2.4	Source of influence
Step 1: Define focal issue (s)	Linked to step 1 of table 2.4	Step 1: Define focal issues	Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008) and Riddel et al. (2018)
Step 2: Identify driving forces of change	Linked to step 3 of table 2.4	Step 2: identify key stakeholders	Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008) and Riddel et al. (2018)
Step 3: Identify key uncertainties (critical uncertainties)	Linked to step 4 of table 2.4	Step 3: identify driving forces of change	Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008) and Riddel et al. (2018)
Step 4: Construct scenarios	Linked to step 5 and 6 of table 2.4	Step 4: Identify key uncertainties (critical uncertainties)	Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008) and Riddel et al. (2018)
Step 5: Quantify scenario drivers	Not linked to table 2.4	Step 5: Construct scenario	Partly by the probability modified trends approach (see 2.4.1.1) and proposed OVAF multimethod
Step 6: Communicate scenarios and implications	Linked to step 7 of table 2.4	Step 6: flesh out scenarios	Schwartz (1996); Schoemaker (1995); Keough and Shanahan (2008) and Riddel et al. (2018)
		Step 7: Communicate scenarios and implications	
		Step 8: Select leading indicators	

Relating the proposed procedure (column 1) to the generic procedure (column 3) in the table 5.1, it can be seen that “identification of key stakeholders” and “selection of leading indicators” were not included in the proposed exploratory scenario approach (OVAF stage 1). Shoemaker (1995) explicitly highlighted “the identification of key stakeholders” as a second step in his 10-step process. However, as explained in table 2.4, Schwartz (1996) embedded this activity within its initial step. Other authors (Keough and Shanahan, 2008; Riddel et al., 2018) did not capture this step in their five-step process. A reason for omitting this step in some procedures is because exploratory scenarios can be developed either through desk approach by experts or through a participatory process that involve stakeholders and experts (see section 2.4.3). Therefore, the inclusion of the step is subject to the peculiarities of the problem context and the scenario team. Where resources are sufficient and the case context supports active stakeholder involvement, then this step can be implemented. However, when the situation does not align with the latter, an expert led desk approach can be followed. The proposed exploratory scenario procedure follows a desk design on the basis that it is suitable for situations where industry stakeholders are difficult to converge, and resources are limited to conduct multiple workshop sessions.

The “selection of leading indicator” step is useful for identifying the drivers to watch out for in the future (Schwartz, 1996). However, this step was omitted from the proposed procedure because it does not fit the purpose of the of exploratory scenario in the OVAF multimethod. The latter would be essential if the exploratory scenario approach is designed as a standalone process. Instead, it serves two critical roles. First, it provides a framework of scenarios for the development of the visions. Second, it provide the values for the uncertain parameters in the optimisation stage. In addition, other authors (Schoemaker, 1995; Keough and Shanahan, 2008, and Riddel et al. (2018) did not include the step in their process. The argument for the inclusion of this step can be flawed on the basis that focusing on already known drivers can be limiting when existing trends could discontinue, and new drivers of change could erupt in the business environment. Therefore, rather than scanning for unique drivers, the step 2 should be carried out to scan the environment of any possible driver of change.

In terms of the adapted steps, in step 1 “define the focal issue” (step 1), it was identified that this step sets scene for the entire scenario process by identifying issues of concern. These issues include the issues affecting the organisation; the scope of the scenario study; the purpose of the study, and the time horizon for the scenarios study. This indicates why all the reviewed approaches explicitly capture this step in their process (see table 2.3 and 2.4). In step 2 “identify driving forces of change”, the environment of the focal organisation becomes the issue of concern. These include the contextual environment as suggested by Schwartz (1996), and the macro-environment. Here, the researcher classed all external factors such as the basic trends, predetermined drivers, or uncertain drivers as drivers of change that potentially affect the focal firm from the external environment. Therefore, “identify basic trends” (Schoemaker, 1995); “identify key factor in local environment (Schwartz, 1996); “key drivers and trends” (Keough and Shanahan, 2008); and “key drivers of change” (Riddel et al., 2018) was combined and termed as “identify driving forces of change”. The researcher argues that while is it evident that forces in the business environment (known or unknown) drive change, the crux is in the magnitude of impact and uncertainty caused by the forces. Therefore, naming the step as the “identification of driving forces” covers both pre-determined drivers and the key drivers.

In step 3 “identify key uncertainties (critical uncertainties)” is influenced by the reviewed exploratory scenario approaches (see table 2.3). Aside the use of the critical uncertainties for the creation of the scenarios, they contextualise the scenarios to ensure the scenario relevance for the focal environment. Different environments have different critical issues in their environment. For example, while the issue of insecurity is a critical challenge in countries in sub-Saharan Africa, this is not the case in the North American region. Therefore, creating scenarios for the latter region with insecurity as the critical driving force may not provide a set of scenarios that will be relevant for the focal sector. Furthermore, the step 4 “construct scenarios” was selected as an important step because it is representing the actual output of the exploratory scenario process. All reviewed studies also account for this step in the process and activities such as ensuring the consistency and plausibility (Schoemaker, 1995), and the fleshing out of scenarios (Schwartz, 1996) were all captured under the broad step “construct scenarios”.

In step 5 “quantification of the scenario drivers” was influenced by the role of the external scenarios in the OVAF multimethod. While the reviewed approaches have not captured the “quantification of the scenario dimensions” under their approaches, this step is critical for linking the exploratory scenario and the network design optimisation problem under uncertainty. Specifically, the quantification provides plausible projected values to the uncertain parameters under the different external scenarios, these values will be inputs for optimising future distribution network design. Finally, in step 6 “Communicate scenarios and implications” involve communicating the scenarios to ensure that the stories of the plausible futures are adequately understood by the audience. Since the scenarios are imaginary creations of plausible future states, creative and captivating storylines or visualisation of the scenario contents would improve the quality of the scenarios and its use. The likely threats, challenges and opportunities caused by these scenarios are also described. This step aligns with the steps of all the authors.

The next section will address the different steps of the external scenario development process with particular emphasis on the methods for each step.

5.3.2 Description of proposed external scenario development steps (stage 1)

A desk research approach is suggested for use in the OVAF for developing external scenarios. However, the review in section 2.4.3 revealed that external scenarios can also be developed through a participatory design. The participatory design involves the use of participatory methods (workshops, focus group sessions and interviews) for the development of the external scenarios. While both designs present their benefits, the participatory design has been rejected for use in the OVAF. The desk research design is selected because it can be applied under time and cost constrained situations. Unlike the participatory design that require the engagement with different stakeholders and professionals through multiple workshops, focus groups or interviews. This process can be time and cost intensive. In some cases, the success of the process is affected by the busy schedules of the participants and the stakeholders are difficult to locate, attract and converge. Consequently, the external scenario (OVAF stage 1) procedure follows an expert-led desk approach.

The figure 5.3 below illustrates the steps and activities involved in the external scenario development stage of the OVAF. The six-steps will be described below.

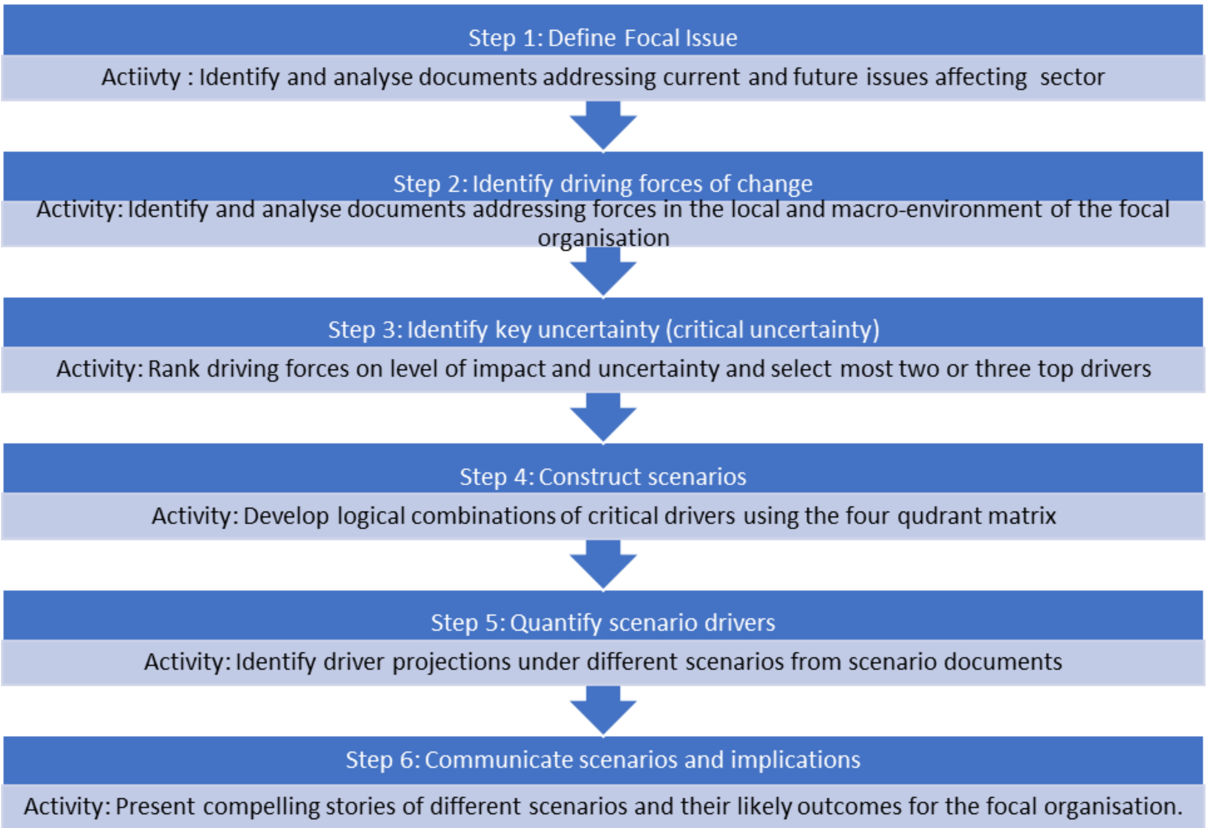


Figure 5.1 External scenario development framework

5.3.2.1 Step 1- Define focal issue

This step is influenced by the scenario design proposed by Schoemaker (1995); Schwartz (1996); Keough and Shannahan (2008); Riddel et al.'s (2018) and described in table 2.3 of chapter 2. It involves the definition of focal issues, purpose, and the time horizon of the scenario development project. The focal issues are the different challenges facing the focal organisation. In defining the purpose, if a scenario project is focused on a new business, the purpose should be to generate new ideas. Alternatively, if it is focused on an old business, its purpose should be to evaluate existing strategies or products (Pastor, 2009). The purpose should either focus on a specific operation or explore the broad scope of the organisation. Finally, with respect to the scenario time horizon, the review identifies that scenarios time horizons range between 15 and 25 years. The time must be long enough to imagine crucial changes, and short enough to create probable scenarios.

As described in section 2.4.3.1 of chapter two, the focal issues can be identified through participatory methods such as structured interviews or focus group discussions with stakeholders (Riddle et al., 2018). However, a document content analysis can be used for identifying the forces (Blanco and Moudon, 2017; Ferganni and Jackson, 2019). In the later, media documents, newspapers, journal articles are analysed are analysed to identify issues affecting the focal organisation. Using a participatory approach presents the benefit of addressing the direct inputs from the professionals in the industry. This is not the case for the desk-based document analysis where the researcher independently identifies the issue by systematically analysing relevant documents. To improve the quality of this process, issues identified using the document analysis must be validated.

The OVAF is designed for use under resource constrained situations, a document content analysis is used because it reduces the challenge of identifying and attracting the stakeholders to be involved in the process. After the document analysis has been used to identify the focal issues, effort must be made to validate the choice of focal issues from selected key stakeholders through telephone interviews or online survey designs. Details on how this process was carried out can be seen in section 7.2.1 of chapter 7. Here, the focal issues were initially identified through document analysis and validated through telephone interviews with few accessible stakeholders in the Nigerian Petroleum industry.

5.3.2.2 Step 2- Identify driving forces of change

The second step involves the identification of the driving forces of change. These forces may pose an unanticipated impact on the focal organisation in the future. They can either be 'predetermined' or "unpredictable" elements. Cornway's (2006) description of this step as presented in chapter two, suggests that the impacts of the predetermined drivers are relatively known while the impact of unpredictable elements in the focal system is high and little is known about their occurrence. Just like the first step, the identification of the driving forces step is informed by the steps proposed by Schoemaker (1995); Schwartz (1996); Keogh and Shannahan (2008); and Riddel et al. (2018). Schoemaker (1995) captures this step under step three and four of his ten-step process; Schwartz (1996) captures it under step three of their eight-step process. Riddel et al. (2018) capture the identification of the driving forces under the second stage of their five-step scenario building model.

As described in section 2.4.2.3 of chapter 2, driving forces of change can be determined either through participatory methods (Ramirez et al., 2015; Svenfelt et al., 2019) or document analysis (Blanco and Moudon, 2017). The participatory methods such as in-depth interviews with acknowledged experts; targeted questionnaire surveys; and brainstorming workshops can be used for identifying the driving forces. While the above method can ensure stakeholder engagement in the process, they can be costly, resource intensive, and sometimes flawed by poor attendance of participants due to practical constraints such as busy schedule of participants. Conversely, the use of document analysis at this step is helpful under resource-constrained situations as it enables the fast identification of drivers without embarking on the resource-intensive process of organising interviews and workshops for experts and stakeholders (Ferganni and Jackson, 2019).

As mentioned in section 5.3.2.1, the OVAF exploratory scenario approach has been designed to be useful under resource-constrained situation. Therefore, a document analysis approach is encouraged for use in this step because it does not involve the participation of stakeholders. While conducting a document analysis, the document inclusion criteria must be set to identify the right documents for analysis. For example, the documents should be published over a time frame that captures contemporary events as well as events in the past. Search keywords should be set and used to identify relevant documents. Details on how the document content analysis was conducted to identify the driving forces of change affecting the Nigerian petroleum products distribution network can be seen in section 7.2.2 of chapter 7.

5.3.2.3 Step 3 – Identify key uncertainties (critical uncertainties)

This step was informed by the step four of Schoemaker's (1995) 10-step scenario approach, and Schwartz's (1996) 8-step scenario building model presented in table 2.3 of chapter 2. The critical uncertainties are selected from the list of global drivers identified in step two. To select the critical drivers, the driving forces are ranked in terms of their impact on the focal issue and their level of uncertainty. Driving forces with highest level of uncertainty and impact on the focal organisation are selected as the critical uncertainties. In addition, the number of critical drivers selected inform the number of scenarios to be created as well as the logic for creating the scenarios. As described in section 2.4.2.3 of chapter 2, researchers suggest the creation of three to six scenarios. The later correlates with the number of critical uncertainties selected: more critical drivers implies more scenarios are created. In the light of this, it is encouraged that two or three most impacting and uncertain drivers should be selected as the critical drivers of change (Cornway, 2006). This decision is in-line with the recommendation of Amer et al. (2013); the Global Business Network (GBN), and the Stanford Research Institute provided in section 2.4.3.3 of chapter two.

Based on the above discussion, the exploratory scenario approach proposed in the OVAF supports the selection of two critical drivers using an expert judgement technique. Selecting two critical drivers will ensure the construction of a manageable number of scenarios that are developed in a logical manner such that the system dynamics are well reflected, and core issues well communicated. To ensure that the critical drivers are relevant and of concern to the case context, multiple evaluators with good knowledge of the issues in the contextual environment should be used to rank all driving forces identified in step 2. Impact and uncertainty scores across each of the drivers are analysed to determine a mean uncertainty and impact score for each driving force of change. The two drivers with highest uncertainty and impact scores should be selected as the key uncertainties or critical drivers of change. Details of the procedure for selecting two critical drivers affecting the Nigerian oil industry operations have been demonstrated in section 7.2.3 of chapter 7.

5.3.2.4 Step 4 - Construct scenarios

In this step, the scenarios are created through the four-quadrant scenario matrix method (FQM). The technique for constructing the scenarios align with Schwartz's (1996) suggestion for plotting scenario drivers to develop different scenarios. However, it differs from Shoemaker's option for developing only two extreme positive or negative scenarios. It is the researcher's position that the development of only two scenarios limits the range of options that could evolve under the scenarios to a negative or positive scenario which may not be the case in reality. Therefore, the FQM is recommended for the creation of four well contrasted external scenarios that reflect the possible eventualities in the future.

As explained in section 2.4.2.5 of chapter 2, where more than two and less than eight critical drivers are selected, a standard approach is considered appropriate. More so, the maximum approach is used when more than eight critical drivers are identified. However, users must note that since one axis creates two quadrants; two axes create four quadrants and three axes create nine quadrants, using more axes runs the risk of making the results complex, hard to visualise and hard to interpret. Other techniques for scenario creation as described in section 2.3 of chapter two include the Wilson matrix (Pillkhan, 2008); Morphological analysis (Zwicky,1962); Cross impact analysis (Bradfield et al., 2005).

Based on the above discussion, the researcher recommends that users of the proposed exploratory scenario approach should objectively select of two critical uncertainties and utilise the FQM technique to generate four scenarios. This process is unique to both the desk, and the participatory approaches. Detailed procedure for applying the FQM technique has been demonstrated in section 7.2.4 of chapter 7 for the construction of four well-contrasted external scenarios for the Nigerian oil industry by 2040.

5.3.2.5 Step 5 - Quantify scenario drivers

In this step, the scenarios drivers within each of the external scenarios are quantified. This step presents a modification to the intuitive approach of the early mentioned authors (Schoemaker, 1995; Schwartz, 1996, Keogh and Shanahan, 2008, and Riddel et al., 2018). While the methods for developing quantified scenarios link to the probabilistic modified trend approaches classified by Amer et al. (2013) and described in section 2.3.1 of chapter two. These methods are not recommended for the proposed scenario approach because they rely on the extrapolation of past data and discount the effect of unplanned future events. Example of such methods include the cross-impact analysis; trend impact analysis, and the interactive future simulation methods (Bradfield et al. 2005).

In this project, the scenarios are quantified by building on projections documented in scenario literature. The values of each driver under the different scenarios are generated from pre-determined projections in future outlook studies. Also, the values are determined based on the minimum or maximum historical value documented in the literature. However, different assumptions are made to adjust the known values to reflect the different possible states of a particular scenario driver. Detailed procedure for the quantification of the scenario drivers is documented in section 7.2.5 of chapter 7.

5.3.2.6 Step 6 - Communicate scenarios and implications

In this step, the external scenarios are communicated to the target audience in a clear, captivating, and concise manner. Like other steps highlighted above, this step is influenced by the implemented steps of other previous authors (Schoemaker, 1995; Schwartz, 1996, Keogh and Shanahan, 2008, and Riddel et al., 2018). Methods for presenting the scenarios include well scripted narratives (Blanco and Moudon, 2017), visualisations (Tight et al., 2011), or role play (Diaz et al., 2009).

While narratives and visualisations are commonly used in communicating scenario contents, role play techniques generally have three types of participants: players, observers, and facilitator(s). It also has three phases: a briefing phase where warm up explanation of the what expected; a play phase where facilitators organise the play settings, props, tech supports and a short introduction to the play: debriefing phase where the role players talk about their experience to the audience facilitated by an appointed instructor that summarises the main points. When the external scenarios are narratively presented through a captivating written story of the scenario snapshots. the user is encouraged to uses the power of the written word to tell the story. The story be presented either as simple bullet points that outline the steps that someone goes through, to a fully flung mini novel. When visualisation methods are used, scenarios can be presented using images describing the story line.

While the different methods are useful techniques for communicating scenarios, users of the proposed exploratory scenario approach are encouraged to utilise any of the techniques that suit their specific needs. In the study conducted in this research, a narrative technique is applied. The narrative uses the compelling power of words to portray the dynamics within each scenario. Details can be seen in section 7.2.6 of chapter 7.

5.4 Vision development – (OVAF stage 2)

The second stage of the OVAF multimethod is the development of scenario-specific visions. The role of the visioning methodology within the OVAF multimethod is to develop desirable future states that are consistent with the different external scenarios that are likely to occur in the future. In this thesis, these visions will always be referred to as scenario specific visions.

5.4.1 Justification for the proposed vision development approach

A six-step visioning approach has been proposed as the second stage of the OVAF multimethod. The proposed approach is similar to the visioning approaches presented in figure 2.4, 2.5 and 2.6 of chapter two. Among all the reviewed visioning designs, the six steps strongly align with the stages and activities of the visioning choices approach (VCA) developed by O'Brien and Meadows (2007) presented in figure 2.6. Evidently, the VCA improves on both the choices approach (CA) and traditional Visioning approaches (TVA). In addition, the proposed steps have been influenced by some of the core arguments discussed in section 2.5 and this has led to the naming of the proposed visioning approach as "Modified Visioning Choices Approach (MVCA)". Table 5.2 below presents the steps of MVCA, its link to the generic visioning steps presented in table 2.5 of chapter two, and the sources of influence for each step.

Table 5.2 Six steps of the MVCA (OVAF stage 2)

Steps of MVCA	**Link to generic visioning steps**	**Generic Visioning Steps documented in table 2.5**	**Sources of influence**
Step 1: Project definition	Linked to Step 1 of table 2.5	Step 1: Project definition	O'Brien and Meadows, 2001, 2007; Tight et al., 2011; Iwaniec and Wiek, 2014; Soria-Lara and Banister, 2017; and Uwasu et al., 2020
Step 2: Plan for Visioning workshop	Linked to step 2 and 4 of table 2.5	Step 2: Stakeholder identification	O'Brien and Meadows, 2001, 2007; Tight et al., 2011; Iwaniec and Wiek, 2014; Soria-Lara and Banister, 2017; and Uwasu et al., 2020
Step 3: Explore Issues	Linked to step 3 of table 2.5	Step 3: Exploring Issues	O'Brien and Meadows, 2001, 2007; Tight et al., 2011; Iwaniec and Wiek, 2014;
Step 4: Generate scenario specific vision elements	Partly linked to step 5 of table 2.5	Step 4: Prepare discussion materials	Influenced by OVAF multimethod; O'Brien and Meadows, 2001, 2007; Tight et al., 2011
Step 5: Produce the scenario specific visions	Partly linked to step 6 of table 2.5	Step 5: Promote Dialogue	Influenced by OVAF multimethod; O'Brien and Meadows, 2001, 2007; Tight et al., 2011
Step 6: Plan for action	Linked to step 7 of table 2.5	Step 6: Producing the Vision	O'Brien and Meadows, 2001, 2007; Tight et al., 2011; Iwaniec and Wiek, 2014;
		Step 7: Plan for action	

In addition to the influence of the VCA and the steps adopted by other highlighted visioning projects, the modification is informed by the role of the visioning methodology within the OVAF framework; the argument for developing scenario-specific visions. external scenarios should be considered during visioning; and if single or multiple visions should be developed (see section 2.5 of chapter two). The researcher argues that while the integration between the exploratory scenarios and visioning can improve the quality of the visions as well as the strategy development process, the procedure for integration play a critical role in preserving the quality of the envisioned options. According to the review provided in section 4.5 of chapter four, during visioning events, a shared vision is developed by stakeholders after reflecting on the different scenarios for the future. Alternatively, only a single external scenario is reflected upon by stakeholders during workshops before the development of multiple visions. These designs have produced useful vision outputs. However, the researcher argues that since the stakeholder perspectives differ on what is considered an ideal future under a single external scenario context, the development of a shared vision under the different external scenarios provides the opportunity for a robust and broader exploration of envisioned options outcomes.

Furthermore, the extension of the “Planning for action stage” of O’Brien and Meadows (2007) visioning choices approach to include a quantification and optimisation of stakeholder vision outputs to support policy actions and investment decision making. Ooutputs from visioning exercises can potentially provide inputs into quantitative analytical exercises. However, the paradigm incommensurability of such anticipated integration remains a challenge for multimethod development. The proposed MVCA stage and the subsequent translation and optimisation stages of the proposed multimethod provides a way to deal with the latter problem.

5.4.2 Procedure for the MVCA

This section provides a description of the steps and methods adopted in the modified visioning choices approach. The MVCA approach presented in figure 5.4 consist of six interconnected steps.

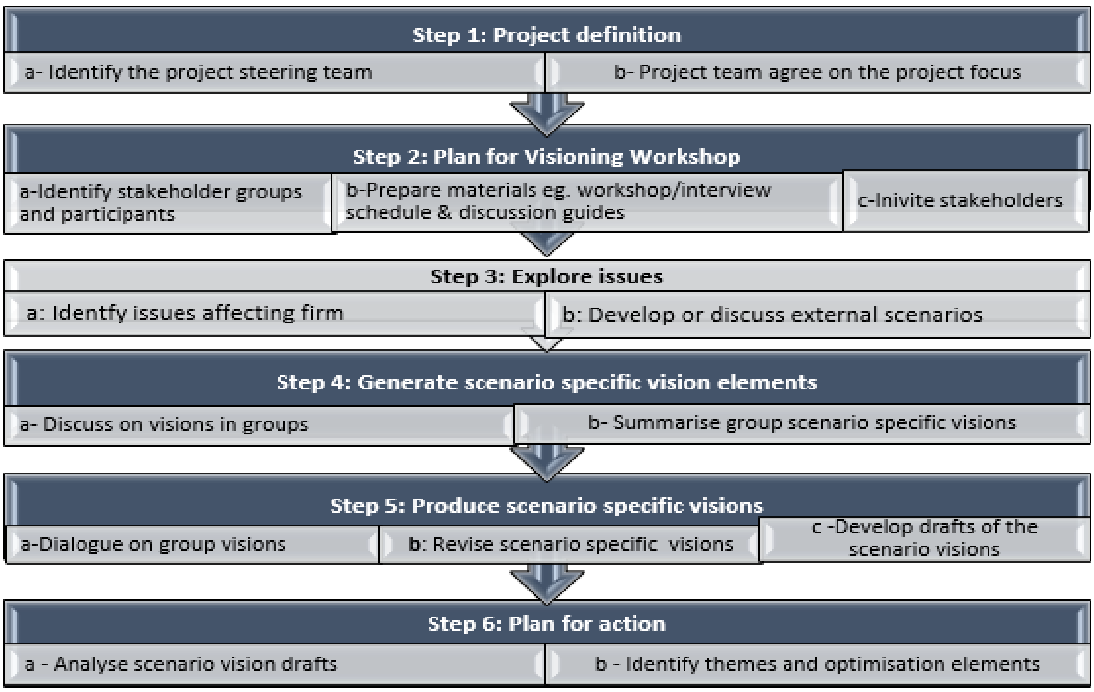


Figure 5. 2 The MVCA Framework

5.4.2.1 Project definition

As earlier explained in section 2.5 of chapter two, the project definition involves setting-up the project steering team that will determine the project focus and explore concerns around the project. The project steering team comprises of a team of experts with keen interest in the change in the focal organisation. The experts can include academic researchers or senior professionals within an organisation, industry or sector at large. This step is influenced by the step one of the choices and the visioning choices approach presented by O'Brien and Meadows (2001:2007) and presented in figure 2.5 and 2.6 under section 2.5.1 of chapter two. The above authors explicitly "defined the project" in the initial step of their visioning approach. Others implicitly embed the project definition under the "identification of stakeholders" or "issue exploration" or "analysis of current situation" stage (Jiminez et al. 1997). Others do not capture the step when presenting the steps in visioning exercises (Minowitz, 2013). In the MVCA, the project definition and issue exploration are captured under step one and named "Defining the project".

In this research, the project steering team was represented by the researcher alone. This was because the project was part of a doctoral research project. The intervention was conducted for the Nigerian oil industry. Therefore, the senior professionals in the Nigerian Petroleum industry were considered as the stakeholders to be consulted for the visioning exercise. Details of the project definition step can be found in section 8.2.1 of chapter 8.

5.4.2.2. Step 2- Plan for visioning workshop/interview

The step two of the MVCA is also influenced by the second and fourth step of the visioning choices approach. The step two (stakeholder identification), and four (prepare discussion materials) of the visioning Choices were compressed into a single step called the "Plan for visioning workshop and interview" under the step 2 of the MVCA. Here, the stakeholder groups and potential participants are identified; documents required to facilitate stakeholder discussions are prepared (such as the summary of external scenarios; workshop/interview discussion guide; schedule of events for the workshops/interviews); invitation of participants; and logistical activities for the visioning exercise (locations set up, recruitment and training of facilitators) are carried out.

The rationale for the allocating the above activities under this step of the MVCA is the need to create a demarcation between the visioning project conceptualization and commencement activities. While the researcher agrees that both steps are preparatory steps that occur prior to the "dialogue and generate idea" (O'Brien and Meadows, 2001) or "promote dialogue" step (O'Brien and Meadows, 2007), the researcher argues that preparatory activities should be structured into the conception and commencement activities. The project definition can be carried out at the conceptualisation stage of the visioning project because it requires limited commitment irrespective of a discontinuity, postponement of visioning exercise. The “plan for workshop/interview” activity can only take place when the project intervention is guaranteed. Activities under the later step includes stakeholder identification, invitation, discussion material preparation, and the recruitment and training of facilitators.

Besides the unique feature of developing scenario specific visions, the split of activities between step 1(project definition) and step 2 (plan for workshop and interview is a feature that differentiates the MVCA from the choices approach and visioning choices approach. Details of the plan for visioning workshop and interview is documented in the application of this step-in section 8.2.2 of chapter 8.

5.4.2.3 Step 3 - Explore issues

As described in section 2.5.1.3 of chapter 2, this step involves the identification of the issues affecting the focal organisation. While authors suggest that the capability of the organisation should be considered, this step focus on the analysis of organisation’s current situation and not the evaluation of the capabilities. The researcher agrees with Ackoff (1993) that visions ought not be limited by the capability of the focal firm. Rather. Therefore, an analysis of issues affecting the organisation propels the participants to imagine where they want to be in the future.

This step is important for maintaining the OVAF design because it presents an opportunity for validating the external scenarios developed through a desk approach. Here, the scenarios developed through a desk driven approach are discussed with the stakeholders to deliberate on the pre-created external scenarios developed through the desk study. Other methods such as the Delphi survey could also be used to convey the details of the external scenario to the participant prior to the visiting workshop event. While the later method has proved to be useful in building consensus, However, the it does not guarantee an engaging and collaborative discussion session among participants.

Consequently, in this research, a workshop event was organised such that the different pre-created external scenarios were presented to the stakeholders. The presentation evoked the stakeholder reactions to the relevance of the scenarios, and how the external scenarios affect their organisation. After each scenario presentation, participants were encouraged to react to the pre-created external scenarios. Also, participants also highlight some of the issues that affect their operations internally or might limit them from achieving their set vision. In some cases, participants could introduce new elements into the scenarios. Therefore, the workshop schedule must be designed to accommodate the modifications and revisions to the developed scenarios. A detailed description of the procedure for exploring issues can be seen in section 8.2.3 of chapter 8.

5.4.2.4 Step 4 - Generate scenario-specific vision elements

This step involves the dialogue among stakeholders to elicit their vision elements. This step is influenced by step four and five of the Visioning Choices approach. Methods for identifying the vision elements are drawn from the methods outlined by Minowitz (2013) and described in section 2.5.1.1 of chapter two. The latter author highlighted that vision elements can be identified through a tabula-rasa or responsive approach. The tabula rasa-approach involves developing a new vision, while the responsive approach is used for improving or ratifying existing vision based on stakeholder perspectives (see table 2.3 and 2.4).

Different methods for the identification of the vision elements under the different approaches have been presented in table 2.3 of chapter 2. However, the choice of data collection methods informs the approach adopted. When new visions are developed, it is important that methods that encourage the active participation of stakeholder as this will support the elicitation of rich data. Drawing from the methods proposed by Minowitz (2013) and presented in table 2.3 of chapter two, focus group, interviews and workshops are suitable methods for use in eliciting the vision elements. Also, the photo and textual diary technique can be embedded within the latter methods to support participants to uniquely express their ideas in text or pictorial formats.

The above methods are beneficial because they are classified as a direct interface method since the participants and the researcher or facilitator are in direct contact during the process. They encourage the active stakeholder participation and supports the researcher/facilitator to monitor the participant's behaviour throughout the Visioning process. Public opinion surveys are better utilised under the responsive situation. Here, pre-determined vision elements are sent to participants through email surveys to elicit the opinions on ways to improve the visions. While this approach can be very resource efficient, they sometimes provide limited data for analysis as compared to the direct methods.

Another important factor that informs the choice of either a direct or indirect interface data collection method relates to the procedure for integrating the external scenario element within the visioning process. Direct methods are better suited when the external scenarios for vision development have been pre-created and not known to participants developing the visions. This creates an opportunity for adequate deliberation on the scenarios and visions. Alternatively, the indirect methods can be used when the external scenarios have been previously created by the same group of stakeholders developing the visions. In the latter case, reaction to the scenarios are already known by stakeholders and the visioning process can be carried out with limited conflicting opinions from the participants.

In this research, direct elicitation methods such as workshops, focus groups, and interview methods were used to identify the vision elements. This choice was made in order to encourage participants to develop visions under the different scenarios. Such a design required adequate facilitation to ensure participants worked with the specific scenario material provided. Details of the procedure can be found in section 8.2.4 of chapter 8.

5.4.2.5 Step 5 - Produce scenario-specific visions

In this step a shared vision that reflects the overall opinion of the stakeholders under each external scenario is developed. The visions are refined through a group consensus-building process where participants or groups are encouraged to review their visions with other participants or groups through an iterative presentation and discussion activity. This step draws insights from the “promote dialogue and generate ideas” stage of the Choices and visioning choices approach. However, the researcher identifies that the illustration of the stage when developing visions for the future of Operations Research (O’Brien and Meadows, 2007) may not have explicitly described a procedure for building consensus during the “promote dialogue and generate idea”.

As described in section 2.5.1.3 of chapter two, the vision refining step is presented as the building agreement on vision elements stage (Minowitz, 2013). Also, methods for building agreement can be developed through consensus conferences or collaborations which are direct interface methods or Delphi surveys or online surveys which are indirect interface methods. It is recommended that direct interface techniques be utilised to build an agreement because it allows participants to interact and arrive at a consensus (Tight et al., 2011). While the Indirect interface methods are useful (Blass et al., 2010, they (delphi surveys and validation mailer methods) can be used when active engagement with participants are not actively required. The latter option does not provide rich data such as the non-verbal gestures and reactions observed when interacting the participants.

A key activity of the refining of this step is drafting of the visions. Here, the groups compile the components of their modified vision to produce a rough draft of their visions. Drafting of visions remains silent as it is not clear if it is to be conducted by the stakeholders or steering group. This activity is vital for the process as it enables all participants to have some final reflections on the suggestions made by other participants. It strongly aligns with the “producing a share vision” stage six of the visioning choices approach. At this point, each group generates a rough draft of their visions for their scenarios. Details of the methods employed in producing the scenario-based visions when workshops or interviews can be found in section 8.2.5 and 8.2.7 of chapter 8 respectively.

5.4.2.6 Step - Plan for action

This step involves the analysis of scenario specific visions by the project steering team. It is influenced by the analysis component of the "Planning for action" step of the of the visioning choices approach described in section 2.5.1.4 of chapter two, In this step, the vision drafts compiled either by the participants during the visioning workshop or the project steering team post workshop exercise are analysed. As described by O'Brien and Meadows (2007), in this stage, the stakeholders and participants from relevant institutions that govern the effective functionality of the sector are invited to make commitments to implementing specific components of the vision developed. While this action-oriented step is critical to successful implementation of outputs of visioning exercise, it can be argued that outputs from visioning exercises are mostly subjective and imprecise and this can limit the effective strategic decision making. Therefore, visioning outputs should be further analysed to identify the concrete implications of the envisioned options before the responsible authority can make appropriate decisions.

The plan for action in this context goes beyond the content analysis conducted in the application of the choices approach in the development of visions for the future OR community. Although the latter study describes an extension to the process where the stakeholder groups or governing organisations extract the action points as targets to be achieved. The MVCA suggests an extension that leads to a more concrete implication of the different envisioned options. The latter extension has not been explored due to the challenge of translating the qualitative outputs to quantitative elements for further quantitative analysis. The numerical analysis will support the optimisation of the envisioned options to identify the rich detail of the implications of stakeholder vision options. The next section introduces the proposed process for translating the scenario specific vision outputs into quantifiable elements for different quantitative analysis.

5.5 Scenario-based visioning output translation approach – OVAF Stage 3

This section presents a procedure for translating the visioning outputs into quantifiable optimisation elements suitable for optimisation analysis. This stage is an extension of the "Analysis of vision" step of the MVCA. As earlier mentioned in section 4.9 of chapter 4, the translation stage is influenced by the issues of complexity and complicatedness in the visioning of future systems. Kemp-benedict (2006) posits that while complexity can be explored through human reasoning and brainstorming methods as demonstrated through the MVCA presented in 5.3, the complicatedness of the visions can be handled through mathematical models. Therefore, the value of scenario-based visions can be improved when the creativity of participants to develop qualitative visions is coupled with the specificity of quantitative modelling.

5.5.1 Procedure for the visioning output translation approach

This section presents the steps of the visioning output translation approach. It also describes the activities carried out under each step.

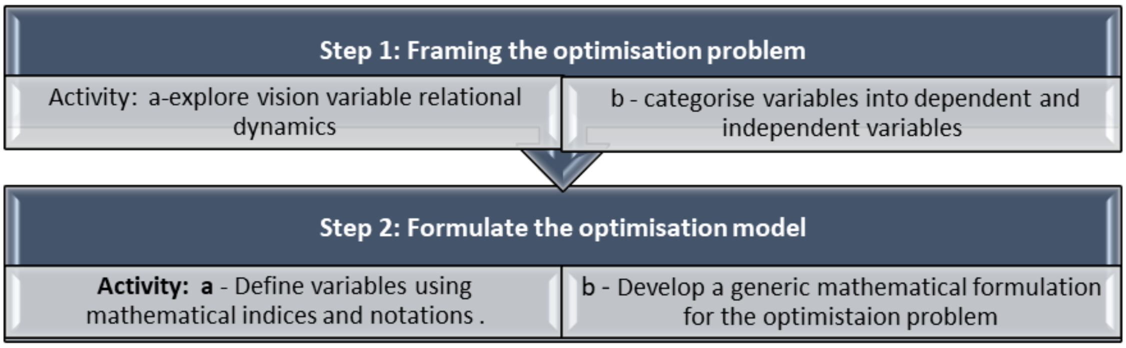


Figure 5.3 The visioning output translation framework

Figure 5.5 above involves two mains steps; i) the qualitative definition of the optimisation variables identified from the vision narratives, and ii) the translation of variables into quantifiable forms. A description of the steps is provided in the subsequent sections.

5.5.1.1 Step 1 – Framing the optimisation problem

In the first step, the network optimisation related variables under the different external scenario-based visions are qualitatively defined. The purpose of this definition is to describe the relationship between the different optimisation variables within the visions. Insights from results of the variable description provides the modelling team with the requisite knowledge of relational dynamics that will inform the optimisation model formulation. It also ensures that interactions embedded within the visions are preserved while translating between the qualitative outputs and the quantitative modelling process (Kok and van Delden, 2009).

In this step, a causal loop diagram (CLD) is used to show the relationships and feedbacks between the vision variable. “The CLD provides a language for articulating our understanding of the dynamic, interconnected nature of our world” (Mallampalli et al. 2016). We can think of them as sentences which are constructed by linking together key variables and indicating the causal relationships between them. By stringing together several loops, we can create a coherent story about a particular problem or issue”. The CLD can be used directly with stakeholders or indirectly by the researcher. When used directly, it can potentially engage the stakeholders and facilitate a better understanding of the dynamics of the interacting elements within the scenario-based visions. Alternatively, it can be used indirectly when the vision development process precedes the translation process that is conducted in isolation of the stakeholders.

Details on how the causal loop diagram was used to qualitative describe the scenario-specific vision variables can be seen in section 9.2.1 of chapter 9.

5.5.1.2 Step 2 – Formulate the optimisation model

In the second step, mathematical notations are developed to represent the defined elements in step one. The numerically defined elements are then formulated into a generic mathematical optimisation problem that captures all the vision components. The optimisation problem is structured into the objective function, the decision variables, and the model constraints.

Different scenario translation methods highlighted by Mallampalli et al. (2016) are described in section 4.9.1 of chapter 2. These methods include the agent-based modelling, fuzzy cognitive maps, fuzzy sets, pairwise comparison; Bayesian reasoning; role-playing games; surveys or semi-structured interviews and literature reviews. While the above methods have provided a way of translating scenario narratives for quantifiable forms, none have been used in the for translating outputs from visioning exercises into quantifiable forms. The translation approach presented is the first to focus on translating visioning outputs. It is unique due to its ability to first represent the scenario specific optimisation elements with mathematical notations and later formulated into a mathematical problem. This form of translation is useful for distribution network design contexts. The details on how the visioning outputs are formulated into a mathematical model and that can be optimised can be seen in section 9.2.2 of chapter 9

5.6 Optimisation of scenario-specific visions- OVAF stage 4

Strategic decisions in real-life contexts are made without prior knowledge of the consequence of the decisions. Also, in most cases, such decisions are characterised by uncertainties about the systems being explored. This section describes an optimisation modelling procedure that captures the different uncertainties in the business environment as well as the stakeholder visions under the varying uncertain but plausible scenarios. The approach can be used for quantitatively analysing the scenario specific visions identified through the MVCA approach described in section 5.4, in order to identify the implications of stakeholder envisioned options.

As described in section 3.3 of Chapter 3, network design problems under uncertainty can be solved through stochastic programming, robust scenario optimisation techniques (Synder et al., 2006;

Govindan et al., 2017). The stochastic optimisation technique has been rejected for use in the OVAF because it assumes that the probability of the uncertain parameters are known in advance and used for the determination of expected costs. However, in most real-life long-term planning problems, the probabilities of the uncertain parameters are not known in advance. Also, drawing on Synder et al's (2006) assertion that the creation of scenarios and identification of parameter associated probabilities can be a cumbersome task when dealing with real-world design problems, its use in this instance is not suitable.

The optimisation stage of the OVAF (OVAF stage 4) adopts the scenario optimisation technique proposed by Dembo (1991) and described in section 3.4.3. The technique was selected because it is computationally simple and easy to understand. Due to its generality, it can handle multiple competing objectives, complex constraints and can be applied in contexts other than optimization. It provides model solutions to the vision options specified under the four external scenarios. The scenario optimisation analyses the scenario-specific visions by treating each scenario as a deterministic model with different assumed values for the parameters under different scenarios. The scenario optimisation is computationally simple and easy to understand by the users unlike the stochastic optimisation.

5.6.1 Procedure for optimising scenario specific visions

The stage of the OVAF involves the description of the optimisation study area, optimisation of the scenario-specific visions, and a reflection of the model results by the stakeholders. Also, step one involves the extraction of data for the new or existing lines from the eternal scenarios stage. In the second stage, the analysis of the visions under the respective external scenarios is conducted. It provides a set of solutions that describe the implication of the different envisioned options.

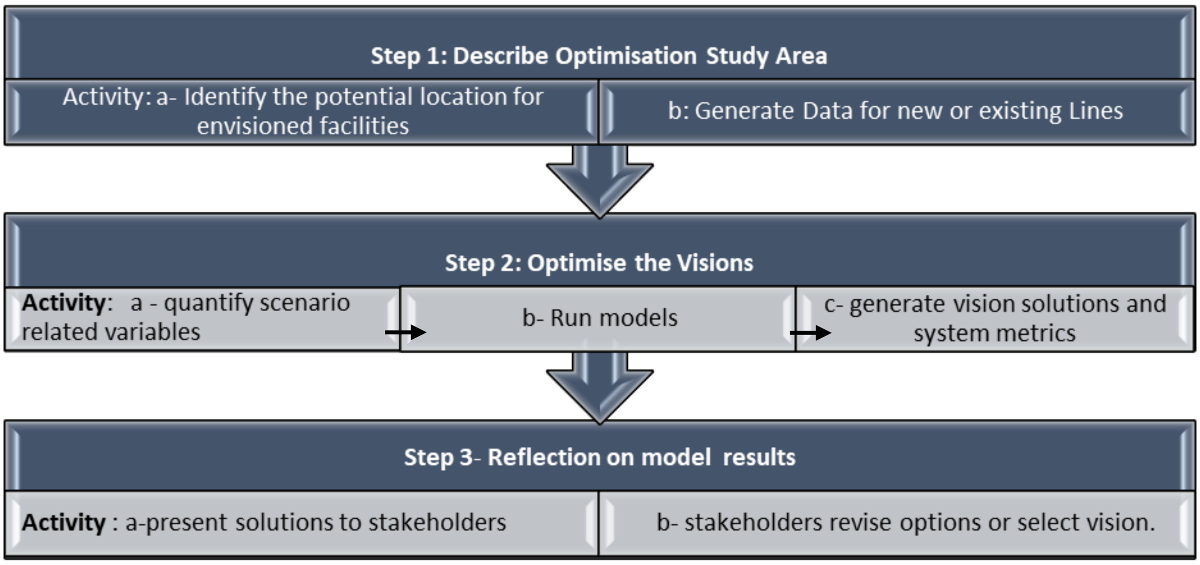


Figure 5. 4 The Optimisation of scenario-specific vision framework

5.6.1.1 Step 1 - Describe optimisation study area

The steps involve the description of the optimisation area where location characteristics are mapped out, and the required data for the envisioned system are retrieved from the external scenario specifications using the exploratory scenario approach described in section 5.2. The identification of potential locations for new and existing facilities is critical for the future network design decision due to the need for expansion on consideration new locations.

Location analysis methods range from the qualitative to quantitative methods. Qualitative technique rating methods where stakeholders are encouraged rank specific locations based on their preference. Alternatively, the load distance, centre of gravity techniques can be classed as quantitative methods. The weighted factor rating method (WFRM) combines participant/stakeholder views on location factors weights and quantitative methods for the determination of potential locations. The WFRM is adopted for its mixed methodological orientation. The technique consist of five steps. In the first step, location factors are identified through a document review or through interviews, focus groups with the relevant stakeholders. In the second step, the relevant stakeholders are contacted and asked to rank the factors on a Likert scale of 1 to 5—one meaning least important and five meaning extremely important factor. In the third step, the ranked scores are translated to location factor weights by normalising the scores from a 1-5 scale to a normalised zero to one scale. In the fourth step, depending on the detail of the model, the region is segregated into city, town, or districts, and each assessed based on the factors and scored on a scale of 0-100. In step five, the weighted score for each location is determined by multiplying the respective factor weights by the location score. Potential locations are ranked and prioritised based on their weighted factor location scores. The details of the procedure for describing the study area across the network are provided in section 10.2.1 of chapter 10.

5.6.1.2 Step 2 - Optimise scenario-specific visions

In this step, the variable range for the quantifiable optimisation variables are identified from the visioning outputs. These ranges are used to create a boundary for each scenario optimisation model run. Other parameter values are extracted from the respective external scenario. Since the different external scenarios provide different parameter values, different optimisation models in line with the number of scenarios are set-up. The details of the procedure for optimising the scenario-specific visions are provided in section 10.2.2 of chapter 10.

5.6.1.3 Step 3 - Reflection on model results

This step represents an iterative loop from where the scenario specific optimisation solutions are presented to the stakeholders through a workshop setting for them to reflect upon. This step links to the “Planning for action stage” of the visioning choices where the implications of the scenario specific visions are presented to the stakeholders for reflection, revision, or commitment to action. The research team must present the solution clearly such that the planners can make an informed decision. It is believed that the stakeholders may choose to make amendments to their initial visions based on the outcome of the optimisation solutions presented. Such an informed decision will limit the risk of either overinvesting, underinvesting, funding the wrong set of projects, funding at the wrong time, and funding the wrong type of project. The procedure for reflecting on the model solutions by the stakeholders was not carried out in this research due to travel restrictions caused by the COVID- 19 pandemic.

5.7 Developing the OVAF multimethod

In developing an integrated OVAF framework, the researcher drew insight from Checkland and Holwell’s (1997) action research model. The model suggests that any research in any mode may be thought of as entailing the following elements: a framework of ideas “F” used in a methodology “M” to investigate an area of interest “A” (see Figure 5.7).

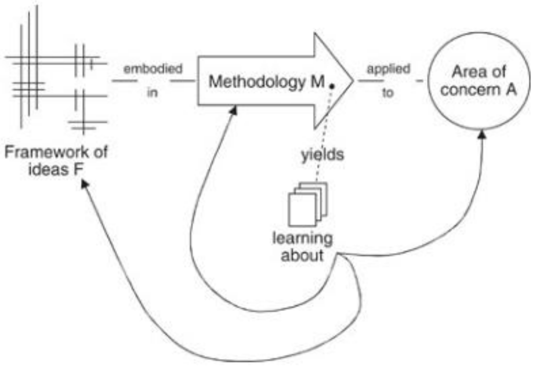


Figure 5. 5 Research framework

Relating the above model to this research, the 'framework of ideas', F, consist of the methods within the OVAF methodology. These methods include the external scenario development approach described in section 5.3, the MVCA described in section 5.4, the vision translation approach described in 5.5 and optimisation method described in section 5.6. Consistent integration of the methods will lead to the formation of the OVAF multimethod, M, that can be applied to an area of concern, A, which in this thesis is how the exploratory scenario, visioning and optimisation methods can be combined for the long-term planning for distribution network design contexts.

To decide what methods to include in the framework of ideas, the researcher was influenced by the context of the case study, which is the long-term planning for the Nigerian petroleum product distribution sector by the year 2040. Long-term planning for the later involves exploring the PPD sector business environment through exploratory scenario planning methodology described in section 5.3. Also, it involves the development of scenario-specific visions for the Nigerian PPD sector through the MVCA described in 5.4. The OVAF also involves the translation of the visions narratives through the narrative translation framework described in section 5.5, and the optimisation of the scenario-based visions for the Nigerian PPD sector to identify the concrete implications of the stakeholder visions. Therefore, an obvious starting point for the framework of ideas is to explore the external scenarios (section 2.3 chapter two); visions (section 2.4 of chapter two) and optimisation concepts (section 3.2 of chapter 3). Also, Chapter two and three have described the different methods for developing the scenarios, visions and for optimising have been addressed in section 5.3, 5.4 and 5.5, and 5.6 respectively.

5.7.1 Methods for Developing the OVAF

The literature review and synthesis method were applied for the development of the OVAF multimethod approach. Since the OVAF approach consists of external scenario, Visioning and optimisation methods, the researcher reviewed the multimethods development field in OR and foresight fields to provide insights to the methodology concepts and contemporary development in the integration of the methods. A search was also conducted using Google Scholar. The searches were made using the following keywords: "criteria" or "scenario planning' or "multimethods" or "integration"; "criteria" or 'visioning" or "multimethods" or "integration"; "optimisation" or "multimethods"; "criteria" and "facility location" and "multimethods". The search was limited to full-text articles in the English language published between 2010 and 2018. The search time frame aligns with Paniagua's suggestion of a maximum time frame of 10 years. The references of all relevant retrieved studies were also searched manually for additional studies.

Eighty-five journal articles met the set inclusion criteria of articles. The search focused on methodological integration within methods with similar or dissimilar paradigms. For example, the scenario studies which focused on the combination of scenario and Visioning methods with other qualitative participatory methods were identified. Similarly, studies which focused on the link between the scenario methods and analytic modelling methods were also identified. On the other hand, due to the broad nature of the mathematical optimisation field, the study focused on the location analysis studies which try to integrate methods from either the soft operational research group or other participatory methods.

The abstract and conclusions of the articles were read once to get a sense of what they are about and to ascertain whether it is worth further reading or inclusion. A structured preview, question, read and summarise (PQRS) approach was adopted. Under the preview stage, three groups of articles were identified, namely; i) multimethods within the foresight domain; ii) multimethods within the hard OR and PSM domains; iii) frameworks for integrating methods in the question stage, questions were asked of each publication. To ascertain the title of the article, the author, the purpose, the methodology used in the study, and the findings from the study. A summary system was used to process the selected literature. The researcher's thoughts about the contents of the articles are captured. Finally, to ensure proper record-keeping, the source and full reference and reference of each article were also included.

5.8 Evaluating the OVAF multimethod

A case study method was used to evaluate the OVAF approach. The case study was drawn from the Nigerian Petroleum Product Distribution (PPD) sector. The case study is selected on the basis that it provides a distribution network planning context characterised by a highly uncertain environment to be explored. Besides, the government, in collaboration with the key players in the energy sector, have echoed the need for proactive long-term planning for the sector. These players believe that such future exploration provides insights into crafting resilient strategies and facilitate an informed investment decision for the sector.

The case study is divided into four integrated case studies presented in chapter 6, 7, 8, 9 and 10. Each study represents the illustration of each stage of the OVAF approach.

In chapter 6, a background for the Nigerian PPD sector is provided. The network design structure is explained. The challenges affecting the sector are also discussed. In chapter 7, the external scenario approach presented in section 5.3.1 of chapter 5 is applied to develop external scenarios for the Nigerian PPD sector for the year 2040. Due to the busy schedule of the oil industry professionals, it was impossible to organise multiple workshops for the development of external scenarios and visions. In addition, the potential participants were willing to engage in a single workshop that spread over one or two days. Therefore, a pragmatic option was to develop the external scenarios through a desk approach and present the scenario results for discussion during the two-day Visioning workshop. The report for the external scenarios developed through the desk approach is presented in chapter 7.

In chapter 8, a visioning exercise was organised and implemented to develop scenario-based visions Nigerian PPD network by 2040. The MVCA presented in section 5.4 was adopted. In the first step, the steering team made up of the researcher, and two recruited researchers were formed. All preparatory activities suggested in step one and two of the MVCA were carried out. While the researcher anticipated an excellent response from the participants for the visioning workshop, some were interested in personal interviews for security reasons. Therefore, workshops and interview designs were used to develop the visions. The analysis of the visioning out was conducted, and this launched into the visioning translation stage. The report of the Visioning exercise is presented in chapter 8.

In chapter 9, the optimisation vision elements were translated into quantifiable elements that are suitable for optimisation. The qualitative elements were described using a causal loop diagram. The relationships between the elements were identified. Mathematical notation was used to represent the variables, and a generic optimisation problem was formulated. Finally, in chapter 10, the generic optimisation problem formulated in chapter 9 was broken down into four scenario related problems and solved using the scenario optimisation technique presented in section 5.5. The report of the translation and optimisation of visions are presented in chapter 9 and 10.

5.9 Reflecting on the case study results

A reflection of the research process is carried out to identify what worked well and what could be improved upon in the OVAF multimethod. The proposed reflective process draws on the arguments proposed in chapter 5 of this thesis. The arguments focus on the theoretical evaluation of OVAF's logical reasoning. It also seeks to answer the question: why was the process so designed?'. On the other hand, arguments address the success in implementation in achieving the anticipated benefits. Both arguments are drawn together in a set of suggestions for the further development of the methodology. The research reflections are presented in Chapter 11.

5.10 Summary of chapter

The methodology presented in this chapter fits with the aims of the research to contribute to how foresight visioning and optimisation methods can be improved through a consistent integration of the exploratory scenario, visioning, and optimisation methods.

The study deployed an action research framework to provide the opportunity for deep insights into the method development process, application, and reflection. While it is possible to combine methods in order to address complex problems, the associated challenges and limitations of such combination are imminent. Based on decisions made in this chapter, it is essential to explore the following questions; How can the vision outputs from a real-world planning problem be transformed into quantifiable elements? What are the outcomes and benefits associated with the development of stakeholder visions that are consistent with different external scenarios? What insights can be gained from applying a desk scenario approach in a case study? What are the potential benefits and shortcoming of the MVCA, the translation approach and optimisation of scenario specific visions?

It is expected that answers to these questions are identified from the studies carried out in chapters 7,8,9, and 10. A post- application reflection on the case studies carried out in chapter 11 will provide the answers to the questions and other aspects that require improvements. The table 5.3 presents a summary of methods options for use in the OVAF, and the selected methods applied in the case study.

Table 5.3. Summary of methods applied in the OVAF and case study

Long-term planning methods	Multimethods options to be included within OVAF	Method options within in the OVAF and applied in case study
Single Methodologies for long-term planning i) forecasting scenario (section 2.3) ii) stochastic optimisation (section 3.4.1) iii) robust optimisation (section 3.4.2) iv) problem structuring methods (e.g. soft systems methodologies and strategic choice approach (section 3.5.1)	Not selected	Not selected
Multimethodologies for long-term planning i) Integrated exploratory scenario, visioning and optimisation (section 4.5 and 4.6)	Participatory exploratory scenario (section 2.4.3.1), participatory visioning (2.5.1), and desk stochastic optimisation (section 3.4.1)	Not in OVAF
	Desk research exploratory scenario (section 2.4.3.2), participatory visioning(section 2.5.1), and desk stochastic optimisation (section 3.4.1)	Not in OVAF
	Participatory exploratory scenario (section 2.4.3.1), participatory visioning (2.5.1), and desk scenario optimisation (section 3.4.1)	Not in OVAF
	Desk research exploratory scenario (section 2.4.3.2), participatory visioning (section 2.5.1), and desk scenario optimisation (section 3.4.2.1)	Desk research using document content analysis for exploratory scenario development (section 7.2), participatory visioning for vision development using workshop and interviews, and scenario optimisation (section 9.2 and 10.2 of chapters 9, 10)

Chapter 6 – Background of the case study

6.1 Introduction

The previous chapter presented an account of the development of a novel multimethod that can be applied for long-term planning in distribution network design contexts. The multimethod was termed "Optimised Visions of Alternative Futures" and abbreviated to OVAF. The OVAF consist of four interconnected stages with each stage addressing different components of the long-term planning problem. This chapter presents an introduction and background to a real-life distribution network planning problem that will be used to test the OVAF approach. Figure 6.1 below provides an outline of this chapter.

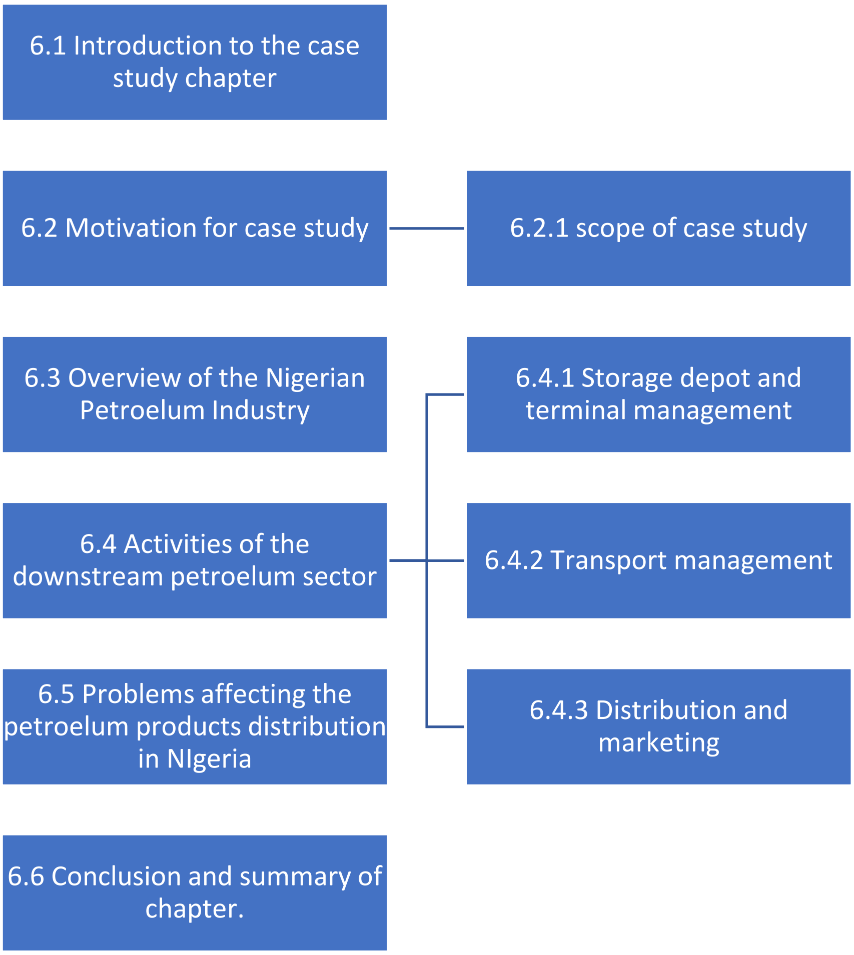


Figure 6.1 - chapter outline

6.2 Motivation for case study

The case study addressed in this research focused on the long-term planning for the Nigerian petroleum product distribution sector. The case is borne out the need to design an efficient network for the distribution of petroleum product in the south- eastern region of Nigeria by 2040. The relevance of this case cannot be overemphasised because of the strategic nature of the petroleum industry to the Nigerian economy. Kimani (2013) notes that the industry is pivotal to the survival of diverse essential services such as the manufacturing, health, transport, and technology. In addition, the sector provides substantial foreign revenue that accounts for 70 percent of the total GDP (Ehinomen and Adeleke, 2012). In addition, the Nigerian Minister of Petroleum highlighted the challenges faced by the sector as well as the impact of these issues on the social-economic activities (Ehinomen and Adeleke, 2012). The Minister in agreement with the leaders of the oil producing and marketing companies in Nigeria echoed the need for robust and resilient strategies that can withstand the influence of the uncertainties in the industry environment. These uncertainties exposes the national economy to severe setbacks (Ehinomen and Adeleke, 2012).

Several authors (Ehinomen and Adeleke, 2012; Kimani, 2013, Mohammed, 2016; Alaba and Agbalajobi, 2014, p.119; Okoli & Oyinda 2013, p. 68) have researched ways to improve the operations of the petroleum product distribution sector. However, no study has contributed to the strategy development for the sector by; developing external scenarios; developing stakeholder visions that are consistent with the different external scenarios and developing quantified visions that support backcasting processes. The is achieved in this research by applying the novel OVAF multimethod developed in chapter 5 to address all components of the long-term planning for the Nigerian petroleum product distribution sector.

6.2.1 Scope of case study

The scope of this case study centres around the strategic decisions for network design of the petroleum products distribution. These strategic network design decisions include where to site large storage depots or transhipment depots; how many depots should be opened, what capacities should these facilities hold, and what is the best mode for distributing products across the network. These decisions are long-term related, very expensive, and hard to reverse. Therefore, adequate attention must be given to such decisions.

The network design in the south-east region of Nigeria was selected as the focus of the study. The researcher’s choice of a region-centric optimisation was due to the unavailability of data for the different regions in the country. Therefore, the researcher focused on the south-east region because manually extracting the data for the south-east region was achievable given the duration of the research. In addition, the south-east region represents an integral component of the Nigerian PPD network because most distribution activities originate from the south-east region. Also, all large depot storage areas are positioned close to the refineries and jetties located in the south-eastern region.

It is important to highlight that the scenario-specific visions developed in chapter 8 addressed the requirements for a desired network design for the PPD network in Nigeria and not a single region. Therefore, the choice of a regional study provided a transparent link between the visioning outputs and the optimisation study. Figure 6.2 presents an extraction of the south-east region from the Nigerian map.

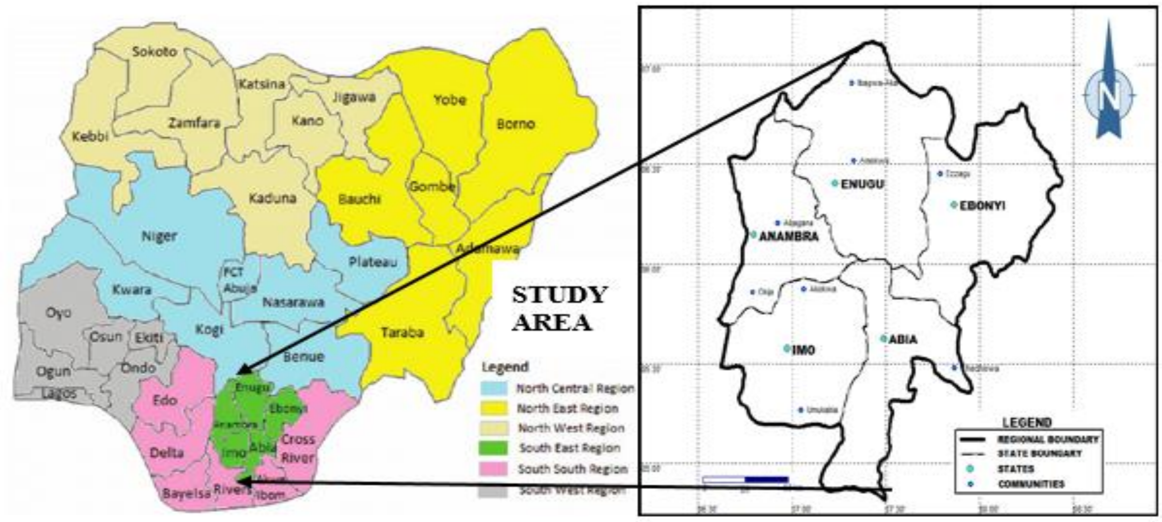


Figure 6.2 Optimisation study sub-area

The south-eastern region of Nigeria is composed of five states: namely, Enugu, Anambra, Imo, Ebonyi, and Abia. The region covers a total surface area of approximately 76,000 square kilometres (29,400 sq. mi). According to the National Bureau of Statistics (NBS, 2018), there are a total of 95 municipal LGAs in the region. There are 17 LGA municipals under Enugu state, 18 LGA municipals under Imo state, 13 LGA municipal under Ebonyi state; 21 LGA municipals under Anambra; and 17 LGA municipals under Abia.

6.2.2 Identifying stakeholders with an interest in designing an efficient distribution network

A stakeholder analysis was conducted to identify the different stakeholder groups that will take part in the visioning of the future of PPD sector in Nigeria. From the analysis conducted in section 8.2.2.1 of chapter 8, the stakeholder groups were: professionals from the major oil marketing and distribution companies in Nigeria; the National Oil Company; regulatory agencies in the petroleum industry; managers of retail fuel stations; academics with a research interest in petroleum products transportation, and leaders of petroleum tanker driver’s association.

Three gate keepers were approached through the Nigerian Petroleum Technology Development Fund (PTDF), recruited, and trained as potential facilitators for the visioning workshops. The gatekeepers are professionals actively working in the petroleum product distributions sector. Therefore, they had good understanding of the activities within the distribution sector of the oil industry. Besides facilitating stakeholder discussion sessions during the visioning workshops, the gatekeepers provided emails of 30 professionals from the different stakeholder groups. Email iinvitations containing the information sheet were sent to the emails of the prospective participants. Among the 25 participants that agreed to take part in the process, 12 of the professionals were willing to attend a workshop, while 13 of the participants opted for a one-on-one interview session. Consequently, an interview visioning design was implemented to complement the workshop.

Details on the procedure for identifying the participants from the groups can be found in section 8.2.2.1 of chapter 8.

6.3 Overview of the Nigerian petroleum industry

The petroleum industry is strategic to the economy of any country as it provides substantial economic flows and supports the transportation sector and other essential services. Globally, petroleum has remained the world's major source of energy and has contributed to the growth of world economies (Kimani, 2013). This is the case in Nigeria, as the petroleum industry has provided about 70 percent of the total energy consumption (Ehinomen and Adeleke, 2012). Based on the critical role of the petroleum industry in the development of any country, any challenge experienced by its sectors negatively affects the social-economic activities of the nation at large (Ehinomen and Adeleke, 2012).

The Petroleum industry in Nigeria is generally categorised into the upstream and downstream sectors. The upstream sector consist of activities such as crude oil exploration, production, transportation, drilling operations, geological activities amongst others (Ehinomen & Adeleke, 2012). The downstream petroleum sector consists of the supply and distribution of refined petroleum products from production plants (i.e. refineries) to transhipment depot and finally to the end-consumers. Donwa et al. (2015) state that these refined petroleum products are transported through a combination of pipelines, rail, road, and sea to retail outlets where consumers across wide geographical locations can acquire these products to meet their energy demand. This suggests the need for adequate storage facilities and efficient distribution networks for an effective supply chain for petroleum products. The next section will provide description of the components of the downstream distribution sector in Nigeria.

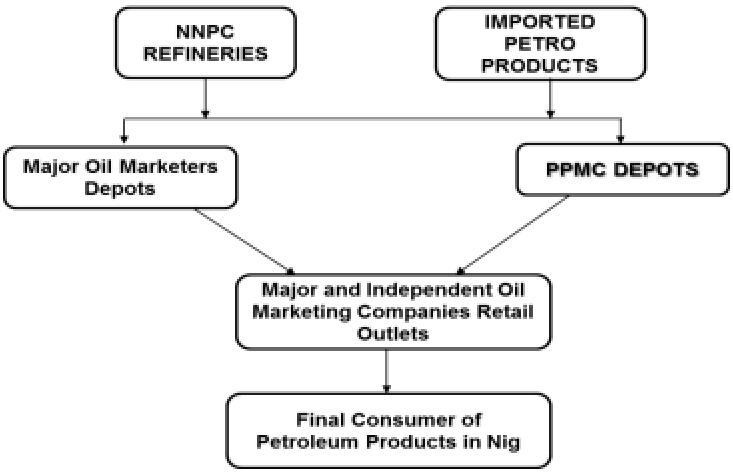


Figure 6.3 The physical flow of products in the Nigerian PPD sector (Source: Adapted from Kabir, 2016)

According to the figure 6.3, in the Nigerian downstream sector, petroleum products are either imported through the import petroleum jetties located along the coastal regions or refined locally at the refineries. The refined petroleum products are received and stored at the major oil marketers' depots or the petroleum product marketing company (PPMC) depots. These products are then distributed through the major and independent marketing company retail outlets to the final consumers of the products.

6.4 Activities of the downstream petroleum sector

The activities within the Nigerian downstream petroleum sector includes supply or trading of crude oil, transportation of crude oil, refining of crude oil, the distribution of the refined petroleum products; and the use of refined petroleum products by consumers (Santos-Manzano, 2005). The highlighted activities are structured into two broad supply chain components, namely: the refining supply chain (procurement and refining of crude oil); and the distribution supply chains (Balasubramanian et al., 2010). These components will be described in following subsections.

The refining supply chain of the downstream sector initiates with the process of converting the crude oil into useful petroleum products for use by the consumers and the petrochemical industries. (Rusinga, 2010, p.11). The refineries are large-scale production plants usually set up close to major markets with complex processing facilities. In Nigeria, the refineries are located close to the source of crude oil in the coastal area of the Niger-Delta region with one refinery located up north to facilitate distribution of products to this area. Some of the major petroleum products from these refineries include: premium motor spirit (petrol or gasoline), automotive gas oil (AGO or diesel), dual purpose kerosene (DPK), aviation turbine kerosene (ATK or jet-A1), liquefied petroleum gas (LPG), industry fuel, bitumen and base oil (Ehinomen & Adeleke, 2012).

The distribution supply chain ensures that the refined petroleum products are distributed to the final consumers. In Nigeria, oil marketing companies usually procure the refined products from the National oil company and transport the required amount and quality of petroleum products to storage facilities near the customer markets. Balasubramanian (2010) explains that for products to be effectively distributed across the network, planning activities such as forecasting, optimization of the distribution network, and the replenishment planning and scheduling must be carried out. These activities are briefly described below.

- **Demand forecasting** - This is the process of determining the quantity of each product to be distributed to the various customer markets (Pienaar, 2010). The knowledge of the demand levels are very essential for the operational planning of the distribution process. Also, insights from the demand forecasting is necessary to optimize the refining operations from months to months (Balasubramanian, 2010, p.3). Demand forecasting also helps the logistics management personnel to determine the demand levels in order to make products available in the right quantity, at the right place and at the right time (Pienaar, 2010, p. 228).
- **Optimization of the distribution network** - This consists of distribution plans that facilitate the efficient transportation of petroleum products from the point of refining through the different transhipment storage locations to the consumers in the supply chain network. The optimisation of transportation and location decisions within the network are essential elements of distribution decisions for achieving seamless product delivery to customers (Balasubramanian (2010, p.4).
- **Replenishment planning and scheduling** - This involves the replenishment of the petroleum products at retail outlets. Two issues that affect product retail outlets are: product stock-outs and retains (holding a loaded truck until there is ullage in the retail station's storage tanks) (Balasubramanian 2010, p.4). The effective planning and scheduling of replenishments for retail stations not only prevents the stock-out situations, they also help to optimise product distribution, thereby reducing the cost of road haulage.

In the downstream sector, refined products are either stored at terminals after production or transported across the network. Therefore, a description on the storage depots operations, and product transportation operations will be provided in sections 6.4.1, and 6.4.2 below.

6.4.1 Storage depot and terminal management

The storage depots and terminals are places where petroleum products are stored for a period. Storage depots are located close to the refineries or jetties to hold products that have been refined or imported into the country. These are designed to hold large volume of products for a given period. Another type of storage depot are the transhipment depots that are strategically located in the country. The transhipment depots ensure products are distributed effectively to different parts of the country. They are usually are situated close to transportation hubs and markets to facilitate products movement (Adendorf et al, 2012).

Figure 6.4 shows the location of the refineries and depots located on the map of Nigeria.

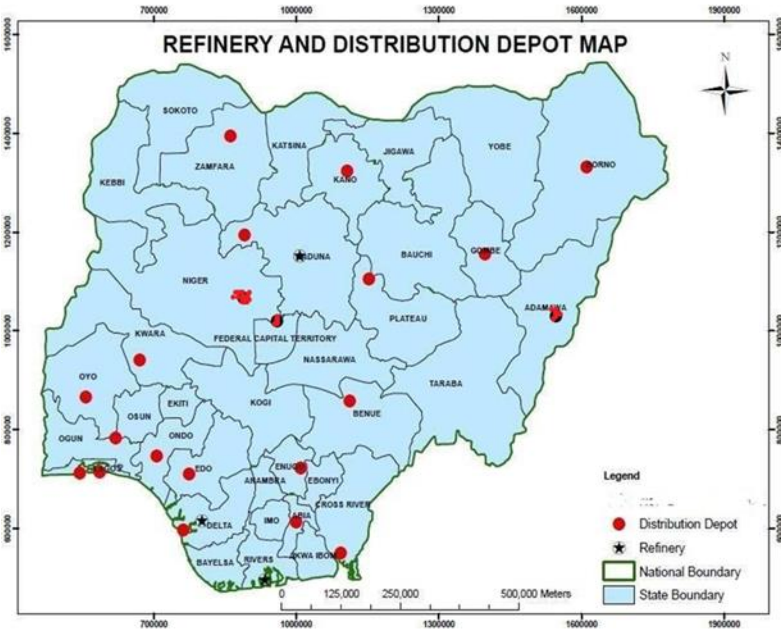


Figure 6.4 The Nigerian refinery and distribution depot map. (Source: PPMC, 2017)

According to the figure 6.4, the red dots represent the transhipment storage depots, and the black stars represent the refinery locations. There are four refineries situated in the Nigeria. Three of the refineries are situated at the coastal regions (Rivers and Warri) in southern part of Nigeria. Another refinery is at Kaduna in the North central region of Nigeria. The refineries operate with an installed capacity of 445,000 barrels per day. There are two offshore jetties, four inland jetties, and over 90 tank farms with different storage capacities to cater for domestic consumption of refined petroleum products (Alaba and Agbalajobi, 2014, p.119). In addition, there are networks of 5,120 kilometres of pipelines, 23 transhipment depots, and 24 pump stations fitted along the network to support the product distribution along the pipeline network (Alaba and Agbalajobi, 2014, p.119; Okoli & Oyinda 2013, p. 68).

6.4.1.1 Storage depot operations

The activities that take place at a storage depot can be grouped into three categories: product allocation; accountability and payment, truck calling and loading. In terms of product allocation, based on the capacity of a particular depot, the operational planning team prepares a daily or weekly product allocation for all the marketers using the pipelines and products marketing company (PPMC) management allocation. Under an ideal situation, the allocation of products to the marketers should be based strictly on daily/weekly programme. However, when there is limited product availability of refined products, the depot manager coordinates with depot sale supervisor, major marketers, independent marketers in the distribution chain to ensure that the allocation is propagated accordingly. The sales supervisor shall process and approve ticket allocated by the co-ordination committee.

Once the allocation activity is complete, the accountability and payment for the products allocated to the marketers starts. Two methods of payment used are the credit or the cash and carry method. All licenced independent marketers enjoy credit facilities, most independent marketers are in cash and carry basis. Those enjoying credit facilities simply secure their meter ticket for loading when they have completed the necessary forms which must be approved by the depot manager and depot accountant. Their ticket will be ready for loading when it is finally approved by the sales supervisor. After loading, the accounts department will bill them for the quantity of product loaded with a particular ticket. Payment is usually on bank draft which must be within one month from the date of loading. On the other hand, the cash and carry marketers, payment for their products are through the sales department with a bank draft. The sale department will raise for such marketers a form called DO7 in which the type, quantity, and the corresponding amount of product which such company is paying for. Then the meter ticket to the accounting department for onward payment to the Central Bank of Nigeria. After clearing from the bank, such marketers will be allowed to leave her location with such meter ticket for products allocated to them.

The loading process commences after payment for allocated of products is completed. Based on daily plan, petroleum product marketers with existing allocations and payment tickets submit their meter ticket for the day’s loading. The sales supervisor at the depot approves the ticket and forwards the meter ticket to the computer supervisor who will process the ticket and send to the trunk entry gate. Trucks are allowed entry into the loading terminal strictly based on the lifting list prepared for the day’s operations. Any trunk that is not available when called to misses its turn due to late arrival shall lose its turn and proceed to the bottom of the list.

6.4.2 Transportation management

Transportation management is important for the effective distribution of petroleum products. This is true because oil refineries all over the world are usually situated far away from the market (Obasanjo, Francis & Williams, 2014). Therefore, transportation is required to ensure the refined products are transported from the point of production to the point of use (Obasanjo, Francis & Williams, 2014). Different modes of transportation can be used for the movement of products from the refineries to the storage depots. Thee modes include pipelines, road transportation, water transportation and rail transportation. Ehinomen and Adeleke (2012) opine that the pipelines mode is suitable for the transportation of liquid substances and hence widely utilised for the transportation of petroleum products. They further explain that the road transportation is a fast and effective means to distribute petroleum products. Also, the latter mode compliments the pipeline mode of transport. However, the road mode of transport is expensive as compared to the pipeline mode. The road mode of transport is also face by countless disruptions since it is not as regulated as the pipeline mode. The water mode of transportation is mainly utilised in the upstream sector for the transportation of crude oil. It is cheaper to transport large quantities of products through the water mode because of it is cheaper when compared to the road and the pipeline.

6.4.3 Distribution and marketing

Distribution and marketing is that component of petroleum products distribution supply chain that is deals with the movement of the refined products from terminals at the refinery to consumers. These products are either sold in bulk or in small quantities to the customers. "Wholesale distribution and marketing" involves the sale of petroleum products in bulk to the customers such the power plants, airlines, transport companies and manufacturing companies. Retail "distribution involves the sale of products in small quantities to retail outlets. The retail stations can either be branded or unbranded. Branded retail stations operate under the brand name of a major marketing company. On the other hand, the unbranded retail stations are operated by private operators in the oil industry. They are not affiliated with any of the major marketers. For most of the branded retail station operated in Nigeria, they can be categorised based on the asset ownership and management of station operations. The ownership structures include company-owned - company-operated, company-owned - dealer operated, dealer-owned - dealer operated, dealer owner - company operated, and independent (Manzano, 2005).

6.5 Problems affecting petroleum products distribution in Nigeria

Different authors have commented on the challenges experienced by the Nigerian downstream petroleum sector (Ehinomen and Adeleke, 2012; Mohammed, 2013; Donwa et al., 2015; Kabir, 2016;

Ode et al., 2019). Analysis of the documents revealed that the PPD sector is affected by the following problems.

i) inadequate supply of refined products.
ii) dysfunctional and insufficient refineries.
iii) insecurity leading to pipeline vandalism.
iv) fuel importation constraints.
v) drop in global oil prices.
vi) poor import planning schedule.
vii) Corruption, diversion, smuggling.

In the case of inadequate supply of petroleum products, the unavailability of petroleum products at retail stations is caused by the limited or inadequate stock availability of poor forecasting measures leading to products not replenished in the right time. Kabir (2016) questions the data integrity of the national oil company, stating that lack of data on the actual volume of product demanded in limits the effective replenishment of stock levels to retails stations to serve the consumers. The author notes that all agencies responsible for the documentation of supply and demand of petroleum products provide widely varied data on the national daily consumption levels. The national oil company and the Petroleum Products Pricing Regulatory Agency (PPPRA) suggest that daily consumption range between an average of 45 and 60 million litres per day, while the other industry figures suggest that consumption range between 30 and 35 million litres. This disparity in accounting for product usage significantly impacts the planning for supply of products across the downstream distribution network.

The challenge of dysfunctional and insufficient refineries strongly limits the efficiency of the PPD sector in Nigeria. According to the NNPC Report (2016), 445,000 barrels of crude oil allocated for domestic refining daily by the refineries (Port Harcourt, Warri, and Kaduna) in Nigeria. However, even at 100% operational capacity, the maximum 10 to 12 million litres can be refined by the operational refineries. The latter is approximately less than 25% of the actual daily demand documented by the national oil company. Despite the funds invested in the overhaling or maintenance of the refineries, the refining system has remained dysfunctional. Consequently, the poor conditions of the refineries, products supply capacity remains low leading to the scarcity of products. This unfortunate tale may have been different if the government or private investors in the oil industry had invested in new refineries at large or modular scales. Ehinomen and Adeleke (2012) notes that none of the 18 licenses awarded to private operators have resulted in a new refining facility.

While it is clear from the above that the refining capacity of Nigerian refineries cannot meet the demand from the country, the strategy by the government to make up for the demand through the importation of refined products has not been a smooth ride. Kabir (2016) highlights that the industry struggles with the constraints with the importation of refined products from oversea suppliers. Due to the international trade issues beyond the control of the Nigerian state, the process of importing refined petroleum products are subject to the myriad of forces at the international oil market. For example, a rise in the price of oil at the international scene directly affects the prices of products petrol at retail stations in Nigeria. This is the case as the oil price also controls other economic drivers such as the cost of transport, handling, depot maintenance. The resultant effect the latter challenge is the increase in the official landing cost of petroleum products from international suppliers. Government's effort to subsidise the landing cost of products means that a huge amount of money are paid to the product importers, and the poor accountability of the required demand for the nation opens up a channel of corruption for the oil industry looters. Successive governments have inherited accumulated debts that have been difficult to offset. Since the subsidy has become an unattractive strategy for the government, the discontinuity has led to higher product price, lowered supply, and scarcity.

The challenge of insecurity has ravaged the Nigerian PPD leading to the constant vandalism of oil industry infrastructure (Kabir, 2016). This challenge is strong tied to the dissatisfaction expressed by the youths of the oil producing communities over the lack of government development effort in the regions despite its contribution to the national economy. Nwogwugwu (2012) opines that the inability of the government to address the need of these communities has triggered the uncontrolled destruction of petroleum pipelines, and sometimes the kidnap of industry workers for ransom. In the case, where the refineries are working at full capacity, their performance are strongly impacted by the availability pf services and the state of the facilities (Kabir, 2006). The National oil company notes that its biggest challenge and uncertainty is to curb the destruction of oil pipelines as this drastically reduces the supply capacity to the consumers on a daily basis leading to scarcity of products. The national oil company comments that over the last decade, there has been approximately about 16,083 reported breaks in the network of pipelines along the network. 80% of this acts were carried out by vandals, while 20% were due to system or poor maintenance issues. Despite punitive measures put in place by the government of the day, this menace have continued to affect the industry.

The unstable price of oil at the global scene has also had a major impact on the Nigerian PPD sector. With prices of the Brent crude dropping to an all-time low of $25 per barrel in 2015, the landing cost of the refined products drops below the official pump price set retail stations, necessitating the product marketers to refund the government. The pricing mechanism “modulation mechanism provides an automatic adjustment that regulated retail price of fuel at the pump against the movement of prices at the international crude oil market to minimise or eliminate subsidy payment” (Kabir, 2016). Since the major and independent marketers constitute majority operational asset of the sector, their withdrawal from the importation responsibility, leaves the national oil with extreme responsibility to import products or refine products that will meet the demand of the country. Due to their low capacity utilisation and poor maintenance culture, the burden would be too much a problem for the national oil company.

The poor import planning schedule of the national oil company has resonated its negative effects of the sectors. Attention has been drawn to the poor planning ability of the national oil company in the advanced planning and monitoring of the refined product stock of fuel at the storage depots all over the country. It is expected that the apex organisation should know when products would run out and ensure that fresh orders are placed within the right cycle time to replenish the depleted stock. Even when product demand pressures arise in the system, there is need for contingency plans to ensure that product short falls are covered. The Minister for Petroleum echoes that the political and insecurity related uncertainty has opened up avenues for constant pressure through panic buying on the demand end of the petroleum supply chain. However, the poor planning measures of the national oil company have not kept up with the changing patterns in the system. The latter has constantly left the system in state of unpreparedness for the dynamics of the industry macro-environment.

The issue of corruption in the petroleum industry is prevalent in the petroleum industry in Nigeria. There is widespread case pf product smuggling and diversion by officials to diverts products allocated to specific depots. Ehinimen and Adeleke (2012) explains that petroleum products subsidised by the government and meant to be supplied to the customers are hoarded and stored in large underground tanks to create artificial scarcity. The scarcity results in the increased price of products. In some situations, these product are smuggled out of the network to neighbouring countries to be sold at higher prices. The Minister of Petroleum in a media briefing confirmed that in an operation period in 2016, about 30% of products allocation destined for different parts of the country are diverted to neighbouring countries like Chad, Cameroon, Togo, and Benin republic. While The national oil company had taken measures to curb such sharp practices by publishing the daily trucks out from depots, such a measure has not deterred the perpetrators of such nefarious activities. Kabir (2016) unravels from an undisclosed source that products are supplied to the marketers at about 20% above the official depot rate. These marketers in turn divert their products to the remote locations where they can sell the products at over 100% profit at the expense of the original consumers in the network.

6.6 Conclusion and summary of chapter

This chapter sought to provide background literature relevant to the Nigerian PPD Sector. The petroleum industry supply chain is complicated; so is the downstream petroleum sector which consists of a long chain of activities beginning with the refining chain all through to the petroleum products retailing end of the distribution chain. Also, the analysis of the review of Ehinimen and Adeleke (2012) and Kabir (2016) has provided insights to the challenges experienced by the PPD sector in Nigeria. Based on the knowledge of some of these problems that have crippled the sector, the next option is to plan towards the future to ensure that the ugly incidents of the past is not observed in the future. For this reason, the subsequent chapters 7, 8, 9 and 10 of this thesis will focus on the long-term planning for the future of the Nigerian PPD sector.

Chapter 7 - Exploratory scenarios for the Nigerian PPD sector by 2040: a desk research approach

7.1 Introduction

The previous chapter introduced the case study being conducted in this research. The chapter addressed the motivation and the scope of the case study. Other sections of the chapter provided a background information on the Nigerian PPD sector. It described the PPD sector as a key component of the oil industry. Also, the chapter described the existing PPD network design and the challenges faced by the network. The chapter concluded by stressing the need for planning for the future of the Nigerian PPD network. Therefore, this chapter initiates with the application of the stage 1 of the OVAF multimethod developed in section 5.3 of chapter 5. The stage 1 focuses on the development of quantified external scenario specifications for the Nigerian PPD sector for the year 2040. The external scenarios address the sector's external environment with an aim to identify the plausible futures that are likely to influence the PPD network operations in the future.

With these comments in mind, the following research objectives are pursued to achieve the aim of the study:

1. To identify the focal issues and driving forces in the Nigerian the PPD sector.

   This objective is linked to the first and second step of the exploratory scenario approach described in section 5.3.2.1 and 5.3.2.2 of chapter 5, and the results are presented in section 7.3 and 7.4 of this chapter respectively.

2. To identify the critical drivers influencing the Nigerian PPD sector.

   This objective is linked to the third step of the exploratory scenario approach described in section 5.3.2.3 of chapter five, and the results are presented in section 7.5 of this chapter.

3. To develop a set of quantified plausible external scenarios that are likely to occur in the Nigerian PPD sector environment by the year 2040.

   This objective is linked to the fourth and fifth step of the exploratory scenario approach described in section 5.3.2.4 and 5.3.2.5 of chapter five, and the results are presented in section 7.6 and 7.7 of this chapter.

4. To provide a set of external scenario narratives that can evoke the stakeholder reactions on the future direction for the Nigerian PPD sector by the year 2040.

   This objective is linked to the sixth step of the exploratory scenario approach described in section 5.3.2.6 of chapter five, and the results are presented in section 7.8 of this chapter.

In the subsequent sections of this chapter, section 7.2 describes the procedure adopted for developing external scenarios for the Nigerian PPD sector in 2040. Section 7.3 to 7.8 documents the results for each step of the exploratory scenario approach. Section 7.9 provides a discussion of the results and implications of the external scenarios for the Nigerian PPD sector by 2040. Section 7.10 provides the conclusions drawn from this study.

7.2 Application of exploratory scenario approach (OVAF Stage 1)

This section provides a description of the procedure employed in the case study for the development of the scenarios. The section is structured according to the steps for developing external scenarios presented section 5.3.2 of chapter 5.

7.2.1 Step 1- Identify focal issue(s)

In this case study, a document analysis method was utilised to identify the focal issues in the Nigerian PPD. This method was useful because it was less expensive and did not require engaging face to face with the industry stakeholders. In order to conduct the document content analysis, oil industry bulletins, media briefings from captains in the Nigerian oil industry, and articles that focus on the challenges of petroleum industry in last 10 years were identified for analysis. The focal issues identified through document analysis were validated through telephone interviews held with three senior professionals in the oil industry. in January 2017. The professionals were selected through a purposive sampling technique and based on their availability to take part in the telephone interview discussion. List of focal issues and source literature can be found in appendix 1.

In addition, the purpose of the scenario study was three-fold; the first was to develop future scenarios that would evoke a debate among the Nigerian oil industry stakeholders and experts on the likely eventualities that could affect their operations in the future. Secondly, the external scenarios will serve as a framework for the development of visions for a desired PPD network Nigeria. Third, the quantified scenario specifications will provide projected values for the uncertain network design parameters under different scenarios. Due to the strategic nature of network design decisions (i.e. expensive and fixed nature of the PPD infrastructure) a 25-year time horizon was selected for the study.

7.2.2 Step 2- Identify driving forces of change

Just like in step 1, a document content analysis technique was employed to identify the driving forces affecting the petroleum products distribution. Documents published between 2010-2017 were reviewed and analysed. Keywords for document search were "driving forces for petroleum product distribution"; "influencing forces to petroleum products transport", "driving forces influencing freighting", "force influencing future of logistics" and "driving forces influencing bulk goods distribution" and "future of freight transport. The search through google scholar electronic database resulted in the initial identification of 125 documents. After skimming through document title and abstracts, 46 documents and materials were suitable for use in the analysis. The 46 documents were read, and words or group or sentences reflecting a specific driver were coded and categorised according to the STEEP technique suggested by Blanco and Moudon (2017) and described in section 2.4.3.2 of chapter two (see appendix 2).

A data corpus was created from the documents which focused on the issues affecting the petroleum product distribution sector in Nigeria, and globally. The documents were imported into the Nvivo 11 qualitative data analysis software. A deductive coding method was adopted because the driving forces will be coded according to the social, technological, economic, environment, and political categories. Each of the 46 documents were scanned for words or group of words which represent the driving forces of change, and the identified drivers were coded under each STEEP category. In addition, to preserve the quality of the analysis, the researcher revised the coding process at different stages to ensure that a manageable number of codes were identified.

7.2.3 Step 3 - Identify key uncertainties (critical uncertainties)

A judgemental technique was adopted for the identification of critical drivers. The researcher consulted two Nigerian based doctoral researchers over a period of three months to select the key uncertainties affecting the Nigerian PPD sector from the list of driving forces affecting PPD identified in step 2. To achieve the later, the team reviewed the world energy outlook for Nigeria (EIA, 2017); the Nigerian Oil Industry Outlook Report (Pwc, 2016); and the Central Bank of Nigeria downstream sector report (CBN, 2015). Based on the insights from these documents, the team ranked all the driving forces of change identified in step 2 on a scale of 1-5. "1" meaning least impact or uncertain and "5" meaning most impact and uncertain. The scores allocated to each driver by each of the researchers were averaged to determine an average impact and uncertainty score for each driver. The two critical uncertainties with the highest mean scores were selected for scenario construction (see table 7.1).

7.2.4 Step 4 - Construct future scenarios

The four-quadrant matrix method (FQM) was used to construct the external scenarios. The FQM was selected because it uses two key uncertainties and two axes to portray the extents the events that are likely to occur in the future. Two critical drivers were selected to ensure the development of a manageable number of well-contrasted external scenarios. The two critical drivers were placed on the axes in a cross formation of four possibility quadrants with different characteristics. Using more axes runs the risk of making the results complex, hard to visualise, hard to interpret with lesser contrast between the scenarios. The resulting double uncertainty matrix and four scenario outlines are shown in figure 7.6.

7.2.5 Step 5 – Quantify scenario drivers

The drivers under the external scenarios were categorised into quantifiable and non-quantifiable drivers. This is to demarcate the already quantitatively defined factors (e.g. global oil price) from the qualitatively defined drivers (social and political drivers). The values of each driver under the different scenarios were generated from projections provided in existing future outlook documents. These documents include: i) World Bank future outlook report for 2040 (World Bank, 2016); the US Energy Information Association future outlook for 2050 (US EIA, 2016); The United Nations, Environmental Protection Agency projections for 2050 (UNEPA, 2016); The International Monetary Fund future outlook report (IMF, 2016), and the Organisation of Petroleum Exporting Country future outlook for 2040 (OPEC, 2016). Where explicit projections do not exist for drivers, values were determined based on the minimum or maximum historical evidence. The values of the drivers in 2016 was used as the reference values, and some of the values were represented as plausible percentage changes from the reference state values in line with the scenario logic.

7.2.6 Step 6 - Communicate scenarios and its implications

While the external scenarios could be communicated using the visualisation, drama or narrative techniques as described in section 5.3.2.6 of chapter 5, the narrative technique was used to tell a concise and captivating story of the developed scenario snapshots. This technique was used because it is commonly used to convey the ideas behind the external scenarios. These narratives represent the short stories of the events that may occur under different scenarios. The stories captured the quantified contents, which were concisely presented to evolve stakeholder reaction during a vision development exercise.

7.3 Result for step 1 - Focal issues affecting the Nigerian PPD

The focal issues in the PPD sector in Nigeria were first drawn from the analysis of the literature on problems affecting the Nigerian PPD reported in section 6.5 of chapter 6. Among the highlighted issues, the issues re-echoed by professionals during an informal interview discussion were: i) insecurity of products at storage points and on transit; ii) scarcity of petroleum products for users; iii) the low capacity underutilisation of the local refineries, and v) the unstable price of Brent crude in the global market (see appendix 1 for the factors and associated references).

Having identified the later issues, the focal question addressed was "*what are the likely futures that the PPD sector can encounter in the future*? The latter question provided the scenario study purpose that was to develop plausible future scenarios that could affect the Nigerian PPD network operations by the year 2040. Due to the longevity, expense, and fixed nature of the PPD infrastructure investments, a 25-year time horizon was selected leading to a time window between the year 2016 and 2040.

7.4 Result for Step 2 - Driving forces of change in the Nigerian PPD sector environment

A total of 22 driving forces were identified from the analysis (see appendix 2). The driving forces were categorised into the social, technological, economic , environmental, and political (STEEP) themes. The code reference was used to represent the frequency of the codes within documents. A higher code reference indicates a higher occurrence of the code in the specific document. A total of 164 code references were generated from the analysis of the 45 documents. The percentage of each driving force was determined by dividing the code reference for each driving force by 164 (the total number of code references). Also, the percentage of each STEEP category was determined by dividing the sum of the code reference in a STEEP category and later multiplied by 100. This gave an indication of the strength of each STEEP category amongst others (see appendix 9 for code summary sheet)

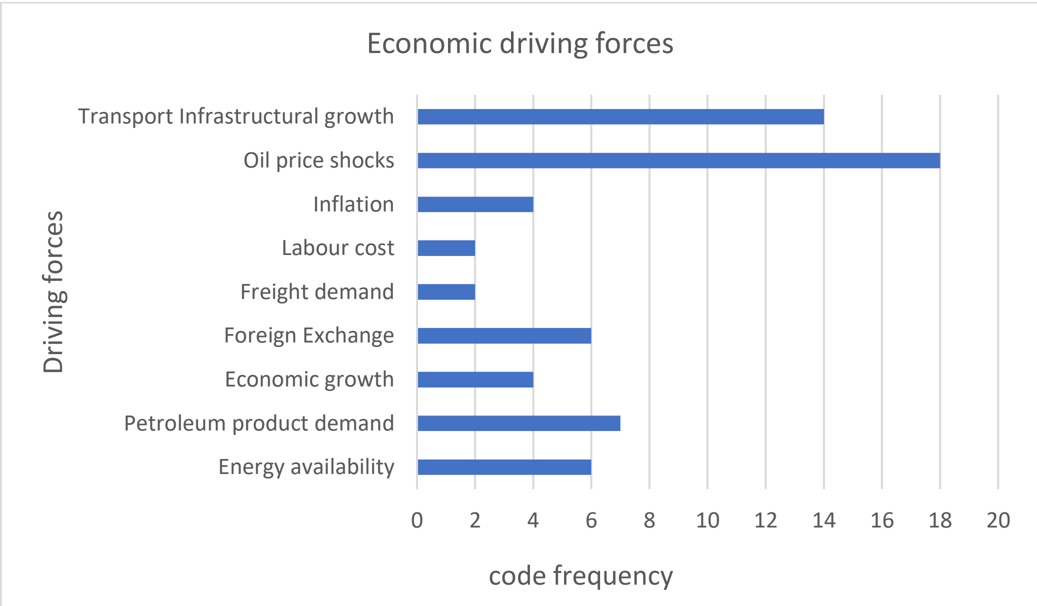


Figure 7. 1 Chart of economic driving forces

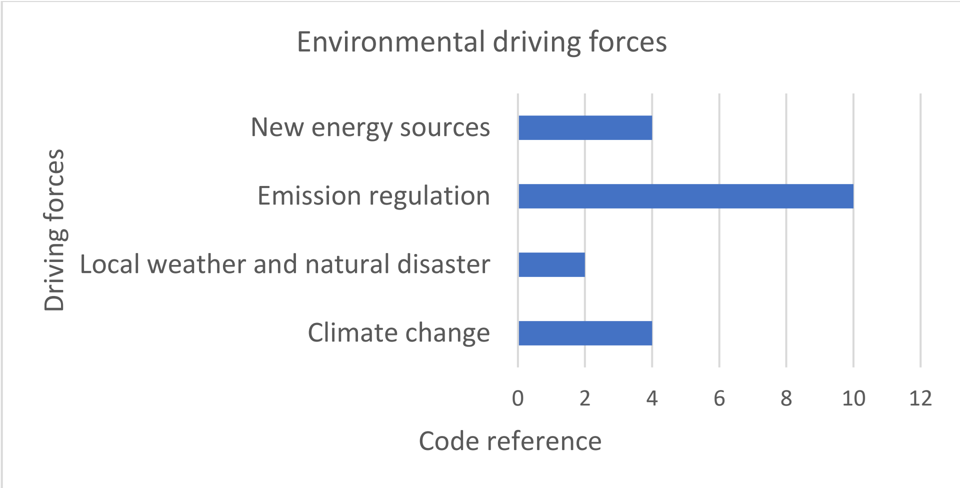


Figure 7. 2 Chart of environmental driving forces

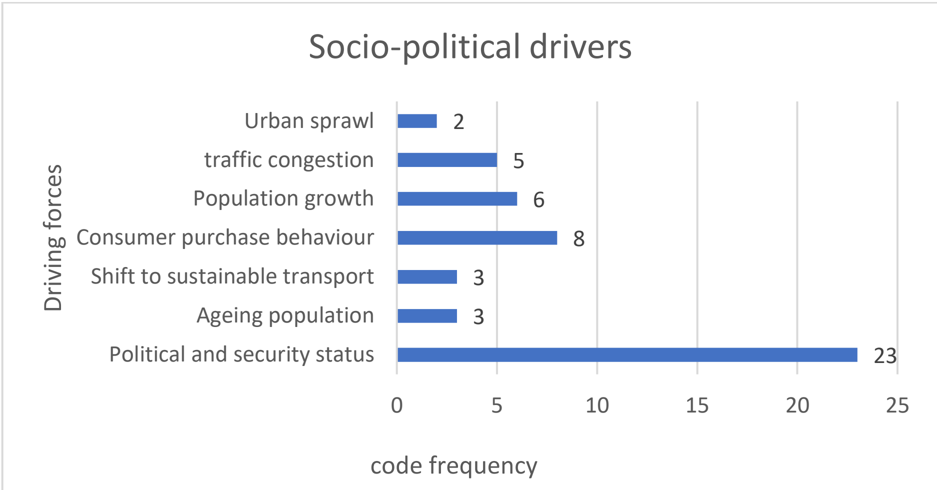


Figure 7. 3 Chart of socio-political driving forces

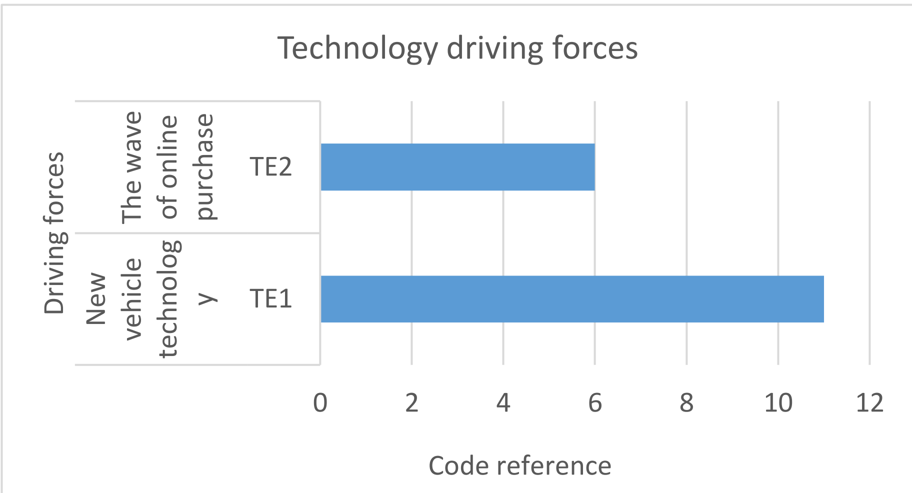


Figure 7. 4 Chart of technology driving forces

Figure 7.1 to 7.4 above provides a detailed analysis of the STEEP categories from the result, 14% of the driving forces were related social drivers; 16% were technology-related drivers, 43% were economic-related drivers; 12 % were environmental related drivers, and 15% were political-related drivers. A code reference was used to reflect the frequency of a particular driver. Figure 7.1 captured the drivers coded under economic theme. Under this theme, the energy availability was mentioned in documents with a code reference of 9%; Petroleum product demand was highlighted with a code reference of 0.7%; economic growth with a code reference of 7%; foreign exchange rates with a code reference of 10.5%; global financial crisis with a code reference of 3%; increased freight demand with a code reference of 5%; increased labour cost in Asia with a code reference of 2%; inflation with a code reference of 5%; oil price shocks with code reference of 30%; growth of transport infrastructure with code reference of 22.8%.

Figure 7.2 captured the drivers coded under the environmental theme. Under this theme, the global climate change was mentioned with a code reference of 7%; changing weather conditions, 7%; emission regulation, 71%; renewable fuels, 15%. Figure 7.3 captured the drivers coded under the social theme. Ageing population which constituted 27% of drivers coded under the social theme; switch to sustainable travel modes represent 1%; changes to consumer purchase behaviour constitute 36.3%; the adoption of new renewable energy sources constitute 1%; and population growth constitutes 18.2%. Also, under the political theme the study identified, political and security atmosphere, new transport policies as the political drivers with 92% and 8% code references respectively. Finally, figure 7.4 captured the drivers identified under the technology theme. Under this theme an integrated distribution network system had a 35.6% code reference; new vehicle technology had a 47% code reference; and the wave of online purchases with a code reference of 18%.

7.5 Step 3 - Key uncertainties influencing the Nigeria PPD sector

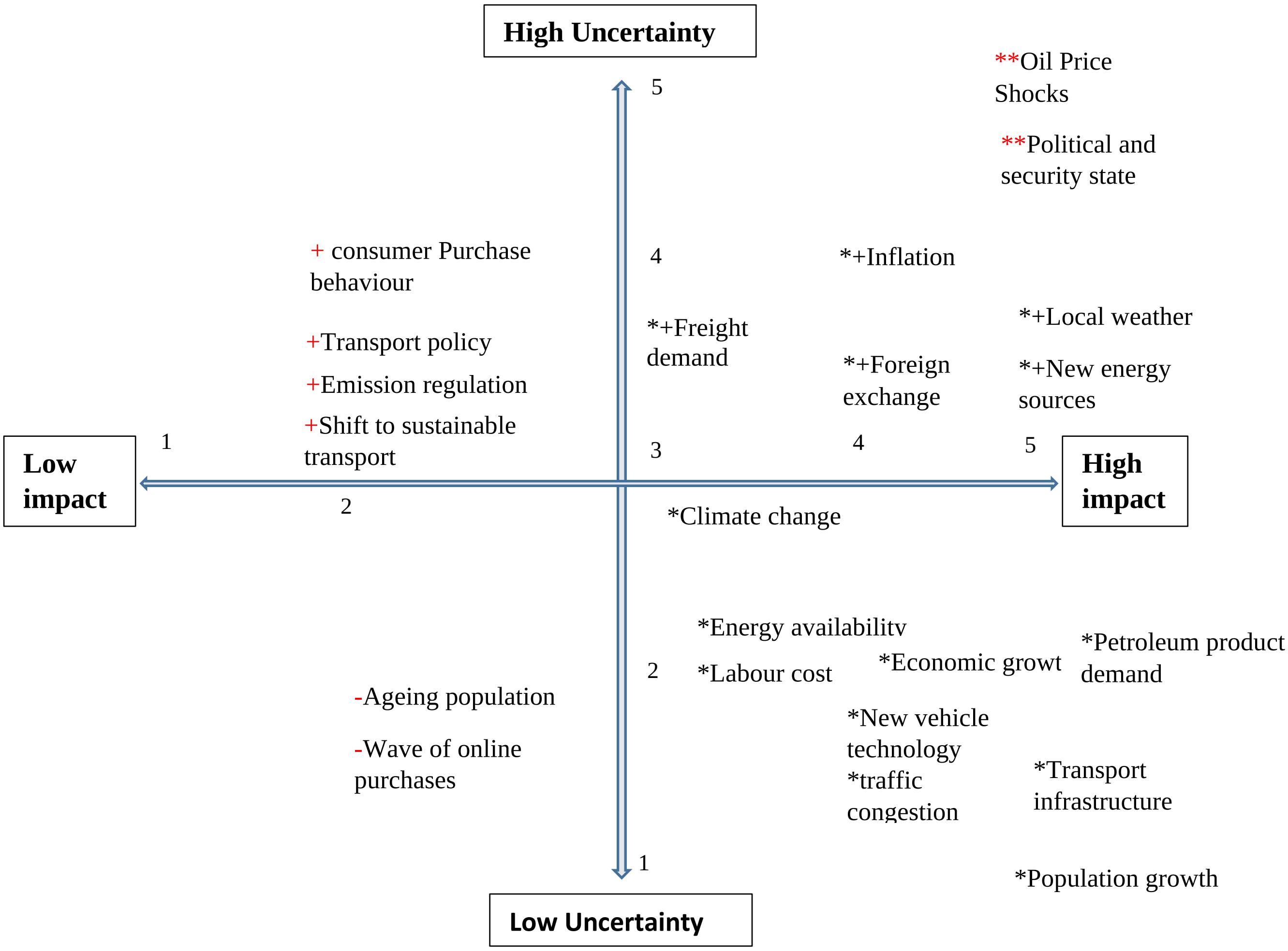
This section presents the result of the ranking of the driving forces of change for the identification of key drivers affecting the Nigerian PPD sector. Table 7.1 shows the scores allocated to the driving forces of change during the ranking of the drivers by the researcher and two consulted professionals. The mean impact and uncertainty score for each driver was determined and presented in columns 6 and 10.

These mean scores were plotted on an uncertainty/ impact matrix chart presented in figure 7.5 below.

Table 7. 1 Ranking driving forces of change

Driving forces	Code	Impact Rank Score			Mean impact	Uncertainty Rank Score			Mean uncertainty
		R1	R2	R3		R1	R2	R3	
Energy availability	EC1	3	2	3	**2.7**	1.0	3.0	1.0	**1.7**
Petroleum product demand	EC2	4	5	5	**4.7**	2.0	2.0	1.0	**1.7**
Economic growth	EC3	4	5	5	**4.7**	2.0	2.0	2.0	**2.0**
Foreign Exchange	EC4	5	3	4	**4.0**	4.0	4.0	5.0	**4.3**
Freight demand	EC5	4	3	3	**3.3**	3.0	2.0	3.0	**2.7**
Labour cost	EC6	4	3	3	**3.3**	2.0	3.0	2.0	**2.3**
Inflation	EC7	5	4	4	**4.3**	4.0	4.0	4.0	**4.0**
Oil price shocks	EC8	5	5	5	**5.0**	5.0	5.0	5.0	**5.0**
Transport Infrastructural growth	EC9	5	5	5	**5.0**	2.0	1.0	2.0	**1.7**
Climate change	EN1	3	3	4	**3.3**	2.0	4.0	2.0	**2.7**
Local weather and natural disaster	EN2	5	5	4	**4.7**	3.0	5.0	3.0	**3.7**
Emission regulation	EN3	2	3	3	**2.7**	3.0	2.0	3.0	**2.7**
New Energy sources	EN4	5	3	4	**4.0**	3.0	3.0	3.0	**3.0**
Political and security state	PO1	5	5	5	**5.0**	5.0	4.0	5.0	**4.7**
Ageing population	SO1	3	2	2	**2.3**	2.0	3.0	1.0	**2.0**
Shift to sustainable transport	SO2	2	2	1	**1.7**	2.0	5.0	1.0	**2.7**
Consumer purchase behaviour	SO3	2	4	2	**2.7**	3.0	3.0	3.0	**3.0**
New energy sources	SO4	3	3	2	**2.7**	3.0	2.0	3.0	**2.7**
Population growth	SO5	5	4	5	**4.7**	1.0	1.0	1.0	**1.0**
Traffic congestion	SO6	5	4	3	**4.0**	2.0	1.0	3.0	**2.0**
New vehicle technology	TE2	3	5	3	**3.7**	2.0	2.0	1.0	**1.7**
The wave of online purchase	TE3	3	1	3	**2.3**	3.0	3.0	1.0	**2.3**

R1-Ranking by Judge 1; R2 - Ranking by Judge 2; R3- Ranking by Judge 3



** key drivers; *+ Warning drivers; *Predictable drivers;

Figure 7. 5 Impact and uncertainty matrix

In figure 7.5, the drivers in the lower left quadrant are characterised by low uncertainty and low impact on the PPD sector in Nigeria. These drivers consist of the external reserve, ageing population, and wave of online purchases. In the lower right quadrant, the drivers possess a low level of uncertainty. However, they are likely a strong impact on the PPD sector if they occur. Drivers under this section include new technology, population growth, energy availability and labour cost. On the top left quadrant, we find the shift to sustainable drivers, emission regulation, transport policy and purchase behaviors. These drivers can have low impact, but their uncertainty is high because their occurrence can be because of changes to the environment that will triggers policy issues at a global and local levels. Finally, in the top right quadrant, drivers such as the oil price shocks, political and security state, local weather, foreign exchange, and inflation. Among these drivers, the oil price shocks, and the political/security state had the highest ranks. Hence, they are selected as the key drivers for constructing the scenarios.

In the assessment of the drivers for the identification of the critical drivers, the oil price shocks driver was selected because of its impact on other on local factors and other drivers in the business environment. Also, the unstable nature of the oil price makes it difficult to predict when oil prices are likely to hit an all-time peak or drop to its lowest level. On the other hand, the political and security state in Nigeria has placed businesses in a highly unstable state. Business are disrupted by unstable political events as well as security issues. Local and foreign investors are not keen to invest or expand their businesses due to the fear of the consequences of a failed state or a breakout of war or uncontrollable crisis.

7.6 Step 4 - Constructed scenarios for the Nigerian PPD sector in 2040

The critical drivers (oil price shocks and political/security state) were used to create the scenarios. According to figure 7.6, two axes were used to frame the scenarios presented on each of the four quadrants. The oil price shocks plotted on the horizontal axis and the political/security state on the vertical axis. Each quadrant on the matrix presents a plausible image of the future and was given a memorable name describing the essence of the scenario.

7.6.1 Snapshots of the External Scenarios

According to figure 7.6 below, two axes were used to frame the scenarios presented on each of the four quadrants. Each scenario was given a memorable name describing the essence of the scenario.

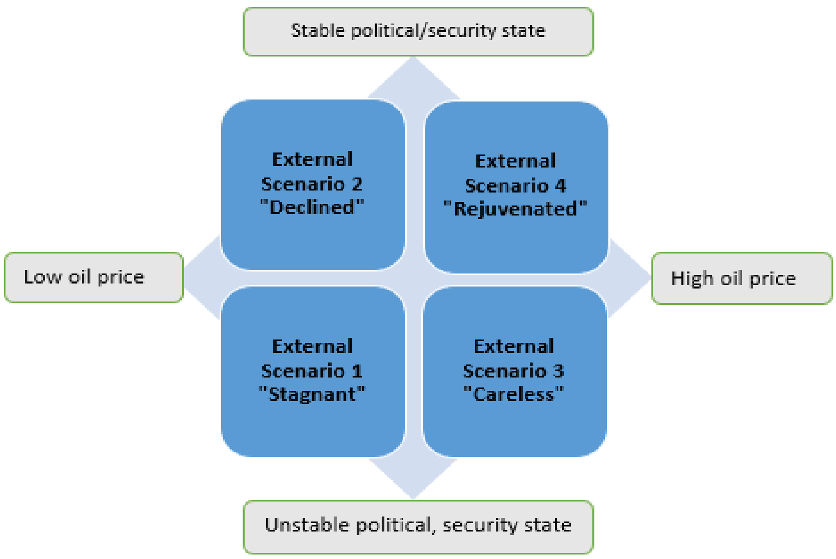


Figure 7. 6 External scenarios on a four-quadrant matrix

External scenario 1: This scenario can be likened to business as usual scenario. It was created on the assumption that the future will continue to develop from the 2016 reference point without any significant changes which could disrupt the trends from the reference year. The scenario is formed on the unstable political/security state and the low oil price. Thus, it was named a "**stagnant future scenario**".

External scenario 2: This scenario also depicts a retrogression of a certain aspect of the society from the reference 2016 state. Thus this scenario was named a "**declined future scenario**". It was created on the assumption that macro-forces such as the oil price, has remained low and dropped below the 2016 reference state. This challenge has thrown the nation's economy into a national recession. Interestingly, there is behavioural cleansing and social transformation at all tiers of the society, the leaders have maintained a stable political system. Not minding the lowered standard of living, citizens have developed trust for the government, and this has brought about a safe, peaceful and secure society.

External scenario 3: This scenario suggests a very economically stable system occasioned by an extreme rise of the oil price and other fiscal parameters such as interest rates and taxes. The scenario indicates a carefree attitude of citizens towards the environment with little or no policy on environmental sustainability. Greed, corruption, nepotism and bad governance trigger dissatisfaction between the ruling class and the lower class. This has led to constant civil unrest and regional discrimination. Thus, this scenario is called a "**careless future scenario**".

External scenario 4: This scenario projects a stable and renewed system where the society is transformed both economically and socially, and technologically. There is total diversification of resource from fossil-based fuel to alternative forms of energy. Cleaner forms of fossil fuel only make a 40% contribution to the energy mix. Governance structures are more embracing and people-oriented. Technology has traversed all aspects of business operations, primarily in the oil industry. Thus, this scenario is called a "**rejuvenated future scenario**".

7.7 Step 5 - Quantifying the scenario drivers

Table 7. 2 Quantified scenario drivers

Drivers(d)/impacts(i)	**Scenario 1, "stagnant future"**	**Scenario 2, "declined future"**	**Scenario 3, "careless future"**	**Scenario 4, "rejuvenated future"**
Oil price shocks	Oil price at an annual average of $44/b. Similar to the price in 2016 (US EIA, 2016)	Oil price at annual average of $26.55/b. 60% below 2016 average prices. Similar to price in March, 2020(US EIA, 2020).	Oil prices at $105.16/b, similar to price in 2007 and 2010. (US EIA, 2017)	Oil prices hit $105.16/b, similar to price in 2007 and 2010. (US EIA, 2017).
Political and security state	Bad governance, unstable political system and insecurity	Good governance, stable political system and security.	Bad governance, unstable political system and insecurity	Good governance, stable political system and security.
Petroleum product daily consumption	***80-85 mld. (60% increase in 2016 levels (OPEC, 2016).***	***65-70mld. (30% increase in 2016 demand) (OPEC, 2016).***	***100-105mld. (100% increase in 2016 demand level) (Assumed based on documented rate).***	***25-30 mld (50% reduction in 2016 demand) (Assumed based on documented demand level).***
Economic growth	Economic growth rate at 2-3% (World Bank, 2016)	Economic growth rate at less than 1% (World Bank, 2016)	Economic growth rate at 5% (World Bank, 2016)	Economic growth rate at 7% (World Bank, 2016)
Inflation/interest rate	The interest rate at 11.55% (World Bank, 2016). Pipeline transport cost: $5 km/barrel Rail transport cost: $15 km/barrel Truck transport cost: $20 km/barrel Pipeline operating cost: $15000/ km TD variable cost/unit$100-150/barrel	The interest rate at 12% (World Bank, 2016) Pipeline transport cost: $5 km/barrel Rail transport cost: $15 km/barrel Truck transport cost: $20 km/barrel Pipeline operating cost: $15000/ km TD variable cost/unit$100-150/barrel	The Interest rate at 13% (World Bank, 2016) Pipeline transport cost: $10km/barrel Rail transport cost: $20 km/barrel Truck transport cost: $50 km/barrel Pipeline operating cost: $15000/ km TD variable cost/unit$100-150/barrel	The interest rate at 14% (World Bank, 2016) Pipeline transport cost: $3 km/barrel Rail transport cost: $10 km/barrel Truck transport cost: $18 km/barrel Pipeline operating cost: $15000/ km TD variable cost/unit$100-150/barrel
Foreign exchange	N350 to $1.Similar to 2016 reference state (IMF,2016)	N500 to $1. 42.8 % rise in the 2016 reference states (IMF, 2016)	N100 to $1. 71.4% decrease in exchange rate from the 2016 level (Assumed). Similar to 2001 rates.	N50 to $1. About 85.71% decrease in the 2016 reference state (Assumed value). Almost similar to 1999 exchange rate.

Freight demand in nigeria	Freight demand at 26.4 million tonnes	Freight demand at 26.4 million tonnes	Additional 350-400% increase in road and rail tonne-kilometre from 2016 reference state	Additional 350-400% increase in road and rail tonne-kilometre from 2016 reference state
Transport infrastructure	No significant investment in the transport sector.	No significant investment in the transport sector.	Development of all modes of transport.	Development of all modes of transport, including pipeline and non-motorised mode.
Traffic congestion	Traffic congestion on 50% of city routes	Traffic congestion on 50% of city routes.	Traffic congestion on 80% of city routes.	Traffic congestion on 5% of city routes.
Climate change	Increased climate change	Increased climate change	Increased climate change	Gradual combat of climate change globally
Emmision regulation	100% fossil fuel energy use. (IEO,2017)	80 - 20% of fossil – non fossil fuel use for transport (IEO,2017)	100% fossil fuel energy use. (Assumed)	60-40% of fossil – non fossil fuel use for transport. (IEO,2017)
New energy sources	Low-level technology globally.	New technologies globally but low-level acquisition and adoption	New technology existence. However, deliberate non-adoption	New innovative technology existence and adoption
Shift to sustainable transport	Fossil fuel private car ownership on the increase	The gradual shift to non-motorised modes due to declined fossil fuel and the rising cost of transport	Fossil fuel private car ownership on the increase	A significant shift towards sustainable transport
Consumer purchase behaviour	Uncontrolled expenses on unsustainable products and services.	Gradual shift towards sustainable products due to the awareness of the decline in fossil fuel.	Uncontrolled expenses on unsustainable products and services.	Strong emphasis on sustainable packaging and products
Population growth in Nigeria	The population stands at 223 million. The growth rate of 0.8% from 2016 levels (UNO, 2011; Delloitte,2014))	The population stands at 223 million. A growth rate of 0.8% from 2016 levels (UNO, 2011; Delloitte,2014)	The population stands at 260 million. The growth rate of 1.6 % from 2016 (Assumed double in 2016 population growth rate)	The population stands at 223million. The growth rate of 0.8% from 2016(UNO, 2011; Delloitte,2014)
Urban sprawl	Urban population doubles from 2016 levels (UNO., 2011; Delloitte,2014)	Urban population doubles from 2016 levels (UNO., 2011; Delloitte,2014)	Urban population doubles from 2016 levels (UNO., 2011; Delloitte,2014)	Urban population increases by 25% from 2016 levels (UNO., 2011; Delloitte,2014)

New vehicle technology	Low-level technologies (IEO, 2017). Conventional fossil-fueled trucks for freight transport at Trucks: 0.10g CO2e emission/km trains: 0.06g CO2e emission/km	Low-level technologies (IEO, 2017).Conventional fossil-fueled trucks for freight transport pipelines- 0.02g CO2e emission/km trains: 0.06g CO2e emission/km trucks: 0.10 gCO2e emission/km	High-level vehicle technology(IEO, 2017).Conventional fossil-fueled trucks and improved technology for freight transport pipelines 0.02g CO2e emission/km trains: 0.03g CO2e emission/km trucks: 0.07gCO2e emission/km	High-level vehicle technology (IEO, 2017). Low-emission driverless trucks and trains used for freight transport pipelines- 0.02g CO2e emission/km trains: 0.03g CO2e emission/km trucks: 0.07gCO2e emission/km
The wave of online purchase	A mix of conventional and online purchases	Conventional purchases from shopping malls and stores	Massive dive towards online purchases	Massive dive towards online purchases

7.7.1 External scenario parameters for optimisation

A wide range of driving forces were identified and presented in table 7.2. While some of these drivers were quantified, others were qualitavely described. The consistent combination of different states of all the drivers result in the rich narratives of plausible scenarios that could occur in the future. Each scenario narrative represent a background context for the creation of a vision. In addition, some of the quantified drivers inform the inputs into the optimisation modelling activity to be carried out in in section 10.2.2.1 of chapter 10. In the next section, the quantified drivers required for optimisation will be described in detail.

7.7.1.1 Petroleum product demand in Nigeria

The petroleum product demand projection is pivotal in the planning for an efficient distribution of petroleum product in the south-east region of Nigeria. Therefore, projected values will be used for the optimisation of the future distribution network in the optimisation study in chapter 10. The projections for the petroleum product demand in 2040 were based on the documented projections of Organisation for Petroleum Exporting Countries scenarios for 2035-2040 (OPEC, 2016). While other reports such as the US EIA Outlook Report (2016), and the Mckinsey Energy Insight Outlook (2017) could have been used to gain inisght on demand projection, the OPEC report was used because the deviations between the projections and actual values between 2005 and 2015 were minimal as compared to the US EIA, the Mckinsey projections. Consequently, table 7.3 presents the petroleum product demand for 2016 reference state and the projections under the four external scenarios in Nigeria.

Table 7. 3 National daily demand projection for petroleum products in Nigeria

Time	Demand projection	Estimated national pms demand (million litres/day)
The demand level at 2016	$x;$ where $x =$ 45 to 60million	52.5 (reference state)
Stagnant scenario	$x + 0.60x$	82.5
Declined scenario	$x + 0.30x$	67.5
Careless scenario	$x + 1.0x$	105
Rejuvenated scenario	$x - 0.50x$	28

Table 7.3 presents the adjustments to the demand based on a growth factor defined under the different external scenarios in table 7.2. Based on the OPEC projections, the demand for fossil-based fuels will increase by 60% from the 2016 reference state (OPEC, 2016), this projection was assumed

could occur under the stagnant scenario. The later projection is triggered by a population growth of 0.8% from the 2016 reference state. Consequently, the demand for petroleum product under the stagnant scenario is equal to the demand in 2016 denoted as x plus a 60% increase of the value in 2016. (see appendix 3 column 4 for stagnant scenario demand projection).

Under the declined scenario, the study assumes that in 2040, the significant rise in oil exploration technology, especially for shale regions, will lead to overproduction and supply of crude. The excess crude supply globally will lead to a decline in demand for Nigeria's Brent crude. As a result of the latter challenge, the level of foreign exchange sales and revenue from Brent crude sale falls. The economic growth declines from 2% in the reference period to less than 1%. The lowered economic growth reduces the national average income per capita, disposable income level, and the ability to purchase vehicles. 30% of the consumers either adopt the use of non-motorised forms of transport or public transport. Eventually, the demand for petroleum products increases by merely 30% from the 2016 reference state compared to the 60% increase in the Stagnant scenario state. (see appendix 3 column 5 for the declined scenario demand projections)

Under the careless scenario, there is an assumed oil price level at $102 per barrel in 2040 from the $38 in 2016. The increased price of oil boasts the national revenue, income per capita, ability to purchase vehicles. One in every five individuals own a vehicle, and this has led to heightened demand for products. Eventually, there is a 100% increase in the demand for products from the 2016 demand level. Finally, under the rejuvenated scenario, the price of oil remains very high at $102 per barrel. However, the issue of climate change and emission control is a concern globally, and actions are put in place to cut down emission levels have materialised. The Nigerian government in a bid to align with emission reduction policies to diversify its energy source from fossil fuel to alternative forms of energy for household and transport. Since a large quantity of Nigerian fossil fuel consumption is for powering the homes, there is higher electricity generation which will drastically reduce the consumption of fossil-based fuels. Eventually, the demand for petroleum products declines tremendously by 50% from the 2016 reference demand level. (see appendix 3 column 6 and 7 for careless and rejuvenated external scenario demand projection)

7.7.1.2 Population growth

The projection for the population in the year 2040 was informed by the UN Outlook Report (2016). The population growth is classified as a predictable driver of change. Hence, it is subject to limited uncertainty. Therefore, the population of countries in sub-saharan Africa is expected to double by

2050. Given the 25 year time horizon for the scenario, it therefore expected that the population in 2040 will rise by 70-75% from the population in 2016 (UN, 2016). This value was used across all the scenarios on the assumption that the projection would follow a similar trend on the asumption that no significant action would be taken to slow the population growth of the sub-saharan Africa. However, it can be argued that population trend breaking events such as the global outbreak of war, the uncontrollable disease could distort the projected growth rate.

7.7.1.3 Urban sprawl

Urban sprawl projection was based on projections made by the United Nations Future Outlook Report (2016), and the World Bank Future Outlook Report (2016). The documents project that by 2040 there is likely to be 68% growth of urban cities. In the stagnant and declined external scenarios, it is assumed that the citizens will flee rural settlement in search of a better life in the urban areas. This will likely be the case for the careless scenario where the government, despite the positive 4-5% economic growth, will fail to develop robust policies that will foster development in all areas of the region. The rejuvenated scenario differs from the three scenarios as it is projected that only 10% of the citizens will need to migrate to the urban areas only to visit loved ones. Under this scenario, the diversification of revenue inflow from the oil-related revenue to alternate revenue sources such as agriculture, education and technology will encourage and equitable distribution of wealth across all areas in the country.

7.7.1.4 Inflation and interest rate projection

The price of goods and services do increase over time due to inflation. Godwin and Cockerham (2018) opine that if one is planning to purchase a good or service in the future, it is incorrect to plan based on the current price. Instead, one should plan based to pay a higher price related to expected inflation rates. On this premise, the expected inflation rates under the different scenarios were used to determine the expected costs.

Figure 7. 7 Chart of Nigeria interest rate between 2007-2020

Source: Tradineconomic.com| CBN

The interest rate projection was based on Dogrul and Soytas's (2010) assertion that oil price and interest rates are positively correlated. Therefore, future interest rates are linked to rates that ever existed in history (see figure 7.7). Under the Stagnant scenario, when the price of oil is projected at \$38 - \$40 per barrel is assumed to be 11.5%. This is similar to the 2016 interest rate of 11.5% when the oil price was \$38 per barrel. The interest rate was adjusted to 6% for the Declined scenario as the oil price fell to an all-time low of \$12 per barrel. Under the Careless and Rejuvenated scenarios, the interest rates were projected at 13% and 14% respectively as the oil price hit its peak of \$102 per barrel, which equivalent to the oil price in 2011.

The above scenario-based interest rate projections informed estimation of the future inbound and outbound unit transport costs, fixed and variable facility costs, and the security costs in 2040 presented in table 10.3 in chapter 10. These costs are the constant inputs into the optimisation modelling analysis. Hence, they were calculated using the formula below;

Future price = Current price x (1 + Inflation rate year 1) x (1 + Inflation rate year 2) x…(1 + Inflation rate year n); where n equals the total number of years.

7.7.1.5 New vehicle technology

The vehicle technology improvements with respect to the emmision levels is an important external scenario parameter that will be required in the optimisation of the network design. The different scenarios present different levels of developments in terms of the emmission reduction in truck, train or other modes of transport. Using standard emmision metrics, it was assumed that under the stagnant scenario, there is no improvement to the technology on emmision reduction. Hence, the truck, rail and pipeline emmisions remain at the 2016 levels of 0.10g , 0.06g, and 0.02g CO_2e/km travelled respectively. It is assumed that this level of technology remains the same under the declined scenarios. However, under the careless scenario, there is significant improvement in the technology, but the adption of such technologies is overlooked by the society. Finally, under the rejuvenated scenario, the emergence advanced technologies that reduce truck, train and pipeline transport emmisions to 0.7g , 0.03g, and 0.02g CO2e respectively is met with a wide adoption by citizens and organisations. Strict genernment policies and emmision incentives are in place to enccourage citizens and organisations to cut down on their carbon footprint.

7.8 Step 6 - Communicate scenarios and implications

The result presented in this section represents the narratives of the different future scenarios. The narration reflects the scenario dynamics of what may occur in the Nigerian PPD sector business environment. The result of the scenario implications have been discussed in the section 7.9.2

7.8.1 A stagnant future scenario in 2040

The uncontrollable forces in the Nigerian PPD business environment have threatened the efficacy of the existing industry strategies. The excess production of crude globally has led to a decline in patronage for Nigeria's Brent crude. However, OPEC, through its oil price control mechanisms, has maintained the price of Brent crude at $38.7 per barrel. This low oil price has adversely affected foreign crude revenue, leading to a decline in the value of the Naira to U.S. dollar to N350-to $1- similar to the price in 2016. The current revenue base affects the economic growth rate at 2%. Population soars at approximately 223million, and 68% of the population reside in the urban cities. This has led to an overshoot of the demand for petroelum products to 82.5mld, and demand for transport service supply. Unfortunately, little has been done to improve the state of transport infrastructures. The road mode of transport remains the surviving mode for movement of freight and passengers. However, the poorly maintained state of the roads has led to constant congestion on the major travel corridors and increased journey time. The high population and rising demand for fossil-fuel increase CO2 emission levels. While new vehicle technology has evolved in the developed world, fossil-fueled vehicles are still in use in Nigeria. Citizens purchase and import banned fossil powered vehicles from developed countries due to their affordability: vehicle ownership, traffic congestion levels lead to more emissions. Acquisition and adoption of new technologies that drive low emissions are limited by the low-level capital and the facilitating conditions such as the availability of power.

Insecurity and political instability remains a significant force impacting society. In the political and social space, corruption and nepotism have ravaged the society. There is little or no effective monitoring and accountability for contracts allocated for transport projects leading to many abandoned transport projects. As a result of poor governance and unaccountable leadership, the citizens are unhappy. There are constant cases of civil unrest and communal clashes between the government and the citizens. In a show of bitterness, angry youths infiltrated with face-less gang groups destroy government infrastructure, loot and steal from even the poor. Ethno-religious connotations are attributed to the actions of the government, leading to a revolution by the citizens of different regions. There is tension everywhere as there could be a breakout of war at any moment. The unsafe business environment has limited foreign direct investments as investors, and marketing companies are afraid to invest in such an uncertain environment.

7.8.2 A declined future scenario in 2040

Today, 12 June 2040, the Minister for Finance has announced that the nation has slipped into recession. This is due to oil prices that has declined to about \$12/b. This low oil price has affected the dollar to the naira exchange rate, which currently stands at N500 to one U.S. dollar. This is horrific, said the Minister for Finance. There is also the concern over the almost depleted oil reserve of 20 billion barrels, which is equivalent to a 50% decline from the 2016 reserve level. The low level of

technology for exploring tar and shale regions has led to the low oil reserve state. Unfortunately, Nigeria's sale of crude oil contributes to 70% of national GDP. The Nigerian economy progresses at less than 1% growth rate. The Organisation of Petroleum Exporting Countries (OPEC) has lost control over the excess supply of products from the U.S. and middle eastern countries. The U.S. and China have explored oil production due to freshly discovered deposits. Their huge investments in exploration technology by the U.S., China and Oil producing countries in the Middle East have led to surplus crude production. Oil reliant developing economies such as Nigeria are at the verge of collapse. Foreign exchange inflow into Nigeria has declined, and the exchange rate between the Naira and dollar is at the lowest level ever seen in history. The high population of Nigeria has also forced the demand for petroleum products to peak up to about 67.5 mld. Government, through the help of international aids, provides support for the petroleum product importation. The local refineries operate far below the capacity. The level of inflation and high lending rates in the nation has forced distribution companies to collaborate with international companies to survive. Traffic infrastructure has remained weak with road mode is the only mode of transport for passenger and freight. The poor state of the roads has led to loss increased travel time due to the high level of congestion on most roads.

Remarkably, the economic downturn has not destroyed every facet of the nation. The good governance of the Nigerian government has transformed the political and social space. Specifically, the restructuring policy has successfully unleashed the productivity and efficiency of every region. This has brought about a reduced level of insecurity, with a feeling of peace and tranquillity in the nation. The safe environment has attracted foreign investors who are willing to develop the nation's energy sector. Citizens and the government are gradually introducing environmental laws, and due to the scarcity of petroleum products, citizens have naturally adjust their comfort to walking and cycling leading to a low demand for petroleum products. The high cost constraint limits the use of new vehicle technology for trucking. Acquisition and adoption of the technology to integrate the supply chains are hindered by the low-level capital and the facilitating condition such as power supply. There is only little investment in transport infrastructure leaving the road mode as the primary mode of transport. Affordability of imported second-hand fossil-fueled vehicles leads to increased vehicle ownership and congestion on almost all roads. This scenario provides an opportunity for foreign direct investment. Foreign investors are willing to collaborate with local distribution companies to import and distribute products within a safe and friendly environment. The transport sector is engaged in public-private partnerships for the construction of roads. However, the fear could be the level of control of the government over the inflow of foreign investment and support—the fear of a second colonisation era by the developed nations.

7.8.3 A careless future scenario in 2040.

The Nigerian economy is currently the fastest growing economy in Africa. This is partly due to the economic benefits of the high oil prices, which has hit an all-time high of $102 per barrel. The high oil

price has positively affected the foreign earning, and the exchange rate is at N100 Nigerian nairas NGN to one U.S. dollar. The economy is growing at a 5% growth rate. Unfortunately, price inflation begins to set due to the excess consumption habits and quest for a luxury lifestyle. The high per capita levels has increased the disposable income of citizens leading to the quest for more purchases. Demand for freight rises by almost 400% compared to the 2016 levels.

There is a high level of private vehicle ownership as citizens place a priority on their comfort before environmental concerns. The high vehicle registration generates a massive level of significant congestion on the roads. The high population of approximately 240 million generates a corresponding high consumption of petroleum products of almost 90 million litres per day. The government of the day operate highly operational oil refineries, with at least 80% capacity utilisation for refining products to meet the daily consumption levels.

Despite economic benefits, wealth generation and distribution have remained an issue yet to be handled by the government of the day. The concentration of infrastructural and business development in major cities has resulted in 68% of 260million people residing in the at the major cities. Demand for petroleum products is approximately 102mld, and due to high level of urban migration, more of the demand are from urban cities. Citizens who reside around the poorly developed communities are at rage because of the discrimination and inequitable distribution of wealth. This is the case for some regions where crude exploration is done — tension due to continuous clashes between the exploration corporations and underdeveloped communities. Ethno-religious connotations have been attributed to the unbalanced wealth distribution. Daily, these communities protest and call for a revolution or restructuring of the economy. The government has refused calls for the restructuring which was recommended by the National planning committee on national unity. Aggrieved youths within the oil-producing communities have resort to the destruction of distribution road and pipeline links. Besides the challenge of insecurity on petroleum product distribution, the high demand for road space by private vehicles has resulted in a zero benefit of the traffic infrastructure investment. This has also resulted in increased travel time due to the high level of congestion on intra-city roads. Corruption and nepotism have become the order of the day. Judicial systems have failed to check the excesses of the executives which have led to citizens dissatisfaction in the governance. The citizens are scared of a breakout of war at any moment. Citizens and the government are not disturbed about the environment as there is no policy on safeguarding the environment. The high population and rising demand for fossil fuel further increase emission levels. In the developed world, new vehicle technology has evolved; however, fossil-fueled vehicles are still in use.

7.8.4 A rejuvenated future scenario in 2040

A brilliant future characterised by a stable economic system, sustainable environment, technology. Globally, the price of oil remains high at $105 per barrel. The Nigerian government revenue from crude

sale boasts the state of the economy. The price of oil and other export services and products accrues high foreign revenue. This high foreign inflow boosts the value of the Naira to the dollar at N50 Nigerian Naira to a dollar. Also, the economic growth rate floats around 7%, a rate which has never been seen in the history of Nigeria.

The Nigerian government has fully diversified its source of revenue with fossil fuel accounting for only 40% of national revenue. Other sectors such as Agriculture, education, technology and gold and tourism account for 25%, 15%, 5%, 5% and 10% respectively. Macroeconomic forces such as inflation are stabilised by the monetary policy implemented by price regulatory agency. The high per capita levels has increased the disposable income leading to the quest for more purchases. However, citizens are more aware of the need for sustainable purchase behaviour. Therefore manufacturers provide recyclable packaging. Most of the products are sustainable products and distributed through vehicles embedded with new technologies that support a sustainable environment. Policies on the environment are enforced at all levels. Incentives are provided residents that utilise public transport, cycling, and walking for trips. Private vehicle ownership falls, and congestion is hardly experienced on the intra and inter-city roads.

Despite the population of approximately 223 million, only about 50% account for the consumption of petroleum products of almost 28mld. Modular refineries operate at full capacity, and they are used for the production of sustainable bio and hydrogen fuels enough to distribute within the country and supply to other countries. Development is adequately spread across all the nation, leading to a less than 10% urban sprawl. The states sustain themselves based on the revenue generated from their resources and investment. States compete, and the citizens are satisfied with the governance structure implemented by the federal government. There is no case of insecurity and political instability, and this has attracted foreign investors to collaborate with indigenous petroleum products marketing companies. Transport infrastructure is fully developed with the road, rail, sea and pipeline modes fully operational. Massive technology abounds, and the majority of manual processes have become automated.

7.9 Discussion

The discussion provided in this section addresses the impact of the critical drivers and the implication of the scenarios to the Nigerian PPD sector.

7.9.1 The impact and uncertainty of critical drivers

The selection of the oil price shock and the political and security state of the future as the critical uncertainties for the Nigerian PPD sector was due to the driver's ability to influence other drivers of change in the sector business environment. Over the last two decades, oil price shocks remains a dominant driver in the oil market (Baumeister and Peerman, 2010). Plunges in oil price affect different countries differently, depending on whether the country in question is an exporter of crude oil or an importer. For an importer or a consumer nation, oil price increase raises the cost of production and hence can lead to (cost-push) inflation, lower economic growth, and even recession (Alley et al., 2014; Mordi and Adebiyi, 2010).

Windfalls that result from oil price surges/shocks overwhelmingly flow through the Nigerian economy; expand the oil sector, and penalise the non-oil sector (Nwanna and Eyadayi, 2016). For example, before the oil price shock that struct the Nigerian economy in 2014, projections were for the continued robust growth of about 7% per year (IMF, 2017). Consequently, in the wake of the decline in oil price, the growth slowed sharply in 2015, and the economy experienced an outright contraction in 2016 (Central Bank of Nigeria, 2015). This contraction triggered a correlated decline in outputs from other non-oil sectors in Nigeria (IMF, 2017). Nigeria's dependence on oil export receipts and fiscal revenue made the foreign exchange follow a negative float with a massive devaluation of the local currency (Akpan and Atan, 2011; Ogundipe et al., 2014; Ogochukwu, 2016). A further variation of the shocks between 2013 and 2014 with nominal oil prices at an average of $90 per barrel decline to $34 per barrel in 2016 (World Bank Data, 2017) exposed the nation to long-term planning disruption (Olomola, 2006).

These effects signal that fluctuation in the price of oil must always be considered as significant factor that influences the operations of the oil industry and other essential services. In the stagnant and declined scenarios, the low oil price has a direct effect on the economy. It reduces the revenue inflow and in turn the capital outlay of oil-importing countries through high-interest and exchange rates. This limits the volume of PMS imported for distribution in the country. Also, the cost of maintaining refineries become high due to high maintenance costs.

On the other hand, the political and security state has a correlated relationship with the operation of different sectors in the economy. Nwaogwugwu (2015) argues that economic marginalisation, environmental degradation, bad governance, and policy inconsistency by the government led to the emergence of militancy in the Niger Delta in early 2006. The activities of these militia groups include kidnapping of foreign nationals working with the oil companies, hijack of oil installations and products on transit. These issues have created a state of general insecurity in the Niger Delta region and the nation at large. Investors are apprehensive if Nigeria is headed for a secured atmosphere and political stability, or an outbreak of uncontrollable conflicts, and crime in the different parts of the country. Will ethno-religious crisis deteriorate into a break-up of national unity of Nigeria in the future? Will the insecurity and political tension disrupts the supply of goods across spatial locations, reduce wealth generation and brings about the stagnation of the Nigerian economy. Consequently, the state of political tension across regions and security issue constitute a critical driver of business for both SMEs and multinationals in Nigeria.

7.9.2 Scenario implications for the Nigerian PPD sector in 2040

These uncontrollable issues identified in the scenarios created pose threats and offer opportunities to the Nigerian PPD sector. The threats and opportunities are discussed below.

7.9.2.1 Threats to the Nigerian PPD sector

The stagnant and careless future scenarios undoubtedly poses threats to the Nigerian PPD sector. The unsafe and insecure business environment has made storage and distribution of petroleum products very difficult. Petroleum product distribution and marketing company employees are violated continuously by angry face-less groups. The constant destruction of oil infrastructures, such as pipelines and storage depots, have impacted delivery timelines and increase the total cost of distribution. Nwogwugwu et al. (2012) posits that persistent insecurity in Nigeria could lead to product losses on transit and increased downtimes of depot facilities. The constant vandalisation oil installation and low capacity operation of local refineries have occasioned the continuous importation of refined product to meet the demand for energy products. Garga (2015) adds that the problem of insecurity in Nigeria has assumed a formidable dimension that not only requires attention from stakeholders at different levels of society. Insecurity correlates with political instability, and these issues trigger unrest crisis which can impact the distribution of products. Under the stagnant and the careless scenarios where insecurity is a significant concern, the planners in the Nigerian PPD sector must seek ways to distribute products amidst the harsh and insecure business environment.

The low level of technology acquisition and adoption described in the Stagnant and Declined Scenarios impacts the operations of the Nigerian PPD sector through the delayed order processing, poor invoice tracking, delayed loading process at product depots, and inability to monitor products flow along the supply chain. The economic situation of the country limits the adoption of technology as considerable investments are required for installing and launching robust security systems, and smart transportation systems to overcome some of the existing challenges of product diversion and loss. Also, the high level of inflation has a strong effect on the redistributing income because prices of all factors do not arise in the same proportion. Entrepreneurs stand to gain more than wage earners or fixed income groups. Speculators, hoarders, black marketeers and smugglers stand to gain on account of windfall profits. This threatens the significant marketers of products and favours the smugglers and illegal refining plants located in unseen locations. Therefore, the government have to spend more on goods and services, including the provision of transport infrastructure, regular maintenance of distribution facilities and driver wages.

Furthermore, transport infrastructure, traffic congestion and transport policy affect the seamless distribution of petroleum products. Congestion on roads increases the products delivery time, which in turn could lead to stock out situations at retail stations. Traffic congestion-related delays are the most significant pain point in the logistics and freight industry (Avittathur and Jayaram, 2016). However, with excellent transport policies put in place to support the provision of transport infrastructure, the DPPD sector will experience a seamless distribution of products. Transport infrastructural development on the rail, sea and the pipeline mode of transport will support the diversification of distribution of links from over-reliance on the road mode seen in the stagnant and rejuvenated scenario. Also, the introduction of emission regulations to support the environment, The pipeline modes may become the valid model for the distribution of products.

7.9.2.2 Opportunities for the Nigerian PPD sector

Considering the opportunities for the sector, especially under the careless and rejuvenated scenario, "the wave of online purchases" has a significant impact on the private car use as well as the freight demand. Increased purchases through online sources would reduce the number of shopping trips made by customers, and this would reduce the demand for petroleum products.

This trend is yet to materialise in the developing countries. However, it has become the norm in most developed countries. Smith (2015) notes that in the first quarter of 2014, 198 million U.S. consumers bought something online, according to comScore's quarterly State of Retail report. That translates to 78% of the U.S. population age 15 and above. This trend will significantly impact trips as both men and women will are actively involved in such purchases. One could argue that since 80% of household spending is controlled by the woman in the home (Smith, 2015), only women will be engaging in online spending. The later trend combined with new technologies under the careless and rejuvenated scenario suggest the possibility of investment in electric and sustainable energy-powered trucks to engage in last-mile delivery to the consumer residence. Its impact on the network of distribution is not left out. With the equitable distribution of wealth contrary to the concentration of development around a few urban cities, The rejuvenated scenario offers the opportunity for an even distribution system to the urban and rural communities. This is unlike in the careless scenario where the urban centres will be rapidly populated, and distribution will be focused around the urban areas.

With the increasing expectation for retail station delivery timelines, the access to available and affordable supply chain technology in the careless and the rejuvenated scenario will be an opportunity for the DPPD sector. Digitisation of business processes has become more of a necessity than a value-add proposition. The use of integrated technology systems would facilitate a better understanding of production and sales levels by the key players in the Nigerian PPD sector. Integrated software and automation systems will help manage and enhance the exchange of information across various supply chain partners, which will eventually retail station demand in a timely fashion (Neiubert et al.,2018). The Nigerian PPD planners must reflect on the details of each these scenarios to ascertain the possible threats or opportunities. They should continually scan their environment for new drivers to get insights about the alternative futures which are likely to emerge in the future.

7.10 Reflections

The use of the document analysis for identification of the focal issue (step 1) and driving forces (step 2) for the Nigerian PPD sector posed some challenges. First, search keywords that specifically targeted the "driving forces affecting the petroleum product distribution" was not very useful. Using such search keywords did not retrieve any document related to the driving forces influencing the distribution of petroleum products. This implied that the keyword was too narrow to capture the driving forces or limited studies that address the driving forces affecting the future of PPD have been carried out.

In light of the later challenge, the researcher relates to the driving forces influencing the future of petroleum product distribution to the generic driving forces influencing freight distribution. Therefore, during the literature search, the researcher assumed that specific generic freight trends to be related to PPD trends. However, in reality, this assumption may not hold as the distribution system differs with respect to the nature of the cargo, its pattern of delivery, and design of the network. For example, we understand that latest technology such a drone and aerial vehicles have been talked about as a means to ease future logistics distribution. However, the PPD sector cannot utilise drones as a means of delivery.

Another issue for reflection is the use of existing scenario document analysis for the quantification of scenario drivers in step five of the external scenario approach. The case study revealed that different scenarios studies have different projections for a particular scenario driver. Therefore, the selection of the projection by a specific document over another was made in the study. For example, the US EIA projected that the global energy demand is projected to grow only by about 20% from 2017 levels until the year 2040 (Exxon Mobil Energy Outlook, 2019). The International Energy Organisation projects that fossil-based energy consumption will fall slightly, from 33% in 2015 to 31% in 2040 (IEO,2017). The OPEC predicts that oil will remain the most significant contributor to the energy mix by 2040, accounting for more than 28% growth from the 2017 levels (OPEC, 2016). These projections indicate what might happen to the demand for fossil fuel in 2040. The researcher's choice was based on the study with the least error between the forecast and actual demand data in previous years. The researcher affirms that the adopted technique for selecting the document whose projections were used can be classed as rough and dirty because there is a possibility that the future projections from other sources could provide a closer estimate to the actual value when compared to the selected document.

7.11 Conclusion

This study set out to develop quantified scenarios for the Nigerian PPD sector by the year 2040. The purpose of the scenario study was to create a set of scenarios to support the development of visions for the PPD sector in 2040. Also, the quantified scenario drivers will be used as inputs into the optimisation modelling study in chapter 10. In the first step, the focal question for the system under investigation was to explore how the Nigerian PPD business environment will change in the year 2040. In order to address the focal question, a desk scenario development approach was adopted. In the second step, a document content analysis was conducted to identify twenty-five driving forces under the STEEP categories(social, technology, economic, environmental, and political) that could influence the operations of the Nigerian PPD sector. In step three, the 25 driving forces were ranked by the researcher and two consulted researchers with adequate knowledge of the PPD sector. A survey technique was utilised to by the researchers to rank the drivers on a scale of 1 to 5, where 1 means the least impact and uncertain, and 5 means most impact and uncertain. Two drivers, namely; the oil price shocks and the political and security state with the highest impact and uncertainty scores, were selected as the most uncertain and impacting drivers on the Nigerian PPD sector. The critical drivers were later used to construct four scenarios named "the stagnant"; the declined"; "the careless"; the rejuvenated scenarios. The driving forces were later quantified based on projections of scenario drivers from five reliable future projections documents. Finally, the narratives of each scenario were developed.

The discussion section addressed the implication of the critical drivers in the Nigerian context as well as the threats posed and opportunities offered by the different scenarios developed. It was identified that the oil price shocks drivers affect other macro-economic drivers such as inflation, economic growth, interest, exchange rate, personal income, vehicle acquisition, congestion, and transport infrastructure. Also, insecurity and political instability instil fear in the business environment as a result of the constant tension and crisis. This also affects the distribution of petroleum product through the constant vandalisation of PPD infrastructures such as pipelines, storage depots and refineries and trucks on transit. Opportunities under the declined scenario include the options for mergers with international PPD companies, the transfer of smart technologies to support effective distribution. The rejuvenated scenarios provides an opportunity for a sustainable transport system that embraces low emission modes of transport.

Two issues for reflection in the study were related to; i) the relationship between the driving forces affecting the distribution of petroleum products as compared to the generic freight. While petroleum products and generic freight are forms of freight transport, the characteristics differ. Therefore, the question in this case is. “do the same driving force of change affects both forms of transport? ; ii) since the quantification was based on projections from existing documents, the question, in this case, is; how can the right document be selected since different documents provide different projection values on a particular driver?.

The desk approach adopted does not replace participatory scenario methods. Instead, it is useful in resource-constrained situations. The use of document review and synthesis for identification of driving forces delineates the stakeholder/expert participation in the process. This could be improved by linking the process to a strategic visioning process where stakeholders are identified and convened in a workshop to envision future. The later process will be captured in the second stage of the OVAF presented in chapter eight of this thesis.

7.12 Summary of chapter

In the next study, the scenarios created in this study will serve as a starting point in the creation of the visions for the future of downstream petroleum product distribution in Nigeria. The scenario developed will be presented to industry professionals for reflection, review, and ratification before creating strategic visions consistent with plausible external scenarios in the next chapter.

Chapter 8 - 2040 Visions for the Nigerian PPD Network; an integrated exploratory-visioning scenario approach.

8.1 Introduction

The previous chapter developed four quantified external scenarios that represent the chain of events that are likely to occur in the Nigerian PPD business environment by the year 2040. The scenarios aim to evoke stakeholder discussions on how the Nigerian PPD network will operate amidst the plausible external scenarios. They are intended to act as a guiding framework for the development of visions for the PPD network in Nigeria by 2040. Therefore, this chapter focuses on the development of visions for the Nigerian PPD network that are consistent with the different scenarios developed in chapter 7. Since the visions will be developed under the respective external scenarios, the visions developed will be called "scenario-specific visions". The MVCA described in section 5.3 of chapter 5 will be applied to develop the scenario-specific visions.

The specific objectives to be achieved in this chapter include:

- To identify the stakeholder reactions to the pre-developed external scenarios likely to influence the PPD network in Nigeria;

The purpose of this objective is to ascertain the stakeholder opinions concerning the external scenarios developed in chapter seven. This objective corresponds to the exploring issue step of the MVCA, and the results are presented under section 8.3.3 of this chapter.

- To identify the scenario specific vision elements for the Nigerian PPD network by 2040;

The purpose of this objective is to elicit the stakeholder perspectives of what is required for an ideal PPD network under the different external scenarios. This objective links to step three and four of the MVCA approach and the results are presented in section 8.3.4 of this chapter.

- To identify optimisation problem variables that influence the efficient design of the Nigeria petroleum product distribution network for 2040;

The purpose of this objective is to elicit the specific stakeholder vision elements to be quantified and used as inputs into the quantitative model for optimising the visions for the Nigerian PPD network. This objective links to step five of the MVCA approach and the results are presented in section 8.3.5 of this chapter.

In the subsequent sections of this chapter, section 8.2 describes how the steps of the MVCA were applied in the case study. Also, it documents the procedure for analysis of data collected. Section 8.3

provides the results in line with the specified objectives. Section 8.4 provides a discussion of the results, and the study conclusion is provided in section 8.5.

8.2 Application of MVCA (OVAF Stage 2) for developing scenario-specific visions for the Nigerian PPD sector

This section documents how the MVCA was applied to the Nigerian PPD network case study. The MVCA consist of six steps and sub-activities described in section 5.4 of chapter 5.

8.2.1 Step 1- Project definition

A steering team consisting of the researcher and three recruited facilitators was set up in October 2017. The recruited facilitators are doctoral research students, and professionals currently working in the Nigerian Petroleum Industry. The researcher was responsible for the design and implementation of the research, while the recruited facilitators were responsible for the facilitating the discussions during the visioning workshop. The focus of the visioning exercise was to addresses the question; "**what are the stakeholder visions for the Nigerian PPD network by 2040"?** In preparation for the visioning exercise, the researcher attended workshops on the following areas: i) how to identify stakeholder groups; ii) ensuring stakeholder representation; iii) organising workshops/interviews; iv) conducting a risk assessment, and v) obtaining ethical approval for research.

8.2.2 Step 2 - Planning for the visioning workshop and interview

This step involved the identification of stakeholder groups and participants; preparation of visioning materials; conducting ethical review and risk assessment; recruiting and training of facilitators; piloting visioning session, and organising other logistical activities.

8.2.2.1 Identification of stakeholder groups and participants

A stakeholder analysis was conducted by the steering team to identify the different stakeholder groups involved in the PPD sector in Nigeria. As previously highlighted in section 6.2.2, the stakeholder groups identified were professionals from the major oil marketing and distribution companies in Nigeria; the National Oil Company; regulatory agencies in the petroleum industry; managers of retail fuel stations; academics with a research interest in petroleum products transportation, and leaders of petroleum tanker driver's association. (see figure 8.1)

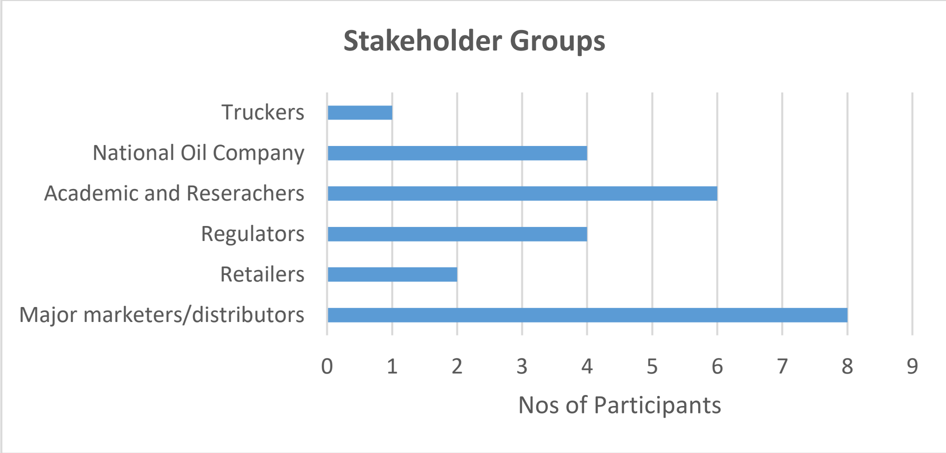


Figure 8.1 Visioning exercise stakeholder groups

A purposive sampling method was adopted to identify the participants with at least 5years experience in the industry and are within the age group of 40-70 years. Gatekeepers such as the recruited facilitators provided emails of 30 professionals from the different stakeholder groups. Email iinvitations containing the information sheet were sent to the emails of the prospective participants. Among the 25 participants that agreed to take part in the process, 12 of the professionals were willing to attend a workshop, while 13 of the participants opted for a one-on-one interview session. Consequently, an interview visioning design was implemented to complement the workshop.

8.2.2.2 Preparation of visioning materials

In preparing materials for the visioning exercise, the researcher initially reviewed issues and current concerns of the industry already identified in the previous step. Also, the researcher developed summary of each external scenario developed in section 7.8 of chapter 7. These scenario summaries provided insights to the Nigerian PPD sector stakeholders on the possible exogenous background contexts for their visions. Also, insights were drawn from the components of a network design problem to inform the design of the discussion and interview guide. A two-day workshop schedule was drawn putting into consideration practical issues such as the risk to participants; location of the workshop; duration of presentations, discussions and breaks; resources for workshop (see appendix 4, 5, and 6 for workshop discussion guide, interview discussion guide and visioning workshop schedule respectively). The Visioning workshop theme was tagged "Envisioning an efficient distribution network for 2040".

8.2.2.3 Research ethics and risk assessment

While the MVCA does not suggest the requirement for ethical approval in all cases, it was necessary for this study because the study was conducted as part of a PhD thesis. Consequently, the researcher obtained ethical approval for the research after consulting the guidelines set out by the University of Leeds Ethics Board before data collection began (see appendix 7 for ethical approval). The study understood the need for voluntary participation and informed consent, as well as the importance of anonymity. Therefore, each participant was approached via email through the researcher's university account with a formal cover letter, along with a participant information sheet.

The ethics board advised that considering the small group of participants from a highly specialised field, it might be easy to identify the interviewees through their answers. While the researcher acknowledged that the risks of identification can never be removed altogether, the researcher sought to minimise such risk by representing each participant using pseudonyms. This created a layer of anonymity. The researcher added that any information shared would be used for research purposes only and not for any professional gain. Each participant was asked to sign a consent form before the interview (see appendix 8 for consent form). In terms of the risk assessment, the research was perceived to be low risk. This was based on the understanding that the study did not involve working with any vulnerable groups but with 'policy elites (see appendix 9 for risk assessment report).

8.2.2.4 Training and logistics

The facilitators were trained for two weeks on the purpose of the visioning workshop; facilitating group discussions, observing participant's non-verbal cues; and generating observatory notes during the visioning workshop. In terms of the logistics, a seminar room at the Federal University of Technology, Owerri Nigeria, was selected as the location for the workshop because the location is approximately two hours from the location of the invited participants. Also, all resource materials were available in the location. Due to the nature of the participants invited, the location was suitable as the adequate security was made available.

8.2.3 Step 3 – Exploring issues

This step was the first step during the actual visioning workshop. Here, the four pre-developed external scenarios developed for the Nigerian PPD sector in section 7.8 of chapter 7 were presented to the workshop participants. After each scenario presentation, participants were encouraged to comment on the scenarios, while the researcher and the three facilitators took note of the comments raised. The researcher and facilitators captured a glimpse of the group dynamics such as the silence of some members when asked to express the views, the hijack of the discussion by some participants, the nodding of participants when other were talking, and the background discussions of the participants. The non-verbal cues compensated for silence of some participants during discussion as most participants expressed themselves through these non-verbal forms. (Refer to participants reactions under results section 8.3.3)

Workshop and one-on-one interview methods were selected as the methods for exploring the issues with oil industry stakeholders. Besides the workshop and interview methods, section 5.4.2.3 of chapter 5 accounts for the use of the delphi survey method to build consensus opinion on the explore issues step. However, workshops and interviews were selected because they provided a platform for the researcher to directly interface with the stakeholders and capture rich non-verbal data on group dynamics in addition to their verbal reactions to the pre-created external scenarios.

8.2.4 Step 4a - Generating scenario-specific vision elements during the visioning workshop

Just like the explore issues stage, the workshop and interview methods were used for generating the scenario-specific vision elements. In this step, the selected methods were useful because they provided an opportunity for facilitating the discussions of the participants and encouraging them on the use of workshop discussion documents. In addition, since the objective was to develop scenario-specific visions, a direct elicitation method such as the workshop and interview methods provide the best platform for facilitating discussions and encouraging the participants to focus on developing vision elements that are consistent with a specific external scenario. Since the purpose of the visioning exercise was not to assess some pre-created visions, the public opinion survey method was not considered a useful method for use.

The 12 workshop participants were split into four groups. Each group was assigned to develop vision elements under one of the four external scenarios. The steering team worked with each group to ensure the groups adhered to the discussion guide. During the discussion session, ice breaker questions were introduced to ignite discussion among participants. Where a participant was observed to be silent during discussion, such participant is politely invited to make a comment by a facilitator. Also, facilitators used probes to elicit a stakeholder definition and interpretation of unclear comments. After the vision elements were developed by the different groups, participants were encouraged to consolidate their group findings. Each group was encouraged to summarise their visions to be presented to the other participants on the second day of the workshop.

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8.2.5 Step 5a- Producing scenario-specific visions during workshop

The second day of the workshop was for the revision of visions and development of drafts of the scenario-specific visions. Each group was allowed 30 minutes to communicate their scenario-specific visions to the other groups. After each presentation, participants of other groups were encouraged to comments on the scenario-specific vision. Based on the comments from participants, each group revised their visions and developed rough vision drafts that captured a shared opinion of the vision under the four external scenarios. Participants were informed that the visions would be analysed to identify the characteristics of their visions and other post-analysis to be conducted.

8.2.6 Step 4b- Generating scenario-specific vision elements during interviews

This section reports the visioning exercise through a one-on-one interview process. While it is known that the combination of interviews with workshops support the triangulation of research findings, it is important to note that the use of the interview method was not to compare its results with the workshop method. It was a backup method for implementation where the participants failed to attend the workshop.

The interviews with 13 participants took place over three weeks. Here, the four external scenarios summaries were first emailed to all the participants for them to read and understand the different future scenarios over the first week. Participants were then encouraged to provide a two-hour time slot over the second and third week for the discussion of the external scenarios and the generation of vision elements. Subsequently, the thirteen participants were divided into two groups A and B. In the 2nd week, discussions on the external scenario 1 and 2 were held with the each of the participants of group A. In the same week, discussion on the external scenario 3 and 4 were held with each of the participants of group B. During the same time in the 2nd week, participants of each group were asked to provide their vision elements under the specific external scenarios they had discussed. The summary of the vision elements from the 13 participants were summarised by the research team.

8.2.7 Step 5b- Producing scenario-specific visions during interviews

In the 3rd week, a summary of the visions developed from group A was discussed with participants of group B. Also, the summary of the visions from group B was discussed with the participants of group A. This provided an opportunity for all the members to review the vision elements from other members. Based on the comments from the participants, the visions were revised. A final copy of summarised visions were emailed to the thirteen participants of the visioning exercise. A summary of the scenario-specific visions produced by stakeholders were combined with the workshop outputs and analysed in the next step.

8.2.8 Step 6 – Plan for action (Analysis of visions)

This section describes how the shared visions were analysed to address the study objectives. A data corpus was collected through the embedded focus group discussions during the visioning workshop activity of 12 professionals; the one-on-one interview sessions from the 13 professionals. A third data set is the observatory notes taken during the focus group and interviews. These data sets had different purposes. The interview and workshop visioning data sets (i.e. the first and second data set) aimed at identifying the reactions to the external scenarios, the generic vision elements, and the variables of the optimisation of the Nigerian petroleum product distribution network.

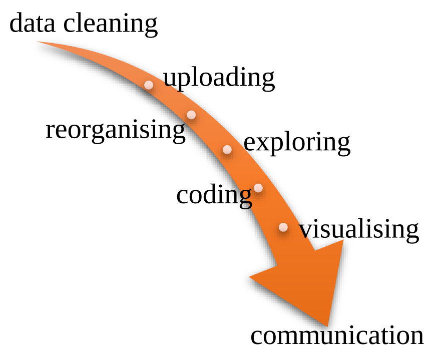


Figure 8. 2 Seven-steps of qualitative analysis (Source:Cresswell, 2007).

According to figure 8.2, the analysis process commenced with the data cleaning activity. All recorded data were transcribed from audio formats into text formats. This was carried out for both the interview and workshop data. Handwritten data were cleaned by editing the typographical errors and ensuring that the texts were typed on a readable word document format. The cleaning also involved writing the document according to headings and research questions. Data was transcribed by converting verbatim into written text. All transcripts were presented under the research questions. Phrases termed as “anchor codes” were then created to represent the research question.

Data were inserted into an excel spreadsheet in a survey format. Each discussion question was presented on a vertical column while the cases (either individual participants or group) where arrayed on the horizontal rows. Next, participants responses already inserted into the excel sheet were uploaded into the Nvivo data analysis software using the survey wizard tool. Subsequently, the data were reorganised by the survey wizard in Nvivo into a survey format. This reorganisation made it easier to organise the data into open-ended interview questions and the closed-ended questions. It also created the classification and attributed to the cases specified. After reorganising and uploading data, the data were explored to understand how the participants responded to the questions; the kind of words used; and the frequency of these words.

The transcripts were read three times by the researcher to be familiar with the nature of the data before the coding started. Information related to each research question were coded using content in-vivo coding technique and grounded coding technique. The coding was carried out in line with the research questions. The first focused on identifying core issues under the reactions to the external scenarios. The second focused on identifying the characteristics of the vision narratives. The third focused on identifying the optimisation related variables from the visions. The transcribed data were coded by grouping participant's responses under the following anchor codes (i.e. scenario issues, vision characteristics, optimisation variables). The initial list of coding categories was further modified during the analysis as new groups emerged. Two coders were used for the coding process to enhance the intercoder reliability. First and second cycle coding schemes were developed and used to refine the codes as well as its number.

8.3 Results

This section presents the results of the analysis conducted in line with the study objectives. Section 8.3.1 and 8.3.2 initiates with a presentation of the background information of the workshop and interview participants. The results of the participant's reaction to the external scenarios are provided under section 8.3.3. The results from the generic scenario-specific vision elements are presented in section 8.3.4. The results to the optimisation variables are presented in section 8.3.5.

8.3.1 Workshop participants background information

The participant's work affiliation, gender, position, age, and years of work experience are presented in this section. Figure 8.3 provides a breakdown of the participants work affiliation. Among the 12 participants, four work for the major petroleum product marketing companies in Nigeria; three academics/researchers with interest in petroleum products distribution in Nigeria.; two employees of the regulatory agencies in the Nigerian PPD sector, and the National Oil Company respectively. One participant work as a supervisor in the Nigerian PPD truck driver's association.

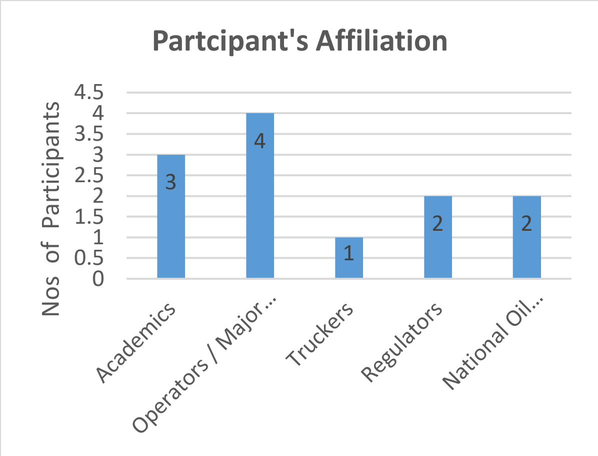


Figure 8.3Workshop participant's affiliation

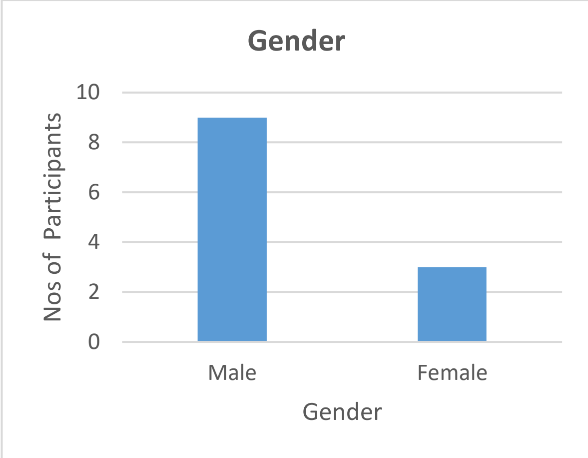


Figure 8.4 Workshop participant's gender representation

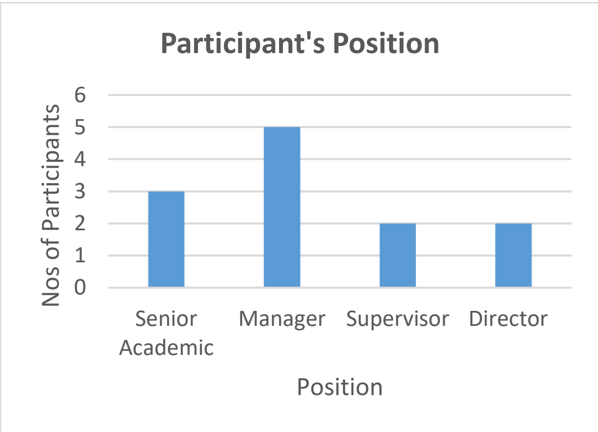


Figure 8.5 Workshop participant's position

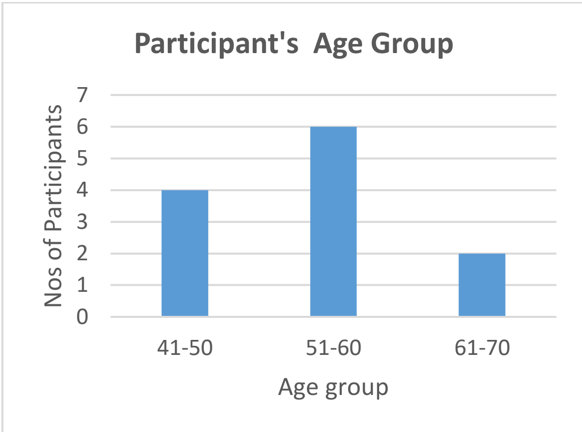


Figure 8.6 Workshop participant's age-group

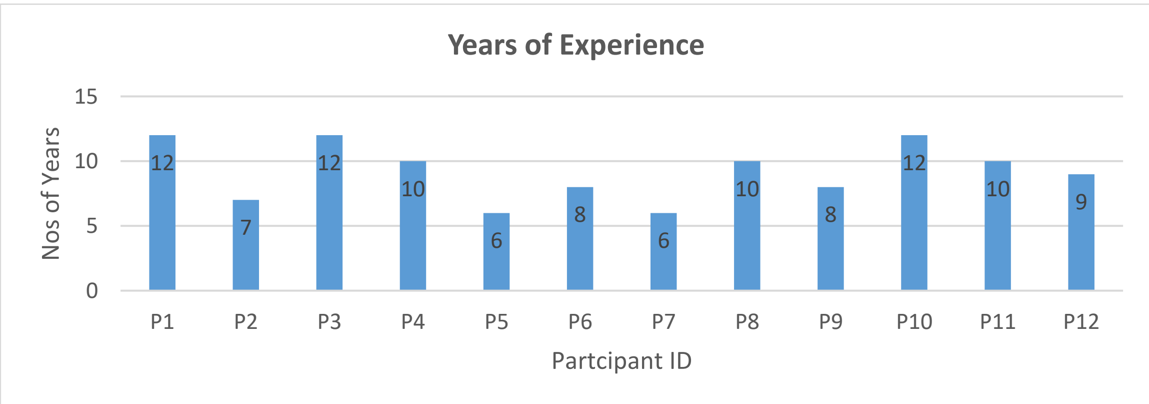


Figure 8.7 Workshop participant's years of experience

Figure 8.4 shows a 75% to 25% male to female gender representation of the participants involved in the workshop. To avoid issues related to power imbalance during discussion, the researcher recruited participants who were at the management positions or above. Consequently, figure 8.5 reveals that three of the participants were senior academics that have made a significant contribution to knowledge and practice in the field of product distribution through their publications in reputable journals. Five of the participants were managers of different units in the PPD sector. Two participants were either supervisors or directors in their establishment. Figure 8.6 reveals that seven of the participant's fall within the 51-60 age group. Four falls within the age group of 41-50, and two of them fall within the 61-70 age group.

During the generation of scenario-specific vision elements, the 12 participants were split into groups of three. Since the participants recruited were either senior professionals in the industry or academics with vast expertise in transport of petroleum products, it was assumed that the issue of power imbalance among participants did not exist. Therefore, members were randomly allocated to each group. The table 8.1 presents the group characteristics.

Table 8. 1 Visioning workshop group characteristics

Vision development groups	Age range	Sex	Years of experience
Cases\\vision element analysis\\Group 1	45-56	All Male	7-12 years
Cases\\vision element analysis\\Group 2	43-59	1 female, 2 Male	6-10 years
Cases\\vision element analysis\\Group 3	45-56	1 female, 2 Male	6-10 years
Cases\\vision element analysis\\Group 4	44-54	1 female, 2 Male	9-12 years

As part of the visioning workshop design which involved the use of focus group discussions. The 12 participants were divided into groups of three to discuss their visions under different scenarios. Group 1 had participants between the age of 45 and 56. They were all male and had at least seven years of industry experience. Also, group 2 had participants between 43 and 59 with a mix of one female and two males, and their experience was at least six years. Members of group 3 had a similar experience and gender make up as group 2. However, the participant's age bracket was between 45 and 70. Finally, group 4 had an age range of 44 to 54 for the participants, with gender, the makeup of one female and two males. This group, however, had the most experienced professionals with a minimum of nine years of experience.

8.3.2 Visioning interview participants background information

Thirteen professionals took part in the one-on-one interview visioning process. The figures 8.8 – 8.12 below present the breakdown of the participants work affiliation in the sector, gender ratio, position in their respective establishment, age range, and professional years of experience respectively.

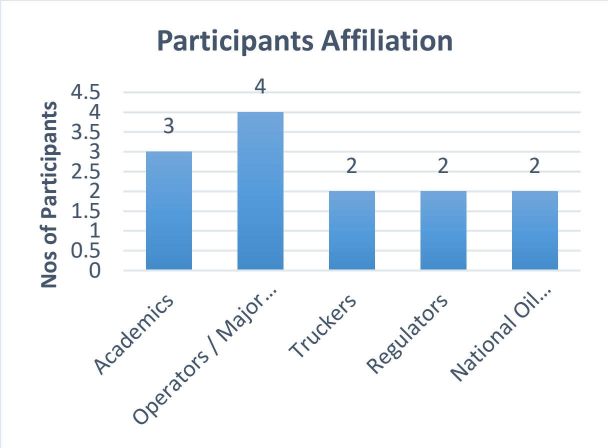


Figure 8.8 Interview participant's affiliation

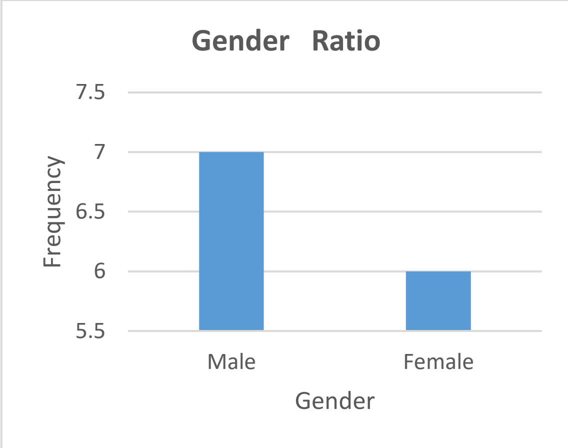


Figure 8.9 Interview participants gender ratio

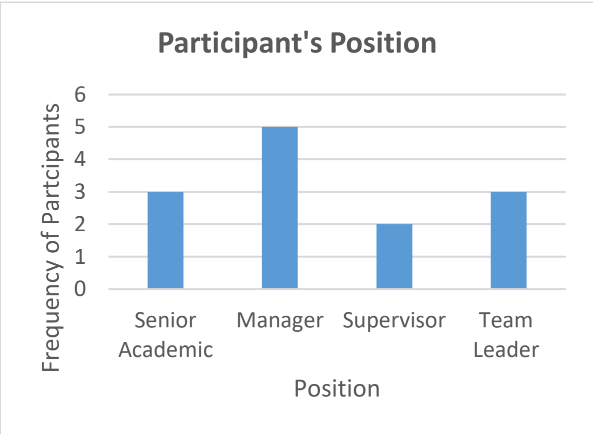


Figure 8.10 Interview participant's position

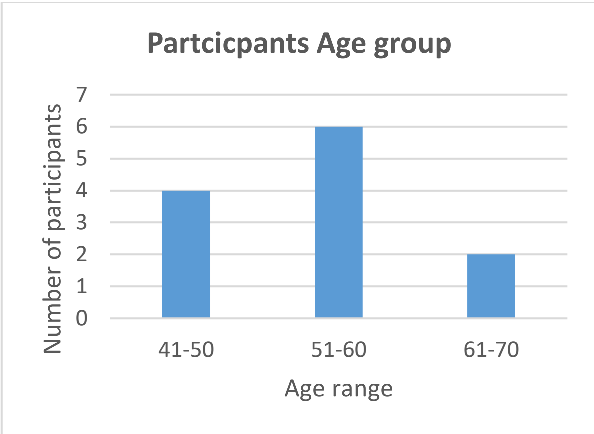


Figure 8.11 Interview participant's age group

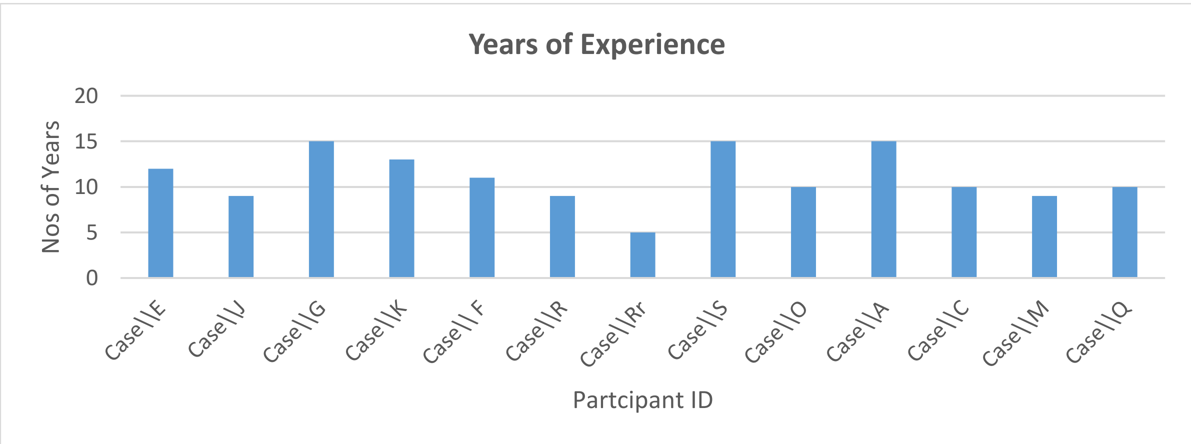


Figure 8.12 Interview participant's years of experience

Participant's names have been represented using pseudonyms to guarantee their anonymity. To ensure that the participants were knowledgeable in the field, their years of experience was explored, and the participants had at least five years' work experience in the field (figure 8.12). Also, eight out of the thirteen participants had more than 10 years of experience, and the maximum years of experience were 15 years. Participants were invited from diverse oil-related organisations to capture the stakeholders involved in the industry. Specifically, four of all the professionals came from major oil marketing and distribution companies. Two of the participants were professionals from the Nigerian National Petroleum Company (NNPC). To capture a regulatory perspective in the Visioning process, two of professionals came from regulatory organisations such as the Department for Petroleum Resources. Two of the professionals came from the trucking sector, and three of professionals came from academia.

An effort was made to recruit participants that were at the management positions. For example, figure 8.10 shows that each of the professionals from the major petroleum product marketing companies is Managers within the different organisations The three academics involved were both above senior lecturer positions in an academic institution, and they have made a significant contribution to knowledge and practice in the field of product distribution through their publications in journals. Others were team leaders and supervisors in the trucking unions and the regulatory institutions.

8.3.3 Workshop participant's reactions to external scenarios

The pre-developed external scenarios were presented to participants at the beginning of the workshop session. After presentation, they were encouraged to comment on the external scenarios. This section provides details of their responses under the different external scenarios.

8.3.3.1 Reactions to the stagnant scenario content

Two issues were raised under the stagnant external scenario. First, some participants likened the stagnant scenario to the current state of the Nigerian PPD business environment in the year 2017. Second, one participant suggested the introduction of "corruption" as a key driver of change under the stagnant external scenario.

In terms of relating the stagnant scenario to the current situation experienced in the Nigerian PPD business environment, P5 likened the stagnant scenario to a "doomsday scenario" and a scenario currently being experienced. In the words of P5:

> *"To me, I think that the stagnant scenario you painted is very plausible and almost the same as what we are currently observing in our environment today. Yes! i say so because we are experiencing an unstable oil price which has thrown the country into recession and*

our nation isn't politically stable". P4 added: "*Yes! What we see today is the same as having a poor economy and an insecure environment".*

There was an agreement on this point as P2, P4, and P7 nodded their heads up and down in agreement with the comments of P4 and P5.

On the issue of "corruption" being a key element in the stagnant scenario, P5 and P10 emphasised that corruption within the judicial and political class has negatively affected the sector operation. They noted that corruption has led to product unavailability at retail stations and high petroleum product prices. In the words of P5; "*Why don't we look at the issue of corruption? For example, we know that today our society has so much corruption and impunity in it. Shouldn't we also be afraid of that in future?". P5* reiterated that when corruption goes unchecked by regulatory institutions within the industry, quality standards are sacrificed at the expense of more profit.

8.3.3.2 Reactions to the declined scenario content

An interesting issue that emerged from the stakeholder reactions to the declined external scenario was "the likelihood of transfer from the use of fossil-based fuel to environmentally friendly energy forms". This feature of the declined scenario was met with diverse opinions. Some participants argued that users of petroleum product such as premium motor spirit (PMS) would not be ready for any form of new energy by the year 2040 due to the harsh economic climate that is presented in the scenario. In the words of P4; "*I will be surprised if people will think of other forms of transport that are environmentally friendly in such a future". The Nigeria we know, if people cannot feed themselves, I doubt how easy it will be for them even to start to think of the environment. I know it can happen in developed nations but not in Nigeria" (P4).*

In addition, P4 drew a positive correlation between the low oil price, weak economy, and political instability. He adds that the harsh economy will reduce the average income of citizens subjecting them to a low standard of living that could make workers unhappy as they can barely meet their needs. This is similar to the situation of the stagnant scenario where political instability triggers insecurity and crisis in society. However, P5 disagreed with the later arguing that regardless of the poor state of the economy, citizens may be satisfied with the governance of the country and appreciate the need for peaceful coexistence, zero violence, and adoption of government policy towards a sustainable and environmentally friendly mode of transport. P8 agrees with P5 on the possibility of having a government which is true to its promise despite the unfriendly economic downturn.

In summary, the scenario was clear to all the participants. Non-verbal cues and the random comments captured by the facilitators suggest the undesirable nature of the scenario under consideration. Participants that did not comment continually waved their heads side-ways. A probe by a facilitator to P4 confirmed that his head signal non-verbal cue to implied *“I don’t think we are going back towards where we had passed” (P4).*

8.3.3.3 Reactions to the careless scenario content

The problem of inconsistency in the scenario content was observed as P4 was not convinced about the consistency of a careless scenario. Participant 4 argued that the high oil price that has brought about a wealthy and buoyant economy could not exist alongside an unstable political atmosphere and insecurity . in the words of P4 *“I would believe that if the government is rich and the GDP is good, there would be no need for people to steal or be sad, so, the society should be safe”*. However, P5 responded that not all buoyant economies have a stable political and secured systems.

In the words of P5, *“there is the possibility of such a scenario because if the government of the day does not secure the peace and unity of the nation, then, we cannot assume that such a future will guarantee a politically stable and secure environment. The leadership and governance structure has an active role in ensuring a stable political system of governance” (P5).* P3 added*; “Yes! I see sense in what P5 is saying. If we have a leadership that is interested in the nation at large, then, the society will be good. So, let think in line with the scenario presented. This is possible” (P3).*

In summary, the participants agreed that the scenario could exist. However, participants stressed the need for strict measures to deal with restive youth rather than soft measures, as suggested by other participants (P4 and P8).

8.3.3.4 Reactions to the rejuvenated scenario content

The rejuvenated scenario evoked an interesting discussion as most of the participants were very keen and smiling while the presentation was made. As participants wished for the realisation of such a scenario. P3 echoed *“This is my dream scenario for the year 2040”*.

P4 commented on the possibility of switching over to solar panels for domestic purposes by the year 2040. He added that such a switch would impact demand for petroleum products. So, there is a need to build systems which are adaptable to the changing times. In reaction, P3 asks in a low tone**.** *“So, if we move to other forms of energy, what then happens to our oil which is our main source revenue?”*

(P3). In response to the question, P10 responds *"the scenario specifies the diversification of the revenue sources to accommodate agriculture, technology, education and alternative energy. The external scenario mentioned the non-reliance of fossil fuel and the availability of technology to meet consumer demand for electricity adequately".*

P8 comments on the concern over the switch to renewable energy forms of energy raised by P4, *" I think the oil industry would struggle to survive in this kind of future if nothing is done before that time. I say this because the industry supplies the nation with products. So, the market for the outcomes of the oil industry is society. When society departs from the use of oil products, what will be the usefulness of our products?" (P8).* The question triggers an innovative idea from P11*, "Yes! We will supply petroleum products to neighbouring countries in the event of such a future"*. P9 agrees with the later, buttressing how the stable and peaceful environment will attract foreign investors to invest in technology and cleaner fuel. In his comments; *"I am less concerned about what happens to the oil reserve or the market to serve. I think that the positive business climate positions us to surpass any mountain before the nation". International communities will even visit us to invest in our economy because we have the market for any business to thrive (P9).*

P10 expressed that 2040 may be too far a future for such a future to be unveiled. He reiterates that with good leadership, it can be achieved in the next ten years. This point was agreed upon by P1, P2, P3 and P4 agreed on governance as a great challenge which could affect their future. They decided that the political and security state of the nation is their greatest fear within the Nigerian context, while the unstable price of oil affects the market from a global standpoint.

In summary, the participants were highly optimistic about the rejuvenated scenario. The non-verbal cues captured were the smiles and positive expressions made which indicates that they were delighted with the scenario content. However, Participant three slightly expressed concerns over what happens to Nigeria if the world switches to non-fossil fuel-based transport.

8.3.4 Generic scenario-specific vision elements for PPD sector in 2040

This section brings together the results obtained from the use of workshop and one-on-one interviews. The vision elements across the four scenarios for the PPD network were built on the following themes: (i) functional regulatory institutions; (ii) effective management; (iii) optimised network design; (iv) adequate technology; (v) security; (vi) integration of distribution processes for operators; (vii) strategic policy; (viii) social transformation; and (ix) sustainability. Not all the visions consist of these themes. Therefore, the next subsections will provide the result of the themes under different scenarios. (Evidence in the vision narratives and the vision elements code book can be found in appendix 10 and 11)

8.3.4.1 Elements of a stagnant external scenario-specific vision

This section presents the results of vision themes identified under the stagnant external scenario.

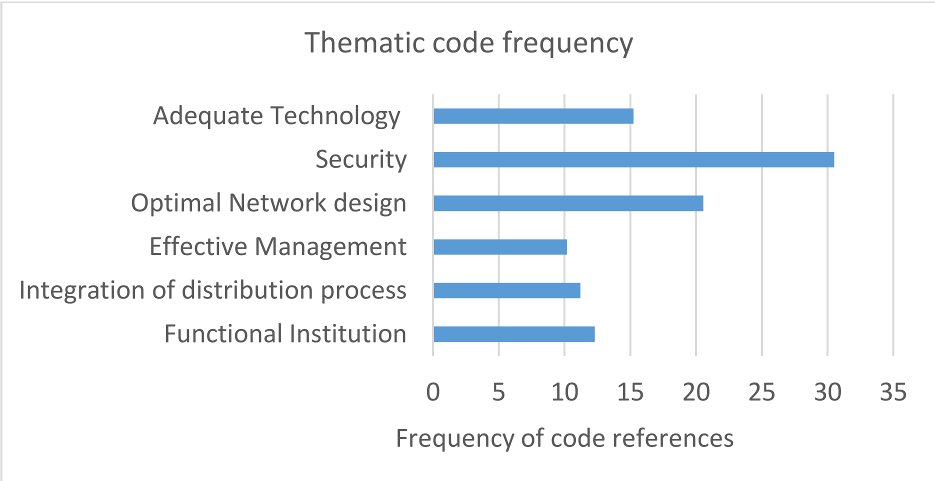


Figure 8.13: Vision elements under a stagnant ext. scenario

According to figure 8.13 below, **security** was a vital elements of the desired PPD network. This would ensure that petroleum products distributed across the network is delivered to the consumers at the best quality, price, and right location. 30% of all coded comments from the workshops and interviews relate to security. In the words of PF,

> *"the level of insecurity has led to the destruction of the major pipelines for transporting products from the large storage depots and jetties to the transhipment depots scattered all over the nation. We have no choice but to resort to the road transportation of petroleum products from the South to Northern Nigeria. In the future, products can be transported through as secure network" (PF).*

The **optimal network design** was another area of concern for the stakeholders. Comments related to the above theme covered about 20.56% of the total coded comments. The participants envisioned a network that is designed to guarantee the least cost for distributing products. A participant during the Interviews with vast experience in the products pricing and distribution of products commented that *"the current network design was based on political reasons and not on the economic and social* *benefits. If we truly want the system to work, we must separate politics from the network structure"* (PK).

The role of **technology** in achieving an optimal network design cannot be overemphasised. Participants stressed that technology must be in place to ensure that their operations are seamless, fast, and efficient. They added that the reason for the loss of the product on transit, diversion of trucks and the imperfect loading process is due to the reduced levels of monitoring and tracking systems. 15.24% of the coded text from the workshop and interview transcripts relate to the importance of technology. Also, participants expressed the importance of depot terminal automation in the future such that all trucks arriving at the loading bay would have electronically transmitted all documents and payment protocols. This will significantly reduce the truck waiting time on arrival at the depot stations.

10% of the comments were related to **effective management** where maintenance works are conducted at the right times, accurate demand planning and deregulation of the business ownership structure. 12.3% of the comments are linked to functional institutions. The participants envisioned a future where the regulatory institutions are empowered to enforce best practice compliance across all players in the sector. P10 with about 12 years of experience in product loading and dispatching expressed that *"we need our agencies to regulate the number of players within the sector. Having a few operators will make it easier to track and monitor operators who do not adhere to best practices"*

12.5% of the coded comments were on **integration of the distribution processes**. P10 added that "with fewer operators all distribution processes can be integrated through information technology platforms. Operation can easily capture demand level information, and crosscheck with the supply levels on the system. When one operator cannot supply, other operators can meet the demand to the customer locations.

8.3.4.2 Elements of a declined external scenario-based vision

This section presents the results of vision themes identified under the declined external scenario

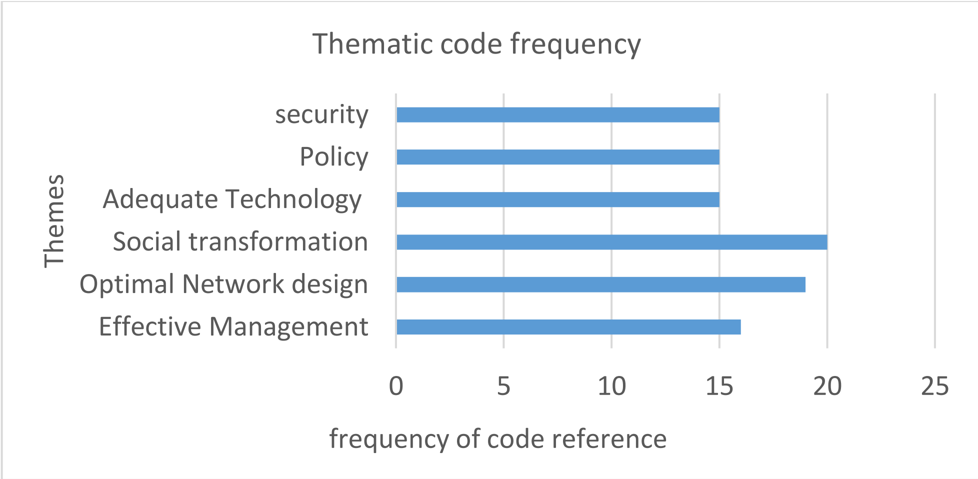


Figure 8.14: Vision elements under a declined external scenario

According to figure 8.14, this vision followed a similar pattern as the stagnant scenario-based vision elements presented in section 8.3.4.1 above. However, it differed by the participant's interest in **social transformation and policies**. Comments related to these themes were identified from the analysis of the vision drafts of the group. From the analysis, 20% and 15% of the comments were about the drive **social transformation** and **sector policies** respectively. Participants drew their inspiration from the background context, which had a depleting oil level, low oil price and recession economy. However, the they highlighted that the sector could leverage on a peaceful and safe environment for doing business to attract foreign investors who can either import products for supply or develop alternative energy forms. This can be achieved through policies that support local and foreign investors. Some of these policies include business mergers, lowered lending rates for importing products, policies to encourage foreign investors. In the words of PG, "*In the developed world, we see corporate organisations supply bicycles for city transportation*. *Organisation involved in the sector must be actively involved in affecting the social sphere through social responsibility*".

19% of the comments made were related to an **optimal network design** for the distribution of their products. Participants suggested a range for the number of transshipment depots that can support the efficient distribution of petroleum products. During the interviews and workshops, each participant suggested a range of number of depots which in their opinion would guarantee an efficient distribution network. According to the result presented in table 8.2, the maximum and minimum number of required transshipment depots suggested by the participants was used to develop a range of number of transshipment depots. Participants also stressed on the use of pipeline as the major inbound transport mode for distributing products from the large depots to the transshipment depots(P5, and P6). Other network related elements which were coded under this theme are the structure of the design. P3 commented that a regional network design would ensure that each region will adequately maintain its network. In his words, *"instead of having a national network that if faulted by poor maintenance or a situation where a problem in one region affects the entire network, it is better to regionally operate our networks*" Under this scenario, PF also suggested that the transshipment depots should be located optimally such that the cost of distributing products must minimised. In the words of PF: "*our network should be designed such that we don't surpass our expected cost of distributing products because it will lead to higher fuel prices at the station*".

15% of the comments were on the **effective management** of the downstream sector. Some of the issues that the workshop and interview participants discussed were the ownership structure and investment strategy. PK envisioned a future system where there would be an influx of foreign investors because of the safe and secure business environment depicted by the external scenario. He added that mergers and alliances with international multinational companies will open the downstream sector to better opportunities. In the words of PK, **"*We can still have private investors from the global setting come in to invest in our system. Private small companies either align with major players or fall out of the industry*."** Other participants highly welcomed this point, and this was confirmed by the way they nodded in agreement while the participant took the stage.

Finally, 15% of the comments focused on the **investment in technology and security** for the distribution network. It was agreed that despite the safe environment, the organisation within the sector must ensure that their processes are well automated. Trucks used for products transfer must be fitted with sensors to track and monitor the products on an online real-time basis.

8.3.4.3 Elements of a careless external scenario-based vision

This section presents the results of vision themes identified under the careless external scenario. The vision under the careless external scenario, 16% of the comments focused on functional institutions, 15.6% on security; 15.25% on effective management; 14% on technology, 12% on both sustainability and optimal design of the network and 10% were related to the integration of distribution processes.

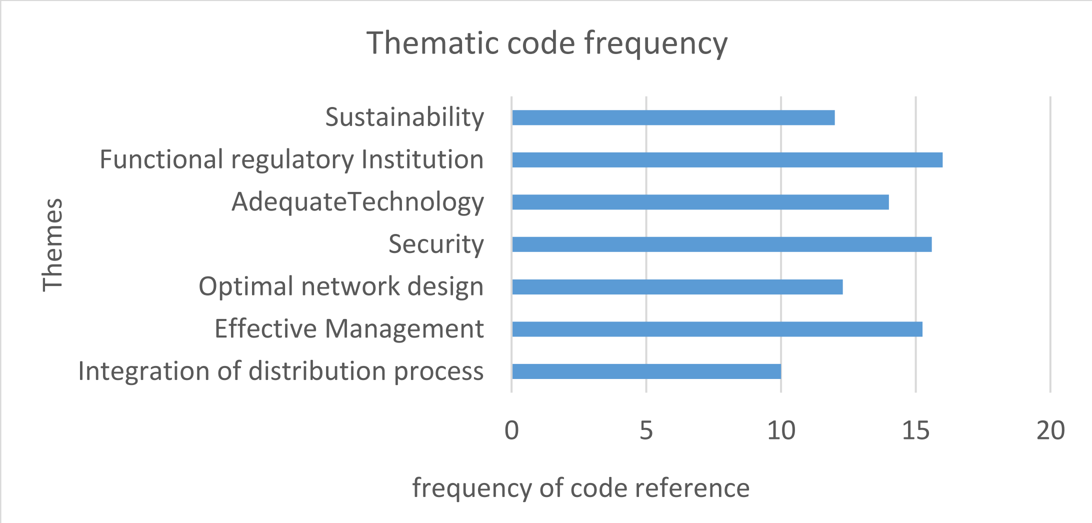


Figure 8.15: Vision elements under a careless external scenario

The participants emphasised **security** systems which must guarantee that the hostilities in the business environment will not affect distribution operations. They added that the security system would consist of both human and technical supervision of pipelines, rail tracks, trucks and the depot tank farms. PS notes; *"aerial monitoring drone systems are used to pre-scan rail routes before products are dispatched for supply. While the products are on transit, there would be a surveillance system monitoring the products sent from the depot to demand point".* PK disagrees with the use of drone systems and suggested that *"human interventions through the police and other security organisations*" will be more beneficial. Other participants agreed on the need for information technology powered security system, which cannot be easily manoeuvred.

The participants echoed the need for functional regulatory institutions because of the high level of non-compliance with the regulatory framework of the downstream sector by industry stakeholders. The preferential consideration given to some players at the expense of others has ruined the opportunity for a fair and level playing ground among the operators. Trust has been broken, and the focus has been shifted from customer satisfaction through constant product availability to accrued revenue and profit. Therefore, the participants stressed the need for neutrality, objectiveness and standardisation of practices which will strengthen the cooperation amongst stakeholders in the future.

A participant from a regulatory agency stressed the need for collaboration amongst stakeholders. He reiterates that in the agency is poised to transform the sector through optimising their supervisory roles ranging from inspections, surveillance to monitoring compliance and enforcement. Besides constant engagement and sensitising of stakeholders on the applicable regulatory requirements will promote the ease of doing business. Regular checks and audits by the agency must be conducted to ensure the operators abide by the set standards and best practices.

Evidence from PG in support of the above states; thus, *"frankly, the government and the regulatory agencies do not have the political will to control the sector now. We want the agencies in charge of ensuring best practices to stand up and do their job".* PR added, *"all agencies and institution must adhere to the best practices. The regulatory agencies, in partnership with the police, must intensify their activities to ensure that those operators who always cause the problem are brought to book". Yes, they should be punished according to the law" (PR).*

8.3.4.4 Elements of a rejuvenated external scenario-based vision

This vision is linked to the global vision on sustainable practices. Group participants were highly excited to discuss their requirements for the vision. One interesting observation was that most of the comments (18.7%) were centred on the social transformation issues. This issue relates to the change in behaviour of both the external environments and the internal environment towards sustainable lifestyles.

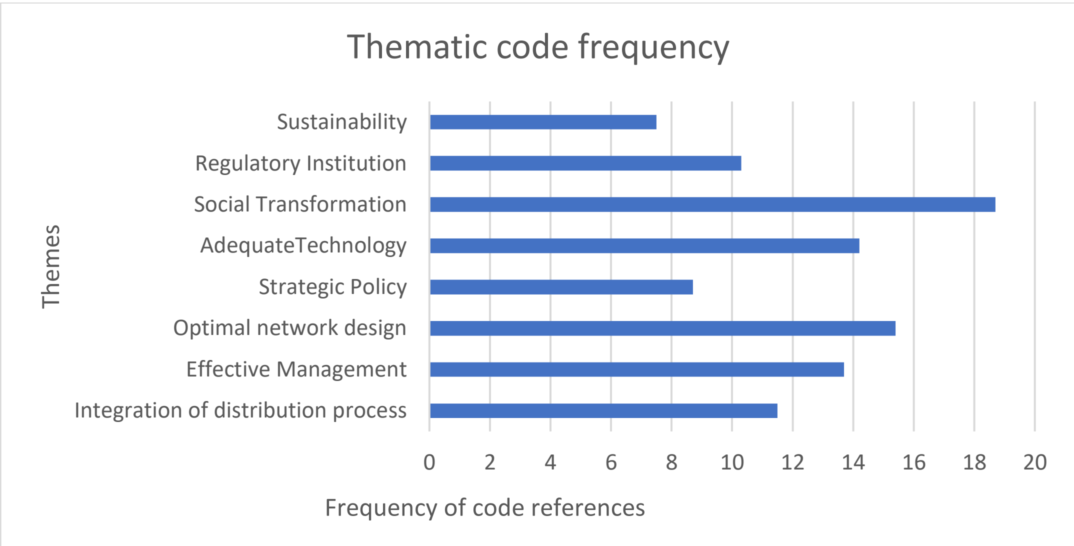


Figure 8.16: Vision elements under a rejuvenated ext.scenario

According to figure 8.16, the participants under this group envisioned a future where new technologies and new fuels have evolved. There is also a rapid adoption of newer fuel and technologies within the distribution chain of petroleum product. From the analysis conducted, 15.4% of the comments focused on an optimal network design structure. The distribution network is designed with the motive to reduce the cost and environmental impacts of the current road distribution process. The participants strongly agreed on a 100% use of pipelines for the distribution of their products. In the words of PG ; "*It is not going to be the case of the trucks even moving these products, we must use pipelines. We don't need trucks to be on our roads causing accidents and crashes every day" (participant G).* PO adds, "*Pipeline is the cheapest, safest mode for moving products in the way that it won't affect the other parts of the society such as the accidents, congestion and destruction of the roads" (Participant O).*

14.2% of the comments focused on the relevance of policies to support the achievement of a sustainable distribution system. 13.7% of the comment addressed requirements on effective management; 11.5% of comments addressed the integration of processes; 14.2% addressed the importance of technology and system automation which in their words they stated**:** "*In the future when all IT systems are in place to support inspection and clearance, I think we should be looking at not more than 20 mins documentation process and the remaining time for travel of 100 minutes for travel" (PE).* 7.5% of comments directly addressed issues of sustainability, and 10.3% addressed the requirements on regulatory institutions "*we expect to see that players are competing on a fairground rather than on political affiliation" (*PK*).*

8.3.5 Identification of optimisation variables

Table 8.2 below presents the optimisation elements identified from the different scenario-specific visions produced from the visioning exercise (see appendix for vision narratives). In the table 8.2, the first column are the direct quotes extracts that reflect the vision elements that were translated in chapter 9 for the optimisation of the visions. The columns 2,3,4 and 5 presents the researchers classification of elements into qualitatively, quantitatively, or semi-quantitively defined under the respective external scenarios. The vision narratives used for the analysis can be found in appendix 11.

Table 8.2 Vision optimisation elements from scenario-specific visions

Vision element quotes	Vision element definition (stagnant)	Vision element definition (declined)	Vision element definition (careless)	Vision element definition (rejuvenated)
“a low cost of distributing products.”	Qual. defined	Qual. defined	Qual. defined	Qual. defined
“improved service level by satisfy customer demand and ensuring customers do not travel far to get products.”	Semi-quant defined ≤50km	Not mentioned	Semi-quant. Defined ≤50km	Semi-quant. defined ≤50km
“an environmentally friendly operation.”	Not mentioned	Not mentioned	Qual. defined	Qual. defined
“Adequate depots to support distribution.”	Semi-quant. defined (4 to 11)	Semi-quant. defined (2 to 5)	Semi-quant. defined (20 to 25)	Semi-quant. defined (15 to 20)
“Strategically locate the depots.”	Qual defined	Qual defined	Qual defined	Qual defined
“Adequate supply to retail stations.”	Qual defined	Qual defined	Qual defined	Qual defined
“Best mode of transport.”	Qual defined Pipeline -truck	Qual defined Pipeline-truck	Qual defined Pipeline-truck/rail	Qual defined Only pipeline
“30-day is ideal for holding capacity products.”	Qual defined	Qual defined	Qual defined	Qual defined
“Staff and products must always be secured.”	Qual defined	Qual defined	Qual defined	Qual defined
“Use technology to improve our operations.”	Qual defined	Qual defined	Qual defined	Qual defined
Send products from large depots to smaller depots.”	Qual defined	Qual defined	Qual defined	Qual defined

Note: Qual- Qualitatively; Quant-Quantitatively

Unlike the result presented in section 8.3.4 that addressed the generic elements of the scenario-specific visions, the analysis conducted in 8.3.5 aimed at identifying the vision elements that are potential inputs into the optimisation analysis to be translated into quantifiable elements and used in the optimisation study in chapter 10.. This analysis supports the purpose of the MVCA within the OVAF multimethod that seeks to integrate outputs from the visioning exercise into quantitative models such as optimisation models.

The optimisation elements were identified by coding the scenario-specific visions using a descriptive coding technique. The first three coded comments emerged from the groups' response to the discussion question, "what is your ultimate objective for your desired distribution network in the future" (see appendix 5 and 6 for discussion guide). Other variables emerged from the question; "what other elements do you envision to be present in your desired distribution network"? These elements were coded appropriately as shown in table 8.2 above.

8.4 Discussion of results

This section provides a discussion of the results identified in section 8.3. The discussion addressed the issues raised by stakeholders under the exploring issues step of the MVCA in section 8.4.1. The themes that represent the generic vision elements were discussed in section 8.4.2. The network optimisation related vision elements were discussed in section 8.4.3. All post-case study reflections have been provided in chapter 11.

8.4.1 Participants reaction to external scenarios

The issues that evolved from the external scenario discussion were: i) the participants' dislike for the stagnant scenario; ii) the introduction of corruption as an issue under the stagnant future external scenario; Under the declined scenario, issues raised were related to; iv) the disbelief that fossil fuel will not be useful in the future; vi) the detest for the declined scenario. Under the careless scenario, the issues were related to; vii) the infeasible combination between a buoyant economy and an unstable political and security society. In the rejuvenated external scenario, participants expressed; ix) satisfaction in the external scenario; x) an utmost desire to experience such a scenario; xi) disbelief that Nigeria will abandon fossil fuel.

8.4.1.1 The issue of corruption in the Nigerian PPD sector

From the result in section 8.3.3, a participant stressed the need for addressing the impact of corruption as the underlying issue which has led to insecurity and political instability in Nigeria. The latter comment agrees with the findings of Donwa et al.'s (2015); Mohammed (2013) and Nwakanma (2003) described in section 6.4 of chapter 6. Donwa et al (2015) explained that corruption in the Nigerian oil sector has a negative impact on the social and economic structure of the governance. Mohammed (2013) adds that it threatens the development of any nation by disrupting good governance and encourages the misappropriation of resources.

In addition, Nwakanma (2003) highlights that some of the corrupt practices within the PPD network in Nigeria include: overpricing, inventory recycling, syndicated bidding, connivance, collusion, and fraud. Overpricing in the PPD network is the thoughtful increase in the price of petroleum products in order to benefit from undue profit. Inventory recycling is the arrangement by which petroleum products supplied are removed from national stock to be re-supplied back to the distribution system. Donwa et al. (2015) notes that syndicated bidding for contracts involves the bidders meeting and agreeing on who wins the bid. Competitors for the bid that concede to the arrangement are paid compensation for the lost opportunity. Other acts of fraud and collusion in the PPD sector involves the diversion of products from the nations supply network to neighbouring states for higher profit (Kabir, 2016).

While the impact of corruption on the other factors and drivers under the STEEP categories cannot be overlooked, the researcher clarified the participants that corruption was not selected as a key driver because its likelihood of occurring can be determined. The researcher adds that corrupt practices within the PPD sector can be minimised if regulatory institutions put measures in place to check the actions of corruptions in the future.

8.4.1.2 The death of fossil-based fuels

Participants commented that the switch from the fossil-based fuels to renewable fuels was not realistic in the Nigerian context. This driver surfaced under the declined scenario and the rejuvenated external scenarios as plausible developments. The participants identified the importance of adopting renewable energy forms in the future. However, they described the total switch from fossil to renewable fuels as impossible in 2040 if significant transformations in the economy is not made. Participants drew on the challenges of renewable energy in Nigeria, stressing the inevitable reliance on fossil fuels due to an overstretched electricity national grid, and a crawling growth of renewable energy solutions in Nigeria.

Without a doubt, the major challenge with conventional renewable energy is intermittency. Greenage explains that wind power is only generated when its windy, solar power is only generated when it's sunny. This creates several fundamental issues. Another issue hinges on space and efficiency issues. Most renewable forms of energy are hardly space efficient. To generate a commercial amount of energy, huge solar farms and hundreds of wind turbines and massive bio crop fields will be required. This becomes even worse if there is need for scaling up the energy needs. In terms of the cost, it is great to know that the sun, wind, and water currents are free. That means that, theoretically, these kinds of technologies only require one-time costs where the initial outlay can be huge, but the continued costs will be less expensive.

On the other hand, evidence from the Renewable Energy Association of Nigeria (REAN) suggest that fossil fuel could lose significant popularity by 2040. The REAN envisions a future where there will be an improved contribution of renewable energy up to 40% of the national energy mix by 2030. Key players in the renewable energy sector are investing rapidly in solar assembly plants generation in Nigeria and sub-Saharan Africa. For example, Auxano Solar, a member of the REAN launched the first solar assembly plant in West Africa. The company also commissioned a 240kW solar hybrid system in Lugbe, Abuja in 2019. Blue Camel energy also completed the largest solar street lighting project worth $9 million in the city of Jos which led to the award of the city as the best lit city in Nigeria. About 30 other projects have been commissioned in all geopolitical zones in Nigeria.

While the argument for switching to renewable energy remains unresolved, the scenarios presented were based on a future where environmental concerns are prioritised in the policy frameworks of the developed and developing countries. Policies are crafted to curtail the reliance on technologies that poison our atmosphere. Therefore, the petroleum industry professionals must reflect on the plausibility of such a future and develop resilient strategies that can evolve in the face of such a future.

8.4.2 Themes of the scenario-specific visions

This section discusses the themes identified from the analysis of the generic vision elements in section 8.3.4. From the results, it can be summarised that the requirements for achieving an ideal PPD network in Nigeria include: (i) functional regulatory institutions; (ii) effective management; (iii) optimised network design; (iv) adequate technology; (v) security; (vi) integration of distribution processes for operators; (vii) strategic policy; (viii) social transformation; and (ix) sustainability. These themes have been presented in an influence diagram in figure 8.17 to demonstrate the interrelationship and functionality of the envisioned system.

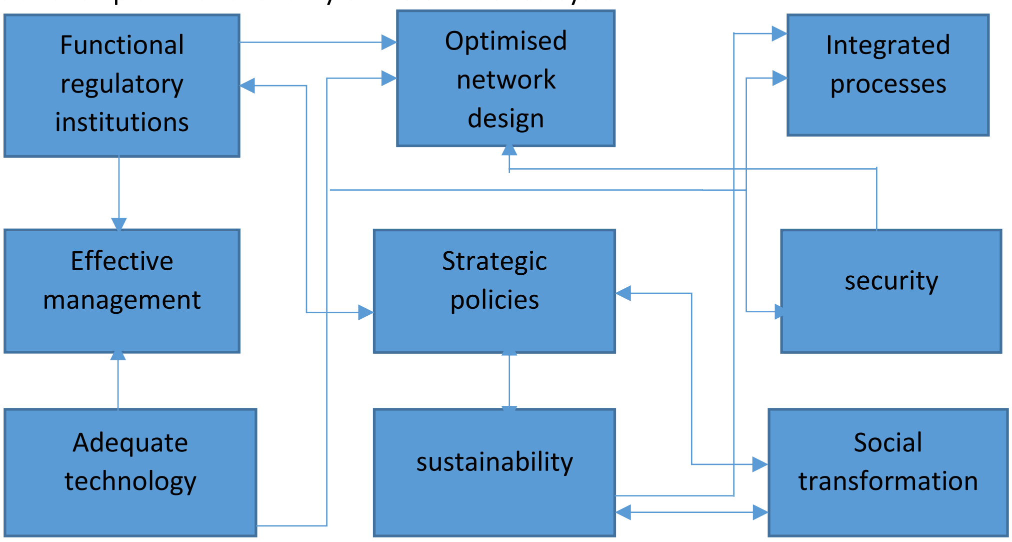


Figure 8.17 Influence diagram showing relationship between themes of generic vision elements

Initiating from the functional regulatory institutions, participants echoed the need for functional regulatory institutions as a requirement for a desired PPD network. The increased level of misappropriation, lack of compliance to best practice standards, and poor accountability can be attributed to poor functionality of the regulatory institutions within PPD sector. Regulatory institutions within the PPD sector must set measures for adherence to best practice and punitive measures must be placed on defaulters.

The functionality of regulatory institutions impacts the optimal design of the distribution network. Participants highlighted the effect of poor operational standards on distribution operations. Countless cases of accidents due to negligence at refineries, jetties, storage depots, pump stations, retail outlets. Such accidents impacts the flow of petroleum products on the distribution network which in turn leads to product unavailability for users. Therefore, regulatory institutions must be empowered to operate independently without undue control by ruling class and the elites in the society. Also, the participants established that regulatory institutions affects the effective management of the PPD sector. Where guidelines on the operational procedures are not followed, effective management of the sector is not guaranteed. Management activities such as regular maintenance of refineries, and storage depots, the hiring and training of qualified skilled workers to operate machineries are sometimes disregarded leading to increased cost of errors. In most cases the accountability of the revenue inflow and expenditure is overlooked thereby creating a loophole for corruption to thrive.

In addition, under the management theme, the participants emphasised the need for mergers between key players in the sector to achieve a fewer number of operators that can be monitored effectively. Few players should be allowed to distribute products, and the numerous independent retailers should be affiliated with the known key distributors. The alliance between operators is particularly relevant under the rejuvenated or declined scenarios as it opens up options for sourcing energy products from foreign partners when oil reserves are depleted or there is need for new forms of energy. Effective management through mergers and alliance with partners in opens up opportunities for the introduction of advanced technologies to support distribution processes. Improved technologies at storage depots and refineries can be harnessed through partnerships between local operators as well as with foreign operators. Local operators can also benefit from training on state-of-the art depot automation systems that can drive efficiency within the PPD sector. Such technologies can support the integration of distribution processes for operators which is characteristics of the envisioned system.

Technology supports the integrated processes of product marketing and distribution operators. Integration provides a transparent supply network where operators cooperate and compete as same time. Having a transparent network supports the effective monitoring of product capacities and product flows across the supply chain. Also, it encourages a responsive supply chain which delineates stockout situations. The latter is guaranteed where technology thrives amongst the players in the sector. Furthermore, technology also support the security system of the distribution network. This is achieved through effective monitoring of products when stored and while on transit. This has been seen in countries with advance monitoring and security systems. While insecurity remains a concern for distribution in Nigeria, technology can alleviate the dreadful impact of oil installation vandalisation through an online real time surveillance over pipelines, truck, and rail wagons distribution products. Motion detector sensors can be installed along pipelines to capture movements near such infrastructure and lead to the early interception of destructive activities by the law enforcement agencies.

Security also impacts the optimal network design as oil depot terminals constantly suffer from the attacks from armed gunmen. This in many ways disrupt the flow of products from the source points to the customer locations. Cases of the kidnap of professionals working at product refining and storage plants are constantly recorded. Oil pipelines are vandalised leading to the loss of petroleum products amounting to millions of dollars. For the above reason, it important to design the network to limit the negative impact of insecurity on the network.

The issue of strategic policy, social transformation and sustainability are highly interwoven because they are underpinned by social orientation of the citizens. For sustainable distribution to thrive, there is need for top-down policies on adherence to use of new forms of energy for distribution. This will trigger emission reduction targets on the existing distribution patterns. Besides, the reduction on emission can be achieved through a bottom-up behavioural transformation from the citizens through reduced car trips, switch to online purchases as compared to shopping trips. The above measures reduces the demand for petroleum products and in turn reduces the emission from fossil-based fuels. There should be policies to reduce the amount of carbon emissions from businesses and households. Such policies can influence the behaviour of individuals and business leading to a reduction in the emission.

8.4.3 Optimisation vision elements

From the results presented in table 8.2, the elements related to the optimisation network design were identified. While the importance of the highlighted elements is evident to the author, one might argue if there are other variables that were omitted? The discussion is important as it supports the transferability of the process when applied by other users. In this study, the first criteria considered for the selection of a variable is the direct impact with the optimisation of the distribution network. Second, most of the elements have been previously used in network design optimisation problems.

The cost of distributing products within supply chains was identified clearly as a standard objective function variable applied in operational research. Also, the improvement of customer service level was is also a known elements that impacts supply chain performance. The desire to achieve an environmentally friendly operation may not have gained popularity in the optimisation network design problems. However, it was considered because the level of environmentally friendly operation can affect the cost of distributing petroleum products. This is true as it involves the lowering of emissions or adhering to a standard or threshold of CO2 emission that can be associated with improved vehicle technology, storage technology.

Other variables such as the number and location of the TDs, the volume of products distributed along the network are quantifiable elements which can be measured. Also, an increase in the value of these parameters influence the distribution cost, customer experience and the sustainable distribution patterns. The mode of transport was also considered an important variable because the unit cost of distributing products through the different modes differ and it affects the distribution cost, and the emissions from the network.

8.5 Conclusion

This study has applied the stage 2 of the OVAF approach for developing visions for the PPD network in Nigeria to 2040. The study developed stakeholder-driven visions under four external scenario backgrounds contexts for the Nigerian petroleum product distribution network. Due to contextual issue of insecurity and busy schedule of target participants, a workshop and one-on-one interview method has been applied for developing the visions. The study identified that to achieve an efficient PPD network in Nigeria by 2040, there is need for following; (i) functional regulatory institutions; (ii) effective management; (iii) optimised network design; (iv) adequate technology; (v) security; (vi) integration of distribution processes for operators; (vii) strategic policies; (viii) social transformation, and (ix) sustainability.

The presence of functional regulatory institution was a requirement the participants envisioned under the stagnant, careless and the rejuvenated scenario-based visions. The technology and optimal network design, Integration of distribution processes and effective management were requirements cut across all the scenarios as a prerequisite for operational efficiency. The security theme was stressed by participants under the stagnant declined and the careless scenario. Strategic Policy was echoed by the participants under the declined and rejuvenated scenario-based visions. The participants also mentioned that social transformation under declined and rejuvenated scenarios. Finally, sustainability was highlighted as an important requirement under the careless and rejuvenated scenario-based visions.

In addition, ten optimisation problem variables, namely; distribution cost, customer experience, sustainable distribution pattern, number of TDs, location of TDs, volume of products transported on the network, mode of transport, capacities of TDs and large depots, security, automation of TDs and the network structure were identified. While these variables represent optimisation problem elements, they contain little or no quantification to support different forms of numerical assessment for strategy development. The latter issue of non-specificity and lack of quantitative details of the optimisation elements will be addressed in chapter 9.

8.6 Summary of chapter

The next study that is presented in chapter nine aims to translate the qualitatively and semi-quantitatively defined optimisation variables identified in this chapter into quantifiable elements suitable for integration in optimisation models. The study aanticipates that the methodological veracity improves with increased detail of quantified representation of the desired network elements for petroleum product distribution network in Nigeria. Consequently, a clear understanding of vision elements will facilitate a more in-depth insight into the implications of strategic decisions.

Chapter 9 - Translating visioning outputs into quantifiable optimisation inputs; a case study of the Nigerian PPD Network.

9.1 Introduction

In the previous chapter, four external scenario-specific visions for the Nigerian PPD sector were developed through a group discussion held over a two-day workshop and 120 hours of interview sessions held with senior professionals from the Nigerian Petroleum Industry. Besides the generic vision elements identified in section 8.4.2, the analysis of the vision narratives in 8.4.3 identified optimisation related vision elements such as: the cost of distribution; customer service level; environmental friendly distribution; adequate depots; strategic location of depots; adequate supply of products to retail stations; mode of transport; capacity of transhipment depots; security; technology, and structure of the network for sending products from large depots to smaller depots also known as transhipment depots (see table 8.2). While the highlighted vision elements influence how the efficient Nigerian PPD network design can be achieved in the future, their qualitative nature makes them unsuitable inputs for the quantitative optimisation of the network design. Therefore, this chapter focuses on translating these elements from their qualitative forms as reported in table 8.2 in chapter 8 into quantifiable inputs for optimisation of the scenario-specific visions for the Nigerian PPD network.

The specific objectives to be achieved in this chapter include.

- To define the qualitative optimisation related elements quoted in the scenario-specific visions narratives, and conceptually modelling the relationships between the defined elements.

This objective relates to the first step of the proposed translation stage of the OVAF presented in section 5.5 of chapter 5. The result of the application is presented in section 9.2.1.

- To develop mathematical formulations that quantitatively represents the optimisation problem embedded within the conceptual model of the visions.

This objective relates to the second step of the proposed translation stage of the OVAF presented in section 5.5 of chapter 5. The result of the application is presented in section 9.2.2.

Section 9.2 of the chapter describes all the procedure for translating the Vision elements into quantifiable optimisation elements. The optimisation problem statement and the mathematical formulation of the problem are developed in section 9.3. A reflection on the translation process is discussed in section 9.4. The chapter concludes with the description and formulation of the network problem to be optimised in section 9.5.

9.2 Visioning output translation approach (OVAF stage 3)

A detailed description of the translation framework and procedure has been provided in figure 5.5 of chapter 5 of this thesis. The translation process consists of two interconnected steps: framing of the optimisation problem; and formulating the optimisation model.

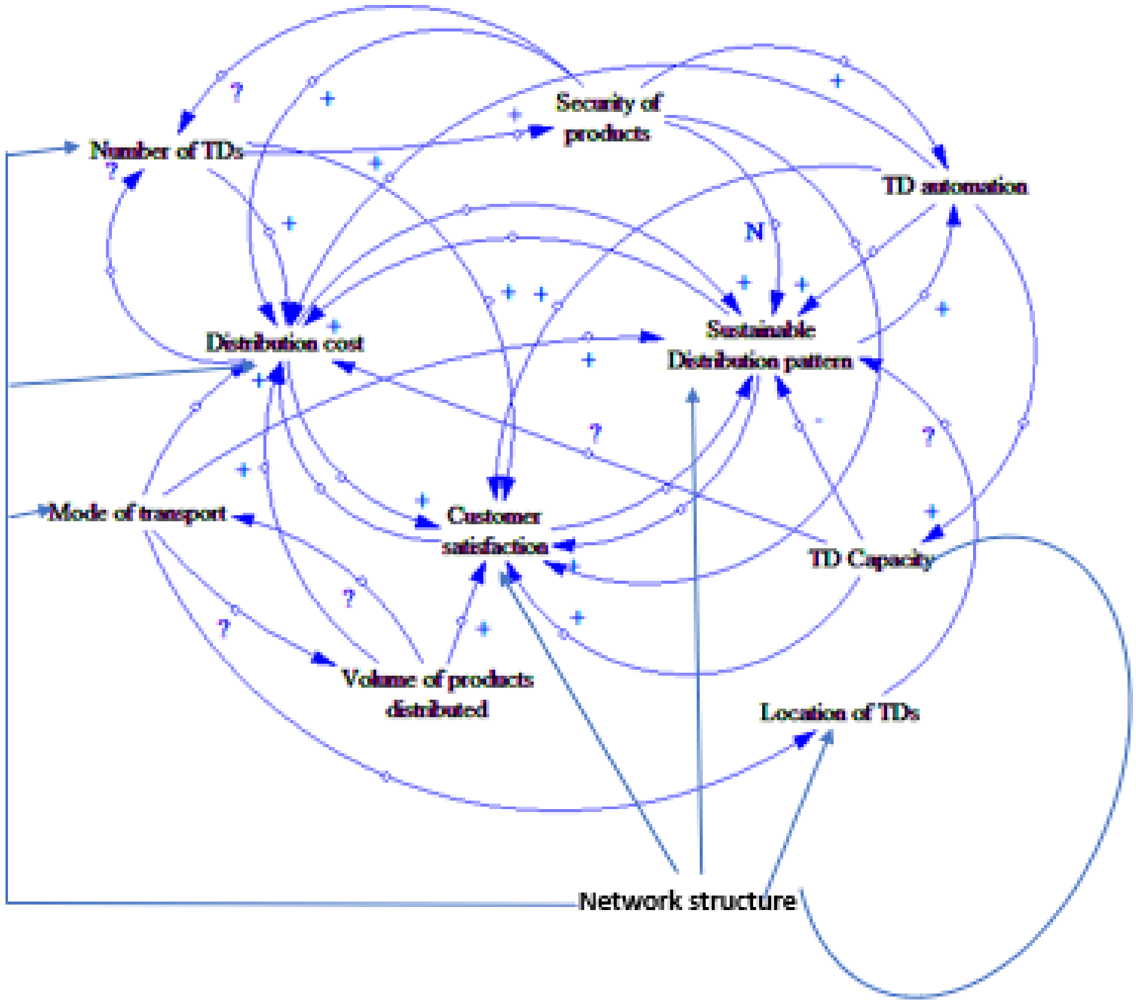
9.2.1 Step 1- Framing the optimisation problem

The table 9.1 captures the researcher's definition of the qualitatively described elements.

Table 9.1 Redefining the qualitative vision elements

Vision element quotes	Variable codes
"a low cost of distributing products."	Distribution cost
"improved service level by satisfy customer demand and ensuring customers do not travel far to get products."	Customer satisfaction
"an environmentally friendly operation."	Sustainable distribution pattern
"Adequate depots to support distribution."	Number of TDs
"Strategically locate the depots."	Locations of TDs
"Adequate supply to retail stations."	Volume of products transported
"Best mode of transport."	Mode of transport
"30-day is ideal for holding products."	Capacity of large depot and TDs
"Staff and products must always be secured."	Security of products
"Use technology to improve our operations."	Automation of TDs
"Send products from large depots to smaller depots"	Network structure

For example, the quote "a low cost of distributing products" drawn from the vision narratives (see scenario-specific narratives in appendix 11) was defined a "distribution cost" variable. The "improve service level by satisfy customer demand and ensuring customers do not travel far to get products" was defined as "customer satisfaction" variable. Furthermore, since the description of elements elucidates the nature of the elements as well as potential relationships between the variables, causal loop diagrams were used to present the relational dynamics between the defined variables. As shown in figure 9.1, each variable is placed in a box, and the connecting lines are labelled with linking signs to explain the connections between the variables.



"+" means positive relationship; "-" means negative relationship; "?" means unclear relationship; and "N" means neutral relationship

Figure 9.1 Causal loop diagram showing the relational dynamics of optimisation variables

According to figure 9.1, some variables are dependent on the changes to other variables. The dependence is explained by the more inward directional arrows from other variables towards specific variables. This group of variables were classed as the target objectives or dependent variables (distribution cost, sustainable distribution pattern and the customer satisfaction). Other variables were classed as independent or precursor variables because changes in these variables can affect the dependent or target variables. The connecting arrows between the variables indicate the direction of influence, and the sign indicates the type of influence. A "+" sign indicate a positive correlation between the pair of variables; a "-" sign indicate a negative correlation between the pair of variables; a "?" sign indicates that no clear judgement can be made on the relationship between the pair of variables; a "N" sign indicates a neutral relationship between the variables.

Table 9.1 presents a list of optimisation problem-related variables which were identified from the vision narratives.

Table 9.2 Summary of findings on the optimisation variables

Variables	Number of inward arrows	Type of variable
Distribution cost	9	Dependent
Customer satisfaction	7	Dependent
Sustainable distribution pattern	7	Dependent
Number of TDs	2	Independent
Locations of TDs	1	Independent
Volume of products transported	1	Independent
Mode of transport	1	Independent
Capacity of TDs	1	Independent
Security (at large depot, TD, and on-transit)	1	Independent
TD automation	2	Independent
Network structure	0	independent

Table 9.1 presents a classification of the variables into a dependent or an independent variable. The criteria for the classification of the variables was based on the inter-variable relationships. The minimised cost, improved customer experience and sustainable distribution were classed as dependent variables since these variables are dependent on the value of other variables. Other variables were classed as independent variables because their values determined the state of the dependent variables. The three dependent variables have been selected based on the perceived influence of the independent variables.

It can be argued that some of the adjudged independent variables could also be termed as objectives. For example, automation can impact capacity because if the TDs are automated, the depot will be able to handle more trucks calls at the TDs for products—indicating a positive correlation between the automation and capacity. Also, the capacity influences the customer experience because, with improved capacity, customer demands will always be met. This also indicates a positive correlation between the capacity variable and the customer experience objective. The automation of TDs can influence the customers experience directly as customers can efficiently process their orders, and supply of the product is faster and stress-free manner.

The relational dynamics of the vision elements can grow from simple to a much more complicated situation where almost all the variables become a target objective to the achieved. However, the researcher has chosen to select the distribution cost, customer experience and the sustainable distribution as the principal objective variables for two reasons; the first being that the content analysis conducted in chapter eight revealed that most of the comments from the different groups focused on the above objectives. Secondly, the objectives were the variables which showed an explainable influence from all the other variables.

9.2.2 Step 2- Formulating the optimisation model

In step two, mathematical notations were used to represent the variables within the optimisation problem framework.

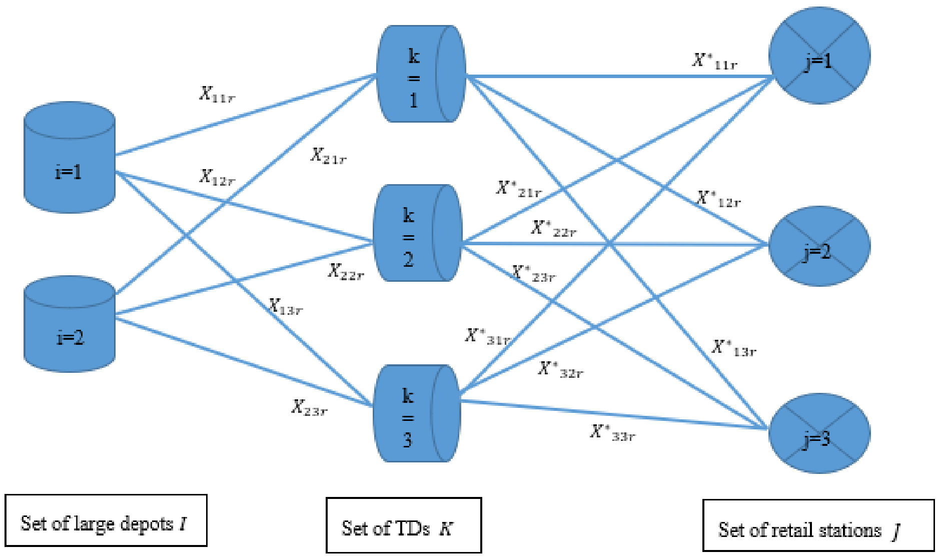


Figure 9.2 Representation of the network design

9.2.2.1 Define variables using mathematical indices and notation

In the multi-mode MILP model, the researcher assumes that there are a set I of large depots i with capacities Q_i, a set K of transhipment depots k with capacities b_k^*, and a set J of demand nodes(retail station) j, available to be served. The transportation mode $t \in K$ moves premium motor spirit (PMS) product from the large storage depot to the TD and from the TD to the demand point (retail station). The notation for the model is summarised below.

Notations and Parameters used in the models

Indices

i index of the large depot; $i \in I$

k index of potential transhipment depots; $k \in K$, j index of demand point(retail stations located at the center of Municipal LGAs); $j\in J$,

r index of transportation modes; $r\epsilon R$; where 1= truck mode; 2=rail mode; and 3=pipeline mode

Parameters

a_j Weekly demand for PMS in litres at the demand node j, $\forall j\epsilon J$,

Q_i the capacity of large depot $\boldsymbol{i}$, $\forall \boldsymbol{i \in I}$,

b_k^* the capacity of transhipment depot k, $\forall k\epsilon K$,

F_k the fixed set-up cost for operating the transhipment depot at location k, $\forall k\epsilon K$,

F^*_i the fixed set-up cost for operating the large depot i, $\forall i\epsilon I$

$\emptyset_i$ the unit variable operating cost at large depot i, $\forall i\epsilon I$

$\emptyset_k^*$ the unit variable operating cost at TDs k, $\forall k\epsilon K$

d_{ikr} the distance in kilometres between a fixed large depot i and potential transhipment depot k over a specific transport mode r, $\forall i\epsilon I$ & $k \in K$

d^*_{kjr} the distance in kilometres between a potential transhipment depot k and demand node j over mode r, $\forall k \epsilon K$ & $j \epsilon J$;

α_{ikr} the transport cost per unit of PMS from large depot i to transhipment depot k over mode r;

μ_{kjr} the transport cost per unit of PMS transported from transhipment depot k to demand node j over mode r,

$\beta_{\mathbf{k}}$ the cost per unit of capacity at the transhipment depot k, $\forall k\epsilon K$,

$S_{\boldsymbol{ikr}}$ the cost for securing PMS on transit from large depot i to transhipment depot k over mode r, $\forall i\epsilon I$ & $k \epsilon K$

$S_{\boldsymbol{kjr}}$ the cost for securing PMS on transit from transhipment depot k to demand node j over mode r, $\forall i \epsilon I$ & $k \in K$

δ_i the amount of CO_2 emission per unit of PMS stored at the large depot i, $\forall i \epsilon I$

δ^*_k the amount of CO_2 emission per unit of PMS stored at the TD k, $\forall k \epsilon K$

ρ_{ikr} the amount of CO_2 emission per ton/kilometer over a specific mode r

ρ^*_{kjr} the amount of CO_2 emission per ton/kilometer travelled through a specific mode

P_{kmin} the minimum number of transhipment depot k $\forall k\epsilon K$ that can be opened

P_{kmax} the maximum number of transhipment depot k $\forall k\epsilon K$ that can be opened

P_{kj} the trip distance for travelling from a retail station demand point j to the nearest potential transhipment depot k, $\forall k\epsilon K$ & $j \in J$

M represents a very big number (e.g. the sum of all demand)

9.2.2.2. Quantitative definition of variables

9.2.2.2.1 Distribution Cost:

The distribution cost variable can be described as the least sum cost of distributing products across the network. The cost can be divided into the inbound and outbound transportation cost, the large depot and TD fixed operating costs, the large depot and TD variable operating cost, the cost of emission from the TDs, and transportation of products.

Inbound transport cost: The inbound transport costs are influenced by the unit cost of the inbound mode of transport variable, the inbound distance travelled, and the inbound volume of products transported. Consequently, the inbound transport cost can be determined by the product of the unit transport cost of a specified inbound transport mode denoted as α_{ikr} , the inbound distance travelled over a specified mode $\mathrm{d}_{\mathrm{ikr}}$, and the volume of products transported over the specific inbound travel distance and mode $\boldsymbol{X}_{\boldsymbol{ikr}}$.

Outbound transport cost: The outbound transport costs are influenced by the unit cost of the outbound mode of transport variable, the outbound distance travelled, and the outbound volume of products transported. Consequently, the outbound transport cost can be determined by the product of the unit transport cost of a specified outbound transport mode denoted as μ_{kjr} , the outbound distance travelled over a specified mode denoted as $\mathrm{d}^*{}_{\mathrm{kjr}}$, and the volume of products transported over the specific outbound travel distance and mode $X^*{}_{kjr}$.

Large depot fixed operating cost: The large depot fixed operating costs are the costs associated with the running of each of the large depots. This cost is independent of the volume of products which is processed at the large depot. Examples of such costs are the monthly rent for the depot premises, the monthly payments for electricity, and phone lines. The large depot i fixed operating cost is represented as $\mathrm{F}^*{}_{\mathrm{i}}$

TD fixed operating costs: The TD fixed operating costs are the costs associated with the running of each of the TD. This cost is independent of the volume of products which is processed at the TD. Examples of such costs are the monthly rent for the depot premises, the monthly payments for electricity, and phone lines. The TD k fixed operating cost is represented F_{k}.

Large depot variable operating cost: This is the cost associated with the running of the large depot. The cost is dependent on the volume of products which is processed. So, the cost is determined by multiplying the inbound volume transported X_{ikr} by the unit variable cost $\emptyset_i$.

TD variable operating cost: This is the cost associated with the running of the large depot. The cost is dependent on the volume of products which is processed. So, the cost is determined by multiplying the total inbound volume transported denoted as $X^*{}_{kjr}$ by the unit variable cost denoted as $\emptyset_k{}^*$.

Inbound and outbound security cost: The security cost is the cost associated with securing petroleum products from large depots to the TDs. Since the security cost is dependent on the distance travelled, the inbound security cost is the product of the inbound unit cost of securing products over one kilometre denoted as S_{ikr} by the inbound distance travelled denoted as $\mathrm{d_{ikr}}$. In the same vein, the outbound security cost represented by the product of the outbound unit cost of securing products over one kilometre denoted as $S_{\boldsymbol{kjr}}$ by the inbound distance travelled denoted as $d^*{}_{kjr}$.

9.2.2.2.2 Customer satisfaction

The customer satisfaction variable as described in table 9.1 is measured by the outbound transport distance and ability to satisfy customer demand. In this instance the outbound trip distance $d^*{}_{kjr}$ must be less than a specified value. Also, customer demand is represented by a_j must be satisfied**.** This is the demand for every demand node j, which belongs to the set J.

9.2.2.2.3 Sustainable distribution pattern

The sustainable distribution pattern variable as highlighted in table 9.1 is measured by the quantity of CO2 emitted during the transportation and storage of PMS in the distribution network over a one-week planning period. The emission is dependent on the emission per unit product transported and stored as well as the time stored and distance distributed. A unit emission value is defined as the amount of emission for either storing or transporting one unit of petroleum product over one kilometer. Therefore, the amount of CO_2 emission per unit of product stored at the large depot and TD are represented as δ_i and $\delta^*{}_k$, respectively. Time of storage at the large depot is represented as π_i and the time of storage at the TD is represented as $\pi^*{}_k$. The storage emission is calculated by the product of the unit storage emission value by the time of storage. The inbound transport emission is calculated by the product of the amount of CO_2 emission per ton/kilometer over a specific mode denoted by ρ_{ikr} by the inbound $d^*{}_{kjr}$. Similarly, the outbound transport emission is calculated by the product of the amount of CO_2 emission per ton/kilometer over a specific mode denoted by $\rho^*{}_{kjr}$ by the outbound distance travelled through a specific mode denoted as $d^*{}_{kjr}$.

9.2.2.2.4 Independent variables

Number and locations of TDs: The number and locations of TDs are variables which influence the cost, customer experience viz-a-viz the outbound trip distance and the sustainability of distribution (see figure 9.1). The range suggested by narratives is defined as the $P\min$ represents the minimum number of transhipment depots specified by the narratives while the the $P\max$ represent the maximum number of transhipment depot specified by the narratives. In addition, the location of TDs is another variable which was specified by the narratives. The location was defined using a binary variable Y_k . The potential locations are determined and $Y_k = 1$ if a location is selected from the list of potential locations. $Y_k = 0$ if a specific location is not selected from the list of potential locations.

The volume of products transported: This represents the volume of products which are being transported under the inbound and outbound segment of the network. The inbound volume is defined as $\boldsymbol{X_{ikr}}$. (i.e. the volume of product transported from each large depot i to potential transhipment depot k over mode r) for all large depots $(i = 1,2 \dots I)$. Similarly, the outbound volume is defined as $X^*{}_{kjr}$ (i.e. the volume of product transported from a potential transhipment depot k to demand for all $(k = 1,2, \dots K)$. Relating to figure 9.2, the inbound volumes X_{11r} represents the volume transported from the large depot 1 to TD 1 through mode r. The X_{12r} represents the volume transported from the large depot 1 to the TD 2 through mode r. This follows for X_{21r}, X_{22r} , X_{13r}, X_{23r} . The outbound volumes $X^*{}_{11r}$ represents the volume of product transported from a TD 1 to customer retails station 1 through mode r. $X^*{}_{12r}$ Represents the volume of products transported from the TD 2 to customer retails station 2 through mode r. This is the same for all the $X^*{}_{13r}$, $X^*{}_{21r}, X^*{}_{22r}, X^*{}_{23r}, X^*{}_{31r}, X^*{}_{32r}, X^*{}_{33r}$.

Mode of transport: The mode of transport impacts the cost of distribution, customer experience and sustainable distribution. This variable has been defined as r and r =1, 2, 3, where 1= truck mode; 2=rail mode; and 3=pipeline mode

Capacity: The capacity of the large depot is defined with a notation Q_{i} which represent the capacity of a large depot i, $\forall\, i \epsilon I$. Similarly, the capacity of a TD is defined with the notation $b_k{}^*$ Which represents the capacity of transhipment depot $k, \forall\, k \epsilon K$. The capacity variable impacts the customer experienced because, with adequate capacity, customer demand can easily be satisfied. Also, with adequate capacity, more products will be processed at the facility over a given period.

Security: This variable represents the amount invested in securing products at storage points and on transit. The cost consists of the cost associated with the use of aerial drone monitoring systems and military patrol teams for surveillance over the network**.** The inbound transport security cost is determined by the product of the unit security cost S_{ikr} over a specific inbound mode, r by inbound distance travelled d_{ikr}. Also, the outbound transport security cost is determined by the product of the unit security cost S_{kjr} over a specific outbound mode r by the outbound distance travelled $d^*{}_{kjr}$.

Automation of TDs: The use of technology to automate the depot operations such as the loading of trucks or payment systems impacts the speed of delivering loading services as TDs. Also, improved technology impacts the capacity of the TD. The improved capacity will yield improved customer experience through prompt customer demand satisfaction. However, the automation of the TDs will impact the cost of distribution because the cost of installing technology will increase the overall network cost. The cost associated with the automation of large depot and TD are represented as the large depot unit technology cost denoted as φ_i and the TD unit technology cost denoted as $\varphi^*{}_k$. The unit technology cost at either the large depot or the TD is multiplied by the total volume processed at either the large depot or the TD over a given period.

9.3 Mathematical formulation of optimisation problem

Based on the envisioned network structure whereby PMS product is transported from the large depots to transhipment depots before being distributed to the retail stations in the regions (see table 8.2 of chapter 8), the problem is modelled as a multi-echelon supply chain network design problem and illustrated diagrammatically in figure 9.2. The structure suggests a network consisting of a two-echelon structure. The structure involves the distribution of a single petroleum product (i.e. premium motor spirit PMS) from a source which in this case is considered as a known large storage depot $i\epsilon I$ to the transhipment depots $k\epsilon K$, and the onward distribution from the transhipment depots to the demand points(retail stations) $j \epsilon J$. In figure 9.2, the researcher assumes that there are a set I of large depots i with capacities Q_i, a set K of TDs k with capacities $\mathrm{b_k}^*$, and a set J of demand nodes (retail station) j, available to be served. The transportation mode $r \in \mathrm{R}$ transports product (PMS) from a large storage depot $i\epsilon I$ to the TDs $k\epsilon K$, and from the transhipment depot to the demand point (retail station).

The envisioned multi-mode design includes the choice between three modes of transport (truck, rail, and pipeline) at either the inbound or outbound stage of transport. In addition to the choice of the mode of transport, other independent variables to be optimised include; i) the optimum number of TDs $k\epsilon K$ to be located in the network; ii) the best location to site the selected TDs from |k| potential transhipment depot locations; iii) the amount of each product to ship from each large depot $i\epsilon I$ to transhipment depot $k\epsilon K$ with mode r ϵR in the inbound transportation; iv) the amount of PMS to ship from TD $k\epsilon K$ to demand node $j\epsilon J$ with mode r in the outbound transportation. The mathematical formulation of the multimodal problem is presented below.

Based on the three objective variables, the problem can be formulated into a multi-echelon capacitated transhipment depot location problem with constrained outbound trip times and security cost. The aim of the optimisation model is to optimise the number and locations of a set of transhipment depots, as well as the volume transported along the inbound and outbound network such that the total cost (TOC) of distribution, outbound trip time (TT) and storage/transport emissions are minimised.

9.3.1 Decision variables, objectives, and constraint formulation

In this section, the study provides a mathematical formulation which describes the objective function, the decision variables, and constraints.

9.3.1.1 Representing the decision variables

Now we consider three decision variables variable $X_{ikr}, X^*{}_{kjr}$, Y_k that are defined below as follows;

$X_{ikr} =$ Volume of product transported from a large depot to potential transhipment depot k through mode ***r*** $\forall$ $(i = 1,2 \ldots I)$; $(k = 1,2, \ldots K)$; $(r = 1,2, \ldots 3$***)***

$X^*{}_{kjr} =$ Volume of product transported from a potential transhipment depot k to demand point j through mode *r* $\forall$ $(k = 1,2, \ldots K)$; $(j = 1,2, \ldots J)$; $(r = 1,2, \ldots 3)$

$$Y_k = \begin{cases} 1, \text{if a particular transhipment depot k is opened} \\ \qquad 0, \text{otherwise} \end{cases} \qquad \forall \ (k = 1,2, \ldots K)$$

9.3.1.2 Representing the objective functions

In this section, the objectives have been formulated as a multi-objective problem in equation 9.1, 9.2. and 9.3 below. The problem aims to achieve the minimised cost of distribution, outbound trip distance and network emission level.

The cost minimisation objective function is written as:

$$Z_1(\mathbf{X},\mathbf{X}^*,\mathbf{Y}) = \sum_{i\in I}\sum_{k\in K}\phi_i X_{ikr}Y_k + \sum_{i\in I}F_i + \sum_{i\in I}\sum_{k\in K}\alpha_{ikr}d_{ikr}X_{ikr}Y_k + \sum_{i\in I}\sum_{k\in K}S_{ikr}d_{ikr}Y_k$$
$$+ \sum_{k\in K}\sum_{j\in J}\emptyset_k{}^*X^*{}_{kjr}Y_k + \sum_{k\in K}F_k\,Y_k + \sum_{j\in J}\sum_{k\in K}\mu_{kjr}\,d^*{}_{kjr}X^*{}_{kjr}Y_k$$
$$+ \sum_{j\in J}\sum_{k\in K}S_{kjr}d^*{}_{kjr}Y_k$$

[9.1]

The objective function in equation 9.1 minimizes the total cost (TOC) of distribution across the multi-echelon network by optimising three variables $\mathbf{X},\mathbf{X}^*,\mathbf{Y}$. The $\mathbf{X}$ and $\mathbf{X}^*$ are n-dimensional arrays containing the individual elements X_{ikr} and $X^*{}_{kjr}$., and where $\mathbf{Y}$ is a vector of the Y_k variables.
The equation consist of eight sections, namely; i) the variable cost at the large depot, ii) the fixed operating cost at the large depot, iii) the inbound transport cost, iv) the inbound transport related security cost, v) the variable TD cost, vi) the fixed operating TD cost, vii) the outbound transport cost, and viii) the outbound transport related security cost.

In the first section of the equation which represents the large depot variable cost is determined by the product of the unit variable cost of the large depot denoted as $\emptyset_i$, and the total volume of products process at the large depot denoted as X_{ikr}, and the binary variable indicating that a supply from the large depot to a potential TD denoted as Y_k . The second section of the equation which represents the fixed operating cost at the large depot denoted as F_i is captured. The third section of the equation which represents the inbound transportation cost is determined by the product of the unit cost of transporting the PMS product over mode r denoted as α_{ikr} and the distance in kilometre from a large depot i $\forall$ $(i = 1,2,\ldots I)$ to a potential transhipment depot k $\forall$ $(k = 1,2,\ldots K)$ denoted as d_{ikr}, and the volume of products transported from large depot i to the potential transhipment depot k $\forall$ $(k = 1,2,\ldots K)$ denoted as $X_{\boldsymbol{ikr}}$.

The fourth section of the equation represents the inbound transport related security cost is determined by the product of the unit cost of securing the product on transit from large depot i to TD k denoted as S_{ikr} , and the distance travelled from the large depot i to a potential transhipment depot k denoted by d_{ikr}, and the binary variable indicating an active supply from large depot to TD which is denoted as Y_k. The fifth section of the equation which represents the variable operating cost at the TD is determined by the product of the unit variable cost of the TD denoted as $\emptyset_k{}^*$, and the total volume of products process at the TD denoted as $X^*{}_{kjr}$, and the binary variable indicating the opening and closure of a potential TD denoted as Y_k . The sixth section which represents the fixed operating cost of TD is determined by the product of the fixed operating cost for a transhipment depot $F_k, \forall\ k\epsilon K,$ by the binary opening and closing variable of a TD Y_k .

The seventh section represents the outbound transport cost is determined by the product of the unit transport cost per kilometer from TD to demand point through specific mode denoted as μ_{kjr} , and the distance travelled from a potential TD k to the retail station denoted by $d^*{}_{kjr}$, and the volume of products transported from a potential TD to retail station j denoted as $X^*{}_{kjr.}$ The section eight that represent the outbound security-related cost is determined by the product of the unit cost of securing the products on transit from a potential TD to a demand point over specific mode S_{kjr} , and the distance travelled from the potential transhipment depot to a retail station $d^*{}_{kjt},$ and the binary variable for opening and closing of a potential transhipment depot Y_k **.**
The second objective function is mathematically expressed as follows:

$$Z_2(\mathbf{Y}) = \sum_{j\in J}\sum_{k\in K} P_{kj}\ Y_k \qquad [9.2]$$

The second objective function in equation 9.2 aims to minimise the network outbound average trip distance by optimising the location of the TDs. The equation 9.2 involves the multiplication of the outbound trip distance denoted as $d^*{}_{kjr}$ by the binary decision variable Y_k .

The third objective is mathematically expressed as follows:

$$Z_3(\mathbf{X}, \mathbf{X}^*, \mathbf{Y}) = \sum_{i\in I}\sum_{k\in K} \delta_i\ \pi_{i_i} X_{ikr} + \sum_{i\in I}\sum_{k\in K} \delta^*{}_{k_r}\pi^*{}_k\, X^*{}_{kjr} Y_k + \sum_{i\in I}\sum_{k\in K} \rho_{ikr}\, d_{ikr} Y_k + \sum_{j\in J}\sum_{k\in K} \rho^*{}_{kjr} d^*{}_{kjr}\, Y_k \qquad [9.3]$$

The equation 9.3 aims to ensure a sustainable distribution network by minimising the emissions associated with the storage and the transportation of products across the network. The equation consists of four sections, namely, the storage emission at the large depot, the storage emission at the TD, the inbound transport emission, and the outbound related transport emission. The first section of the equation 9.3 represents the storage emission for storing products at the large depot. The large depot storage emission is determined by the product of the emission per unit stored at the large depot denoted as δ_i, by the total time of storage over a given period denoted as π_i , by the capacity of the large depot. The second section of the equation represents the total emission at the TD. This is determined by the product of the emission per unit at the TD denoted as $\delta^*{}_{kr}$ by the time of storage at the TD over a given period denoted as π^*,

By the capacity of TD denoted as $\mathrm{b_k}^*$ by the binary variable which determines the opening and closure of a specific depot denoted as Y_k. The third section of the equation represents the inbound transport related to emission associated. This is determined by the product of the emission per unit transported from large depot to TD denoted as ρ_{ikr} , by the inbound distance travelled denoted as d_{ikr}, by the binary variable Y_k. The fourth section represents outbound transport emission. This is determined by the product of the emission per unit transported from the TD to the demand point denoted as $\rho^*{}_{kjr}$, by the outbound distance travelled denoted as $d^*{}_{kjr}$, by the binary variable Y_k.

9.3.1.3 Representing the constraints

$\sum_{\mathrm{j}} X^*{}_{kjr} \leq Q_i \quad \forall \ i \in I;\ k \in K;\ and\ j \in J$ [9.4]

Explanation: The volume of products being transported from the potential TDs k to the demand points j must be less than or equal to the total supply capacity from the large depot i over a given period. This constraint is linked to the capacity variable that ensures that sufficient TD capacity is available to hold the PMS to be supplied to the retail stations in their region.

$\sum_{\mathrm{j}} X_{kjr} \geq D_j \quad \forall \ i \in I;\ k \in K;\ and\ j \in J$ [9.5]

Explanation: the total volume of product transported from the potential transhipment depot k to demand points must be greater than or equal to the sum of demand from all the demand points j. This constraint is linked to the customer satisfaction variable that specifies that all the volume of PMS supplied must be greater than the demand of all the retail stations in the region.

$X_{jkr} - M_{jk}Y_k \leq 0 \ \forall \ j, k$ [9.6]

Explanation: This is a linking constraint which differentiates the transportation problem from a facility location problem. It controls the switching on and off the depots if active and ensures the connection between the fixed cost component of the objective function and the outbound cost component.

$\sum_{\mathrm{k}} Y_k \geq P_{min}$ [9.7]

Explanation: The sum of all the active depots must be greater than a specified minimum number of depots;

$\sum_{\mathrm{j}} Y_k \leq P_{max}$ [9.8]

Explanation: The sum of all the active transhipment depots must be less than a specified maximum number of depots;

$X_{ikr} \geq 0 \quad \forall \ i, k$ [9.9]

Explanation: This is a non-negativity constraint which state that no negative volume is transported;

$X^*_{kjr} >= 0 \quad \forall \ k, j$ [9.10]

Explanation: This is a non-negativity constraint which state that no negative volume is transported;

$Y_k = \{0,1\} \ \forall k$ [9.11]

Explanation: This indicate binary nature of the location variable;

$P_{kjr} \leq \ Tmax$ [9.12]

Explanation: The trip distance for product delivery from a medium depot k to demand point j must be less than or equal to a specified maximum distance or travel time;

9.3.2 Optimisation problem assumptions

The following assumptions have been made under the problem;

- only the premium motor spirit is selected as petroleum products for distribution because PMS is the most widely distributed products in the country. Most vehicles and domestic generators run on this product. However, it is the most widely stock out product in most retail stations across the country.
- A one-week period of the analysis is selected because products are distributed over a week time window from depots to retail stations.
- The unit transporting cost for transporting products along the arcs does not differ as under the primary outbound and inbound segment of the distribution system; i.e. the cost of transporting PMS from the large depot through the transhipment depot to the demand points on a mode of transport is the same. This enables the utilisation of a constant cost value per kilometre to be used over the entire trip. Although, it is arguable that transportation cost per kilometre when subject to external conditions such as congestion may not necessarily remain fixed. The author acknowledges this fact but disregards its impact due to the issue of generalisability. However, the cost per km differs across the truck, rail, and the pipeline mode.
- Specific modal cost per kilometre has been put into consideration like the pipeline, and the cost per kilometre from the large depot to the demand points over the pipeline mode is not influenced by congestion factors. This situation only occurs with truck modes as they conflict with other vehicles enrooted to the densely populated urban metropolis.
- The demand from all the demand points has a strong influence on the location and number of depots. This is because they differ across the retail stations.

- The capacity of the different transhipment depot is assumed to be the same.
- We assume that the large depots are located at fixed points.

9.4 Discussion

9.4.1 Interpretation of vision elements

The interpretation of the participants envisioned elements is a critical factor to be addressed under this section. A wrong interpretation of the elements could divert the direction of the optimisation problem. Therefore, the researcher was very cautious in interpreting the elements of the narratives. The first step which was taken was to adopt an invivo coding method during the coding of the narratives during the vision analysis in the previous chapter. This enables the researcher to capture the exact words used by the participants during the discussion. However, a challenge or a potential limitation of the process involved the ability to reflect the meaning of the stakeholder envisioned elements correctly. For example, a participants opinion of a sustainable form of distribution could imply several aspects of sustainability such as the type of fuel used for running plants, type fuel used for vehicles distributing the products, the nature of materials used in the infrastructure of the network, other externalities such as noise pollution or safety issues associated with the distribution of the petroleum products distribution in the network.

9.4.2 Purpose of visioning activity and choice of translation method

The argument presented in the section is that the translation process and content depend on the nature of the purpose of the Visioning exercise. This assertion agrees with Mallampalli et al. (2016) position that the choice of the narrative translation method should be influenced the purpose of the scenarios and the level of analysis necessary in the scenario development process. In this study, the purpose of the Visioning and scenario development activity was to provide insights for strategic decisions for the Nigerian petroleum industry. Such insights are not limited to the requirements for the future network design they have specified during the Visioning exercise. It extends to the quantified elements which can be optimised to ascertain the implications of the envisioned options. The OVAF methodology uniquely supports the determination of an optimal strategy, and this can only be achieved through the optimisation analysis of the envisioned options. Consequently, it was necessary to translate the narrative vision elements into optimisation model requirements.

The latter comments introduce issues related to incomplete or omission of qualitative visons elements for translation. On the one hand, the identified vision elements are not be selected for translation due to the nature of quantitative analysis to be integrated into the Visioning exercise. For example, finding from section 9.3.4 revealed general requirements for future distribution systems. Some of these elements were management, institutional and policy related. Some of these elements could be quantified and used for different forms of quantitative analysis. It can be implied that the choice of the element for translation is dependent on the type of quantitative analysis to be conducted. In another way, the sentiments or interest of the participants conflict with the overall aim of the process. Senior professionals from competing firms within the industry may withhold the unique vision elements which could transform the network. In this instance, such elements will not be identified for translation.

9.5 Conclusion

In this chapter, the scenario-based visioning translation approach was applied to translate the optimisation network design related vision elements (variables) identified in section 8.5 of chapter from its qualitative and undefined states into quantifiable elements suitable for the optimisation of the Nigerian PPD network for the future. This approach involved two steps, namely; i) the framing of the optimisation problem; ii) the formulation of the optimisation model. In the first step, a causal loop diagram was used to map the variables and provide insight into the relationship between the variables. Variables such as the distribution cost, customer satisfaction, and the sustainable distribution pattern were classed as optimisation problem objectives. Other variables such as; the number of TDs, the locations of the TDs, and volume of products distributed on the network were selected as the decision variables. The first optimisation objective focused on the minimisation of the total distribution cost (transport and depot cost) across the network. The second aimed to maximise the customer satisfaction through minimised outbound trip distance and demand satisfaction. The third objective aims to ensure a sustainable distribution pattern by minimising the emissions during product storage and transportation of the products along the distribution network. Notations were created and used to develop a mathematical formulation which represents the vision elements.

The ability to accurately interpret the vision elements within the narratives and define the element as a decision variable is a central area for consideration in the translation process. Wrongly interpreting the elements from the narratives can limit the success of the OVAF approach. When the optimisation related elements are not clearly identified, deliberately omitted due to variable complexity or the researcher’s inability to quantify variable, there is the risk of the wrong understanding variables being optimised. Besides the latter problem, the OVAF translation approach through this case provides a procedure for linking vision narratives to optimisation models for long-term planning for the petroleum product distribution network. The study sets the scene for a transition between the visions narratives and optimisation modelling thereby fostering complementarity and linkage between the participatory visioning and mathematical optimisation paradigms within the context of long-term facility planning for petroleum network designs.

9.6 Summary of chapter

The chapter focused on the translation between the narratives developed from the visions and the external scenarios. It applies the translation framework and successfully generated quantitative inputs which will be used in the optimisation study in the next chapter.

Chapter 10 - Optimising scenario-specific visions for the Nigerian petroleum products distribution (PPD) network design

10.1 Introduction

This chapter draws on the problem statement and model formulations developed in section 9.3 of chapter 9 to optimise the scenario-specific visions for the future of the south-east Nigerian PPD network. In the external scenario development study, four external scenario specifications were developed and summarised in table 7.2 of chapter 7. In the visioning study conducted in chapter 8, four scenario-specific vision narratives were developed by the stakeholders and summarised in (see appendix 11 for narratives). Optimisation related elements were summarised in table 8.2 of chapter 8. The figure 10.1 below illustrates the link between these external scenario outputs, the vision development outputs, and the optimisation of the scenario-specific visions carried out in this chapter.

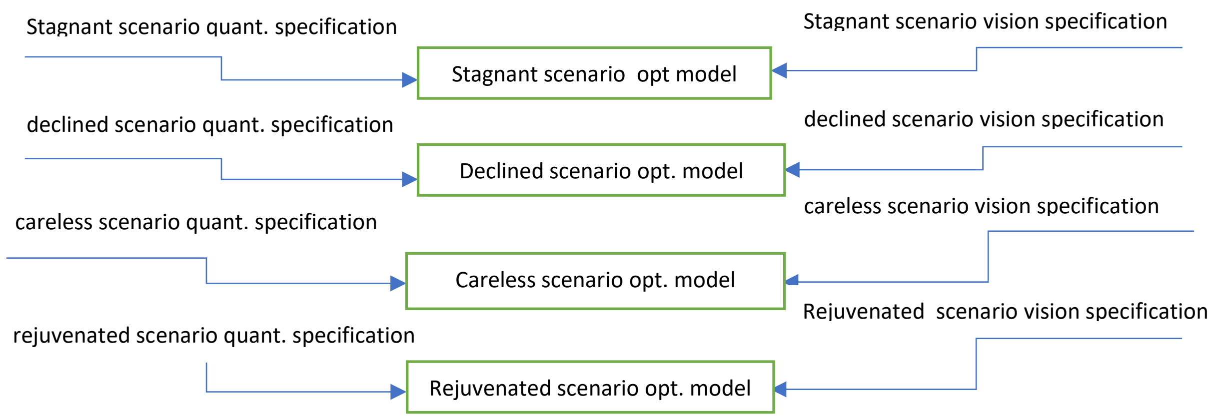


Figure 10.1 Optimisation model framework

In this chapter, four optimisation models were developed in line with the external scenario and visioning specifications provided under table 7.2 and 8.2 of chapter 7 and 8. The optimisation related elements were defined as 11 variables in table 9.1 of chapter 9 and mathematically formulated in section 9.3 of chapter 9. Besides the stakeholder vision specifications identified from the visions, the results of the quantified external scenario specifications identified in section 7.7.1 of chapter 7 will informs the values of the external scenario parameters. The summary of the external scenario and visioning outputs are provided in section 10.2.2.1 and 10.2.2.2 of this chapter respectively.

Section 10.2 of this chapter provides a description of the procedure for the optimisation of visions in line with OVAF stage 4 presented in section 5.5. of chapter 5. Section 10.3 presents an algorithm for conducting the optimisation analysis. Section 10.4 presents the model results. The discussion of the results and conclusions are provided in section 10.5 and 10.6 respectively.

10.2 Application of scenario optimisation technique (OVAF stage 4)

According to the OVAF stage 4 procedure for optimising scenario-specific visions specified in section 5.6.1 of chapter 5, three steps were followed for the optimisation of the scenario-specific visions for the Nigerian PPD network for the year 2040. The steps include i) describe the optimisation study area ii) optimise the scenario specific visions (iii) present the scenario-specific model solutions to the key oil industry stakeholders for reflection and commitment to action. The procedure for highlighted steps are described below.

10.2.1 Step 1 - Description of optimisation study area

In this case study, the south-east Nigerian PPD network was selected as the focus of the optimisation study. The characteristics of the south-east region as well as the motivation for the selection of the case study were provided in section 6.2 of chapter 6. The vision for the PPD network presents a case for exploring the new lines of distribution. Consequently, prior knowledge of potential TD locations does not exist. Therefore, in the description of optimisation study area, a weighted factor location method was applied to identify the set of potential TD locations for the future regional distribution network.

In the determination of the potential TD locations it is assumed that the customer demand points (retail stations) were located at the centre of each municipal LGA in the region. It can be argued that this assumption does not reflect the reality of spatial location and number of retail stations in the region. While the latter standpoint remains valid, the decision to assign the retail stations locations at the centre of each regional municipal LGAs was due to the unavailability of the data on the discrete location of retail stations in the south-eastern region. Also, it reduced the problem complexity that will be encountered if all retail stations were discretely represented for the problem.

10.2.1.1 Identification of potential TD locations in the south-eastern region of Nigeria

A weighted location factor rating (WLFR) method was deployed to identify the potential locations for the TDs in the south east region of Nigeria. First, the factors considered for siting the TDs include; i) proximity to suppliers; ii) cost of the land/rents; iii) proximity to the retailers; iv) weather and climate condition; v) impact on nearby residents; vi) implications for traffic congestion; vii) access to transport links, and viii) attitude of the host community. Second, weights were determined for each factor based on the opinion of the petroleum industry professionals. Here, four senior professionals from the Nigerian petroleum industry were contacted and asked to rank the factors on a Likert scale of "1" to "5". Where "1" means "least important" and "5" means "extremely important" factor.

Table 10. 1 Weight determination for location factors

Factors	R 1	R 2	R3	R 4	Mean weight
Proximity to suppliers(A1)	0.05	0.05	0.05	0.1	0.06
Cost of land/rent (A2)	0.15	0.05	0.1	0.1	0.10
Proximity to retail stations(A3)	0.2	0.25	0.2	0.3	0.24
Weather and climate condition(A4)	0.05	0.05	0.05	0	0.04
Impact on residents (A5)	0.05	0.05	0.15	0.05	0.08
Impact on traffic congestion(A6)	0.1	0.15	0.1	0.15	0.13
Access to transport links(A7)	0.3	0.2	0.3	0.2	0.25
Attitude of host community(A8)	0.1	0.2	0.05	0.1	0.11
	1	1	1	1	1.00

According to table 10.1, to determine the weights of each factor, the scores allocated to each factor was converted from a scale 1-5 to a 0 to 1 scale which represents the weights of the associated factors. The weights assigned to each factor by each participant (R1-R4) were averaged to determine the mean weight**.** This weight represents the level of importance of a particular factor when selecting a potential location for transhipment depot. Access to transport links was considered the most important factor. Hence the weighted score of 0.25. Next, the proximity to the retail stations weighted 0.24. Next, the negative impact of traffic congestion weight of 0.13. The attitude of the host communities weighed 0.11, indicating that efficient product storage can only be achieved when the communities hosting the depot are peaceful and supportive. The cost of the land and the impact on the residents weighed 0.10 and 0.08, respectively. Least weight scores were allocated to the proximity to suppliers and the weather and climate condition of the location.

After the factor weights were determined, the 95 municipal LGA's within the South-Eastern region was assessed on the eight criteria and scored on a scale of 0-100. Code A1 to A8 were allocated to the factors where A1 represent proximity to suppliers; A2 represents the cost of land/rent; A3 represents proximity to retail stations; A4 represent weather and climate conditions; A5 represents the impact on residents; A6 represents the impact on traffic congestion; A7 access to transport links; A8 represents the attitude of the host community.

To measure the proximity to suppliers, the google map was used to calculate the distance between each south-eastern municipal LGA and the envisioned oil refinery or jetty in the region.

The proximity score P_{kscore} for each location was calculated using the formula below.

$$P_{kscore} = \frac{\text{Ɣ}_{ki}}{\sum_1^n \sum_1^m \text{Ɣ}_{ki}} *100 * \ w_{A1} \qquad \text{where k = \{1, 2… m\} and i= \{1, 2… n\}} \qquad [10.1]$$

Where P_{kscore} represents the proximity score for each municipal LGA; Ɣ_{ki} represents the distance in km between a municipal LGA k and a fixed large oil depot i; and w_{A1} represents the weight assigned to factor$A1$.

The demand and population of each LGA were used as a proxy for evaluating the locations under the proximity to retail stations (A3), and access to transport link (A7). The researcher assumed that higher populated LGAs are likely to generate more demand for products and have more retail stations compared to low populated cities. These municipals are populated because of the level of development which is also an indicator of the transport links for the locations. It would not be wrong to infer that municipals with greater population will have more transport links as compared to the smaller municipals. The population was also used as a proxy for the cost of land (A2); impact on residents (A5); and the impact of traffic congestion (A6). However, they were considered negative factors. Therefore, locations with lower population density were scored higher points under these three factors.

The researcher argues that siting the TDs around municipals with smaller population ensures a lowered cost of land/rent; reduces the impact on traffic congestion, and impact on the residents. Locating facilities in populated cities tend to incur a higher cost of land acquisition and rent. Also, under a scenario where the road mode is the prevalent mode of transport, there is a tendency for an increased level of traffic congestion on the major roads. Populated LGAs will suffer the negative effects of depots such the noise pollution from trucks and processing machinery. Therefore, the scores assigned under the A3 and A7 criteria were reversed to generate the location scores for the A2, A5 and A6 criteria.

Table 10.2 Thirty potential TD locations in south-eastern region of Nigeria

LGA	**Daily demand at 2016**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**Weighted score**
Weight		**0.063**	**0.1**	**0.238**	**0.038**	**0.075**	**0.125**	**0.25**	**0.113**	1.002
Idemili North	144765	37	10	100	50	10	10	100	50	61.68
Aba South	143558	63	10	90	50	10	10	90	50	58.44
Ihiala	101536	100	20	70	50	20	20	70	50	54.01
Aguata	124255	46	10	80	50	10	10	80	50	52.49
Nsukka	103932	65	10	70	50	10	10	70	50	48.81
Enugu East	93083	84	20	60	50	20	20	60	50	48.12
Igbo Eze North	86938	62	20	60	50	20	20	60	50	46.74
Ukwa East	19538	40	100	10	50	100	100	10	50	44.95
Onicha	79478	99	20	50	50	20	20	50	50	44.19
Anaocha	95470	1	20	60	50	20	20	60	50	42.89
Enugu North	81339	74	20	50	50	20	20	50	50	42.61
Osisioma Ngwa	74125	63	20	50	50	20	20	50	50	41.92
Aboh Mbaise	65415	90	30	40	50	30	30	40	50	41.74
Ukwa West	29332	50	70	20	50	70	70	20	50	41.46
Udi	80045	55	20	50	50	20	20	50	50	41.42
Awka south	63689	82	30	40	50	30	30	40	50	41.24
Ikwo	72193	52	20	50	50	20	20	50	50	41.23
Dunukofia	32415	88	60	20	50	60	60	20	50	40.85
Udenu	60015	72	30	40	50	30	30	40	50	40.61
Izzi	79504	42	20	50	50	20	20	50	50	40.60
Isiala Mbano	66488	65	30	40	50	30	30	40	50	40.17
Onitsha south	46072	94	40	30	50	40	40	30	50	40.11
Obi Ngwa	61100	62	30	40	50	30	30	40	50	39.98
Bende	64690	60	30	40	50	30	30	40	50	39.85
Isiala Ngwa South	45896	88	40	30	50	40	40	30	50	39.73
Ehime Mbano	43854	87	40	30	50	40	40	30	50	39.67
Ohafia	82612	22	20	50	50	20	20	50	50	39.34
Nkwerre	26951	44	80	10	50	80	80	10	50	39.20
Nkanu West	49490	76	40	30	50	40	40	30	50	38.98
Ohaukwu	65669	46	30	40	50	30	30	40	50	38.97
Ezeagu	57303	46	30	40	50	30	30	40	50	38.97
Ogbaru	75010	16	20	50	50	20	20	50	50	38.96

The attitude of the host communities (A8) was very complex to measure. An approach would have been to assess the behaviour of host communities on the number of previous crisis and destruction of petroleum resources that has occurred in these areas. However, it would be incorrect to rate a location based on the number of crisis that previously occurred in these communities because of these communities have never hosted any oil-related infrastructure. Therefore, it may be misleading to assume that locations with no history of crisis are safer than areas with history of crisis. Therefore, a uniform score of 50 was allocated to all locations. Similarly, the weather and climate condition (A4) was allocated a score of 50 because the climate condition is uniform across all the South-Eastern region of the country. Table 10.2 shows the result of 30 selected potential locations from all the 95 municipal LGAs in the south-east region of Nigeria.

To determine the weighted score for each location, the site scores allocated to the 95 municipal LGAs were multiplied by the respective factor weights. The weighted score for the 95 locations in the south-eastern region was populated and ranked from the highest score to the least score. The top 30 locations were selected as the potential locations and presented in table 10.2.

10.2.2 Step 2 – Optimise the scenario-specific visions

The scenario optimisation (SO) technique described in section 3.4.2.1 of chapter 3 was employed for optimising the scenario-specific visions. The generic problem formulated in section 9.3 of chapter 9 was adapted to the four scenario solutions where each scenario $s \epsilon S$ - {set of all scenarios}. Each of the scenario-specific vision model was solved as a deterministic model. The subsequent sections present the uncertain parameter data extracted from the four external scenarios (10.2.2.1) and the stakeholder visioning outputs (10.2.2.2).

10.2.2.1 Uncertain parameter data

Projected values for the uncertain parameters were drawn from the external scenarios developed in section 7.7.1 of chapter 7. Example of such data include i) petroleum product demand data from the 95 retails stations in south-east Nigeria; ii) cost data; iii) emission data. Table 10.3 present a list of uncontrollable data inputs.

10.2.2.1.1 Petroleum product demand data

Only the premium motor spirit was considered in the problem and treated with the base unit, litres. The different products are not considered as important when the objective of the model is to identify the number of facilities and their respective locations. Though the product (PMS) originates from different locations and are transported to different locations, all the products are stored in tanks. The volume of PMS in barrels are translated into litres by multiplying the number of barrels by 158.9. This is in line with the US petroleum product conversion index.

Table 10. 3 Uncertain parameter data

Uncontrollable Inputs	Stagnant ext. scenario	Declined ext. scenario	Careless ext. scenario	Rejuvenated ext. scenario	Source
Petroleum product demand data	2016 demand +60%	2016 demand +30%	2016 demand +100%	2016 demand -50%	Table 7.7.1.1 of chapter 7
Pipeline transport cost/unit	\$5/barrel	\$5/barrel	\$10/barrel	\$3/barrel	Est. from section 7.7.1.4
Rail transport cost/unit	\$15/barrel	\$15/barrel	\$20/barrel	\$10/barrel	Est. from section 7.7.1.4
Truck transport cost/unit	\$20/barrel	\$20/barrel	\$50/barrel	\$18/barrel	Est. from section 7.7.1.4
Monthly pipeline operating cost	\$15000 per km	\$15000 per km	\$15000 per km	15000 per km	Est. from section 7.7.1.4
TD variable operating cost/unit	\$100-150	\$100-150	\$100-150	\$100-150	Est. from section 7.7.1.4
Unit large depot storage emission	0.05g CO2e	0.05g CO2e	0.02g CO2e	0.02g CO2e	Est. from section 7.7.1.5
Unit TD storage emission	0.05g CO2e	0.05g CO2e	0.02g CO2e	0.02g CO2e	Est. from section 7.7.1.5
Truck Emission/litre/km	0.10g CO2e	0.10g CO2e	0.07g CO2e	0.07gCO2e	Est. from section 7.7.1.5
Train emission/litre/km	0.06g CO2e	0.06g CO2e	0.03g CO2e	0.03g CO2e	Est. from section 7.7.1.5
Pipeline emission/litre/km	0.02g CO2e	0.02g CO2e	0.02g CO2e	0.02g CO2e	Est. from section 7.7.1.5
Unit transit security Cost	\$150/mile	\$0/mile	\$200/mile	\$0/mile	Est. from section 7.7.1.4
Distance Matrix	See Appendix	See Appendix	See Appendix	See Appendix	Google maps

10.2.2.1.2 Retail station demand by customer location

Retail station demand data utilised in this model was derived based on demand projections under four different scenarios presented in chapter seven. The 2016 reference demand were adjusted based on a uniform growth factor to the 2016 data indicating the influence of macro-economic forces under the different scenarios. The projected demand for the retail stations located at the 95 municipal LGAs in south-eastern Nigeria is presented in appendix 12 of the thesis. The 2016 demand data was used as the baseline reference scenario data. The demand for PMS from the retail stations under the stagnant scenario was adjusted by a 60% increase in the 2016 demand data. The demand for the declined scenario was adjusted by a 30% increase in the 2016 demand data. The demand for the careless scenario was adjusted by a 100% increase in the 2016 demand data. The demand for the rejuvenated scenario was adjusted by 50% reduction in the 2016 data.

10.2.2.1.3 Facility data

These are the optimisation input data related to the fixed and variable costs, and the capacity of the facility(large depots and TDs). The fixed cost represents the cost of operating a facility through the operating period, which in this case is a one-month period. This is different from the capital cost associated with the acquisition of the land, building and machinery. These costs are spread throughout the lifetime of the business. The variable facility costs are the cost accrued as a result of increased units processed through the facility. The capacity of the facility is also considered.

Monthly fixed TD operating cost: This is a facility cost associated with operating a TD over an analysis period. Example of such costs is the monthly rent for the depot premises, the monthly payments for electricity, and phone lines. These costs do not change according to how much products are transported or stored in the depot. Data on this cost were collected from the annual reports of the petroleum products marketing companies in Nigeria. Previous depot operating cost data were extracted from five product marketing companies, namely, Oando Plc, MRS, Total, Conoil and Forte plc. The costs under the different scenarios were determined by adjusting the 2016 reference year cost based on the inflationary assumptions under the four external scenarios.

Variable monthly operating expense: This is another facility cost associated with the handling and processing of products at a TD. These include the cost of servicing the loading gantry, loading each truck, and performing safety checks on trucks. The unit cost was determined by extracting the variable operating expense from the National Oil Company and Petroleum Product Marketing Companies annual reports. Just like the monthly fixed operating cost, the variable cost for the different scenarios were determined based on the inflationary assumptions made under the four external scenarios.

10.2.2.2 Visioning variable inputs

Table 10.4 presents optimisation problems variables identified from the visions. Some of the variables were defined by the stakeholders as shown in table 8.2 and used as model objectives, decision variables, and constraints. Other variables that could not be determined by stakeholders during the visioning exercise will be determined by the model. Table 10.4 clarifies the inputs and their values.

Table 10.4 Vision optimisation elements

Optimisation Problem Variables	**Group 1: Variable values for the stagnant ext. scenario vision**	**Group 2: Variable values for the declined ext. scenario vision**	**Group 3: Variable values for the careless ext. scenario vision**	**Group 4: Variable values for the rejuvenated ext. scenario vision**
Distribution cost	Minimisation of distribution cost	Minimisation of distribution cost	Minimisation of distribution cost	Minimisation of distribution cost
Customer satisfaction	Maximisation of customer satisfaction	Not mentioned	Maximisation of customer satisfaction	Maximisation of customer satisfaction
Sustainable distribution pattern	Not mentioned	Not mentioned	Not mentioned	Minimisation of distribution network CO2 emission
Number of TDs	Between 4 and 11 in the region	Between 2 and 5 in the region	Between 20 and 25 per state	Between 15 and 20 per state
Locations of TDs	?	?	?	?
Outbound/inbound Volume distributed	?	?	?	?
Mode of transport	Pipeline-Truck	Pipeline-Truck	Pipeline-Truck/Rail	Pipeline-Pipeline
Capacity of TDs	50,000,000 (assumed)	50,000,000 (assumed)	50,000,000 (assumed)	50,000,000 (assumed)
Capacity of Large Depots	150 million litres (assumed)	150million litres (assumed)	150 million litres (assumed)	150million litres (assumed)
Nos of Large depots	2	4	2	2
Max average outbound trip distance	$\leq 50\text{km}$	unconstrained	$\leq 50\text{km}$	$\leq 50\text{km}$
Automation	None	None	None	Low emission modes, e.g. pipeline, electric trucks
Network structure	Regional design	Regional design	State design	State design

Table 10.4 captures the vision specifications generated by the groups under the respective external scenarios. As shown on the table 10.4, some of the variables were qualitatively defined (e.g. distribution cost, customer satisfaction, the sustainable distribution pattern, mode of transport, automation, and the desired network structure); some were presented in ranges (e.g. number of TDs and maximum average outbound trip distance), and others could not be specified (e.g. location of TDs and volume distributed to and from TDs, and the volume of product to be distributed along the network to satisfy customer daily demand). In terms of the mode of transport, participants were specific in their desired mode of transport across the visions. Also, based on their expertise, participants assumed capacity for the large and TD in the region. The number and location of the large depots were assumed to be fixed. Similarly, an acceptable travel distance was set by the participants under the visions. No outbound distance was set for the visions under the rejuvenated scenario because of the nature of the transport mode, which did not require truck travel to pick up products. Specifically, group four envisioned the use of low emission modes of transport to achieve a sustainable distribution objective. Finally, participants echoed the need for either a regional system of distribution or a state-based design under the visions.

10.3 Model Results

This section presents the results of the optimisation analysis for the four-external scenario-based visions. As highlighted in section 10.1, four optimisation models underpinned by the four-stakeholder scenario-specific visions have been analysed in this section. Each optimisation model presents a unique insight to PPD network for the future, and the analysis and results have been presented in an increasing level of complexity.

10.3.1 Model results for the declined external scenario specific vision

This section presents the optimisation model results for the declined scenario-specific vision. The objective of this model was to minimize the total distribution cost (transportation and depot cost) for PPD network in south-east Nigeria.

The analysis conducted addressed the following questions:

i) what are the costs associated with opening the 2 to 5 TDs in the region?

ii) what is the average outbound distance associated with opening between 2 to 5 TDs?

iii) where should the TDs be sited in the south-east region and what daily volume of products would be transported across the network to satisfy the demand of retail stations?

iv) based on the volume transported, what TD capacity adjustments should be made to ensure a balance between capacity utilisation and costs?

v) How does the system design influence daily trucking operations of products in the region?

vi) what is/are the best locations and number of TD to opened in the region to ensure a minimised total distribution and depot cost?

The vision specified that set I corresponds to 4 large depots located at PHC, IRC, ARC, and IRC in the south-eastern Nigeria. The set K corresponds to 2 to 5 envisioned number of TDs located in the south-east region. The set J corresponds to the retail stations located at 95 municipal LGAs in the south-east region of Nigeria. It was assumed that each large depot i $(\forall\ i = 1,2, \dots I)$ has a 30- day product holding capacity Q_i fixed to 150 million litres. Each TD $k\ \forall\ (k = 1,2, \dots K)$ has a 7-day product holding capacity b_k^* that is fixed to 50million litres.

The fixed operating cost F_k for operating a TD $k\ \forall\ (k = 1,2, \dots K)$ over a period of 7-days is set between [N50,000, N98000] for all the 30 potential locations. The TD variable cost per unit was set to $0.3(equivalent to 105 Nigerian Naira at an exchange rate of N350 to $1). A pipeline model was set for inbound transport and truck mode for the outbound in line with the visions. The inbound and outbound transportation cost per unit kilometre was set to $5(equivalent to N1750) and $15(equivalent to N5250) respectively. Since a pipeline mode was envisioned as the inbound transport mode, the inbound distance was determined based on straight line distance between locations, while the outbound distances were determined based road mode distance. It was also assumed that since the product will be distributed by truck, the speed should range between 50-60km/hr in line with global best practice. Security cost was set to zero since security was not considered a problem under this scenario.

10.3.1.1 Findings from model analysis

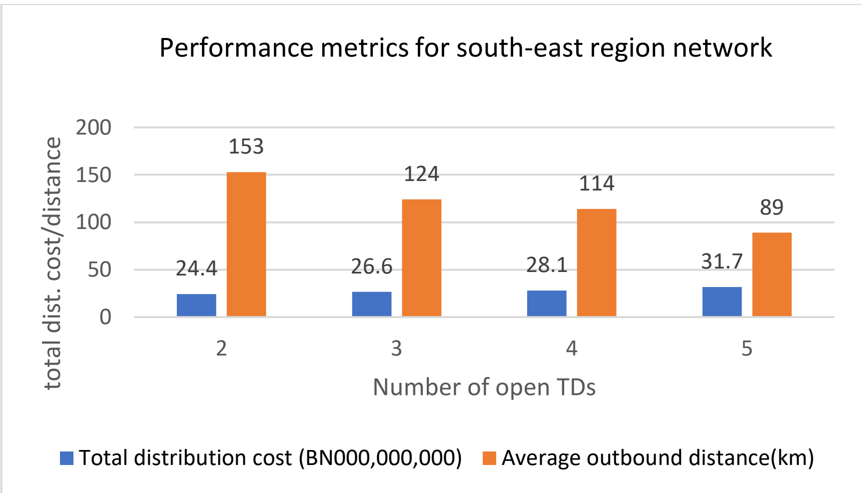


Figure 10. 2 Chart of model results under the declined external scenario-based vision

The result presented in figures 10.2 and 10.3 provides answers to the questions raised in section 10.3 First, the figure 10.2 shows the total distribution cost and the outbound travel distance associated with opening the envisioned number of TDs (2 to 5) in the south-east region. Here, in terms of the total distribution cost, the least total distribution cost of BN 24.4 will be incurred when 2 TDs are opened in the region. On the other hand, the maximum total distribution cost of BN 31.7 will be incurred when 5 TDs are opened in the south east region. These TDs are all serviced by two large depots located at ARC and IRC locations in the south-east region. Since no outbound travel distance constraint was enforced in this model, the result simply show the distance associated with opening an additional TD. The maximum average outbound travel distance of 153km will be travelled when 2 TDs are opened. The travel distance decreases by 30km, with a corresponding 8% increase in total cost. The travel distance decreases by 10km and 25km while the total distribution cost rises by 5.6%, 12.8% respectively as TD number increases up to 5. By implication, as number of TDs rise from 2 to 5, the distribution cost increases by 30% while the average outbound travel distance reduces by 41%.

Figure 10.3 provides a closer look into the locations for the siting the TDs and the volume of PMS distributed from the different TDs to the retail stations.

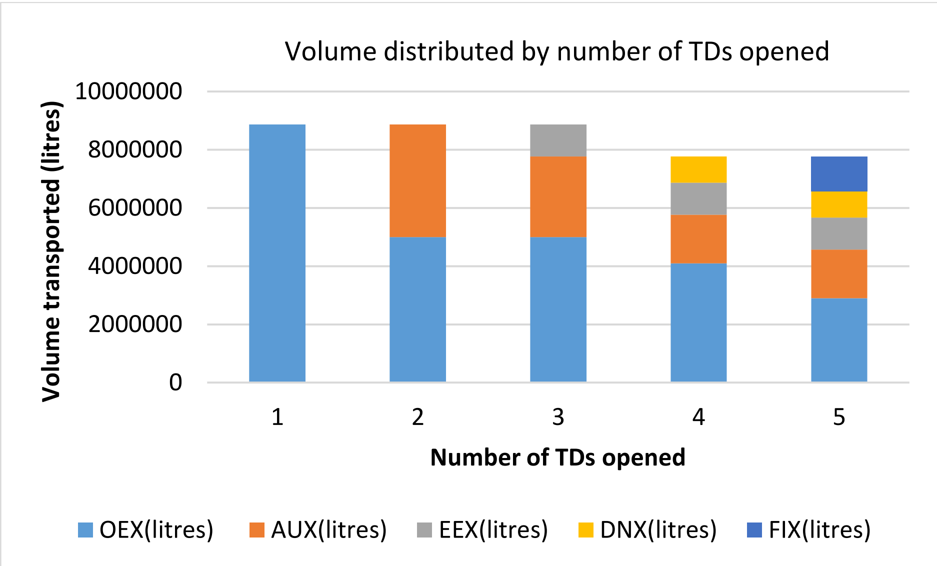


Figure 10.3 Volume of PMS distributed under the decline scenario in the south-east region network

The result provided in Figure 10.3 will provide deeper insights into the capacity adjustments that could be made to improve efficiency; number of trucks required for operations, and truck parking lot allocation. The result revealed that when 2 TDs are opened, they are located at OEX and AUX locations, and 3.8 million and 5 million litres of PMS are transported daily from these TDs to the 95 retail stations in the south-eastern region of Nigeria.

When three TDs are opened, 5million, 2.7million and 1.1 million litres will be transported from the large depots at IRC and ARC to the TDs located at OEX, AUX and EEX. When four TDs are opened, 0.89million, 1.1million, 1.6million and 4.1 million litres are transported from the large depots to the TDs located at DNX, EEX, AUX, and OEX locations. Finally, when five TDs are opened, 1.2 million, 0.89million, 1.1million, 1.6million and 2.9 million litres be transported from the large depots to the TDs located at FIX, DNX, EEX, AUX and OEX.

This implies that none of the TDs utilised more than 10% of their capacities for their daily distribution. Also, as the number of TDs increased, the capacity utilisation reduced. Therefore, a maximum of 32million litres TD capacity will be needed to hold products if 2 TDs are to be opened. 21 million litre TD capacity is required for each TD if 3 TDs are to be opened. 16 million litres per TD capacity will be needed if 4 TDs are to be opened; and about 13million litre TD capacity is needed if 5 TDs are to be opened in the region. These insights will reduce the facility fixed and variable costs. Furthermore, since trucks will be utilised for the outbound transport, in order to satisfy the daily demand of the retail stations, 267 trucks with a capacity of 33000 litres will be required for the outbound product transportation from the open TDs. These insights will also support other operational decisions such as the number and speed of the loading gantry; and the space required for the trucks to park when awaiting loading at the TD.

Finally, in terms of the best locations and number of TDs, table 10.5 show that as the TDs numbers increase from 2 to 6, the outbound distance reduces from 153km to 71km, and the total distribution cost increases from 24.4 BN to 33.5 BN.

Table 10.5 Declined scenario visions solutions for stakeholder reflection

No of open TDs	Total distribution cost (BN)	change in total dist. Cost (BN)	Outbound travel distance (km)	Change in outbound travel distance(km)
2	24.4	0	153	0
3	26.6	2.2	124	29
4	28.1	1.5	114	10
5	31.7	3.6	89	25

This indicates that the interaction between the total distribution cost and the outbound travel distance indicates a conflict between cost savings and travel time savings. Therefore, in order to minimise the maximum change in distribution cost, and maximise the minimum travel time savings, the computations of the travel time savings, and the change in the distribution cost is presented in table 10.5 and will be presented to the stakeholders for deliberation during the third step of the OVAF stage 4.

10.3.2 Model results for the stagnant external scenario-specific vision

This section presents the model results for the stagnant scenario-specific vision. In addition to the minimisation of the total distribution cost addressed in the declined scenario-specific vision model (see section 10.3.1), this model seeks to maximise the customer satisfaction of the retail stations also termed as the customers in this study. This problem explored the trade-off between the level of service coverage (% of the retail stations covered under 50km) and the total distribution cost. While this problem presents a multi-objective optimisation problem, the model was not solved as a multi-objective problem. The customer satisfaction objective was translated into a constraint that specifies that the maximum outbound travel distance should be less than or equal to 50km (retail station trucks should not travel more than 50km to the nearest TD).

Additional insights to be mined from this analysis include:

i) what network design support a maximum outbound travel distance of 50Km?

ii) how does the specified travel distance constraint impact the coverage of retail stations in the network?

iii) What other network design implications occurs as a result of restricting outbound travel distance?

The range for the envisioned number of TDs in the region was between 4 and 11 TDs. The participants envisioned an inbound pipeline mode and an outbound truck mode for product distribution. The fixed cost F_k for operating a TD $k \ \forall \ (k = 1,2, \dots K)$ for 7-days was set between [N25,000, N50,000] for all the 30 potential locations. The variable cost per unit was set to $0.5. The inbound and outbound transportation cost per unit kilometre was set to $7 and $15, respectively. It was also assumed that since the product will be distributed by truck, the speed should range between 50-60km/hr in line with global best practice. Security cost was captured under this problem where the unit transit security cost was set to $150/km. It was assumed that the cost of security was embedded within the fixed depot operating cost.

10.3.2.1 Findings from model analysis

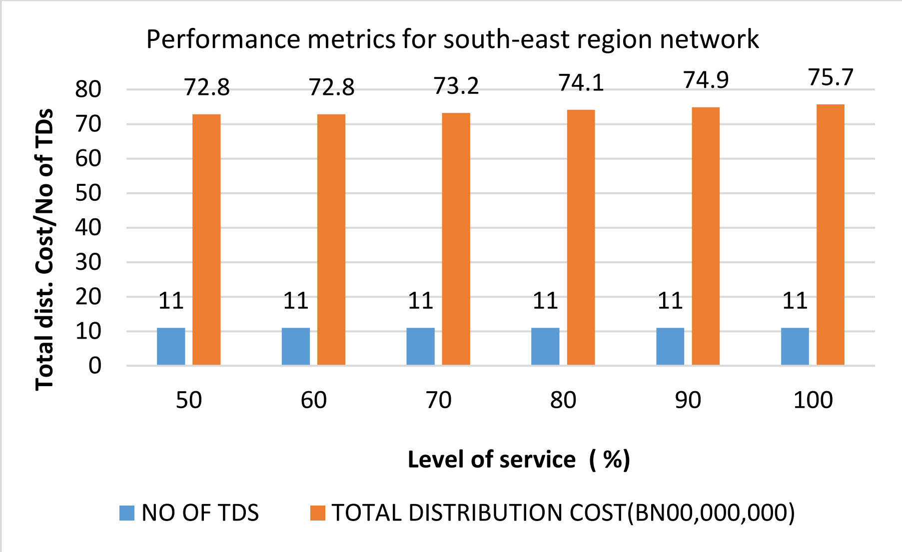


Figure 10.1 Chart of model results under stagnant eternal scenario-based visions

It was identified when 4 to 10 TDs are opened, less than 30% of the demand points are covered under a 50km outbound distance. This result showed that the stakeholder visions between 4 and 10 would only satisfy a maximum of 30% of the retail stations. (see appendix 13). However, result on figure 10.4, revealed that opening 11 TDs provides 50%-100% coverage of the demand points (retail stations) within the south-east region. However, the result also showed that increasing the service level from 50% to 100% coverage will lead to higher total distribution cost. Further analysis of the 11 TDs is presented in figure 10.5 below.

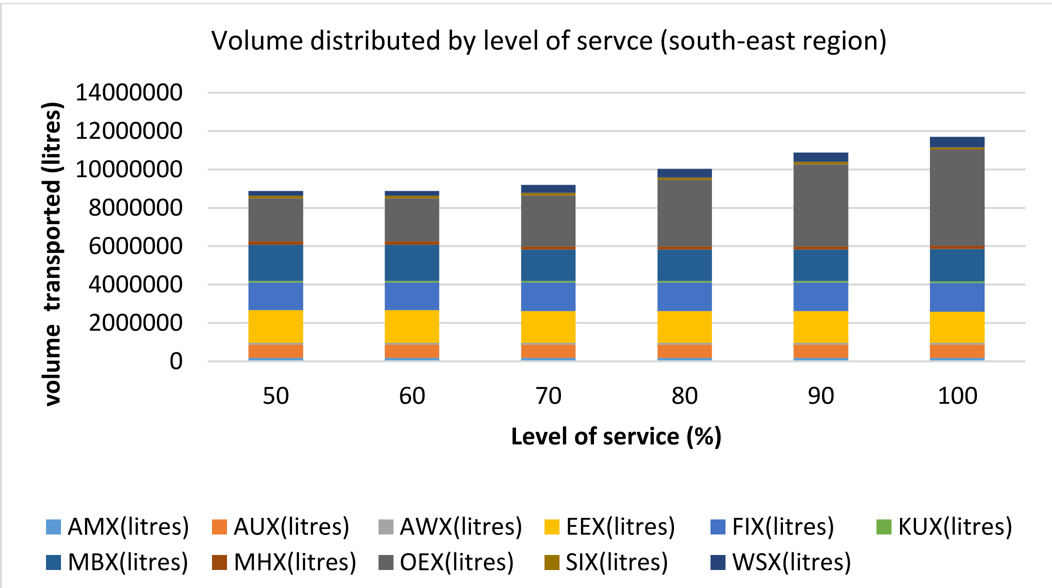


Figure 10.5 Volume of PMS distributed under the stagnant scenario in the south-east region network

From the results, two large depots located ARC and IRC locations should supply 3.9 million and 7.2 million litres of PMS daily to the 95 retail stations through the TDs strategically located in the south-eastern region of Nigeria. At a 50% level of service (i.e. 50% of the retails station demands can be served by a TD located 50km from the TD), eleven TDs should be opened in the region costing BN72.8. The TDs should be opened at AMX, AUX, AWX, EEX, FIX, KUX, MBX, MHX, OEX, SIX, WSX locations. The result also revealed that the same number and location of TDs (11) should be opened at a 60%, 70%, 80%, 90% and 100% level of service. However, the total cost of distribution increased by an average of 1% (BN0.725) as the level of service increased from 50% to 100%.

Six of the 11 TDs maintained their supply capacity to the demand points as the service level increased from 50 to 100%. While five of the TDs fluctuated in the volume supplied as the service level increased. For example, 1.7 million litres of PMS was constantly supplied from TDs located at AMX. 0.6 million litres from TD located at AUX, 0.1million litres from the TD located at AWX, 1.4million litres from TD located at FIX, 0.16 million litres from the TD located at MHX. 0.12 million litres was transported from the TDs located at SIX. In terms of the other five TDs. 1.6million litres was transported from TD located at EEX over 50% to 90% level of service, there is an observed 1.6% (27752litres) reduction in supply to when a 100% level of service is desired. Also, there was approximately 13% (254,883litres) reduction in the volume transported from TD located at MBX when the level of service is increased from 60% to 70%. There was a constant increase of 0.4, 0.8, 0.8 and 0.7 million litres of PMS transported from the TD located at OEX as the level of service increased from 60% to 100%. Finally, there was an increase of 0.1, 0.03, 0.03 and 0.05 million litres of PMS for the TD located at WSX when the level of service is increased from 60% through till 100%.

The latter analysis provides insights into the preferred TD locations. This also suggest that when a TD maintains a constant supply volume despite the increase in the level of service, such TD locations are the most strategically located TDs. Therefore, immediate planning decisions can be made on such TDs. Another insight drawn is the balancing of the supply capacity. If the volume transported from a particular TDs is below the installed capacity, effort can be made to either reduce the redundant capacity or channel more demand to those TDs. Finally, in terms of best design, that guarantees the best service level as well as the best distribution cost, table 10.6 shows that as the number TDs remain fixed at 11, the service level increases from 50% to 100%, and distribution cost increases from 72.8BN to 75.7BN.

Table 10.6 Stagnant scenario visions solutions for stakeholder reflection

Level of service (%)	Number of retail stations covered	Total dist. Cost (BN)	change in total dist. Cost (BN)
50	48	72.8	0
60	57	72.8	0
70	67	73.2	0.4
80	76	74.1	0.9
90	86	74.9	0.8
100	95	75.7	0.8

This indicates that the interaction between the total distribution cost and the level of service indicates a conflict between cost savings and number of retail stations covered. Therefore, the computations of the cost savings, and the changes in the number of retail stations covered are presented in table 10.6 and will be presented to the stakeholders for deliberation during the third step of the OVAF stage 4.

10.3.3 Model results for the careless external scenario-specific vision

This section presents model results for the careless scenario-specific vision. The model analysis in this section seeks to achieve the minimisation of total distribution cost, and maximisation of customer satisfaction objectives pursued in the stagnant scenario-specific vision in 10.3.2. In addition, this model introduces a decentralised network structure where a range of TDs are located in each state in the five south-eastern states of Nigeria (see table 10.4). Hence, a constraint that specified that sufficient TDs must be located in the five states in the region. Each state must have control over their TDs and must ensure that all supply within the state must be distributed from the state-based TDs.

In this instance, the vision specified a set I corresponds to 2 large depots located at ARC and IRC in the south-eastern region of Nigeria. Set K corresponds to the number of TDs within a range $20 \text{ and } 25$ to be in each state in the region. The set J corresponds to the retail customer stations located at each municipal LGA in the states. Other scenario specifications include: a fixed capacity Q_i of 150 million litres for each of the large depots; a capacity $\mathrm{b_k}^*$ of 25million litres per TD located in the state.

In the external environment, the demand for petroleum products has doubled from 2016 demand levels. Therefore, the variable cost for handling the products at TDs is set to \$0.6 (approximately N300). Due to heightened interest rates, fixed cost F_k for operating the TDs $k \; \forall \; (k = 1,2, \dots K)$ in each state for 7-days range between (N150,000 and N200,000) for all the potential locations in the state. The pipeline inbound and truck outbound transportation cost per unit kilometre was estimated at $10 and $20, respectively. Also, it was assumed that the speed for products distributed by rail range between 50-60km/hr in line with global best practice. Security was important in this vision as the stakeholders envisioned the use of drones and aerial surveillance for monitoring products on transit; this cost was assumed to be approximately $200 per kilometre. The customer satisfaction objective was also highlighted under this scenario; therefore, a constraint specifying that the maximum outbound travel distance should be less than or equal to 50km.

10.3.3.1 Findings from model analysis - Imo state

This section presents the result of the optimisation problem for the envisioned PPD network in Imo state, south-east Nigeria. There are 27 demand locations within Imo state. However, the stakeholders have envisioned that 20 and 25 TDs be located in the state.

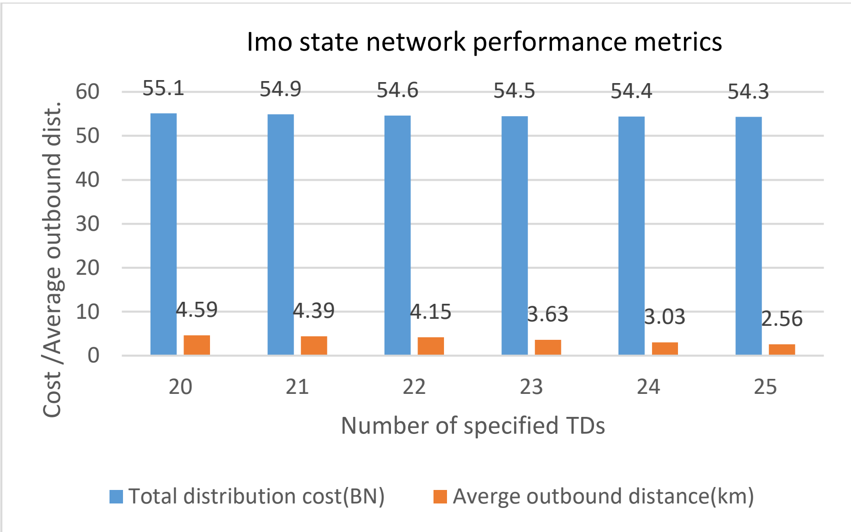


Figure 10.6 Chart of model results for PPD network in Imo state

According to the result presented in figure 10.6, the constraint that the outbound travel distance should not exceed 50km travel was met with the opening of 20 and 25 TDs in the state. Opening such number of TDs guaranteed that the outbound travel distance was less than 5km. This low outbound distance is explained by the low depot operational cost that led to the opening of a TD at almost every municipal LGA. However, the cost of distribution can be explained by the inbound travel distance between the two large depots and the TDs. It was also observed that as more TDs were opened from the 20 to 25 TDs, the cost of transportation and operating the depots reduced by an average of BN 0.16.

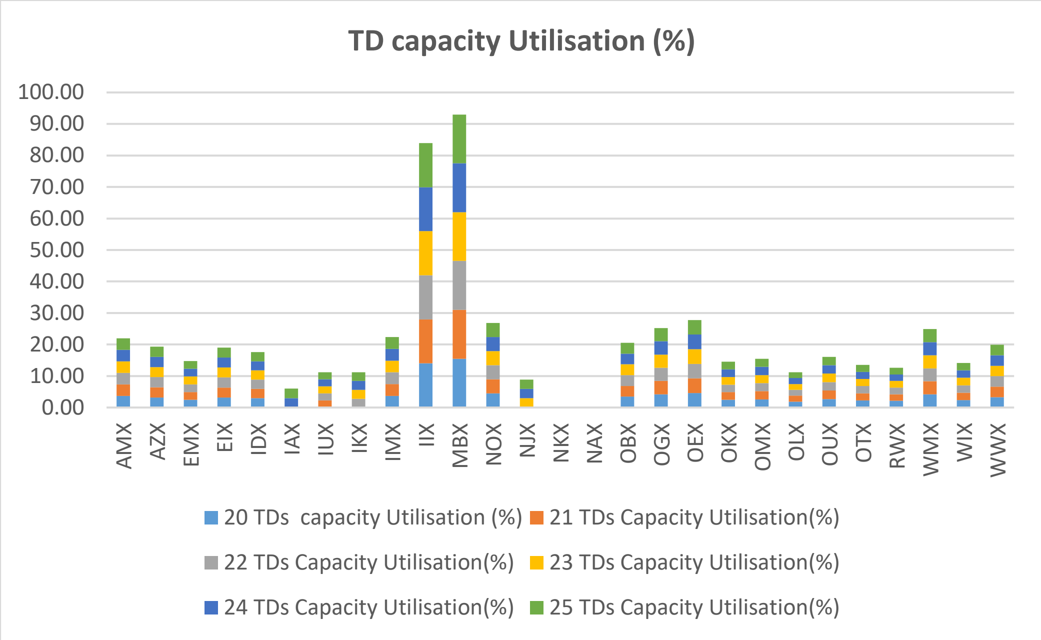


Figure 10. 7 TD capacity utilisation rate in Imo PPD network

While the TDs were opened at almost every municipal LGA, TDs will not be opened at NAX and NKX locations. Instead, products will be transported from the TD located at MBX and IIX to the respective locations. The low depot operating cost is responsible for the opening of the TDs at almost all municipal LGAs where the retail stations can easily access. The result also revealed that while outbound distance is a key performance metrics that represent the customer satisfaction, a lump sum of the distribution cost is left at the inbound transport component. Therefore, it can be said that among the options specified by the stakeholders, the opening of 25 TDs at all 27 municipal LGAs to serve the retail stations is the best option since it provides the least cost and outbound travel distance and the overall least transportation cost.

Since a TD is located at almost every municipal, it is important to understand how the TDs were utilised. The capacity utilisation was computed by dividing the volume supplied to and from each TD when 20 to 25 TDs are opened. According to result on figure 10.7, the TDs at MBX and IIX locations recorded the highest level of utilisation of 15.5% and 14.99% as the number of TDs increased from 20 to 25. This implies that the envisioned capacity of the TDs was far above the required capacity. Therefore, a reduction of the TD capacity from 25million litres to a maximum of 5million litres will be sufficient to hold a 7-day supply of PMS. While the suggested capacity for the TDs located at MBX and IIX hold the highest capacities, other TDs can hold a 5 million litre capacity. The reduction in the capacity will lead to a reduction in the TD construction costs, land acquisition or rental cost and space for the truck parks at the TD premises. Details of the actual volume supplied across the network are presented in Appendix 13.

10.3.3.2 Model results from Abia state PPD network

This section presents the result of the optimisation problem for the envisioned PPD network in Abia State, south-east Nigeria. 17 demand locations exist at the 17 Municipal LGAs in the state. While the visions made a generic specification of 20 to 25 TDs, this was not followed in this case because the number of municipals are 17. Therefore, the model was tested for the best number of TD that satisfies customer demand and the associated cost.

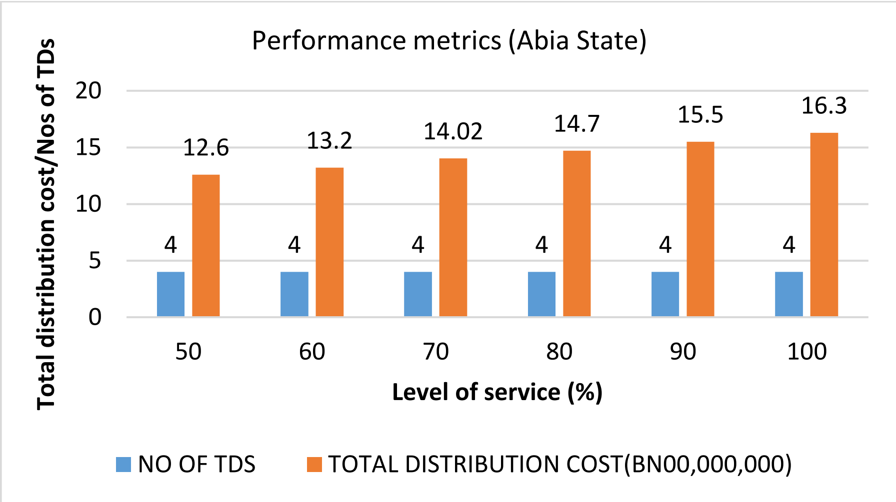


Figure 10.8 Chart of model results for PPD network in Abia State

According to the result presented in figure 10.8, the model prescribes that only four TDs should be opened in Abia state. Four TDs was used to test the service level conditions and the result showed that as the level of retail stations covered increased from 50% to 100%, the total distribution cost increased by 29%. There was an average 6.7% increase in the total distribution cost as the more retail stations are covered. Therefore, the stakeholders need to decide on an acceptable level of service.

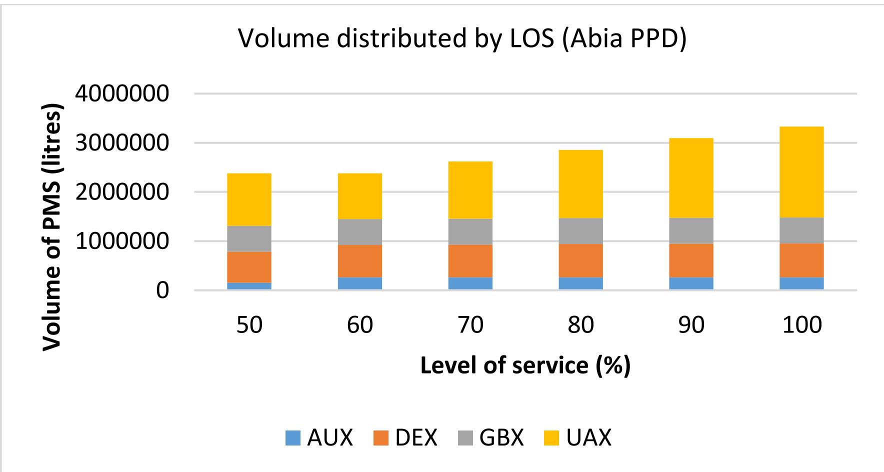


Figure 10. 9 Volume of PMS distributed at different level of service in Abia PPD network

From the result in Figure 10.9, a total of 3.3miliion litres of PMS is distributed from the large depot located at ARC to four TDs located at AUX, DEX, GBX, and UAX locations. No supply was made from the large depot located at IRC location. The 3.3 million litres is split across the four open TDs.

When 50% of the retails stations are within 50kms from the TDs, 6% of the total volume is shipped from the TD at AUX, 27% of the total volume is shipped from TD at DEX, 22% of the volume are shipped from TD at GBX , and 45% is shipped from TD at UAX. When 60% of the retails stations are within 50kms from the TDs, 11% of the total volume is shipped from the TD at AUX, 28% of the total volume is shipped from TD at DEX, 22% of the volume are shipped from TD at GBX , and 39% is shipped from TD at UAX. When 70% of the retail stations are within 50kms from the TDs, 10% of the total volume is shipped from the TD at AUX, 25% of the total volume is shipped from TD at DEX, 20% of the volume is shipped from TD at GBX, and 44% is shipped from TD at UAX.

When 80% of the retail stations are within 50kms from the TDs, 9% of the total volume is shipped from the TD at AUX, 24% of the total volume is shipped from TD at DEX, 18% of the volume is shipped from TD at GBX, and 49% is shipped from TD at UAX. When 90% of the retail stations are within 50kms from the TDs, 9% of the total volume is shipped from the TD at AUX, 22% of the volume is shipped from the TD at DEX, 17% of the volume is shipped from TD at GBX, and 52% is shipped from TD at UAX. When 100% of the retail stations are within 50kms from the TDs, 8% of the total volume is shipped from the TD at AUX, 22% of the volume is shipped from the TD at DEX, 16% of the volume is shipped from TD at GBX, and 56% is shipped from TD at UAX.

10.3.3.3 Model result for Ebonyi state PPD network

This section documents the model result of the optimisation of the PPD network under Ebonyi State in south-east, Nigeria. Since the number of municipal LGAs are less than the number of envisioned TDs, each of the 13 LGAs were potential locations for siting the TDs. Also, there are 13 demand points at the municipal LGAs.

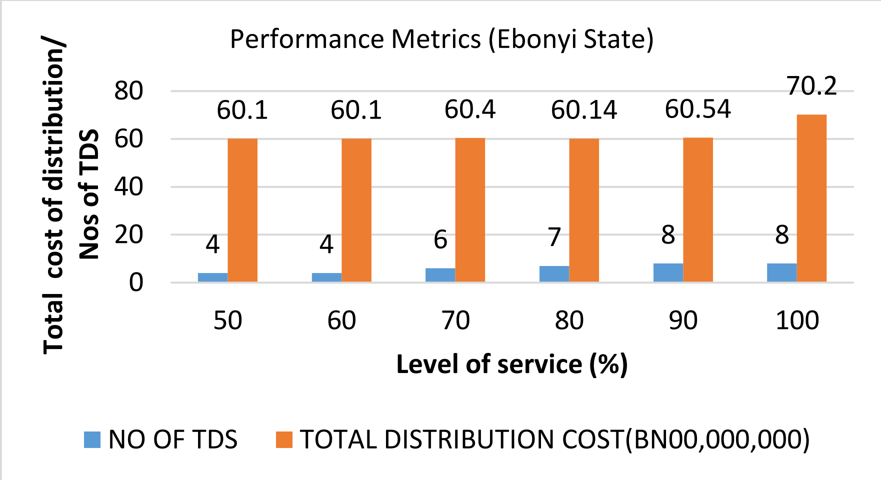


Figure 10.10 Chart of model results for PPD network in Ebonyi state

According to the result presented in figure 10.10, the model revealed that at 50% and 60 % level of service (i.e. to ensure a 50% coverage of all the retail stations within a 50km outbound travel distance) four TDs should be opened at HAX, KOX, NIX, and VOX locations at a total distribution cost of BN60.1 respectively. At 70% level of service, an additional TD should be opened at FSX location at a total distribution cost of BN60.4. At 80% level of service, an additional TD should be opened at ZSX at a total distribution cost of BN60.14. Finally, at 90% and 100% level of service, addition TDs should be opened at ZNX and HKX at a total distribution cost of BN65.4 and BN70 respectively. The result revealed an average of 3% (BN2.02) increase in the total distribution cost as the level of service increased from 50% to 100%.

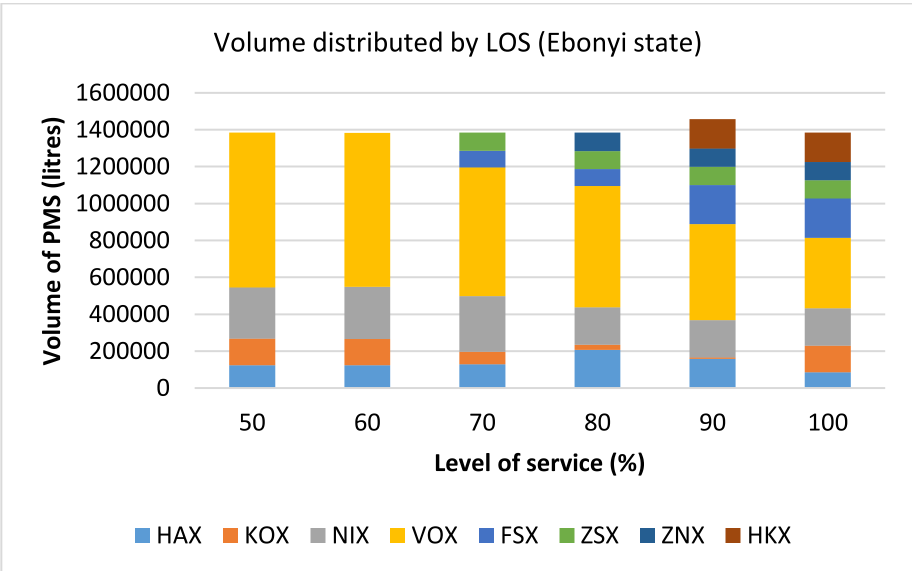


Figure 10. 11 Volume of PMS distributed at different level of service in Ebonyi PPD network

Figure 10.11 shows the flow of products in the Ebonyi state PPD network. From the result, a total of 1.3miliion litres of PMS is distributed from the large depot located at IRC location. No supply was made from the large depot located at ARC location. When 50% of the retails stations are within 50kms from the TDs, 9% of the total volume is shipped to the TD at HAX, 10% of the total volume is shipped to the TD at KOX, 20% of the total volume is shipped to the TD at NIX, and 61% is shipped to the TD at VOX. In the same vein, when 60% of the retail stations are within 50kms from the TDs, the volume shipped to all the four TDs are same except for a 1% reduction in the volume shipped to VOX.

Furthermore, when 70% level of service is required (i.e.70% of the retail station demand are within a 50km outbound distance), there is a 5% reduction in volume transported to the TD at KOX, a 2% increase in the volume shipped to the TD at NIX, a 10% reduction in the volume shipped to VOX, and 6% of the volume is transported to a new TD located at FSX location. When 80% level of service is required, the volume transported to the TD located at HAX increases by 6%, with respect to the 70% level of service. The volume transported to KOX, NIX, VOX is reduced by 3%, 7% and 2%. Product transported to ZSX remain the same, and 7% is transported to anew TD located at ZNX location.

Finally, when a 90% or 100% level of service is required, 6% of the total volume is transported to the TDs at HAX, less than 1% and 10% of the total volume are transported to the TD located at KOX, 15% of the total volume are transported to the TD located at NIX, 38% and 28% respectively are transported to the TD located at VOX under the respectively, 15% of the volume is transported to TD located at FSX, 7 % of the total volume is transported to the TD located at ZSX. Finally, 7% and 11% of the volume are transported to the new TDs at ZNX and HKX locations.

10.3.3.4 Model result for Anambra state PPD network

The model below is the result of the optimisation of the PPD network under Anambra State in South-east Nigeria. Twenty-one potential locations have been set for the siting the TDs in the state that will distribute PMS to the retail stations located at the 21 Municipal LGAs in the State.

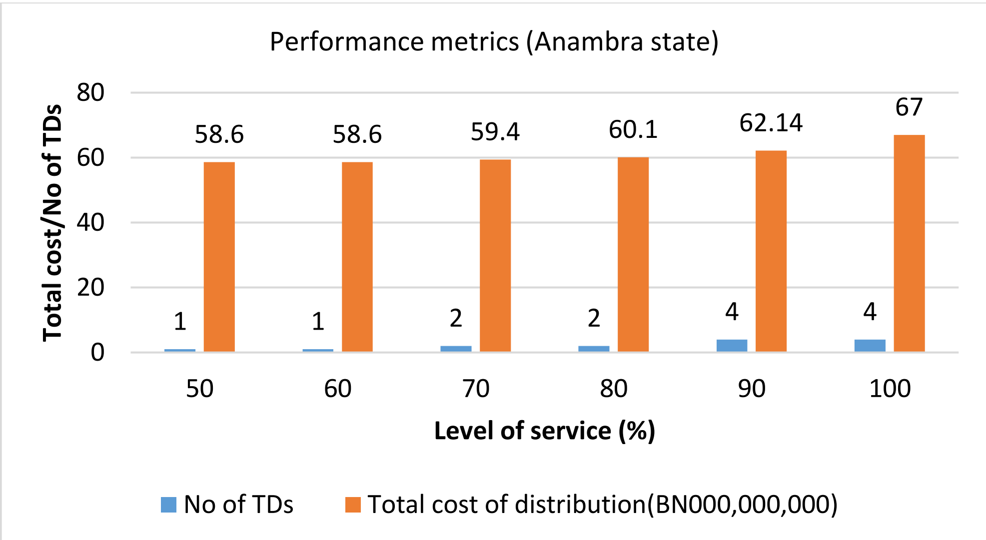


Figure 10. 22 Chart of model results for PPD network in Anambra state

According to the result presented in figure 10.12, the model revealed that at 50% and 60 % level of service (i.e. to ensure a 50% coverage of all the retail stations within a 50km outbound travel distance) one TD should be opened at IHX location at a total distribution cost of BN58.6 respectively. At 70% and 80% level of service, an additional TD should be opened at WSX location at a total distribution cost of BN59.4 and BN60.1 respectively. At 90% level of service, two additional TDs should be opened at GUX and DSX at a total distribution cost of BN62.14. Finally, at 100% level of service, an additional TDs should be opened at THX at a total distribution cost of BN67.4. The result revealed an average of 2% (BN1.68) increase in the total distribution cost as the level of service increased from 50% to 100%.

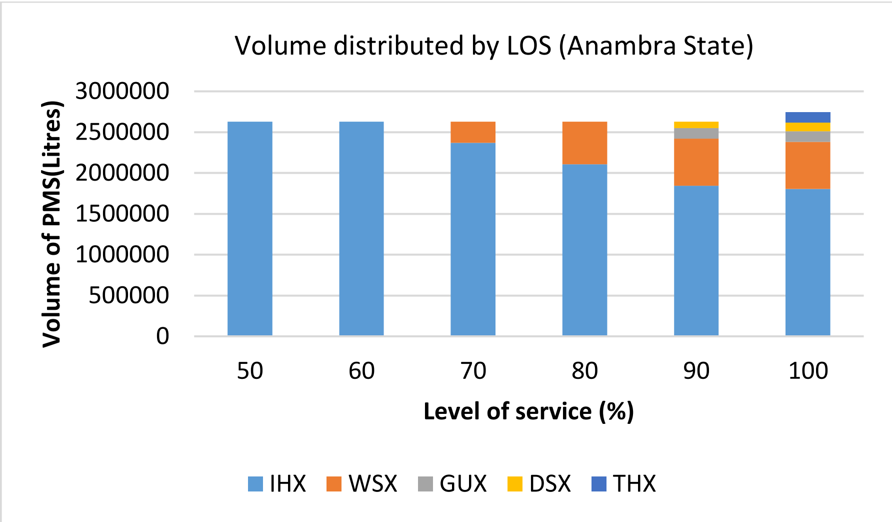


Figure 10. 133 Volume of PMS distributed at different level of service in Anambra PPD network

Figure 10.13 shows the flow of products in the Anambra state PPD network. From the result, a total of 2.7 million litres of PMS is distributed from the large depot located at IRC to the TDs for outbound distribution. No supply was made from the large depot located at ARC location. At 50% and 60% level of service, 100% of the volume are transported to the TD located at IHX location. When 70% level of service is desired, 90% and 10% of the total volume are shipped to the TDs locate at IHX and WSX. At 80% level of service, 80% and 20% of the volume are transported to the TDs located at IHX and WSX. At 90% level of service, 70%, 22%, 5%, and 3% of the total volume are transported the TDs located at IHX, WSX GUX and DSX. At 100% level of service, 69%, 22%, 5%, 4% and 5% to the TDs located at IHX, WSX, GUX, DSX, and THX.

10.3.3.5 Model result for Enugu state PPD network

The model below is the result of the optimisation of the PPD network under Enugu State in South-east Nigeria. Seventeen potential locations have been set for the siting the TDs in the state that will distribute PMS to the retail stations located at the 17 Municipal LGAs in the State.

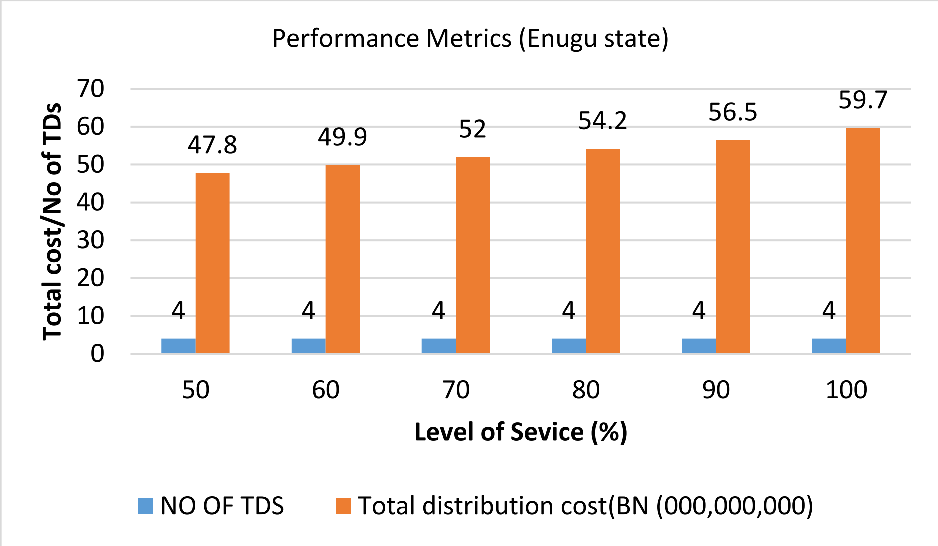


Figure 10. 14 Chart of model results for PPD network in Enugu state

According to the result presented in figure 10.14, the at 50% level of service (i.e. to ensure a 50% coverage of all the retail stations within a 50km outbound travel distance) four TDs should be opened at ANX, AWX, EEX, ESX location at a total distribution cost of BN47.8. At 60%, 70%, 80%, 905 and 100% level of service, the model prescribes opening of the four TDs at the same location. The total distribution cost for opening the TDs at the following locations are BN49.9, BN52, BN54.2, BN56.5 and BN59.7 respectively. The result revealed an average of 5% (BN 2.38) increase in the total distribution cost as the level of service increased from 50% to 100%.

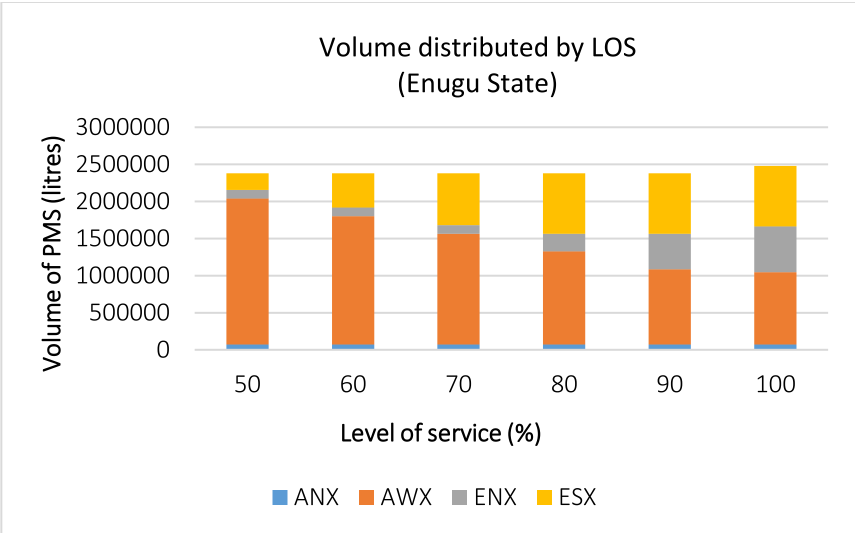


Figure 10. 15 Volume of PMS distributed at different level of service in Enugu PPD network

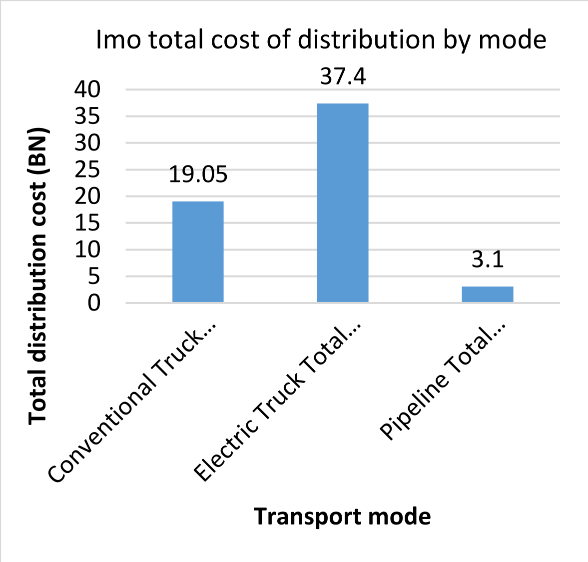
Figure 10.15 shows the flow of products in the Enugu state PPD network. From the result, a total of 2.3miliion litres of PMS is distributed from the large depot located at ARC to four TDs located at ANX, AWX, ENX and ESX locations. No supply was made from the large depot located at IRC location. From the result, the capacity of the TD at AWX was utilised mainly as compared to other three TDs. The results also reveal that as the higher level of service is sought, the utilisation of the TD at AWX reduced while the Td at ESX increases. However, this increases the total distribution cost. Specifically, only 3% of the total volume is transported to the TD at ANX from 50% to 100% level of service. At 50% level of service 83%,5% and 9% of the total volume is transported to the TDs located at AWX, ENX and ESX. At 60% level of service, 73%,5% and 19% of the total volume are shipped to the TDs located at AWX, ENX and ESX. At 70% level of service, 63%, 5% and 29% of the total volume are shipped to the TDs located at AWX, ENX and ESX. At 80% level of service, 53%, 10% and 34% of the total volume are shipped to the TDs located at AWX, ENX and ESX. At 90% level of service, 43%, 20% and 34% of the total volume are shipped to the TDs located at AWX, ENX and ESX. At 100% level of service, 41%, 26% and 34% of the total volume are shipped to the TDs located at AWX, ENX.

10.3.4 Model results for the optimisation of rejuvenated scenario vision

This section introduces a sustainable distribution pattern objective in addition to the cost minimisation, improved customer satisfaction objectives. Just like the careless scenario-based visions, the model presents a state-based network design. The additional layer of complexity is introduced involves ensuring a sustainable distribution pattern in adherence to global best practices. Therefore, the model explored the emission levels associated with different modes of transport. to identify CO2e emission/km related to the different modes of transport. The models will provide the stakeholders with the emission levels associated with their choice of a particular transport mode for the distribution of products.

The vision specified a set I of 2 large depots located at ARC and IRC in the south-eastern region of Nigeria. Set K corresponds to the number of TDs within a range 15 and 20 to be in each state in the region. The set J corresponds to the retail customer stations located at each municipal LGAs in the states. The specifications include: a fixed capacity Q_i of 150 million litres for each of the large depots; a capacity $\mathrm{b_k}^*$ of 10million litres per TD located in the state. Fixed cost F_k for operating the TDs $k \; \forall \; (k = 1,2, \dots K)$ in each state over a period of 7-days range between (N300,000 and N400,000) for all the potential locations in the state. The demand for petroleum products has reduced by half from the 2016 demand levels due to switching to non-fossil-based fuels for vehicle and home energy. Variable cost for handling the products at TDs is set to $0.3 (approximately N40) due to increased value of the naira. A pipeline mode of transport is used for both inbound and outbound transport. The inbound and outbound transportation cost per unit kilometre was set to $10, respectively. Security was important in this vision as the stakeholders envisioned the use of drones and aerial surveillance for monitoring products on transit; this cost was assumed to be approximately $200 per kilometre.

10.3.4.1 Network cost and emission by mode for the Imo state PPD network



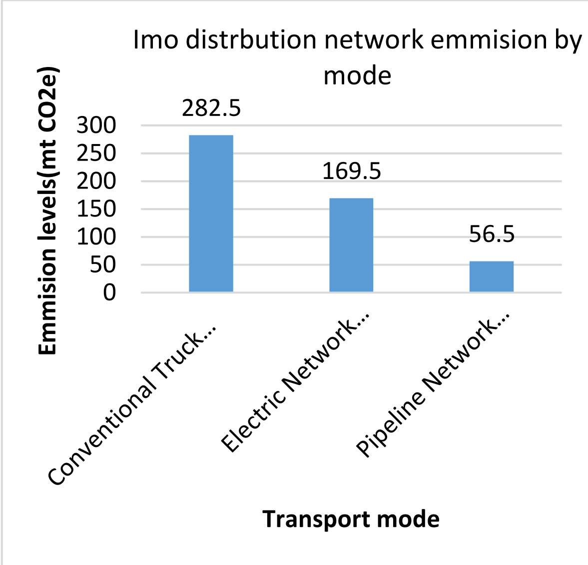
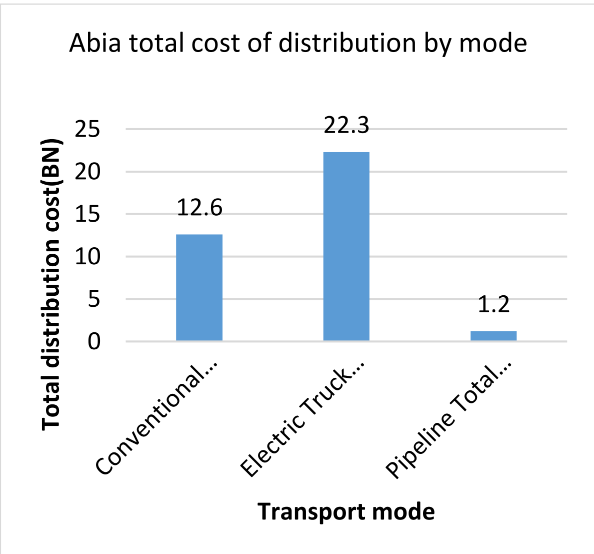


Figure 10.16 Imo total distribution cost by mode Figure 10.17 Imo PPD network emission by mode

Figure 10.16 and 10.17 reveal the total cost of distribution and the total emission from the network when different types of modes are used. According to figure 10.16, the model prescribes that one pump station TD be opened at location OEX at a total distribution cost of BN3.1 and emission of 56.5mtCO2. Comparing the total pipeline cost of distribution and emission to electric trucks and conventional trucks mode of transport. When a conventional truck is used for the pickup of products from the TDs, a total cost of distribution of BN19.05 is incurred, and 282.5 mtCO2 is emitted. When an electric truck is used for the pickup of products from the TDs, a total cost of distribution of BN37.4 is incurred, and 169.5 mtCO2 is emitted.

10.3.4.2 Network cost and emission by mode for the Abia state PPD network



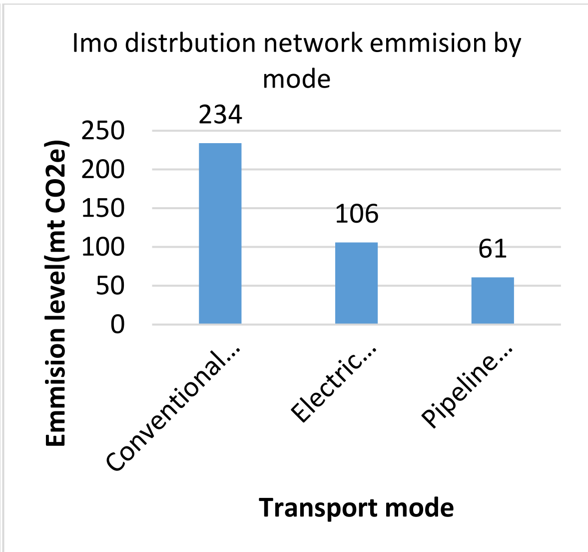
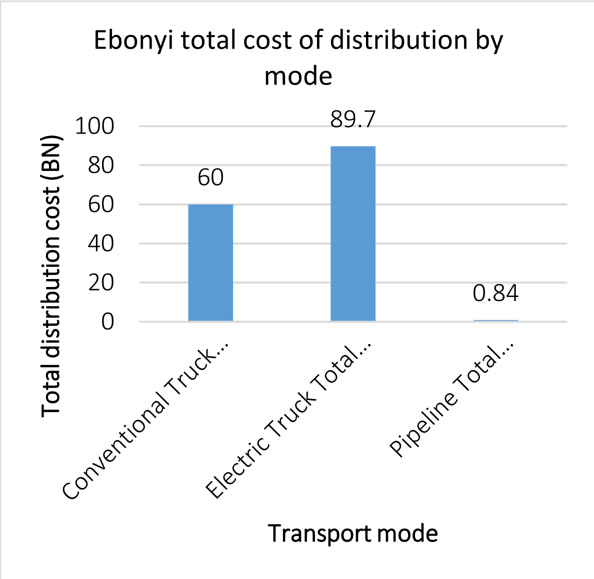


Figure 10.18 Abia total distribution cost by mode Figure 10.19 Abia total emmision by mode

Figure 10.18 and 10.19 reveal the total cost of distribution and the total emission from the network when different types of modes are used. The model prescribes that one pump station TD be opened at location UAX at a total distribution cost of BN1.2 and emission of 61mtCO2 Comparing the total pipeline cost of distribution and emission to an electric trucks and conventional trucks mode of transport. When a conventional truck is used for the pickup of products from the TDs, a total cost of distribution of BN12.6 is incurred, and 234 mtCO2 is emitted. When an electric truck is used for the pickup of products from the TDs, a total cost of distribution of BN22.3 is incurred, and 106.5 mtCO2 is emitted.

10.3.4.3 Network cost and emission by mode for the Ebonyi state PPD network



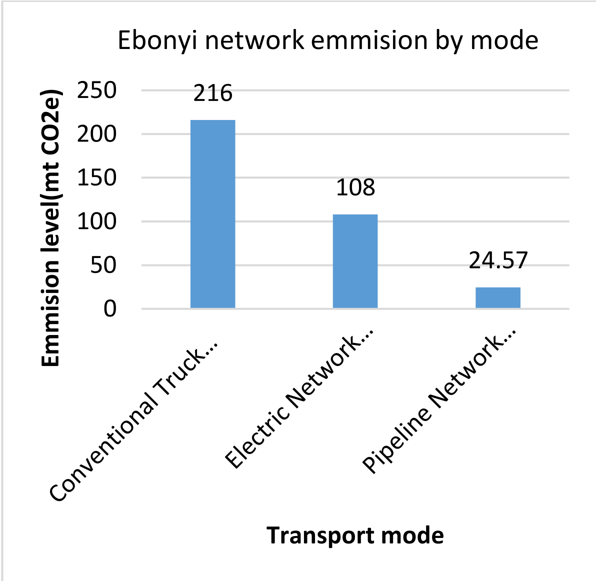
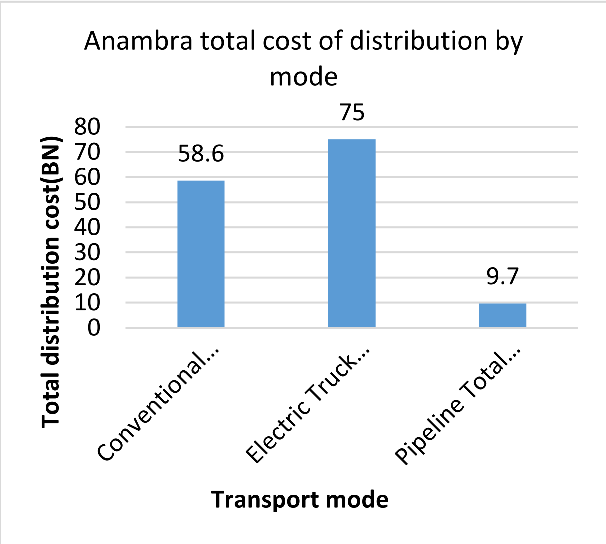


Figure 10.20 Ebonyi total distribution cost by mode   Figure 10.21 Ebonyi total emmision by mode

Figure 10.20 and 10.21 reveal the Ebonyi state total cost of distribution and the total emission from the network when different types of modes are used. The model prescribes that one pump station TD be opened at location VOX at a total distribution cost of BN0.84 and emission of 24.57mtCO2. Comparing the total pipeline cost of distribution and emission to electric trucks and conventional trucks mode of transport. When a conventional truck is used for the pickup of products from the TDs, a total cost of distribution of BN60 is incurred, and 216 mtCO2 is emitted. When an electric truck is used for the pickup of products from the TDs, a total cost of distribution of BN89.7 is incurred, and 108 mtCO2 is emitted.

10.3.4.4 Network cost and emission by mode for the Anambra state PPD network

Figure 10.22 and 10.23 reveal the Anambra state total cost of distribution and the total emission from the network when different types of modes are used. The model prescribes that one pump station TD be opened at location IHX at a total distribution cost of BN9.7 and emission of 56.5 mtCO2. Comparing the pipeline total cost of distribution and emission to electric trucks and conventional trucks mode of transport. When a conventional truck is used for the pickup of products from the TDs, a total cost of distribution of BN58.6 is incurred, and 189 mtCO2 is emitted. When an electric truck is used for the pickup of products from the TDs, a total cost of distribution of BN75 is incurred, and 85 mtCO2 is emitted.



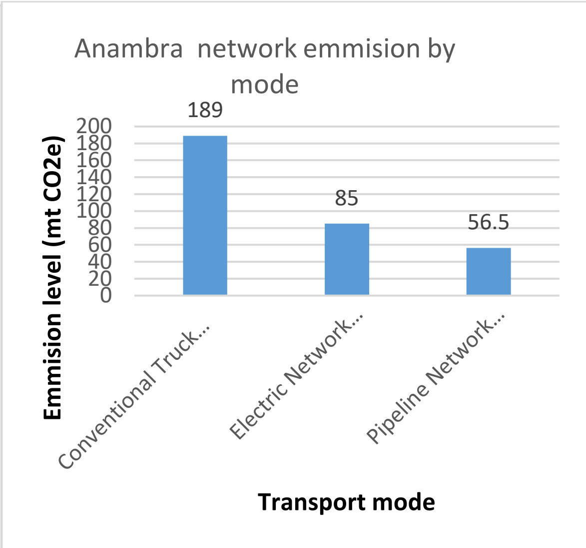
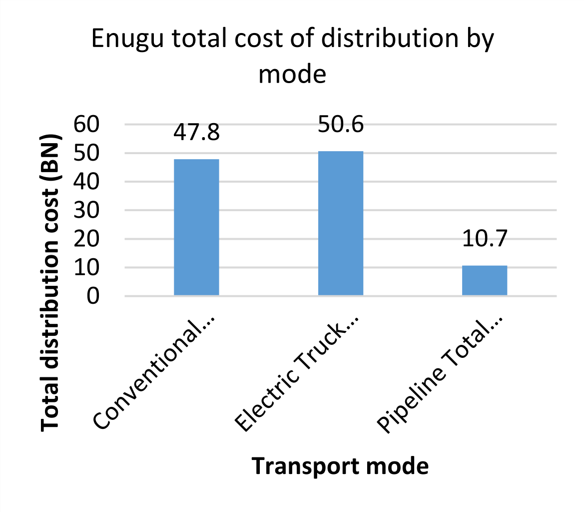


Figure 10.22 Anambra total dist. cost by mode   Figure 10.23 Anambra total emmision by mode

10.3.4.5 Network cost and emission by mode for the Enugu state PPD network

Figure 10.24 and 10.25 below reveal the Enugu state total cost of distribution and the total emission from the network when different types of modes are used. The model prescribes that one pump station TD be opened at location IHX at a total distribution cost of BN10.7 and emission of 82.7 mtCO2. Comparing the total pipeline cost of distribution and emission to electric trucks and conventional trucks mode of transport. When a conventional truck is used for the pickup of products from the TDs, a total cost of distribution of BN47.8 is incurred, and 136 mtCO2 is emitted. When an electric truck is used for the pickup of products from the TDs, a total cost of distribution of BN50.6 is incurred, and 105 mtCO2 is emitted.



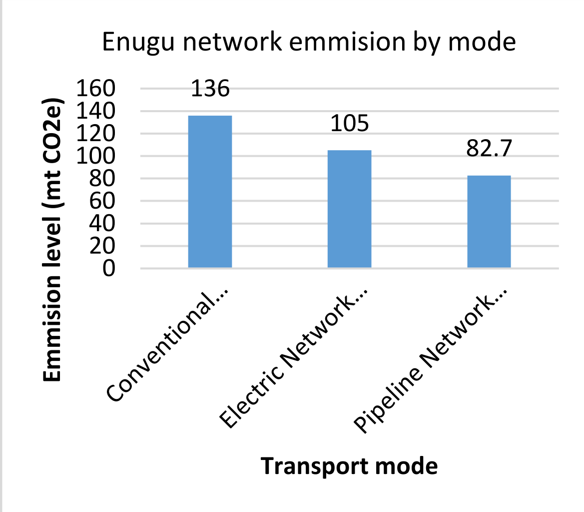


Figure 10.24 Enugu total distribution cost by mode   Figure 10.25 Enugu total emmision by mode

In summary, there is an observed increase in the total distribution cost as conventional trucks and electric trucks are used for distributing petroleum products across the network in the different states. On the other hand, the network emissions from the transportation of product reduce as conventional modes are switched to electric modes. Generally, the pipeline mode of transport across the network resulted in the least distribution cost and least emission.

10.4 Discussion

This section relates the model results to the visions to access the viability of the visions. An initial line of discussion question relates to the relationship between model results developed under each scenario-specific vision with the vision specifications to identify if the stakeholder visions align with the results of the models. The subsections of section 10.4 will address this issue.

10.4.1 Discussion of model results under the declined scenario-based vision.

In the first instance the stakeholder visions under the declined external scenarios specified a range of 2 to 5 TDs to be in the south-east region of Nigeria. Since no outbound distance constraint was considered. The result in figure 10.2 revealed an increasing total distribution cost from BN24.4 to BN33.5 as the TDs range from 2 to 5. Also, the average outbound distance from the retail stations to the TDs reduced from 153km to 71km as the TDs increased from 2 to 5 in the region. Apparently, there is a trade-off between the outbound travel distance and the total cost of distribution. As more TDs are opened closer to the retail stations, the total cost of distribution increases. The latter cost increase is due to the steady rise in the inbound pipeline transportation cost. If two TDs are to be opened in the region, they must be situated as close to the large TDs to reduce the inbound and the total distribution cost. This can be seen from the result in figure 10.3 that when only 2 TDs are enforced to be opened, they are opened at location OEX and AUX which are closest to the large depots located at ARC and IRC, and the total distribution cost is BN23.4.

While opening 2 TDs could yield the least distribution cost, it involves an average outbound travel distance of 153km to the nearest TD. Therefore, maintaining a balance between the inbound and outbound transport cost can yield significant cost savings and outbound travel distance. Hence, the 3, 4, 5 and 6 TDs were opened to explore the cost implication. From the result in figure 10.3, opening of the 6 TDs may have provided the least travel distance but it also accrued the highest distribution cost. Since the focus of the model is to minimise the overall distribution cost, the option that yields a significant reduction in the total distribution cost will be the best option. Considering the latter criteria, the opening of 5 TDs at locations OEX, AUX, EEX, DNX, and FIX with a cost savings of BN3.6 is chosen as the best option.

In addition, the volume of product processed across the `TDs can inform planning decisions on issues such as capacity utilisation of the TDs; number and capacity of trucks for transporting product over a planning period, and space allocation for truck parks when waiting to loaded at a particular TD. For example, since 2.9 million litres are processed weekly at the TD located at OEX location, the tanks at the TD have the capacity to hold 11.6 million litres of PMS for one-month supply with an excess capacity of about 35million litres. This implies that the envisioned capacity for the TDs should be reduced to at most 20million litres capacity. This will reduce the TD construction and maintenance costs. Also, based on the volume processed at the TD, 89 tanker trucks with a capacity of 33000 litres will be required for the weekly, transport of product from the OEX TD. It is also important to note that the number of trucks processed at the TD is influenced by the loading gantry operations at the TDs. Where more products are to the processed, the gantry operations must be improved to meet up the required demand.

10.4.2 Discussion of model results under the stagnant scenario-based vision

In the second instance, the stakeholder visions under the stagnant external scenario envisioned the need for satisfying the customer by not allowing any customer to travel beyond 50km to the nearest TD. Hence, a 50km maximum outbound travel distance was introduced into the model. The analysis also explored the cost implication of the different service levels (retail station coverage under specified number of TDs).

From the result reported in figure 10.4, it was identified that only less than 30% of the TDs were covered between the 4 to 11 range specified in the vision. Exploring further, it was identified that by situating 11 TDs in the region, 50%, 60%, 70%, 80%, 90% and 100% of retail station could access the

11 TDs at a rising cost between BN72.8 and BN75.7. Figure 10.5 also revealed that the 11 TDs should be situated at AMX, AUX, AWX, EEX, FIX, KUX, MBX, MHX, OEX, SIX, and WSX to ensure the least cost for distributing products across the network. The results also exposed that the capacity of the TDs was not adequately utilised and depot operational costs can be further reduced by significantly reducing the holding capacity of the TDs to a maximum of 10million litres.

Based on the result, it can be said that the 4 to 10 vision specifications were not a feasible number of TDs as they were not able to satisfy the envisioned service level of the customers. Interestingly, the locations selected under the declined external scenarios model was also selected under the stagnant scenario.

10.4.3 Discussion of model results under the careless scenario-based vision

The result of this model analysis presented section 10.3.3 involves a state-based network design problem with a constraint that 20 to 25 TDs must be in each state in the region, and the 50km outbound transport constraint. From the results reported under this section, there was a deliberate deviation from the analysis of the stakeholder envisioned range because the specifications were not considered a smart option. Since a maximum 50km outbound travel distance was set, situating 20-25 TDs in each state or one TD per municipal LGA would be too many and there is room for reduction in the number of TDs while maintaining the envisioned service level. To expand on the latter point, the result on figure 10.6 revealed that an average outbound distance of 3.72 km is travelled if 20 to 25 TDs are to be in the Imo state PPD network. This outbound travel distance metric falls below the maximum limit of the 50km envisioned by the stakeholders.

For the above reason, it was very clear that opening 20-25 TDs or one TD at every municipal LGA would result in a maximum outbound travel distance of 5km, therefore, subsequent result for the other states in the south-east identified the best number of TDs for varying levels of service. The model result in figure 10.9 revealed that four TDs be situated at AUX, DEX, GBX, and UAX in Abia state. While only four TDs were opened, the level of coverage in relation to the distribution cost provided more insights. This comparison provides stakeholders with an issue for deliberation: to what extent should we increase our coverage and what cost can we be accommodated.

Under the model result for Ebonyi PPD presented in figure 10.10, 4 to 8 TDs should locate to serve the state at varying levels of service. Four TDs were only able to guarantee that 50% of the customers will travel to at less than 50km to the nearest TDs. However, as the number of TDs increased to eight, 100% service level was achieved at an expense of addition 8% of original distribution cost. This result indicates that lump cost in the distribution cost can be found under the outbound segment of the network. As the TD increases from four to eight, more TDs are closer to the customers thereby reducing the outbound transport cost and increasing the inbound transport cost. As the TDs are located closer to the customers, other externalities such as noise, traffic congestion caused by trailers, traffic accidents, and increased air pollution occur.

Under the model result for Anambra PPD network presented in 10.12, it was identified that one to four TDs were identified to be suitable for the distribution network in Anambra. However, as the service level increased from 50% to 100%, the total distribution cost increased by 14% from when one TD is opened to when five TDs are opened. Since the analysis follows a similar pattern as the Ebonyi model analysis, similar issue related to the outbound distance cost reduction and increase in inbound cost is observed in this case. However, in the case of Enugu state, only four TDs were enough to serve the state. However, as the service level increased from 50% to 100%, the cost increased by a 25%.

An important insight gained from this analysis was that on defining the concrete implications of the vision options it was realised that the options under the disaggregated design were too ambitious. This explains the importance of the optimisation model to analyse the options. However, it must be emphasised that while the range envisioned were not entirely helpful, the definition of an outbound travel distance constraint among others was useful in shaping the modelling procedure. Therefore, it can be concluded that the optimal number TDs for each state were outside the range specified by the visions. The latter conclusion was based on the deviation from the analysis of the envisioned option to an expert driven intent to identify the best design for the network. Other insights related to the capacity reductions of the TDs also apply under the respective state designs because it was identified from the volume transported from the TDs that each TD was extremely under utilised. Therefore, an option would be to reduce the holding capacities of the TDs.

10.4.4 Discussion of model results under the rejuvenated scenario-based vision

In the fourth instance, the stakeholder visions under the rejuvenated external scenario specified that a pipeline network be constructed across the state such that products are transported through pipelines from the large TDs and to the retail stations in the states. A pipeline network is constructed to connect all retail stations discretely positioned along the roads. The model results under the rejuvenated scenario computed the amount of emission given off across the network and when a sustainable distribution pattern is desired. CO_2 emission across the network were computed when a pipeline mode is used in comparison to the conventional truck and electric trucks. Generally, the result revealed that pipeline mode has the least network-related emission of 56.5mtCO2e for the Imo PPD network; 61mtCO2e for the Abia network; 24.57mtCO2e for the Ebonyi network; 56.5mtCO2e for the Anambra network and 82.7 mtCO2e for the Enugu network.

It can be argued that the pipeline mode recorded the least emission across the network because it had the least unit emission value of 0.02gCO2e as compared to the electric and conventional trucks that were 0.045gCO2e and 0.10gCO2e respectively. However, the electric truck mode recorded the highest total distribution cost across the network after the conventional trucks. The pipeline mode recorded the least cost of distribution. Therefore, if a sustainable distribution pattern must be achieved to the peak, the model prescribes the switch from the outbound truck modes of transport to the pipeline mode of transport across the entire network. This solution aligns with the visions which specify for the use of pipeline mode of transport as the only mode which ensures a low emission, safe and secured distribution network. The pipeline mode also eliminates the challenge of traffic congestion caused by trucks on major roads and petroleum product depot corridors in Nigeria.

10.5 Reflections on the optimisation results

This section provides a reflection on some of the case study related decisions, and how such decisions impact the optimisation model results.

10.5.1 Implication of analysing only the south-eastern Nigerian regional PPD network as compared to the national PPD network

The optimisation models for the scenario-specific visions were analysed on a regional and state-based scale. Specifically, the optimisation models for scenario specific-visions 1 (see section 10.3.1) and 2 (see section 10.3.2) focused on the regional south-east PPD network, while the scenario-specific visions 3 (see section 10.3.3), and 4 (see section 10.3.4) focused on a state-based model within the south-eastern region. The decision to conduct an optimisation of the south-eastern PPD network in Nigeria as compared to the national network is reflected upon in this section.

One would wonder at this point the implication of focusing on single region as compared to the entire regions in the country. For this reason, a discussion around the following questions will be addressed:

- Would the optimisation of the national distribution network, which consist of six regions have provided better insights as compared to optimising a single region?
- Would the results from the optimisation of a region or state scale with increasing size?

Yin (2014) explains that the reliability of the conclusions drawn from case studies can be improved when multiple case studies are carried out. While it is true when the result from one case is compared with the results from another case or other cases, the purpose of this case study was to illustrate the application of the OVAF. The researcher explains that there would not have been any methodological difference when applying the optimisation to other region PPD network. Rather, the difference would be in terms of the model results derived from the regional study as compared to a national study.

The latter argument can be assessed by comparing the summation of the optimal solution for the state-based models in the south-east region to the regional models. Here, the result revealed an optimised network where 11 TDs are opened and located at AMX, AUX, AWX, EEX, FIX, KUX, MBX, MHX, OEX, SIX, and WSX at a total distribution cost of BN75.5. This is compared to the optimal state-based model which prescribed opening a total of 24 TDs. i.e. three in Imo at OEX, WMX, IIX locations, four in Abia at AUX, DEX, GBX, UAX locations; four in Enugu at ANX, AWX, ENX, ESX locations; eight in Ebonyi at HAX, KOX, NIX, VOX, FSX, ZSX, ZNX, HKX locations and five in Anambra at IHX, WSX, GUX, DSX, DSX, and THX. Locations similar across the regional and the state-based design are AUX, AWX, MHX, OEX, and WSX. Based on the latter deductions, it can be implied that the state-based design did not scale proportionally with the regional design.

Furthermore, the researcher highlights that the problem of model complexity and data availability are two drawbacks to solving the problem on a national scale. Solving a petroleum product distribution network problem where several nodes and connecting links are involved could lead to a very complicated problem. For example, the current regional problem involved a network characterised by 95 retail station location, a maximum of four large depots and a maximum of 30 potential TD locations. Demand data was sourced for the 95 demand locations under four scenarios, and a 30 by 95 distance matrix was manually generated using google maps. The situation could have been worse if a national focus was furthered. This would have involved the distribution of products from approximately 12 large depots through not less than 100 potential TD locations to retails stations at least 753 municipal LGAs in Nigeria. At such a level the number of decision variables would have increased exponentially. In addition, since it was difficult to find distance matrix data for all the demand points in the Nigeria, the challenge of sourcing data such as the distance matrix for all the 753 municipals would have been a challenge.

Besides the problem of model complexity and data availability to optimise national network, it must be noted the downscaled network design problem of the states did not yield a regional design in terms of cost, number of TDs and the TD locations. Therefore, in practice, if the problem aims to optimise the national network design, a cumulative model of the regional design should not be followed as this would not represent the national system.

10.5.2 Implications of assuming the municipal centroid as the demand point.

Due to the unavailability of research data on the number of retail stations in the south-eastern PPD network, it was assumed that each of the 95 demand points were located at the centroid of each municipal LGA. By implication, all the fuel stations in the south-east regions is centrally located at the municipal LGA. Clearly, this assumption does not represent the spatial arrangement in a real-world network design. This assumption was useful under the regional design addressed in section 10.3.1 and 10.3.2 because it allowed for outbound transport cost to be identified. However, it must be said that this outbound transport cost was not adequately captured because the outbound component was treated as a single link which does not represent a single link.

The latter problem is amplified under the optimisation of scenario vision 3 and 4 where the stakeholders envisioned a design where each state must have specific number of TDs situated in each state or in each LGA in the state. This created a problem as the pre-defined assumption set up the demand locations to also exist at the municipal LGA. Therefore, the cost of transporting the products from the TDs located in the LGA to the demand point at the centre of the LGA was approximately zero. This may have affected the model results under the careless scenario because the outbound transport cost component was not adequately captured.

10.6 Conclusion

This chapter set-off to optimise four vision options developed for the south-east PPD network in Nigeria. The generic optimisation problem and model formulation was developed in chapter 9 of this thesis and used to structure the optimisation framework. Since four scenario specific visions were developed, the purpose of the analysis was to optimise the four scenario- specific visons to identify the concrete implications of the different visions, as well as identify the best solution or set of solutions for the PPD network. The scenario related optimisation were presented in an increasing order of complexity. The declined scenario visions were first analysed because the focus was on the minimisation of the total distribution cost (depot and transport costs). Under the stagnant scenario-specific vision the minimisation of total distribution cost, and maximisation of customer satisfaction level. Under the careless scenario vision, the model was disaggregated into a state-based designs, and in the rejuvenated scenario vision, the objective of improving the sustainable distribution pattern through the reduction of total CO_2e in the network design. The decision variables to optimise were the number of TDs, location for the TDs, and the volume of products to be distributed along the network under the different scenarios.

The optimisation of the visions provided concrete implications of each vision option, such as the location for siting facilities, the number of the facility to be sited, the volume to be transported across the network. Based on the volume transported along the outbound segment of the network daily, details such as the number of trucks required to transport products, space required for trucks to wait before loading can be easily computed. These insights generated support informed decision making during long-term planning. Also, the study found out that while stakeholder visions were useful for framing the optimisation problems, not all the vision specifications were meaningful. Therefore, entirely adhering to the specifications of the stakeholder does not provide the optimal design for the PPD network. Consequently, it is important to constantly provide the feedback solutions from the modelling activity to the stakeholder for re-evaluation. In addition, due to the lack of data on the actual number of retails stations in the system, and the complexity associated with representing such number of demand points, an assumption that each demand point is located at the center of the 95 LGAs in the region. However, this assumption did not adequately account for the outbound cost component in the model. This is major problem when optimising visions for new distribution networks where existing data does not exist.

10.7 Summary of Chapter

This chapter optimised the scenario based-vision options to identify different solutions to the optimisation problem under the four external scenarios. The next activity of presenting the optimisation model solutions to the stakeholders through a workshop or interview methods for review or modification has not been achieved in this research due to the travel restriction occasioned by the COVID-19 pandemic. However, the researcher intends to carry out this step later. The next chapter will document the researcher reflection while evaluating the outputs from the case study.

CHAPTER 11 - Research Reflections

11.1 Introduction

This chapter presents the discussion of the researcher's reflections with respect to the study research questions highlighted in section 1.6 of chapter 1. Since the research aimed at developing a long-term planning approach that consistently combines the exploratory scenarios, visioning, and optimisation, the questions addressed in this research are split into integration-based questions, and stage-based questions. The integration questions address issues of integration between the combined methods within the OVAF framework. Also, they directly align with the research gaps highlighted in section 4.8 of this research. Furthermore, the stage-based research questions address the important discussions in literature around exploratory scenarios, visioning, and optimisation.

Insights from the integration of the methods (RQ1) will be reflected upon in section 11.2. The subsections of the each of section 11.2 will address the sub research questions related to the integration of the methods. Lessons learnt as regards questions raised under the external scenario development case study in chapter 7 are reflected upon and presented in section 11.3. The lessons learnt from the development and application of scenario-specific vision are reflected upon and presented in section 11.4. Similarly, the experience from the development and application of the visioning output translation and the optimisation of scenario specific visions are presented in section 11.5 and 11.6 respectively. The reflections made under each stage draws on the experience gained from the application of the four stages of the OVAF developed in section 5.3 to 5.6 and applied in chapters 7,8,9, and 10.

11.2 Reflections on the integration of exploratory scenarios, visioning, and optimisation for exploring the future of Nigerian PPD network.

The discussion provided in this section addressed research question (RQ1) highlighted in section 1.5 of chapter 1. The research question states: how can exploratory scenarios, visioning and optimisation be consistently combined to address long-term distribution network planning problems? Three interesting questions (RQ1a, RQ1b, and RQ1c will be discussed under the broad question (RQ1).

11.2.1 Reflections on the usefulness developing multiple scenario specific visions

The discussion provided in this section answered the question RQ1a: How useful is the development of multiple scenario-specific visions by stakeholders during a visioning exercise? This question is an integration related question because it introduced a novel approach for integrating the exploratory scenario and the visioning methodology during visioning exercises. This question informed the visioning approach (OVAF stage 2) developed in section 5.4 of chapter 5 and applied for the development of scenario-specific visions for the Nigerian PPD sector by 2040 in chapter 8.

This approach to combining exploratory scenarios and visioning differ from the designs reviewed in section 4.5 of chapter 4 where some participants develop a single shared vision after reflecting on different external scenarios or (Kok. 2011; van Vliet and Kok, 2015; De Bruin et al. 2017). Others agree on the need for developing multiple visions. However, they tend to retrofit the external scenarios to each vision after its development (Tight et al., 2011). In the design adopted for combining of the methods, the participants were split into groups and asked to generate visions elements that are consistent with one specific scenario. A description on how this was conducted is provided in section 8.2.4 of chapter 8.

Results in section 8.3.4 revealed that themes such as adequate technology, security, optimal network design, effective management, integration of process were common across the visions developed by the different groups. However, themes such as functional institutions were unique to visions developed under the stagnant, careless, and rejuvenated scenarios. The social transformation themes were unique to the declined and the rejuvenated scenarios, and sustainability theme was unique to the visions under the rejuvenated scenarios. The latter implies that while some commonalities exist in some of the vision elements generated by the different groups differed across the scenarios. Similarly, it was identified that at a disaggregate level where the optimisation vision elements (the optimal network design requirements) were sought(see section 8.3.5), the different groups envisioned different variable ranges for the number of transhipment depots, and acceptable outbound travel distances. Therefore, it can be inferred that to some extent, the participants adhered to the external scenario content within their discussion materials.

Furthermore, it was also identified that when the exercise progressed to the consensus-building stage where each group presented their visions to other groups, some of the vision elements suggested by each group was modified due to the opinion of other groups. At this point, it was observed that the vision elements under some scenarios like the declined and stagnant began to converge. The careless scenario was modified in terms of the network structure and range for the number of transhipment depots. The vision elements developed under the rejuvenated scenarios were also different in terms of the network structure, mode of transport, number of transhipment depot and the sustainable distribution pattern. Therefore, it can be said that with adequate facilitation during the visioning workshops, participants would effectively utilise their discussion materials to develop distinct vision themes (elements) that are unique to specific external scenarios. Also, sharing of group visions with other groups led to a knowledge-sharing process which to some extent reduced the uniqueness of the scenario-based visions.

The above findings agrees with comments of Kok. 2011; van Vliet and Kok, 2015 for the development of multiple visions as compared to their study that developed a single preferred vision. The authors argued that developing a single vision cannot be feasible across all external scenario contexts. Therefore, it limits the reality of the long-term planning process. Multiple visions that are specific to different external scenario contexts provide the planner with viable and alternative options to adopt and implement as the changes occur in their business environment.

11.2.2 Reflections on the quantification of stakeholder scenario-specific visions

The discussion provided in this section answered the question RQ1b: What are the issues associated with the quantification of stakeholder scenario-specific visions?" This question is an integration related question because it introduced a novel approach for integrating the exploratory scenario, visioning and optimisation. This question informed the visioning output translation approach (OVAF stage 3) developed in section 5.5 of chapter 5 and applied for the translation of the scenario-specific visions for the Nigerian PPD sector into quantifiable variables for optimisations analysis in chapter 8.

As previously mentioned in the review provided in section 4.8 of chapter 4, authors have echoed the need for combining methods from both field in order to develop a robust approach that addresses both complex and complicated components of planning problems (van Vliet and Kok, 2015; Soria-Lara and Banister, 2017; Durbach and Stewart, 2003; Kotiadis and Mingers, 2006). However, it was also highlighted that since these methods are underpinned by methods from different paradigms, its combination has remained complicated task (Voinov and Bousquet, 2010; Alcamo, 2009). Cognitive, practical, and philosophical challenges were highlighted as challenges experienced by authors when combining exploratory scenario methods with quantitative methods such as optimisation, simulation, and multicriteria decision analysis (MCDA) techniques. Wu et al. (2016) also identified that the level of technical expertise of the stakeholders can be an issue when combining methods underpinned by qualitative and quantitative methodologies.

The steps of the visioning translation approach developed in section 5.5 and applied in chapter 9 were the framing of the optimisation problem and the formulation of optimisation problem. The researcher translated the qualitatively described optimisation elements within the visions into measurable forms and mapped the relationship between the variable using causal loop diagram. The variables were also categorised into dependent and independent variables (see section 9.2.1). Since the translation was carried out by the researcher independent of the stakeholders, an issue for reflection was the correct interpretation of optimisation related vision elements under the scenario-specific visions or the modelling of the unfamiliar parameters by the researcher.

The highlighted challenge was experienced during the framing of the petroleum product distribution problem in section 9.2.1. Initially, during the translation process, the sustainability element emphasised in the group visions developed under the rejuvenated external scenario (see table 8.2) was omitted. Other objectives such as the distribution cost and customer satisfaction variables that were familiar to the researcher were represented in the generic optimisation model. The researcher perceived the sustainability element as an environmental component of the network design problem that is beyond the researcher's field of expertise. However, on closer assessment of element and consultations with other environmental modelling experts, the researcher gained insight on a unique way to represent the variable in the framing of the optimisation problem in 9.2.1.

This experience aligns with the findings associated with the translation of stakeholder inputs presented in section 4.7 of chapter 4 (Morgan, 2015; Booth et al., 2016; Titeux et al., 2016; and Wu et al., 2016). Where such a problem is overlooked, a challenge of developing an optimisation problem that will not be relevant to the case being considered. The introduction of the sustainability objective transformed the optimisation model into a multi-objective problem with conflicting objectives. Solving the latter problem provided better insights to planners on the trade-offs between the cost minimisation, customer satisfaction maximisation and emission minimisation in the network design for the future as reported in the result section 10.3. Therefore, it can be concluded that insufficient domain expertise can limit the effectiveness of the process when translating the visioning outputs. Where the latter problem is not identified and addressed, there is possibility of oversimplifying the optimisation problem thereby jeopardising the outcome of the process.

A strategy to mitigate the above problem could be to redesign the OVAF stage 3 to be conducted by the stakeholders during the visioning workshop. For example, the stakeholders engage in the framing the optimisation problems. However, Wu et al. (2016) identifies this option as suitable when the group of stakeholders are well knowledgeable in technicalities and willing to take on more responsibility during the visioning workshop. Where this avails, the responsibility of the determination of the variable relationships is transferred from the researcher to the stakeholders, thereby eliminating the potential errors of selecting the wrong target objectives. It is also important to state that while the above recommendation may be beneficial for a highly experienced and enlightened group of participants, it could present some difficulty for a non-technical audience.

11.2.3 Reflections on the optimisation of scenario-specific visions

The discussion provided in this section answered the question RQ1c: what are the issues associated with the optimisation of scenario specific visions? The scenario optimisation technique (OVAF stage 4) presented in section 5.6 was applied in chapter 10 for the optimisation of the scenario-specific visions for the Nigerian PPD sector by 2040. Based on the decisions made in chapter 5, this section provides the discussion of the reflections on the above question.

In section 5.6 of chapter 5, the scenario optimisation technique was introduced as a method for optimising the network design under uncertainty. This approach was described in section 3.4.2 of chapter 3. The optimisation process was designed to draw its inputs from the exploratory scenario and visioning stages in the OVAF. The optimisation model formulation was drawn from the generic model formulation in section 9.3 of chapter 9. The ranges for the decision variables were extracted from the visioning outputs in section 8.3.5 of chapter 8. The external scenario specifications were drawn from the quantified scenario projections of the uncertain parameters in section 7.7.1 of chapter 7. The results of case study in chapter 10 identified the following issues for reflection:

I. the issue of optimising network designs for non-existing distribution lines.
II. the balance between the use of the visioning specifications by optimisation modellers during the optimisation of scenario-specific visions.

In the first issue, drawing from the results in section 8.3, it was identified that the development of multiple scenario-specific visions provided themes and network design variable requirements that were unique to the different scenarios. Consequently, the results from the optimisation analysis provided the opportunity for richer insights on the concrete implication of the different scenario specific visions that support strategy development process. Interestingly, each of the optimisation model results presented in sections 10.3.1 to 10.3.4 provided different insights to support strategy development processes for distribution network design.

Result from the optimisation of the declined scenario specific visions presented in section 10.3.1 provided insights into the total distribution costs implications for opening the stakeholder prescribed number of TDs. The optimisation of the visions under the stagnant scenario presented in section 10.3.2 provided insights into the total distribution cost implications and the associated level of service for opening the prescribed number of TDs in the network. The optimisation of scenario specific visions under the careless scenario provided insights to the total distribution cost and service level for opening the stakeholder specified number of TDs within each state in the region. Finally, insights on the level of C02 emission associated with the use of either a conventional fuel truck, electric truck or pipeline transport mode was identified from the optimisation model carried out under the rejuvenated scenario.

The above result supports the findings drawn from RQ1a that developing multiple scenario-specific visions provide the planners with alternative vision options to implement in event of unplanned changes to the business environment. It also agrees with conclusions drawn from the studies of Kok. 2011; van Vliet and Kok, 2015 that multiple visions that align with different scenario provide the opportunity for more realistic planning. Therefore, the concrete definitions of the different vision options provide planner with detailed and quantified planning options that can be integrated into strategy development processes.

While the highlighted benefit of optimising scenario-specific visions cannot be overemphasised, some challenges could limit the success of the process. First, since the stakeholders envisioned the siting of new TDs in a region where there is no existing network design, it was crucial to model the flow of products across new distribution lines within the envisioned network design. This implied that data on the cost of transportation and setting up a facility at these new locations would be required. This was a challenge in the optimisation as there was limited data availability to model the new lines.

The highlighted challenge experienced by the researcher aligns with the practical and cognitive challenges associated with multimethod application discussed in the review provided in section 4.4 of chapter 4. While the study of Schneider and Rist (2014) combined two qualitative methodologies (exploratory scenarios and visioning), they agree that practical and cognitive challenges such as time, data constraints and the knowledge of participants can limit the success of process. Kotiadis and Mingers (2014) and Durbach and Stewart (2003) in their attempt to cross between qualitative and quantitative methodological paradigms identified data requirements as a challenge that limits the successful application of multimethods in real-world interventions. Therefore, users of the OVAF should explore strategies for data collection for the new lines within the envisioned distribution network.

Another issue identified in the optimisation of the scenario-specific visions is the ability of the researcher to rely on the vision specifications suggested by stakeholder, when the analysis suggest that such stakeholder specifications does not provide the optimal design for the envisioned network. This can be validated by the optimisation results captured in section 10.3 of chapter 10. The findings suggest that while the stakeholder’s visions provided boundaries for variables such as the number of TDs, the acceptable outbound travel distance, some of these options did not capture the best results for the network. For example, while optimising, the visions under the careless external scenario, the visions specified that at least 20-25 TDs would be enough in each state of the region. By interpretation, this means that in state that has 25 municipal LGAs, should have at one TD in each LGA. The latter option resulted in an average outbound distance of less than 3.7 km as compared to the envisioned 50km threshold. Therefore, a continued optimisation of the vision range under this situation would result in a sub-optimal design for the network.

The latter issue raises the question: to what extent should modellers rely on stakeholder visioning outputs when optimising scenario-specific visions? The question aligns with Booth et al's (2016) position on the need for correctly representing conceptually developed elements within quantitative models during scenario narrative translation. While this research agrees with Booth et al's position, it is crucial to report the result of the stakeholder specifications and potential improvements to the specification of the stakeholders. Stakeholders can benefit from an iterative process where the implications of their options are presented to them for revision and further analysis. This strategy will address Titeux et al's. (2016) concern for the possible reduction of the rich qualitatively described narratives to one-dimensional and straightforward representations during the translation to model inputs (Titeux et al., 2016). It also allays Kok's (2009) concern for preserving the assumptions and interactions contained in the qualitatively described scenarios.

11.3 Reflections on the external scenario development - OVAF Stage 1

The discussion provided in this section answered the question RQ2: How can external scenario specifications be developed to support vision development and optimisation of the visions? The desk exploratory scenario approach (OVAF stage 1) presented in section 5.3 was applied in chapter 7 for the development of external scenarios for the Nigerian PPD sector by 2040. Based on the decisions made in chapter 5, this section provides the researcher's reflections on the three research questions (RQ2a, RQ2b, RQ2c) raised under this stage.

RQ2a: How many external scenarios are ideal to support the development of stakeholder scenario-specific visions?

RQ2b: How useful is a desk external scenario design as compared to the participatory design?

Section 11.3.2 provides a reflection on the usefulness of adopting a desk design for as compared to the participatory design employed by the previous authors.

RQ2c: How did the exploratory scenario stage address its purpose within the OVAF multimethod?

Section 11.2.3 provides a reflection on the usefulness of the exploratory scenario within the OVAF multimethod.

11.3.1 Reflections on the number of external scenarios?

The number of scenarios to be created during scenario projects has remained a debate among scenario developers. As described in section 2.4.2.5 of chapter 2, the number exploratory scenarios range between 2 to 6 scenarios. Therefore, it was recommended in section 5.3.1.4 of chapter 5 that four scenarios should be developed using the FQM technique. According to Schwartz (2009), the construction of four scenarios provide a logical, manageable, and well contrasted number of scenarios. This study agrees with Schwartz as the developed scenarios covered a broad range of plausible eventualities that could evolve in the Nigerian PPD sector environment. It can also be said that the contrasted nature of the four scenarios informed the unique vision themes identified under scenario-specific visions (see section 8.4 of chapter 8).

While the above benefits were identified, the reaction of stakeholders to the scenarios presented in section 8.3.3 revealed that some participants disliked the pessimistic scenarios and were reluctant to engage with such scenarios. Specifically, participants wished to work on the optimistic scenarios (rejuvenated and careless) as compared to the pessimistic scenarios (the declined and the stagnant scenarios). The declined and stagnant scenarios were likened to a “doomsday” scenario. While the researcher clarified the need to focus on all possible scenarios to the participants, the dislike for certain scenarios triggers the question; - was developing four scenarios a good idea?

There are three options to get participants to work with the scenarios. First, the participants could have been forced to work on a specific scenario. Second, each group of participants is asked to work with two scenarios consisting of one optimistic and pessimistic. Third, the participants are allowed to select their preferred scenario to work with. The first option was carried out in the case study and the result was that some groups did not like their scenarios. But this was ideal given the limited time available to conduct the exercise. However, where there was more time, and the stakeholders had the ability to handle more than one scenario, the second option would have been more suitable. Participants may have to develop focus on the optimistic visions and latter address the other. The third option appears to be the most liberal. However, the drawback of this option would be that since there were four groups, each group would simply pick one optimistic scenario and abandon the pessimistic scenarios.

The latter issue is subject to debate in the scenario field. However, the researcher concludes in line with the Schwartz (2009) that four scenarios developed through the FQM technique is the most logical number of scenarios to be developed. Also, groups should be encouraged to focus on each scenario.

11.3.2 Reflections on the usefulness of the desk design for external scenario development?

The use of document analysis to identify focal issues, driving forces of change, and quantify the scenario drivers formed a critical component of the desk design. The experience from the application of this design for developing external scenarios for the Nigerian PPD sector for 2040 revealed that use of the desk design is suitable for situations where the target stakeholders are unable to take part in scenario development workshops due to their busy schedules or other context specific concerns. Also, the use of the desk design was less expensive as compared to the use of participatory design that would have required to conduct multiple workshops or interviews. These findings align with the findings of Bowen (2009) that document analysis is responsive to the cost and time of collecting and analysing survey data. It is also in line with the finding of Fergnani and Jackson (2019) that document analysis for scenario development supports the rapid identification of expert views about the future without the need to interview an inaccessible number of stakeholders and experts physically. Besides the usefulness of the desk design highlighted above, the following issues emerged for reflection from the case study; i) the challenge of misrepresenting the industry concerns; ii) issues of internal consistency.

In the case of misrepresenting the industry the stakeholder concerns, the case experience revealed the risk of selecting the key drivers of change that are not considered to be critical by the stakeholders in the focal organisation or sector. The issue was observed in the results of the exploring issue step presented in section 8.3.3.1. Here, participants were asked to react to the pre-created external scenarios, a participant commented on the need for including “corruption” as key driver affecting the operations in the PPD sector. This issue was resolved by the researcher by clarifying that while it is clear that corruption is a problem that impacts the PPD sector, it has a low uncertainty and can be controlled through regulatory measures. However, the latter problem could have threatened the relevance of the scenarios for the oil sector. Also, this can be considered as limitation in the use of document analysis as the lack of sufficient documents on critical issues in the public space could impact the knowledge on contextual issues by the team responsible for identifying the key drivers.

In terms of the scenario inconsistency, the result in section 8.3.3.2 revealed that some participants disagreed with the internal consistency of a scenario that consist of the combination of a poor economy as a result of the low oil price and stable political and security atmosphere. Although other participants clarified these issues during the workshop, such an issue could have been averted If the stakeholders were involved in the process of developing the scenarios. This issue was considered during the design of the exploratory scenario approach in section 5.2 of chapter 5, and during the case study, Consequently, the researcher engaged two researchers with over ten years work and research experience in the Nigerian oil industry to take part in the identification of the key drivers.

The researcher and these two consulted researchers were responsible for ranking the generic drivers and selecting the drivers with the highest impact and uncertainty. Table 7.1, presented under section 7.5 of chapter 7, shows the results of the ranking of the generic driving forces by the two consulted researchers and the main researcher. Despite this measure that was put in place, the earlier highlighted inconsistency issue was still perceived by some of the participants. Based on this experience, it is advised that when a desk design is used for developing external scenarios, measures must be taken to revise the scenarios with the stakeholders in order to gain a shared opinion and understanding of the scenarios. Measures such as the use of multiple evaluators should be encouraged to ensure that the right critical drivers are selected for the creation of the external scenarios. Also, the delphi methods can be used to remotely gain the consensus opinion of stakeholders on the critical drivers before creating the scenarios.

11.3.3 Reflections on the role of exploratory scenario approach in the OVAF

As described in section 5.3 of chapter 5, the roles of the OVAF stage 1 were; i) to develop external scenarios that can be used as a framework for developing visions; ii) to develop quantified scenario drivers under the different external scenarios that will be used for quantifying the optimisation model parameters. Details on how these roles were met can be found in the case study results in sections in section 7.7 and 7.8 of chapter 7. While the latter results met the earlier highlighted purpose of the exploratory scenarios approach, the researcher reflects on the possibility of the use of trend impact analysis (TIA) approach proposed by Gordon (1994) and described in section 2.4.1.1 as an alternative approach. Since the role of the exploratory scenario was to develop a set of internally consistent quantitative scenarios.

By adopting the TIA, baseline scenarios for each uncertain parameter required for optimisation could have been first created by fitting a curve to the corresponding historical data set and extrapolating the trend into the year 2040. Subsequently, expert judgements could have been used to ascertain the future events that could occur and cause deviations to the extrapolated trend. The latter approach has been criticised for not capturing a complete list of events that could affect the baseline scenarios, and the accuracy of the probability and judgements made by experts. In the case of the OVAF, since quantified projections of selected uncertain parameters were required for the optimisation stage (see section 7.7), the highlighted limitation of the TIA for not considering so many events may not be problem. However, in the role of developing scenario narratives that can be used to evoke stakeholder discussions during the vision development, the social, economic, political, environmental, and technological components of the scenarios may not be captured by the TIA. In addition, the logic behind the construction of the scenarios using the FQM ensures that a wide span of all possible realisations fall within one of the scenario quadrants. This is not the case for the TIA that is criticised for incomplete consideration of events.

The above argument on the suitability of either methods for developing quantified external scenarios when using the OVAF suggest that either methods presents their unique benefits. On one hand, the TIA could have helped to focus on the quantification of the uncertain parameters under the different scenarios needed for optimisation. On the other hand, the exploratory scenario approach captured the broad range of issue likely to occur in a firm's environment thereby providing a richer scenario detail that informed the development of scenario specific visions. process. The researcher concludes that the exploratory scenario would perform better especially when the user focuses on the quantification of the uncertain parameters required for the quantitative analysis.

11.4 Reflections on the vision development - OVAF Stage 2

The discussion provided in this section answered the question RQ3: what issues are associated with developing scenario specific visions? The modified visioning choices approach MVCA (OVAF stage 2) presented in section 5.4 was applied in chapter 8 for the development of scenario-specific visions for the Nigerian PPD sector by 2040. Based on the decisions made in chapter 5, this section provides the researcher's reflections on three research questions (RQ3a, RQ3b and RQ3c) raised under this stage.

RQ3a: How does the participants characteristics during visioning exercise affect the visions developed?

Section 11.4.1 provides a reflection on the impact of the participants characteristics such as the age of the participants on the visions developed.

RQ3b: How does visioning workshop schedules impact the quality of visions developed?

Section 11.4.2 provides a reflection on how the adopted workshop schedule affect the visions developed.

RQ3c: How does visioning interview schedule impact the quality of visions developed?

Section 11.4.3 provides a reflection on how the adopted interview schedule affect the visions developed.

11.4.1 Reflection on the influence of participants characteristics and sample size on vision outputs

As described in section 2.5.1.2, the diversity of participants can have significant effect on the nature of the visions (Soria-Lara and Banister, 2017). Previous visioning studies reveal that elderly participants are less creative when compare to the younger participants. However, it has been stressed that in order to balance the creativity of younger participants with the realistic visions of the elderly, the participants should be recruited from the different age groups. For, the latter reason, an age criterion of 40-70 years was to recruit potential participants (see section 8.2.2.1). In addition, in order to ensure the heterogeneity of stakeholder groups emphasised 2.5.1.2, participants were drawn from a broad range of players in the oil sector. Details of the different stakeholder groups can be found in figure 8.1 of under section 8.2.2.1.

Result from the analysis provided in section 8.3.4 revealed that most of the senior oil industry professionals emphasised on management and institutional issues (e.g. Ownership structure, investment patterns), while the trucking association leaders focused on issues of security. The academics and researchers that took part in the exercise focused on policy related and theoretical issues such as design of the network. In addition, the case study did not confirm Soria-Lara and Banister's (2017) assertion on the relationship between age and creativity during vision development. The different groups contained participants from different age ranges and the level of creativity from each group could not be linked to the younger participants. Therefore, while the researcher agrees with Soria-Lara and Banister (2017) on the need to ensure heterogeneity in the stakeholder groups as different groups addressed important elements in the vision, the results does not suggest any relationship between age and creativity.

In terms of the sample size, the original intention was to recruit a sample larger than 40 participants. Unfortunately, some of the participants declined the invitation due to issues of insecurity and their busy schedules, and a sample size of 25 participants was used in the study (see 8.2.2.1). On one hand, this was not considered an issue in the case study because previous visioning projects especially in the transport field have been conducted successfully with small samples (Zimmermann et al., 2012; Soria-Lara and Banister, 2017). However, it must be stated that since the visions led to the evolution of themes that represent the characteristics (elements) of a desired distribution network, a larger sample may have revealed more in-depth findings that would have been assets for policy and strategy development. Nevertheless, since the purpose of the visioning project was to demonstrate how the visioning process can be improved by linking the visioning outputs to quantitative models in order to improve long-term decision making. Therefore, the success of the process was not measured by the content of the visions which may have been limited by the sample size, but the quality of the process of linking the visioning method to quantitative models.

11.4.2 Reflections on the impact of workshop design on the quality of visions

According to the result of the visioning exercise presented in section 8.3 of chapter 8, the researcher identified that the workshop design can impact the quality of visions developed. When scenarios are developed through an expert-led desk approach, and the professionals have no prior knowledge of the developed external scenarios prior to the visioning exercise, there is a risk that the stakeholders will not engage with all the scenarios where they disagree on the content of the scenarios. Hence, using the scenarios to develop the visions during the same workshop may not work out well.

The strategy adopted in the case study was to discuss the scenarios with the stakeholders under the exploring issue activity (step 3) prior to the generation of the vision elements later the same day. This strategy was classed as a high-risk strategy as result in section 8.3.3 revealed that in one case, a participant commented on the need to introduce "corruption" as a key influencing factor in the Nigerian context (see section 8.3.3.1). Also, another participant commented on the likely inconsistency of the combination between a high oil price and unstable political and security state see section 8.3.3.3). While the latter comments were resolved by the researcher and other participants, it could have led to significant alterations in the scenario content which may not be possible given the schedule of the workshop. Therefore, time for alterations and modification should be considered prior the vision development. An alternative design would be to conduct the activities over multiple workshops. However, in reality the latter option is not always feasible as stakeholders are only able to offer one or two days.

In addition, where resources are limited, and it becomes difficult to organise different workshops at different times, indirect data collection methods can be used to capture stakeholder opinions on the external scenarios before the Visioning exercise. For example, a delphi survey could be used to identify the participant's perspectives on external scenarios (Soria-Lara and Banister, 2017). This can be achieved over multiple rounds. In the first round, the content of the external scenarios should be sent to the stakeholders to evoke their opinion on the different scenario features. In the second round, the views of different participants are exchanged anonymously across participants to build consensus. The integration of the Delphi survey will reduce the risk of developing external scenarios that do not reflect participants views. Outputs from the Delphi process are structured into different external scenarios and presented to the participants for the creation of the visions (Blass et al., 2010).

11.4.3 Reflections on the usefulness of interview design for vision development

While the workshop method was the primary method for the visioning exercise, the interview method was used as a backup method where the participants refused to attend the visioning workshop. From the experience in the case, the backup option was useful as 13 of the participants were unable to attend the workshop. Hence, they opted for a personal interview.

The initial challenge with the use of a one-on one interview method was how to present the external scenarios and develop the visions under the two-hour allotted time agreed by the participants. This was a concern as It was also apparent that presenting external scenarios, accommodating stakeholder reactions, modifying the scenarios, and developing the visions will be challenging to achieve over the two hours. A strategy used was to email the summary of the external scenarios to the participants in advance, and participants were encouraged to review the scenarios and document their views for discussion during the allotted interview period. This strategy was not very useful as the participants had very little comment about the external scenarios during the interviews. Unlike in the workshop where inputs were made to the scenarios, However, they were only useful for consciousness raising of the participants on the scenario contents before the generation of the visions commenced.

Two lessons were learnt from this section; First, when the participants were individually asked to comment on the external scenarios, most of the participants had very little to say as compared to the workshop sessions. One reason could be that the participants did not fully understand the scenarios and found it hard to make independent comments about the scenarios. The latter observation align with O'Brien and Meadow's (2007) position that active group participation and facilitation during workshops improve the knowledge sharing is guaranteed. Second, when the participants were asked about the vision elements, they were very keen to express their views on what they desired for the distribution network for the future. Given the latter challenge, users of the interview method must ensure that the participants understand the scenarios by revising the scenarios with participants with participants and encouraging them to respond.

Although the results in section 8.3.4. reflected the summarised opinion of the stakeholder on the optimisation elements under the different scenarios, it was also identified that the vision specifications provided from the interviewed participants constituted the outlier opinions. For example, when the participants were asked to provide a range to represent what they consider to be "enough TDs", some of the participant's values were far from the range expressed during the workshop. This further justifies the earlier assertion that group activity helped shape the opinion of participants. An option to limit the latter challenge could be to provide the interview participants with a range of information previously suggested by workshop participants in order to evoke their opinions. However, the downside of the latter option could amount to leading the participant to an opinion rather than appreciating their unique perspectives.

11.5 Reflections on visioning output translation and optimisation – OVAF stage 3 and 4

The reflections under the translation and optimisation stage has been discussed under section 11.2.2 and 11.2.3 of this chapter. The research question raised in these sections were considered as the integration elements of the OVAF. Therefore, they were discussed under RQ1.

11.6 Reflections on the relevance of OVAF for long-term planning

This section presents the researchers reflection on the policy related relevance of the OVAF.

11.6.1 Application of the OVAF for wider planning contexts

The OVAF has been developed for long-term planning for distribution network design contexts and applied in the long-term planning for the petroleum product distribution sector in Nigerian. Evidently, not all aspects of the OVAF have worked perfectly, the multimethod remains in its early development stage and can be improved. It is recommended that the OVAF tool can be applied in different supply chain network design planning contexts and not just the petroleum products distribution contexts.

The OVAF can provide insights into the likely futures a sector might encounter in the future. It also will help the stakeholders develop visions that are consistent with the plausible external scenarios that will likely evolve in the future. Finally, the approach will provide the users with the concrete implications of the different visions which in turn will support in the investment decision making process of the industry planners. In addition, the OVAF has the potential to be applied in other sectors as the optimisation of scenario specific visions for public services such as the health care systems; the location of fire stations, hospitals, and schools.

11.6.2 Relevance of OVAF for strategic planning

The optimisation has provided the quantitative definition of the stakeholder visions. This quantification is a significant contribution to the existing visioning process. The visions developed in the case study specified a range for the number of transhipment depots(TDs) and like Mallampalli et al. (2016) pointed out, the lack of technical skills of the stakeholders makes it difficult for the participants to specify the best number or the location where these TDs should be located. This gap is bridged by the OVAF optimisation stage where the optimisation models developed for the visions under the different external scenarios, analysed the stakeholder defined range and identified the best number of TDs and the location(s) within the stakeholder options.

In addition, the stakeholder visions specified the minimised cost, maximised customer experience, and sustainable distribution pattern as the objectives for the distribution network for the year 2040. While these statements depict what the stakeholders desire for the future distribution network, it does not define what an acceptable minimised cost, customer experience, and sustainable distribution pattern imply in quantitative terms. The optimisation complements the visioning by numerical analysing the visions to identify the distribution cost implication of different options; the level of service that customers experience at different strategy-related options, and the emission levels associated with different forms of transport infrastructure.

The optimisation carried out did not suggest a single solution to the long-term planning distribution planning; instead, it explored the range of solutions within the stakeholder specifications to provide flexible solutions to inform stakeholder decision making. The researcher acknowledges that a next stage in the OVAF was to revisit the stakeholders to present the optimisation solutions for them to reflect and decide upon an acceptable option that aligns with the organisation business model.

11.6.3 Relevance of the OVAF for backcasting process

In addition to the definition of the visions and determination of the quantitative implications of the vision options, the optimisation carried out will provide inputs for the pathway formation, otherwise called the backcasting process. As explained in chapter two, the researcher posits that since the visioning focused on the determination of the desired future image, the backcasting addresses the pathways to reaching the desired visions. The researcher posits that the optimisation modelling results will add value to the backcasting planning process by providing rich data for the pathway formation. For example, if the Nigerian oil industry professional envisioned a future distribution network that achieves a reliable service level for the retail fuel stations in Nigeria, the optimisation defines the number of TDs, the location of the TDs, the volume of products to transport through a specific mode to meet customer demand at least cost. The latter data will provide rich information for planners during the development of pathways to achieve the set vision.

11.7 Reflections on the skills needed for an OVAF practitioner

This section provides a discussion of the hard and soft skills required by a user of the OVAF for a real-world intervention. Apparently, the initial design of the OVAF in chapter 5 of this research splits the OVAF into four distinct stages: namely, exploratory scenario, visioning, visioning translation, and optimisation. Three of the stages of the OVAF (exploratory scenario, visioning output translation, and optimisation are carried out by the expert. The visioning stage is carried out by both experts and the relevant stakeholders. The mix suggest that the OVAF must be applied in collaboration between a team of researchers or experts in long-term planning domain and the relevant stakeholders in the specific sector or organisation under focus.

To eliminate cognitive related issues, the user(researcher or expert) of the OVAF must have a good understanding of the use of qualitative and quantitative methods for data collection. A good of knowledge of qualitative content analysis of documents, interview, and focus group data is required to accurately develop scenarios and scenario-specific visions. Also, the user is required to possess quantitative analytical skills to translate the qualitatively described problem into quantifiable dimensions and formulations before optimising the visions. In addition, soft skills are required especially during the visioning stage where data is collected directly from the stakeholders. Expert facilitation skills that ensure effective group dynamics management, active participation, and dialogue among groups participants is essential for success of the visioning stage.

Findings from the study suggest that to ensure correct interpretation of stakeholder views within the quantitative models, the framing of the optimisation problems should be conducted with the stakeholders. This places a practical and cognitive challenge on the stakeholders involved in the visioning exercise. First, sufficient time must be allotted to the exercise to ensure that problem is conceptually defined by the stakeholder during the visioning workshops. Also, to ensure that the latter is achieved, the criteria for the selection of the stakeholder must include the good knowledge of technical details. While the need for a good technical knowledge by stakeholders s important for the OVAF, Voinov and Bousquet (2010) perceive this to be a challenge that a limited the ability to develop technical details during stakeholder discussions. Where the stakeholders are technically oriented, the procedure must include multiple iterative loops between the experts and the stakeholders to ensure that the model developed represents the detail stakeholder specifications.

11.8 Limitations of the research

This research has been successfully executed to address the research questions raised in section 1.5 of chapter 1. However, the research was affected by some uncontrollable challenges. These challenges include:

- the distance between the researcher’s location during the study and the case study location.
- the impact of insecurity in the case study location on the participant’s involvement in the visioning exercise.

- the impact of the COVID-19 pandemic on the execution of the last step of the stage 4 of OVAF.

The researcher was resident in the United Kingdom when conducting the research while the case study was for the south-eastern region petroleum product distribution network in Nigeria. This naturally limited the required communication between the players in the Nigerian oil industry and the researcher. At specific points where validation of data collected through document analysis was required, it was a challenge to obtain sufficient stakeholders to discuss the issues over the telephone. The cost of physically obtaining such data would have been enormous given the budget of the research. Therefore, at specific validation points such as: the validation of focal issues affecting the Nigerian oil industry identified through document analysis. This resorted to the reliance on the comments of three professionals for the validation of the focal issues.

The insecurity challenges currently experienced in sub-Saharan Africa and Nigeria in particular played a significant role in limiting the participation of professionals in the visioning exercise. Due to this challenge, some of the invited professionals declined the invitation while some opted for a one-on-one interview at a location that was considered secure by the participant. This was not a surprise as the oil industry professionals are among high income workers in Nigeria and makes them the target of kidnappers in the country. Unfortunately, all effort to convince some of the invited professionals of the security of the workshop location proved abortive. This led to the researcher engaging in multiple trips for long distances to these secure locations to interview the participants.

Finally, the emergence of COVID-19 pandemic contributed to non-execution of an important stage of the OVAF. This activity involved presenting the model solution generated from the optimisation of the scenario-specific visions to the stakeholders during a visioning assessment activity. During this activity, the stakeholders are expected to reflect on the concrete implications of their specified options, and where necessary, they are expected adjust their original visions. While some may argue that remote methods such as delphi surveys could have sufficed as an approach to communicate to the stakeholders, this activity requires a direct elicitation methods such as the focus group or workshop. These methods will improve the shared learning process among the participants and engender a better understanding of the researcher's interpretation of the visioning outputs.

11.9 Summary of chapter

This chapter presented an account of the researcher's reflections based on the lessons from the case study. The researcher confirms that positive insights were generated from the case study application of the OVAF, there is a need for improvement to the OVAF for application. Areas for improvement in the OVAF will be described in the conclusions provided in the next chapter.

Chapter 12 – Summary and conclusion

12.1 Introduction

This research developed a multimethod for long-term distribution network design planning, and this multimethod was labelled "Optimised Visions of Alternative Futures (abbreviated to OVAF). The OVAF consist of four interconnected stages, namely, the external scenario development: vision development, visioning output translation, and optimisation stage. The foresight methods (exploratory scenario and visioning) through its problem structuring ability addressed the complex components of a long-term planning problem, while the optimisation methods addressed the complicated components of the distribution network design problem. The OVAF stages were evaluated through interconnected case studies presented in chapter 6,7,8,9, and 10. The reflections on the post-application of the OVAF documented in chapter 11 will inform the conclusions drawn in this chapter.

This research was informed by the research gaps highlighted in section 4.8 of chapter 4. The first gap identified while some studies have either combined exploratory scenarios and visioning or exploratory scenarios and optimisation, no study has consistently integrated exploratory scenario, visioning, and optimisation into a multimethod approach. The second gap is linked to the integration between the exploratory scenarios and visioning. Here, the research argues that while different authors have tried to combine exploratory scenarios with visioning in different ways, none has explored the usefulness of developing scenario-specific visions during visioning workshop events. The third gap echoes that no study has developed quantified scenario-specific visions.

Quantified visions provide concrete details of stakeholder envisioned options that are required for strategy development processes. Furthermore, this research argues that visioning can be improved as its outputs can potentially provide useful inputs into the quantitative analysis, such as optimisation. However, since vision outputs consist of elements that are imprecise or lack explicit quantification, integrating the visioning to quantitative methods in the OR field remains a challenge. As a result of the latter gap, the third gaps calls for a vision output translation approach for converting the imprecise vision elements into quantifiable elements for quantitative model analysis.

Bridging the highlighted research gaps will contribute to knowledge by providing a needed improvement to the visioning and the optimisation methods. Visioning outputs will progress from the provision of action points that are qualitatively defined to the provision of a detail assessment of the implications of the stakeholder envisioned options that support strategic decision making. It also bridges the gap between the qualitative and quantitative methodological paradigms in the long-term planning for distribution networks.

In the subsequent sections of this chapter, section 12.2 will provide a summary of the development and evaluation of the OVAF. A summary of each stage of the OVAF is provided under this section. Section 12.3 presents the conclusions drawn from the discussions on the integration-based research question (RQ1) in section 11.2 of chapter 11. Sections 12.4 and 12.5 will provide conclusions on the research questions 2 and 3 (RQ2 and RQ3). Sections 12.6 and 12.7 will provide the policy related recommendations and suggestions for future research respectively.

12.2 Summary of the development and evaluation of the OVAF approach

The exploratory scenario stage of the OVAF (OVAF stage 1) was developed by first reviewing and analysing the exploratory scenario procedures proposed by Schoemaker (1995); Schwartz (1996); Keough and Shanahan (2008); and Riddell et al. (2018). This analysis resulted in selection the eight generic steps for exploratory scenario development presented in table 2.4 in chapter 2. Five out of the eight generic steps informed the proposed exploratory scenario procedure presented in section 5.3.2 of chapter 5. The “identification of stakeholder step” was not included in the proposed exploratory scenario approach because the OVAF was designed for use under resource constrained situations or situations where stakeholders are not available to develop the scenarios. Also, the “selection of leading indicators” step was not included in the exploratory scenario approach because scanning for leading indicators in the business environment after the development of the quantified scenarios did not fit into the purpose and logic of OVAF multimethod framework.

The visioning approach (OVAF stage 2) was developed by first reviewing and analysing existing visioning procedures such as the choices approach (6-steps), visioning choices approach (7-steps), and other visioning procedures applied in visioning projects. Insights from the analysis revealed that visioning exercises generally consist of the 7-steps highlighted table 2.5.1 of chapter 2. These steps informed the steps of the proposed visioning approach that was labeled as the “Modified Visioning Choices Approach (MVCA) presented in section 5.4.2 of chapter 5. In addition, the argument for the consideration of separate visions for each external scenario also influenced the design decisions. This led to: i) the developing scenario specific visions; ii) allocating a single external scenario to a particular stakeholder group during the visioning workshop and interview session.

The visioning output translation approach (OVAF stage 3) developed in section 5.5.1 of chapter 5 was influenced by the framework for integrating stakeholder inputs within quantitative modelling activities as described in section 3.6 of chapter 3. Also, the procedure ensured that the stakeholder specified vision elements and their relationships between the optimisation variables are adequately reflected in the problem formulation.The proposed translation approach has been applied in a real-world distribution network design problem for the Nigerian PPD network. In chapter 9, the approach was applied to translate the stakeholder visioning outputs into quantifiable elements for optimising the PPD network design for year 2040.

In section 5.6.1 of chapter 5, the scenario optimisation technique suitable for optimising the scenario specific vision options are selected as the suitable technique as compared to the stochastic optimisation. The scenario optimisation technique proposed by Dembo (1991) is described in section 3.4.2 of chapter 3. Also, the optimisation process was designed to draw its inputs from the different stages in the OVAF. The optimisation model formulation was drawn from the generic model formulation in section 9.3 of chapter 9. The ranges for the decision variables were extracted from the visioning outputs in section 8.3.5 of chapter 8. The external scenario specifications were drawn from the quantified scenario projections of the uncertain parameters in section 7.7.1 of chapter 7.

12.3 Conclusions on the integration of exploratory scenarios, visioning and optimisation methodologies for addressing long-term distribution network planning problems?

This section presents the research conclusions drawn from the discussion of the research questions (RQ1a, RQ1b, and RQ1c) addressed under the broad research question RQ1 in section 11.2 of chapter 11.

In terms of the integration-based research question (RQ1a) discussed in section 11.2.1: how useful is the development of multiple scenario-specific visions by stakeholders during a visioning exercise? It can be concluded that developing multiple scenario-specific visions provides an opportunity for the identification of unique vision themes under respective scenarios. While the possibility of generating common themes across some scenario-specific visions cannot be discounted, two of the scenario specific visions retained its distinct features.

From the case study, themes such as adequate technology, security, optimal network design, effective management, integration of process were common across the scenario-specific visions. However, the functional institution was unique to stagnant, careless, and rejuvenated scenario visions. The social transformation theme was unique to the declined and the rejuvenated scenarios, and sustainability theme was unique to the visions under the rejuvenated scenarios. In addition, it must be stressed that as the visioning exercise stretches to a consensus building activity, stakeholders tend to adjust their opinions based on the views of other stakeholders. The latter is true because when participants interact, knowledge is shared, and learning is achieved. Consequently, it is encouraged to develop scenario-specific visions during visioning exercises as they provide planners with distinct options to implement as changes occur in the external environment.

In terms of the integration-based research question (RQ1b) discussed in section 11.2.2: what are the issues associated with the quantification of stakeholder scenario-specific visions? The results in section 9.3 presented a central issue of the comparison between the adopted expert-led translation process as against the stakeholder driven translation. The experience from the case study showed that the use of an expert-led process exposed the process to the risk of misrepresenting the stakeholder views within the optimisation model. Therefore, the research concludes that insufficient domain expertise or misrepresentation of vision elements can oversimplify the optimisation problem thereby limiting the efficacy of the modelling process to address the complicatedness of the long-term planning problem.

In the light of the above, the researcher suggests that the OVAF can be modified by involving the stakeholders in the translation process during the workshops. This agrees with the position of Wu et al. (2016) that stakeholder inputs contributes to the framing of the optimisation problem where the optimisation problem objectives, decision variables and constraints are defined and modelled. However, the the translation of decision variables into measurable criteria should be led by the expert post visioning workshop exercise. The latter process should be led by the expert as it could be perceived as too technical for the stakeholder during the visioning workshop. Where the researcher does not understand the vision variables, it should advisable to consult the professionals from the required field.

In terms of the integration-based research question (RQ1c) discussed in section 11.2.3: what are the issues associated with the optimisation of scenario-specific visions? The results in chapter 10 presented some issues for reflection. These issues include (i) the issue of optimising network designs for non-existing distribution lines and (ii) the balance between the use of the visioning specifications by optimisation modellers during long-term planning.

Drawing from the conclusion above in section 12.3 that the development of scenario-specific visions provided themes that are unique to the different scenarios. Each of the optimisation of scenario-specific visons in sections 10.3.1 to 10.3.4 provided different insights to support strategic network design planning. In addition, the optimisation stage revealed that stakeholder vision specifications do not suggest a global optimal design for the envisioned network design. Hence, there is need for an iterative communication between the modelling team and the stakeholders to enlighten them on the implication of their visions, and where necessary modify the specifications to achieve the best results.

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The challenge associated with the modeling of new distribution lines within the network design evolved as a challenge for optimising scenario-specific visions. The stakeholders envisioned siting TDs in the south-east region. This implied that data on the transport and facility set-up costs at these new locations would be required to conduct the optimisation analysis. This was a challenge in the optimisation as there was limited data availability to model the new lines. Although the researcher adopted manual techniques for extracting the data for the new lines, it remains a significant challenge in the OVAF. Therefore, future users of the OVAF should explore strategies for data collection for the new lines within the distribution network.

The latter issue that addresses the extent modellers should rely on stakeholder visioning outputs when optimising scenario-specific visions? Stakeholders can benefit from an iterative process where the implications of their options are presented to them for revision and further analysis. This strategy will address Titeux et al's. (2016) concern for the possible reduction of the rich qualitatively described narratives to one-dimensional and straightforward representations during the translation to model inputs (Titeux et al., 2016). It also allays Kok's (2009) concern for preserving the assumptions and interactions contained in the qualitatively described scenarios. However, it must be noted that executors of the OVAF must selected stakeholders with good knowledge of the variable relationships.

12.4 Conclusions on how external scenario specifications can be developed to support vision development and optimisation of the visions

This section presents the conclusions drawn from the discussion of the research questions (RQ2a, RQ2b, and RQ2c) addressed under the broad research question RQ2 in section 11.3. For the external scenarios specifications to adequately support the vision development and optimisation, the right number of external scenarios and the design for the external scenario must be adequately articulated.

In terms of the exploratory scenario stage-based research question (RQ2a) discussed in section 11.3.1: how many external scenarios are ideal to support the development of stakeholder scenario-specific visions? The latter issue remains a debate in the scenario field as different authors support the development of different number of scenarios. However, based on the findings from this research, it is concluded in line with the Schwartz (2009) that four scenarios developed through the FQM technique is the most logical number of scenarios to be developed. Also, groups should be encouraged to focus on each scenario. However, groups should be enlightened on the importance of addressing each scenario as a possibility of occurring in the future. While the alternative options discussed in section 11.3.1 are also viable, the OVAF practitioner must consider the practical requirements associated with adopting any of the options.

Furthermore, based on the reflections of the exploratory scenario-stage question RQ2b discussed in section 11.2.3, it is important to note that where a desk design is solely adopted for scenario development, there is a risk of developing scenarios that are not relevant to the stakeholder concerns. Also, there is a likelihood of a perceived internal inconsistency of the scenarios by stakeholders if they do not take part in the scenario development process. Consequently, it is advised that when a desk design is used for developing external scenarios, measures must be taken to revise the scenarios with the stakeholders in order to gain a shared opinion and understanding of the scenarios. Measures such as the use of multiple evaluators should be encouraged to ensure that the right critical drivers are selected for the creation of the external scenarios. Also, the delphi methods can be used to remotely gain the consensus opinion of stakeholders on the critical drivers before creating the scenarios.

In terms of the exploratory scenario stage-based research question (RQ2c) discussed in section 11.3.3: how did the exploratory scenario stage address its purpose within the OVAF multimethod? The research concludes that the trend impact analysis method may have focused specifically on the quantification on the drivers required for optimisation. However, the exploratory scenario approach captured the broad range of issues likely to occur in a firm's environment thereby providing a richer scenario detail that informed the development of scenario specific visions. Therefore, the external scenario stage of the OVAF must maintain a balance between developing detailed scenarios that capture different aspects of the business environment and focus on identifying the optimisation parameters required for the numerical analysis of the visions.

In addition, the use of a document analysis for data collection during scenario development succinctly supports the harnessing of views about the future without interviewing or conducting workshops for an inaccessible number of subjects on the focal issue. Also, the desk scenario design can precede the participatory scenario and visioning where the scenarios developed through a desk design are presented to stakeholders for discussion and onward vision development.

12.5 Conclusions on issues associated with developing scenario-specific visions

This section presents the conclusions drawn from the discussion of the research questions (RQ3a, RQ3b, and RQ3c) addressed under the broad research question RQ3 in section 11.4 of chapter 11. The questions addressed under this section are; i) RQ3a: how does the participants characteristics during visioning exercise affect the visions developed? ii) RQ3b: How does visioning workshop schedule impact the quality of visions developed? iii) RQ3c: how does visioning interview schedule impact the quality of visions developed?

In terms of the scenario-specific vision stage-based question RQ3a, the conclusions drawn from the discussion on the relationship between age of participants and their level of creativity; and the impact of a small sample on the visions developed in 11.4.1 suggest that the age of professionals do not impact the level of creativity in developing visions. This finding conflicts with the position of Soria-Lara and Banister (2017) that younger participants are more creative in developing visons. However, it can be said that the professional's affiliation influenced the focus of the visions developed. In terms of the effect of sample size, the study agrees with Soria-Lara and Banister (2017) that small samples have been used in developing quality visions. However, it is important to state that large samples support the validation of tentative findings. In the case of the OVAF, the success of the MVCA was assessed on the ability to consistently link the visioning outputs to the optimisation modelling component, and this was achieved using the sample used in the study.

In terms of the scenario-specific vision stage-based question RQ3b, the conclusion drawn from discussion on the impact of workshop design on the quality of scenario-specific visions in 11.4.2 suggest that when external scenarios are developed through a desk approach as specified in the OVAF, the stakeholders involved in the vision development tend to have no prior knowledge of the developed external scenarios prior to the visioning exercise. There is a risk of stakeholders not engaging with all the scenarios or disagreeing with the content of the scenarios. Hence, designing the workshop over a single day to discuss the scenarios and develop the visions may not feasible. . Therefore, time for alterations and modifications should be considered prior the vision development workshop. An alternative design would be to conduct the activities over multiple workshops. However, users must consider the practical requirements of organising such workshops for more than one day.

In terms of the scenario-specific vision stage-based question RQ3c, the conclusion drawn from discussion on the impact of interview design on the quality of scenario-specific visions in 11.4.3 suggest that proxy methods can be employed to email the summary of the external scenarios to the participants in advance, and participants should be encouraged to review the scenarios and document their views for discussion during the allotted interview period. This strategy will accommodate stakeholder reactions, and modification of the scenarios contents where necessary before developing the visions over the allotted interview hours. Furthermore, to limit the challenge of outlier opinions by interview participants, the participants should be provided with a range of information previously suggested by workshop participants in order to evoke their opinions. However, the downside of the latter option could amount to leading the participant to an opinion rather than appreciating their unique perspectives.

12.6 Recommendations for policy implications

The OVAF has been developed for long-term planning for distribution network design contexts. Hence, it has been applied in the long-term planning for the Nigerian PPD networks. While the OVAF may not have worked perfectly in all it its components, it remains its early development stage and can be improved. However, it is recommended that oil industry stakeholder should use the OVAF as a tool for long term planning. Having applied it in the case study, the OVAF can help provide insights into the likely futures they sector might encounter in the future. It also will help the stakeholders develop visions that are consistent with the plausible external scenarios that will likely evolve in the future. Finally, the approach will provide the users with the concrete implications of the different visions which in turn will support in the investment decision making process of the industry planners. In addition, the OVAF has the potential to be applied in other sectors as the optimisation of scenario specific visions for public services such as the health care systems, the location of fire stations, hospitals, and schools.

12.7 Recommendations for future research

The areas for future research are drawn from some of the issues experienced from the research conducted**.** Below are some of the areas recommended for future research.

1. The use of the OVAF extends beyond the link between the visioning and the optimisation models where decision variables such as the number and location of facilities within the distribution network are optimised. There is a potential for linking the quantified visioning outputs to multivariable regression analysis. Having defined the vision elements and identified

the relationship between the variables, the different variables can be regressed against one another to identify the variables with the most significant impact on the objective. Such insights can also provide rich information to planners and decision makers during strategic investment planning.

2. An area for future research that was not carried out was the feedback component of the OVAF. Here, the solutions from the optimisation stage are presented to the stakeholders for deliberation. This was not possible due to the outbreak of the pandemic which disrupted the anticipated feedback Visioning exercise. The research was not able to get feedback from participants after the vision exercise. However, conducting this research will complete the original design of the OVAF.

3. The reflection revealed that a measure to reduce the researcher's translation misrepresentation was to either conduct framing the optimisation problem with the stakeholder during the visioning workshop. Alternatively, a test-retest reliability check of the researcher's translation should be conducted. To operationalise the latter, the researcher should contact the participants with summary of the visions and qualitative models derived from the translation process. The participants should be asked to confirm if the translated vision elements into the model formulation reflects their desires expressed in the visions.

4. Since it was identified that participants can be sometimes be pessimistic about certain scenarios, future research could consider asking each group during the visioning workshop to develop visions under two or three scenarios as compared to developing visions under a single external scenario. It would be interesting to explore the lessons that will emerge from such a visioning design.

5. Since it was identified that stakeholders could disagree on the consistency or plausibility of scenarios when scenarios are developed using a desk design. Therefore, future research can explore how a delphi method within the desk scenario design can build consensus on the opinion of stakeholders about the content of each external scenario.
6. Finally, a computerised toolkit that incorporates all the stages and activities of the OVAF should be developed with a user friendly and interactive platform for easy adoption and use in different long-term planning contexts.

12.8 Concluding remarks

The present research developed a long-term planning approach that potentially explores the complexity of planning for distribution network design to produce insights to planners to reduce the errors associated with wrong strategic investment decision making. For this purpose, a novel multimethod termed the Optimised Visions of Alternative Futures (OVAF) approach has been developed. The developed approach considers both soft and hard components of the planning problem. The exploratory scenario explores the uncertainty in the distribution network environment to develop the future scenarios likely to affect the business operations in the future. The visioning method deals with another soft component of the problem by developing visions for the distribution network design that are consistent with the different external scenarios that exist in the future. The optimisation method draws on the inputs from the translated vision elements into quantifiable optimisation elements, and the quantified scenarios specifications to quantitatively analyses the envisioned options to provide insights to the implications of the stakeholder envisioned options.

The OVAF has been evaluated through a case study of the Nigerian PPD sector. The case study provides four integrated studies which illustrate the application of each step of the OVAF approach. It is inferred from the research that the OVAF is useful in addressing complex long-term planning problems for distribution network design contexts and provides a useful tool which experts from the foresight and OR discipline can utilise independently or collaboratively for exploring future distribution systems. When compared to previous methods either in the foresight or OR domain, The OVAF is the first approach which extends the analytical component of the "planning for action" by providing quantitative and precise implications of the stakeholder visions for policy action purposes. It is also, the first triple PSM-Hard OR combination between the scenario, visioning and the optimisation in the operational research domain. The achieved results indicate a positive potential for further research in the form of further evaluation and practice in other real-life distribution planning contexts.

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Appendices

Appendix 1 Summary of literature on focal issues affecting the PPD in Nigeria.

. Factors	Documents reviewed	websites
I. Inadequate supply of refined products	Ehinomen and Adeleke (2012); Akpan and Nnamseh (2014); Obasanjo and Nwankwo, 2014. Donwa et al. (2015); Kabir, 2016; Mohammed, 2013; https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr;	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr. NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly
ii. dysfunctional and insufficient oil refineries	Ehinomen and Adeleke, 2012; Kabir, 2016; Nwogwugwu, 2013; Obasanjo and Nwankwo, 2014; Donwa et al., 2015; Mohammed, 2013.	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr; NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly
iii. insecurity leading to vandalism of oil infrastructure	Ehinomen and Adeleke, 2012; Nwogwugwu, 2013; Obasanjo and Nwankwo, 2014; Donwa et al., 2015; Mohammed, 2013.	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr; NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly
iv. fuel importation constraints	Kabir, 2016; Ehinomen and Adeleke, 2012; Donwa et al., 2015; https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr; NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly
v. drop in global oil prices	Ehinomen and Adeleke, 2012; Donwa et al., 2015; Kabir, 2016	
vi. poor import planning schedule	Kabir, 2016; Ehinomen and Adeleke, 2012	
vii. corruption, diversion and smuggling	Ehinomen and Adeleke, 2012; Kabir, 2016; Nwogwugwu, 2013; Obasanjo and Nwankwo, 2014; Donwa et al., 2015; Mohammed, 2013.	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly
viii. over reliance on road mode of transport	Ehinomen and Adeleke, 2012; Ode et al., 2019; https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr	https://www.dpr.gov.ng/nigerians-now-taking-centre-stage-in-downstream-sector-says-dpr; NIGERIA'S OIL AND GAS INDUSTRY: ISSUES, CHALLENGES – Nigeria Oil Gas Monthly

Appendix 2 – Nvivo code workbook - DRIVING FORCES AFFECTING THE PPD

Name	Description	Code reference
Nodes\\Social category	**Social related drivers were coded under this theme**	**23**
Ageing population		3
Switch to sustainable modes		3
Change in consumer purchase behaviour		8
Adoption of new energy forms		1
Population growth		6
Urban sprawl		2
Nodes\\Technology category	**Technology related drivers were coded under this theme**	**27**
Wave of online purchases		**6**
New vehicle technologies		**11**
Integrated supply system		**10**
Nodes\\Economic category	**Economic related drivers were coded under this theme**	**71**
Availability of energy		**6**
Petroleum product demand	What will happen to petroleum product demand	7
Labour cost	The cost of labour could increase or decline	2
Distribution company mergers	Will companies merge to gain competitive advantage or operate alone	2
Economic growth	Will the economy grow or decline in future	4
Foreign exchange	Exchange rate could either drop or increase	6
freight demand	Will freight demand increase of decrease	2
Inflation	Inflation affects prices in the future	4
oil price shocks	Oil prices shocks affect the prices of good s and services	18
traffic congestion	Population growth leads to higher vehicle ownership	5
Transport infrastructural growth	Improved transport infrastructure	14
Nodes\\Environmental category	**Environmental related drivers are coded under this theme**	**20**
New energy source		4

Name	Description	Code reference
Emission regulation		10
Local weather and natural disaster		2
Climate change		4
Nodes\\Political category	**Political related drivers are coded under this theme**	**25**
Transport policy		2
Political and security issues		23

Appendix 3: Petroleum product demand data for modelling

Demand Nodes	Code	Daily Demand at 2016	Stagnant scenario demand	Declined Scenario demand	Careless scenario demand	Rejuvenated scenario demand
Aba North	**AT**	**35896**	**57433**	**46665**	**71792**	**17948**
Aba South	**AU**	**143558**	**229693**	**186626**	**287116**	**71779**
Abakaliki	**AB**	**50286**	**80458**	**65372**	**100573**	**25143**
Aboh Mbaise	**AM**	**65415**	**104664**	**85039**	**130830**	**32707**
Afikpo North	**FN**	**52622**	**84195**	**68408**	**105244**	**26311**
Afikpo South	**FS**	**52901**	**84642**	**68771**	**105802**	**26451**
Aguata	**GU**	**124255**	**198808**	**161532**	**248510**	**62128**
Ahiazu Mbaise	**AZ**	**57366**	**91786**	**74576**	**114732**	**28683**
Anambra east	**AE**	**51098**	**81757**	**66428**	**102196**	**25549**
Anambra west	**AA**	**56200**	**89921**	**73061**	**112401**	**28100**
Anaocha	**AO**	**95470**	**152751**	**124110**	**190939**	**47735**
Aninri	**AN**	**45758**	**73213**	**59485**	**91516**	**22879**
Arochukwu	**CH**	**53129**	**85006**	**69068**	**106258**	**26564**
Awgu	**AW**	**56869**	**90991**	**73930**	**113739**	**28435**
Awka north	**WR**	**66261**	**106017**	**86139**	**132521**	**33130**
Awka south	**KU**	**37670**	**60272**	**48971**	**75340**	**18835**
Ayamelum	**AY**	**63689**	**101902**	**82795**	**127377**	**31844**
Bende	**DE**	**64690**	**103503**	**84096**	**129379**	**32345**
Dunukofia	**DU**	**32415**	**51865**	**42140**	**64831**	**16208**
Ebonyi	**BN**	**42722**	**68355**	**55538**	**85444**	**21361**
Ehime Mbano	**EM**	**43854**	**70166**	**57010**	**87708**	**21927**
Ekwusigo	**EK**	**53205**	**85128**	**69167**	**106410**	**26603**
Enugu East	**EE**	**93083**	**148934**	**121008**	**186167**	**46542**
Enugu North	**EN**	**81339**	**130143**	**105741**	**162678**	**40670**
Enugu South	**ES**	**66510**	**106415**	**86462**	**133019**	**33255**
Ezeagu	**EZ**	**57303**	**91685**	**74494**	**114606**	**28652**
Ezinihitte Mbaise	**EI**	**56683**	**90693**	**73688**	**113366**	**28342**
Ezza North	**ZN**	**49093**	**78549**	**63821**	**98187**	**24547**
Ezza South	**ZS**	**44880**	**71807**	**58343**	**89759**	**22440**
Ideato North	**ID**	**52464**	**83942**	**68203**	**104927**	**26232**
Ideato South	**IA**	**53634**	**85815**	**69725**	**107269**	**26817**
Idemili North	**DN**	**144765**	**231625**	**188195**	**289531**	**72383**
idemili south	**DS**	**69451**	**111121**	**90286**	**138902**	**34725**
Igbo Etiti	**IE**	**69968**	**111949**	**90959**	**139936**	**34984**
Igbo Eze North	**IN**	**86938**	**139100**	**113019**	**173875**	**43469**
Igbo Eze South	**IS**	**49490**	**79184**	**64337**	**98980**	**24745**
Ihiala	**IH**	**101536**	**162458**	**131997**	**203073**	**50768**
Ihitte/Uboma	**IU**	**40122**	**64195**	**52159**	**80244**	**20061**
Ikeduru	**IK**	**50293**	**80469**	**65381**	**100586**	**25146**
Ikwo	**KO**	**72193**	**115509**	**93851**	**144386**	**36097**
Ikwuano	**UO**	**46306**	**74089**	**60197**	**92612**	**23153**
Ishielu	**SH**	**51251**	**82002**	**66626**	**102502**	**25626**
Isi Uzo	**IZ**	**49913**	**79861**	**64887**	**99826**	**24957**
Isiala Mbano	**IM**	**66488**	**106381**	**86434**	**132976**	**33244**
Isiala Ngwa North	**SG**	**51741**	**82786**	**67264**	**103483**	**25871**
Isiala Ngwa South	**LG**	**45896**	**73433**	**59664**	**91791**	**22948**
Isiukwuato	**KW**	**38896**	**62233**	**50565**	**77792**	**19448**
Isu	**II**	**55195**	**88312**	**71754**	**110391**	**27598**

Ivo	VO	40767	65228	52997	81535	20384
Izzi	ZI	79504	127206	103355	159008	39752
Mbaitoli	MB	79756	127610	103683	159512	39878
Ngor Okpala	NO	79756	127610	103683	159513	39878
Njaba	NJ	53025	84839	68932	106049	26512
Njikoka	JK	48195	77112	62654	96391	24098
Nkanu East	NE	49829	79726	64778	99658	24914
Nkanu West	NW	51580	82529	67054	103161	25790
Nkwerre	NK	49490	79184	64337	98980	24745
Nnewi North	WN	26951	43122	35037	53903	13476
Nnewi South	WS	52215	83544	67880	104430	26108
Nsukka	NS	78386	125418	101902	156772	39193
Nwangele	NA	103932	166291	135112	207864	51966
Obi Ngwa	GW	42878	68605	55742	85756	21439
Obowo	OB	61100	97760	79430	122200	30550
Ogbaru	BU	39439	63103	51271	78878	19720
Oguta	OG	75010	120016	97513	150020	37505
Ohafia	FI	47805	76488	62147	95610	23903
Ohaji/Egbema	OE	82612	132179	107396	165224	41306
Ohaozara	HA	61439	98303	79871	122878	30720
Ohaukwu	HK	49804	79687	64745	99608	24902
Oji River	OR	65669	105071	85370	131339	32835
Okigwe	OK	43245	69192	56218	86490	21622
Onicha	NI	44561	71298	57929	89122	22281
Onisha North	TH	79478	127166	103322	158957	39739
Onisha south	UH	42290	67664	54977	84580	21145
Onuimo	OM	46072	73715	59894	92144	23036
Orlu	OL	33366	53386	43376	66732	16683
Orsu	OU	47951	76722	62337	95903	23976
Oru East	OT	40390	64625	52507	80781	20195
Oru West	RW	37537	60059	48798	75073	18768
Orumba North	MT	38854	62166	50510	77708	19427
Orumba South	MH	58028	92845	75436	116056	29014
Osisioma Ngwa	SI	61988	99181	80584	123976	30994
Owerri Municipal	WM	74125	118600	96363	148250	37063
Owerri North	WI	42098	67356	54727	84195	21049
Owerri West	WW	59220	94752	76986	118439	29610
Oyi	YI	34171	54673	44422	68342	17085
Udenu	UD	56505	90408	73456	113010	28252
Udi	UI	60015	96024	78020	120031	30008
Ugwunagbo	GB	80045	128072	104059	160091	40023
Ukwa East	UT	28665	45865	37265	57331	14333
Ukwa West	UA	19538	31260	25399	39075	9769
Umuahia North	NH	29332	46931	38132	58664	14666
Umuahia South	AH	74946	119913	97429	149891	37473
Umunneochi	NC	46716	74746	60731	93432	23358
Uzo-Uwani	UU	54793	87668	71230	109585	27396

Appendix 4: Workshop Discussion Guide

Activity 8: Focus group discussion time and questions **Day 1, 1:10- 3pm**

Background questions

- What do you think are the issues militating against effective and efficient distribution of petroleum products today in Nigeria?
- What are some of external forces that affect your operation which you cannot control today?
- In your view, which among these forces are most impacting on your system and uncertain?

After questions have been discussed, researcher presents the different future scenarios.

Vision elements stage

Based on your understanding of the plausible futures that are likely to exist in future we are going to envision how we want the future of the system to be. So, let us imagine ourselves in a time machine and we are in the year 2040 under our respective external scenarios.

Design and operational questions

- What structure of distribution system do you see in the future?
- Given the structure you earlier envisioned, what kinds of modes are used to distribute petroleum products?
- What pattern of distribution do you envision under your envisioned structure?
- What nature of storage and transportation system do you envision?
- Can you give an indication of range for the number of depots under your scenario?
- What do you think about the number of refineries that exist in the future?
- In terms of product pick-up at depots, how do you envision the process to be?
- How long do you envision the product pick-up at loading stations to be?
- How long do you envision trucks travel in to get products?
- How do you envision the documentation process to be?
- What do you think about the locations of the depots?

<u>Strategic questions</u>

- What is your imagination of an efficient distribution system?
- What is your view of achieving a faster loading process at depots?
- What is your view of how trucking cost can be reduced?
- What is your view of truck driver’s behaviour when delivery products to stations?
- What is your view of the importance of other modes of transport in distributing products?
- Do you think that present freight and logistics situation in Nigeria can be improved to reach the envisioned state?

<u>Ending Questions</u>

In the light of your understanding of the different external scenarios;

- Do you think it a good idea for organisations to engage in future thinking?
- Do you think you will want to practice such visioning process in your own business?
- Finally, is there any other point, recommendation or opinion you would want to share.

Appendix 5: Interview Discussion Guide

Interview Schedule for Visioning Workshop (Revised Version2)

You are welcome and thank you for volunteering to participate in this interview session, which is undertaken as part of the PhD research at the Institute of Transport Studies, University of Leeds, United Kingdom.

My name is Chikwendu David Uchechukwu, PhD research student of the University and also a member of CILT, Nigeria.

Please, I would like you to introduce yourself,

It is important to let you know that your invitation is based on your experience and expertise as Senior Oil industry professional or Academic.

The subject of this research is "Exploring the future of the Nigerian Oil and Gas Downstream Distribution system: Integrating Visioning and Optimisation methods". The research method requires a stakeholder involvement in developing Future Visions for the Industry and this is why I am are here today.

There is no wrong or right answer to questions. The essence of the discussion is to develop Visions for the Industry based on perspectives of professionals like you. The visions developed will enable us model the future distribution system to identify concrete details of future system requirements.

Scenario Presentation Opening Questions

- What do you think are the most common issues militating against effective and efficient distribution of petroleum products today?
- Why do you think it is necessary to think about the future of the Oil Industry?
- What do you think are the issues that may affect an efficient distribution of products in the year 2040?
- What are some of external forces that affect your operation which you cannot control?
- In your view, which of these external forces are most impacting on your system?

After questions have been discussed, brief participant of the different future scenarios.

Transition Questions (Vision elements stage)

Based on your understanding of the plausible futures that are likely to exist in future we are going to envision how we want the future of the system to be. So Imagine you are in a time machine and you are in the year 2040.

- What do you envision of the distribution system for the system generally?
- What do you think about the number of depot system that exists in the future? Regionally or Nationally.
- What do you think about the number of refineries that exist in the future?
- What do think about the service time at depots for trucks that come for loading at the depots?
- What do you think about the time it takes to for a truck to travel and collect products?
- What do you think about the locations of the depots?
- What do you think the modes of transport used in distributing products?

Main Question

- What is your view of achieving a faster loading process at depots?
- What is your view of truck driver's behaviour when delivery products to stations?
- What is your view of the importance of other modes of transport in distributing products?
- Do you think that present freight and logistics situation in Nigeria can be improved to reach the envisioned state?

Ending Questions

Appendix 6 – Visioning Workshop Schedule

VISIONING WORKSHOP PROCESS (REVISED VERSION2)

Activity 1: Registration/Meet and Greet	**Day 1 9:00am-9:30am**
Activity 2: Introduction	**Day 1 9:30am-10:00am**
Activity 3. Overview of the Research Project	**Day1 10:00am-10:15am**
Activity 4: External scenario presentation	**Day1, 10:15-11:00am**
Activity 5: Reactions by participants to scenarios	**Day 1, 11:00-11:40am**
Activity 6: Lunch Break	**Day 1, 12:00-1pm**
Activity 7: Brief introduction to visioning process	**Day 1, 1:00-1.10pm**
Activity 8: Focus group discussion	**Day 1, 1:10- 3pm**
Activity 9: Group summary and collation of materials	**Day 1, 3:00-3:30pm**
Activity 10: Closing remark by lead facilitator	**Day 1, 3:30-4:00pm**
Day 2 Workshop	
Activity 1: Brief introduction on activities for the day.	**Day 2, 10:00am-10:20am**
Activity 2: Vision presentation by group 1	**Day 2, 10:20 -10:40am**
Reactions to Vision 1	**Day 2, 10:40 -11:00am**
Activity 3: Vision presentation by group 2	**Day 2, 11:00 -10:20am**
Reactions to Vision 2	**Day 2, 11:20 -11:40am**
Activity 4: Break	**Day 2, 11:40 -12:30pm**
Activity 5: Vision presentation by group 3	**Day 2, 12:30 -12:50pm**
Reactions to Vision 3	**Day 2, 12:50 - 1:10pm**
Activity 6: Vision presentation by group 4	**Day 2, 1:10 - 1:30pm**
Reactions to Vision 4	**Day 2, 1:30 - 1:50pm**
Activity 7: Refining Visions by Groups	**Day 2, 1:50 - 2:30pm**
Activity 8: Hand over of vision drafts by Groups	**Day 2, 2:30 – 3:00pm**
Activity 9: Closing remark and appreciation	**Day 2, 3:00pm-3:30pm**

Appendix 7 - - Ethical Approval

The Secretariat
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

David Chikwendu
ITS
University of Leeds
Leeds, LS2 9JT

ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee
University of Leeds

9 October 2017

Dear David

Title of study: **Exploring the future of the Nigerian Downstream Sector: Integrating Visioning and Optimisation Models**
Ethics reference: **AREA 16-168**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 16-168 Committee Provisional 2.doc (response)	1	06/10/17
AREA 16-168 Participants information sheet V3.doc	3	06/10/17
AREA 16-168 Consent form V4 (2).doc	3	06/10/17
AREA 16-168 Response to ethical review comments.docx	1	23/08/17
AREA 16-168 Chikwendu Ethical Review Form V3 signed.doc	2	23/08/17
AREA 16-168 Risk Assessment form Version 2 signed.doc	1	27/06/17
AREA 16-168 Invitation letter to Participants.docx	1	27/06/17
AREA 16-168 Visioning Workshop focused group Questions Version 2.docx	1	27/06/17

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee

CC: Student's supervisor(s)

Appendix 8- Consent Form

36-40 University Road
University of Leeds
Leeds LS2 9JT

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F +44 (0) 113 343 5334
W www.its.leeds.ac.uk

UNIVERSITY OF LEEDS

Consent to take part in a Workshop on "Exploring the Future of the Nigerian Oil and Gas Downstream Industry; Integrating Visioning with Optimisation methods".	Add your initials next to the statement if you agree
I confirm that I have read and understand the information sheet dated July 1, 2017 explaining the above research project and I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw at any time before or during the workshop without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. Lead Researcher: David Chikwendu Phone Number:+447459261113	
I give permission for members of the research team to have access to my anonymised responses of both written and recorded form. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.	
I agree for the anonymised data collected from me to be stored and made available for further research conducted under the auspices of an institutional ethics committee. Data will also be archived at the University of Leeds research data repository.	
I understand that my words may be used anonymously in publications, reports, web pages, and other research outputs.	
I agree not to disclose the identity of other participants in this workshop.	
I understand that data collected during the study may be looked at by auditors from the University of Leeds.	
I agree to take part in the above research project and will inform the lead researcher should my contact details change during the project and, if necessary, afterwards.	

Name of participant	
Participant's signature	
Date	
Name of lead researcher or person taking consent	CHIKWENDU DAVID UCHECHUKWU
Signature	
Date*	July 1, 2017.

*To be signed and dated in the presence of the participant.
Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/ pre-written script/ information sheet and any other written information provided to the participants. A copy of the signed and dated consent form should be kept with the project's main documents which must be kept in a secure location.

Appendix 9- Fieldwork Risk Assessment

Fieldwork Assessment Form (High Risk Activities)

Fieldwork Project Details	
Faculty School/Service	Faculty of Environment , Institute for Transport Studies
Location of Fieldwork	Owerri, Nigeria (5°29′01″ N, 7°01′59″ E)
Brief description of Fieldwork activity and purpose *(Include address, area, and grid reference and map where applicable).*	The field work activity is focused on organising a workshop where Senior Oil and Gas professionals and Academic experts in Petroleum and Transport related disciplines will meet to develop Future Visions for the distribution of refined petroleum product in southern Nigeria. These visions serve as guide post for the industry when planning for its future. The first step would be to conduct a stakeholder analysis in order to identify those that will be participating in the workshop. It is estimated that a breakdown of 6 academic experts, 6 Senior Oil distribution Professionals, 6 Truck operation Supervisors and 6 fuel station Managers would be a reasonable sample to conduct the workshop. All participants to be invited to the workshop must be resident either in Owerri City in Imo state Nigeria or Portharcourt City in Rivers State Nigeria(4°49′27″ N, 7°21′1″ E). This is to ensure that the participants are not exposed to any danger by coming from very distant locations. Both states are located in the Southern Nigeria and the maximum driving time from the centre of each of the City to the other is 2hrs. The Process of developing Visions would be carried out through a Visioning Workshop scheduled to take place at a convenient and secured location at the Transport Management Conference Hall, Federal University of Technology, Owerri Imo State (5°24′N, 7°01′E). The purpose of the Visioning is to identify the desires of Oil industry professionals and academic experts for the future of the distribution system. Visions developed would be analyse to develop concrete details and implications of the visions for planning of the future Oil and Gas distribution systems.

Appendix 10 - Nodes\\Group responses (initial coding scheme) on Visions for 2040 in Nigeria Oil Industry

Name of codes	Description	Sources	References
stakeholder vision requirements for a stagnant future state	This node represents the stakeholder perceptions and visions of the petroleum product distribution network for the year 2040 under stagnant society.	0	0
Institutions and agencies	This theme captures the need for regulatory institutions and agencies	5	6
Equity and fairness	Fair practices must be carried out all the time	1	1
Integration	This theme captures both the physical integration which has to do with the connectivity of facilities and modes in system. it also deals with the operational interconnectivity	3	5
connectivity of facility		1	6
integrated regulatory agencies		1	1
Management	Captures issues that has to do with cost of distribution, ownership, and planning	6	8
cost of distribution		1	1
ownership structure		1	3
planning and forecasting		1	2
network design	This theme relates to the network design elements	9	15
mode		1	7
quantitative variables		2	7
Security		1	2
Technology requirements	This theme is concerned with the automation of depot terminal for processes.; the use of technology devices to monitor the pipeline and distribution outlets; the use of technology to checks and balances thereby reducing human interference.	0	0

Name of codes	Description	Sources	References
Depot Terminal automation		1	6
monitoring systems		1	3
reduced human interference		1	1
Envisioned stakeholder requirements for declined future state	This node represents the stakeholder vision for the distribution system under a decline state of the society in 2040	0	0
Attractiveness	This theme encompasses the business climate, attractiveness of society to global investors	0	0
global attractiveness		1	1
investment climate		1	1
Externalities	this theme relates to code such as road safety and traffic congestion	0	0
road safety		5	8
Management	this theme encompasses codes like demand planning and forecasting, ownership structures, investment patterns	5	0
Forecast and planning demand		1	3
global and private sector investment		1	6
ownership strategy		1	3
partnerships		1	3
strategic investment		1	2
Network design parameters		1	10
mode		1	4
quantitative variables		1	2
service level		1	1
Technology	This theme has to do with the terminal automation process, IT monitoring systems and survey system	0	0

Name of codes	Description	Sources	References
automation		1	2
monitoring systems		1	1
Envisioned stakeholder requirements for rejuvenated future state	This node represents the state of the society under a transformed and rejuvenated future state.	1	1
Externalities	captures codes related to congestion and road safety	0	0
congestion free		1	1
safety		1	1
Management		0	0
planning and forecasting		1	6
rural demand supply		1	1
Network design	This theme captures all the codes related to the network design parameters and variables.	1	8
decentralised piping		1	1
mode		1	5
quantitative variable values		1	4
service level		1	1
turnaround time		1	2
Technology	This theme encompasses codes that have to do with technology in process is captured here	0	0
automated ordering and payments		1	1
Transitioning	The theme relates to construction of construction to meet new best practices. e.g new energy plant for new energy types and the expansion to accommodate better capacity	0	0
capacity		1	2

Name of codes	Description	Sources	References
construction		1	4
expansion		1	1

Appendix 11 Narratives of scenario-specific visions

Under this section, the researcher draws elements from the stakeholder visions, identified characteristics and variables to creates a captivating narrative of the scenario-based visions.

A11.1 Vision narratives under a stagnant external scenario

Below is a narrative of the stagnant scenario-specific vision. This vision was produced by group 1 during the workshop and the six participants interviewed. The vision was revised with group 2, 3, 4 and other seven participants interviewed.

"The vision represents a widespread implementation of a functional version of the current distribution system. Our ultimate objective is to ensure we distribute products to every location where products are needed at the lowest possible cost. We want to improve our service level to our customers by meeting all retail station demand for products. and ensuring they do not travel beyond 50km to get their products. While our future distribution system models the existing physical architecture, we envision a system without the breakdown of refineries and depots within the distribution network. However, due to the insecurity in the external environment, security we have invested rapidly in security to ensure that our products are distributed securely. Specifically, we have reinforced the existing pipeline network with underground pipelines for inbound transportation of products from large storage depots located around functional refineries at Eleme Port Harcourt, Rivers jetty, and newly constructed refineries and Ohaji Egbema and Ukwa East municipal LGA's respectively. In the future, we have invested rapidly in drones surveillance systems and manpower for supervising routes for distribution. Well maintained and road worthy tanker trucks (BRV's) are used for transporting products from strategically located transhipment depots to retail stations. To ease the negative effect such as pollution, noise, or accidents on highways we have agreed with state governments to only distribute products between 11pm and 5am. Due to the ethno-religious crisis across the nation that has led to truck hijack and diversion on inter-regional routes, we have resorted our activities to a regional structure. Up-country product transportation by road does not exist, rather, well-maintained pipeline network used to service distant transhipment depot. Based on the regional system, we envision there will be adequate TDs in the regions to hold products supplied from large depots to 4-11 transhipment depots that are located strategically anywhere in each region. The large depot and TD capacities must be sufficient to accommodate a 30-day product volume.

We envision the use of advanced technology to improve depot and transportation operations. As such, the waiting time on arrival at loading station must not exceed one hour. Also, to reduce the truck turnaround time, trucks must not also travel for more than one hour before reaching the nearest regional depot, and total turnaround time must not exceed and acceptable time of two hours. TD terminal will be fully automated with state of art technology to ensure the faster loading procedures. The overall management of personnel and infrastructure will not be left out in our vision. There will be continuous truck driver and employee training on demand forecasting and depot terminal automation processes" as this will improve the employee skills in predicting the possible future demand. We also envision a system where we will have a streamlined number of operators such that the few distributors of products can be integrated. Finally, we envision the existence of regulatory institutions that set standards according to best practices or deal with defaulters that do not adhere to set standards".

A11.2 Vision narrative under the declined external scenario

Below is a narrative of the declined scenario-specific vision. This scenario-specific vision was produced by group 2 during the workshop and the six participants interviewed. The vision was revised with group 1, 3, 4 and other seven participants interviewed.

"The vision represents a widespread implementation of the ideal of the current situation despite a worsened external background context. Highly likened to an ideal current state without the breakdown of depots and distribution network. Our ultimate objective is to ensure that products are distributed across the network at the lowest possible cost. We envision a network design similar to the existing network. However, with adequate maintenance, and good investment in the security of products on transit our operations will be efficient. This will ensure that our personnel and infrastructure always secured. Our organisation have set up exceptional policies that will transform our operations for better. Some of these policies will include our investment in social responsibility, and development of the communities we operate. We will increase our investment in the developing schools, hospitals, and good roads for transportation. Our policies will dampen the emergence of civil unrest and restiveness of the oil producing communities.

Although we are concerned about ours depleting oil reserve, we will form strong alliance and mergers with energy companies with state-of-the art technology in the extraction of oil from shale regions. We will align our expertise with global companies to provide cleaner fuel that will meet the sustainable energy needs of the 21st century. Our employees will be trained in the best technology skills to manage demand for energy to limit or eradicate issues associated with scarcity of products. We intend to use the best modes of transport to ensure that our product distribution guarantees safety and security. We have reinforced underground pipelines for transporting products from large storage depots to transhipment depots located in around the cities to serve the growing population. Well maintained and road worthy trucks (BRV's) deployed for the transport of product from transhipment depots to retail station operation. The local time-based strategy implemented for midnight truck delivery to limit the effect of congestion. To limit the problem of traffic congestion on interstate routes, we have restricted our distribution to a regional structure. Up-country product transportation by road does not exist. Based on the regional system, we envision approximately mega depots situated at fixed strategic locations close to refineries in the regions supplying about 2 to 5 transhipment depots located strategically anywhere in the region. All transhipment depots must ensure that adequate products are distributed to the retails stations to ensure that demand is satisfied at all time. Our large depots capacity must be able to hold products demanded for at least 30 days. Similarly, our TDs must have capacity to hold products for 30 days. Depots waiting time on arrival at loading station must not exceed one hour, also, to reduce the truck turnaround time, trucks must not also travel for more than one hour before reaching the nearest regional depot. Terminal automation for faster loading, continuous truck driver and employee training on demand forecasting and depot terminal automation processes".

A11.3 Vision narratives under a careless scenario

Below is a narrative of the declined scenario-specific vision. This scenario-specific vision was produced by group 3 during the workshop and the six participants interviewed. The vision was revised with group 1, 2, 4 and other seven participants interviewed.

"The vision represents an ambitious and transformed petroleum product distribution network characterised by massive investment accrued from the revenue generated from the high price of Brent crude in the global energy market. Our ultimate objective is to ensure an improved level of service that ensures the satisfaction of demand for products; easy access of products for retail stations. While our desire to satisfy our customers is at the forefront of our goal for 2040, we also intend to distribute product at the least cost. and e Highly likened to an ideal current state without the breakdown of depots and distribution network. Our ultimate objective is to ensure that products are distributed across the network at the lowest possible cost. Our vision cannot thrive without functional institutions that will ensure that all practices of key players are in line with global best practices. To ensure adequate monitoring of activities of our operators, we envision a few number of players with an integrated distribution process. We envision a system committed to massive growth in the sector through investment in technology for depot operations. All manual operations for loading at the depot and the tracking of products on transit will be monitored with hi-tech aerial drone systems supported by ground security personal. Product volume on transit will be monitored to avoid product diversion to unauthorised channels. Our business profile for the future will be heightened through mergers with hi-tech energy company globally. These companies will share systems for product distribution monitoring and evaluation on real-time online basis.

As a result of the heightened instability in the political space and insecurity at all levels in the society and the infused level of dissatisfaction in the distribution of resources across all regions. We envision a proactive system that encourages the distribution of petroleum products by the different states in the regions. For example, the five states in the south-eastern region should have control over the distribution of the products to the local government areas in the state. Within each state, we envision sufficient number of TDs to ensure that products are made available to the retail stations within each LGA. At least, each municipal LGA should have a TD or between 20 and 25 TDs to ensure that the outbound trip distance to the nearest TD falls below the 50km threshold. Trucks must be adequately maintained to ensure safety on the roads and less pollution to the environment. All state TDs must be connected to the large storage depots strategically located close to the refineries in the region. The large depots and the TDs must be designed to hold products for at least 30 days. The performance of each state network is measured and determined by the features and specifics of the state. This will ensure that each state maintains an excellent system. The best mode of product transportation is needed to ensure efficacy. The rail and pipeline modes are fully functional, and they are used to transport product from the large depots to the medium depots. In the case where rail lines are considered insecure, the pipelines are used to transport products from the large refineries/jetties/storage depots to the transhipment depots. Also, large trucks are used to transport products from the medium transhipment depots to the retail stations. Fully autonomous trucks used for transporting products from the transhipment depots to retail stations. Truck safety check must be passed, and certification of approval must be faxed to the depot station before payment approval is granted. With all the processes automated, the service time, which consists of loading and document checks, must not exceed 60 minutes. Due to the constant insecurity issues in the environment, the pipelines are well constructed underground with a concrete surface. Due to urban migration, we will ensure that TDs are located close to the big cities. This will ease the regular supply to major cities in each state. The federal pipeline transport products from the large depots to the interconnected state-owned depots. The state depots must locate such that the trip time from a retail station in the state to the nearest depot must not exceed thirty minutes. Waiting time on arrival at the depot must not exceed thirty minutes. We will engage in constant skill improvement scheme to ensure employees meet with the best practice globally.

A11.4 Narratives under the rejuvenated external scenario

Below is a narrative of the declined scenario-specific vision. This scenario-specific vision was produced by group 2 during the workshop and the six participants interviewed. The vision was revised with group 1, 2, 3 and other seven participants interviewed.

Our distribution system can be compared to the best in the world. Our ultimate objective is to ensure the least cost of distributing petroleum product across the network. We also intend to provide an exception service that ensures the constant replenishment of demand at retail stations when needed. The target is to ensure a zero stockout scenario. Global policies on energy emission reduction has mandated all energy companies to reduce emission in line the global targets. For this reason, we envision the adoption of an environmentally friendly distribution system that guarantees the lowest emission level from our network. Technology is used to support this fight to reduce emission. All terminal depot process will be automated. Automated systems have been installed in all depots to ensure fast and error free loading and pumping of products across the network. The electronic data interface is used to check retail station stock order placement. Trucks will only be required supply manufacturing plants when other forms of energy are not available. Regular maintenance works are put in place to ensure regular operation of the depot system and pipelines.

Each retail station will be connected to an integrated network of pipelines in the state. The pipeline mode of transport will be utilised to ensure seamless transportation of products from the large depot through to the retail stations. Pipelines are well constructed and positioned deep under the concrete surface. There will 24-hour surveillance using aerial drones and sensors to monitor product transfer processes. The network of the distribution will ensure enough distribution depot strategically located in every state in the country. These depot will function as back up site for product storage and will only be used when pipelines are not used for product distribution. Large depots are situated at fixed locations close to refineries or jetties in the nation. These large depots supply products to about 15 to 20 TDs strategically located in each state. The time from when payment is made to when loading is scheduled will not exceed 60 mins due to payment approval and documentation.

Employees with cognate freight planning skills are employed, and others must have the requisite licence or certification to work in the sector. Skill improvement scheme always conducted to ensure employees are at their best. The current deregulation policy has created platform private oil marketing and distribution companies to operate the sector.

Appendix 12 – Model summary under declined scenario specific visions (inflow outflow uploaded as attachment)

Number of open TD =2

Problem Summary		Solution Summary	
Objective Sense	Minimization	Solver	MILP
Objective	Totalcost	Algorithm	Branch and Cut
Objective Type	Linear	Objective	Totalcost
		Solution	Optimal within
Number of	3000	Objective	2454729404
Bounded Above	0		
Bounded Below	2970	Relative	8.8150659E-8
Bounded Below	30	Absolute	24547294046
Free	0	Primal	0
Fixed	0	Bound	0
Binary	30	Integer	0
Integer	0		
		Best Bound	24547294046
Number of	191	Nodes	1
Linear LE (<=)	65	Solutions	2
Linear EQ (=)	30	Iterations	328
Linear GE (>=)	96	Presolve	0.05
Linear Range	0	Solution	0.08

Number of Open TDs =3

Problem Summary		Solution Summary	
Objective Sense	Minimization	Solver	MILP
Objective	Totalcost	Algorithm	Branch and Cut
Objective Type	Linear	Objective	Totalcost
		Solution	Optimal within
Number of	3000	Objective	26591231252
Bounded Above	0		
Bounded Below	2970	Relative Gap	8.8150659E-8
Bounded Below	30	Absolute Gap	26185678673
Free	0	Primal	0
Fixed	0	Bound	0
Binary	30	Integer	0
Integer	0		
		Best Bound	26591201152
Number of	191	Nodes	1
Linear LE (<=)	65	Solutions	2
Linear EQ (=)	30	Iterations	328
Linear GE (>=)	96	Presolve Time	0.08
Linear Range	0	Solution Time	0.10

Number of Open TD = 4

Problem Summary		Solution Summary	
Objective Sense	Minimization	Solver	MILP
Objective	Totalcost	Algorithm	Branch and Cut
Objective Type	Linear	Objective	Totalcost
		Solution	Optimal within
Number of	3000	Objective	28131421252
Bounded Above	0		
Bounded Below	2970	Relative Gap	8.8150659E-8
Bounded Below	30	Absolute Gap	25266857867
Free	0	Primal	0
Fixed	0	Bound	0
Binary	30	Integer	0
Integer	0		
		Best Bound	28131420001
Number of	191	Nodes	1
Linear LE (<=)	65	Solutions	2
Linear EQ (=)	30	Iterations	345
Linear GE (>=)	96	Presolve Time	0.15
Linear Range	0	Solution Time	0.18

Number of open TDs=5

Problem Summary		Solution Summary	
Objective Sense	Minimization	Solver	MILP
Objective	Totalcost	Algorithm	Branch and Cut
Objective Type	Linear	Objective	Totalcost
		Solution	Optimal within
Number of	3000	Objective	31692221052
Bounded Above	0		
Bounded Below	2970	Relative Gap	0.0000000E+0
Bounded Below	30	Absolute Gap	0
Free	0	Primal	0
Fixed	0	Bound	0
Binary	30	Integer	0
Integer	0		
		Best Bound	31692201887
Number of	191	Nodes	1
Linear LE (<=)	65	Solutions	2
Linear EQ (=)	30	Iterations	323
Linear GE (>=)	96	Presolve Time	0.11
Linear Range	0	Solution Time	0.12

Appendix 12- Model summary under declined scenario specific visions (inflow and outflow uploaded as attachment)

Open 4 TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	993909454092
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	3.201421E-10
Bound Infeasibility	0
Integer Infeasibility	0
Best Bound	993909454092
Nodes	47
Solutions Found	2
Iterations	9677
Presolve Time	0.06
Solution Time	3.84

Open 5 TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal within Relative Gap
Objective Value	794681454837
Relative Gap	0.000051526
Absolute Gap	40944676.589
Primal Infeasibility	1.164153E-10
Bound Infeasibility	0
Integer Infeasibility	0
Best Bound	794640510161
Nodes	59
Solutions Found	3
Iterations	2308
Presolve Time	0.07
Solution Time	1.00

Open 6TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal within Relative Gap
Objective Value	772466178267
Relative Gap	0.0000189632
Absolute Gap	14648190.069
Primal Infeasibility	1.091394E-10
Bound Infeasibility	1.455192E-11
Integer Infeasibility	1.110223E-16
Best Bound	772451530077
Nodes	1
Solutions Found	1
Iterations	434
Presolve Time	0.07
Solution Time	0.57

Open 7 TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal within Relative Gap
Objective Value	767187269680
Relative Gap	0.0000398479
Absolute Gap	30569599.594
Primal Infeasibility	3.274181E-11
Bound Infeasibility	1.455192E-11
Integer Infeasibility	1.110223E-16
Best Bound	767156700081
Nodes	1
Solutions Found	1
Iterations	434
Presolve Time	0.07
Solution Time	0.61

Open 8TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	762330371790
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	1.8626451E-9
Bound Infeasibility	1.455192E-11
Integer Infeasibility	1.110223E-16
Best Bound	762330371790
Nodes	1
Solutions Found	2
Iterations	392
Presolve Time	0.06
Solution Time	0.30

Open 9TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	760010799143
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	1.455192E-10
Bound Infeasibility	0
Integer Infeasibility	1.110223E-16
Best Bound	760010799143
Nodes	23
Solutions Found	6
Iterations	1068
Presolve Time	0.06
Solution Time	0.36

Open 10 TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	758754493251
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	2.401066E-10
Bound Infeasibility	0
Integer Infeasibility	1.110223E-16
Best Bound	758754493251
Nodes	15
Solutions Found	5
Iterations	928
Presolve Time	0.06
Solution Time	0.35

Open 11 TDs

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal within Relative Gap
Objective Value	757864351030
Relative Gap	6.1084531E-8
Absolute Gap	46293.785278
Primal Infeasibility	2.910383E-10
Bound Infeasibility	0
Integer Infeasibility	2.220446E-16
Best Bound	757864304737
Nodes	1
Solutions Found	2
Iterations	320
Presolve Time	0.06
Solution Time	0.21

Appendix 13- Model summary under careless scenario specific visions

Open 20 TDs at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	551366652635
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	5.820766E-11
Bound Infeasibility	0
Integer Infeasibility	4.440892E-16
Best Bound	551366652635
Nodes	1
Solutions Found	4
Iterations	155
Presolve Time	0.01
Solution Time	0.04

Open 21 TDs at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	548558312635
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	2.910383E-11
Bound Infeasibility	9.387127E-18
Integer Infeasibility	1.110223E-16
Best Bound	548558312635
Nodes	21
Solutions Found	8
Iterations	438
Presolve Time	0.01
Solution Time	0.06

Open 22TDs at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	546265141835
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	2.0070723E-9
Bound Infeasibility	5.820766E-11
Integer Infeasibility	6.661338E-16
Best Bound	546265141835
Nodes	25
Solutions Found	6
Iterations	457
Presolve Time	0.01
Solution Time	0.06

Open 23 at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	544886664835
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	1.74623E-10
Bound Infeasibility	0
Integer Infeasibility	1.110223E-16
Best Bound	544886664835
Nodes	31
Solutions Found	8
Iterations	440
Presolve Time	0.02
Solution Time	0.09

Open 24 at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	544028687835
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	0
Bound Infeasibility	0
Integer Infeasibility	0
Best Bound	544028687835
Nodes	24
Solutions Found	9
Iterations	336
Presolve Time	0.02
Solution Time	0.07

Open 25 TDs at Imo PPD

The OPTMODEL Procedure

Solution Summary	
Solver	MILP
Algorithm	Branch and Cut
Objective Function	Totalcost
Solution Status	Optimal
Objective Value	543494961835
Relative Gap	0
Absolute Gap	0
Primal Infeasibility	3.442133E-10
Bound Infeasibility	1.110223E-16
Integer Infeasibility	1.110223E-16
Best Bound	543494961835
Nodes	7
Solutions Found	10
Iterations	305
Presolve Time	0.01
Solution Time	0.05

Detailed optimisation model outputs have been submitted as an attachment, useful inputs from the output has been extracted and used to present the results.