



# Challenges facing government revenue from the Nigerian oil industry: A system dynamics approach

Idris Musawa

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**CHALLENGES FACING GOVERNMENT REVENUE  
FROM THE NIGERIAN OIL INDUSTRY: A SYSTEM  
DYNAMICS APPROACH**

By

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**University of Bedfordshire**

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NIGERIAN OIL INDUSTRY: A SYSTEM DYNAMICS APPROACH

By

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# CHALLENGES FACING GOVERNMENT REVENUE FROM THE NIGERIAN OIL INDUSTRY: A SYSTEM DYNAMICS APPROACH

IDRIS ABUBAKAR MUSAWA

## ABSTRACT

Extractive industries (including oil, gas and mining) generally afford an opportunity for the host government to generate the revenue to fund sustainable growth and development. It is therefore not surprising for conventional economic theory to suggest this is a readily available revenue source for resource blessed countries. However, contrary to this reasonable expectation, several of these economies were found to be suffering a financial handicap. Nigeria, despite being the largest crude oil producer in Africa and the tenth largest in the world, has so far found realising the full financial benefits of this nature's gift unattainable. Using both qualitative and quantitative data as well as grounded theory in the analysis of the qualitative data, this research work has been carried out to develop a model of Nigerian oil industry using System Dynamics modelling methodology in order to understand these challenges. Specifically, the research develops an System Dynamics model to capture and quantify the various potential revenue streams to the Nigerian government from the oil (petroleum) industry with the objective of providing an explanatory model of the causal factors and then using the model to construct policy experiments in order to evaluate policies that may optimise these revenues. Findings show that, the development of the model for the Nigerian oil industry was successfully undertaken. The model was used to evaluate two government policy interventions that were aimed at improving government revenue from the industry. Moreover, a range of alternative scenarios which suggested increase of transparency policy, reduction of rate of gas flare and reduction of time taken for repairs of vandalised facilities were used in the model. The relevant system actors in the Nigerian oil industry were impressed with the modelling idea, particularly in its ability to represents all the economic challenges facing the industry, which offered a better understanding of the system they are dealing with. Overall, the model was able to depict some potential policy points thus serving as a decision-making tool.



## **DECLARATION**

I hereby declare that no aspect of this research work in the thesis has been submitted elsewhere as an application for another degree or qualification in any other university or institution of learning.

## **DEDICATION**

This thesis is dedicated to the Almighty ALLAH (SWT) for all HIS showers and blessings.

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## LIST OF ABBREVIATIONS

CLD	Causal Loop Diagram
DPR	Department of Petroleum Resources
EITI	Extractive Industries Transparency Initiatives
EW	Economy Watch
FIRS	Federal Inland Revenue Services
GT	Grounded Theory
IEO	International Economy
IMF	International Monetary fund
JVA	Joint Venture Agreement
NEITI	Nigerian Extractive Industries Transparency Initiatives
NNPC	Nigerian National Petroleum Corporation
OPEC	Organisation of Petroleum Exporting Countries
PAP	Presidential Amnesty Program
PHD	Doctor of Philosophy
PPT	Petroleum Profit Tax
PSC	Production Sharing Contract
RW	Revenue Watch
SD	System Dynamics
SDM	System Dynamic model
SFD	Stock and Flow Diagram
ST	System Thinking
TI	Transparency International
WB	World Bank

## CHAPTER ONE: INTRODUCTION

### 1. Introduction

System Dynamics (SD) research that aims to provide practical solutions to real world problems remains of increasing relevance in the contemporary world (Coyle,1977; Richardson and Pugh 1981; Ford, 1999 Morecroft 1999). Since its inception over fifty years ago with Industrial Dynamics (Forrester 1961), the technique has witnessed the application of several pioneering SD models: Urban Dynamics (Forrester 1969), World Dynamics (Forrester 1971), Limit to growth (Meadows et al., 1972), and further application in other areas such as sustainable development (Saeed, 1998), social welfare (Zagonel et al., 2004), public health (Cavana and Clifford 2006), security (Ghaffarzadegan 2008), and energy (Ansari and Seifi 2012; Madani 2014). These and other SD works enhanced the establishment of the idea that modelling within the framework of SD not only assists in understanding and describing systems, but also serves as a technique for exploring likely scenarios to address real world problems. The utility of SD application is not contestable thus manifested in its long history in analysing problems of complex nature in different areas.

This explains why the application of SD models in other areas such as the energy sector has also continued to receive a boost. It can therefore be observed that over the past few decades, many SD models of energy problems have been developed (Naill, 1973; Naill 1976; Naill and Belanger 1989; Ford, 1997; Ford, 1999; Ford, 2002; Samii and Teekasap, 2009; Ford, 2011; Ansari and Seifi, 2012; Prambudia and Nakano, 2012; Qudrat-Ullah, 2013; Aslani and Helo, 2014; Aslani and Wong, 2014). On the basis of this, it is evidently clear that SD has proved to be an impressive methodology in systems research and application in the energy sector. While the application in the energy sector is considerably high, yet studies have mainly focussed on specific dimensions such as: energy-related policies (Prambudia and Nakano 2010; Samii and Teekasap 2009; Badzik and Naill 1976; Nail & Balanger 1976), influence of energy on economic growth (Naill 1976; Prambudia and Nakano 2012), finding accurate an forecasting method (Sterman

and Richardson 1985), investigating Hubbert peak theory (Kiani et al., 2010; Tao and Li, 2007), energy economy (Sterman 1980) and energy demand, supply and revenue (Kiani and Pourfakrael, 2010). In this research, the principles of SD methodology developed by Forrester (1961) are utilised to analyse economic challenges facing an energy sector, specifically the Nigerian energy sector.

Concerning the application of SD on the global scale and dimension, SD has received a wider acceptance universally in policy related issues particularly in the developed and other, emerging economies, thus utilised to support the evaluation of energy policy and economic planning, for example, the Threshold 21 (T21) model framework of the Millennium Institute (MI) in China (MI, 2002) and Denmark (MI, 2008). Other specific examples include Mali (MI, 2003), Malawi (MI, 1997), Mozambique (MI, 2003), and Ghana (MI, 2003). This unprecedented feat serves as a booster and motivation for embarking on the development of a similar model for Nigeria. Sadly enough, to date there has not been an encouraging effort in the application of such a model to aid informed the decision-making process in Nigeria in general and in the Nigerian energy sector in particular, notwithstanding its global applicability.

While this attempt is pursued, it is worth noting that SD relies heavily on qualitative data in order to acquire the information necessary for developing a robust model. This research combined the qualitative data gathering and analysis techniques developed by social and management researchers as reflected by the involvement of system actors for information elicitation and model validation throughout the exercise of model building. The utilisation of this qualitative data collection and analysis technique in this research is justified by Luna-Reyes and Andersen (2003) as they pointed out that notwithstanding the central role of qualitative information in the process of developing a system dynamics model, the System Dynamics field lacked standard protocols for the elicitation and analysis of qualitative data from the mental model of research subjects, and thus adopts well known research methods from social sciences for qualitative data collection and analysis. Luna-Reyes and Andersen (2003) further assert that this includes qualitative data collection techniques such as interviews, observations, focus groups, and qualitative data analysis techniques such as ethnographic decision models and grounded theory. This informed the utilisation of effective methods for

qualitative data elicitation and analysis over the years by several System Dynamics modellers in the model development process (Vennix, 1996; Luna Reyes and Anderson, 2003; Wolstenholme, 1990).

### **1.1. Background to the Problem**

Negative socio-economic fortunes of countries are not uncommon throughout history. But what has remained persistently puzzling is a situation where such a negative socio-economic fortune is evident despite the endowment of the country with natural resources, as opposed to the absence of such resources. In our contemporary world, it is abundantly clear that natural and extractive resources afford considerable economic opportunities for resource-dependent countries (McPhail 2008). While this assertion is largely correct, Ndikumana and Abderrahim, (2010) added that a superb opportunity for the achievement of optimum growth and development, precisely through the mobilisation of wealth, is provided by the endowment of natural and extractive resources. This assertion was also corroborated by the general consensus among development economists from the early 1950s that natural resource endowment would assist backward nations to reverse their capital gaps through the generation of revenues for their governments for the delivery of public goods and also to bail their populaces out of poverty (Ross, 2003).

Contrary to this assertion, these resources were sometimes discovered to be the root cause responsible for the negative socio-economic outcomes of some resource-dependent countries, such as Venezuela, Nigeria and Angola (Weinthal and Luong 2006, Budina and van Wijnbergen 2008; Sachs and Warner 1995) referred to this phenomenon as a resource curse resulting in these countries' inability to achieve their developmental goals. Since the 1990s, a growing amount of academic literature has established an association between resource-endowment and a number of social and economic problems. Natural resource endowment has been linked and associated with slow economic growth (Sachs and Warner 1995), extreme disparity and poverty for the majority of a country's citizens (Ross 2004), undue corruption (O'Higgins 2006; Bhattacharyya and Hodler 2010), and increased threat of civil disturbances (Collier et al. 2010)

On the other hand, the experience of other natural resource endowed economies (USA, Norway and Botswana) revealed divergent results, showing considerable and impressive outcomes of natural resource endowment thus suggest that natural resource wealth may occasionally be a blessing (Davis 1998, Ahammad and Clements 1999, Iimi 2007). These extractive and natural resources defined as petroleum (oil and gas) and mining resources (International Accounting Standard Committee, 2000), present enormous economic growth and development opportunities (McPhail, 2008).

Amongst those countries blessed with abundant natural mineral resources is Nigeria (Oyedepo2014), including crude oil, making it the largest reserve holder in Africa, the seventh largest among OPEC member countries (EIA 2011) and the tenth largest in the world (Onakoya et al., 2013). The Nigerian economic history has shown that crude oil has largely contributed to the economic growth of the country (Kadafa 2012). Nigerian has a high GDP (Nkechi et al., 2012) recording US\$510 billion of GDP in 2013 which exceeds South Africa's GDP of \$370.3 billion making Nigeria the biggest economy in the African continent (Ainofenokhai, 2014). Notwithstanding this, it can be argued that Nigeria represents a classical illustration of the negative impact of natural resource wealth (African Development Bank, 2009), since a substantial proportion of its population still remains in poverty (Ighodalo, 2012) with a high rate of unemployment (Nkechi et al., 2012).

Although the Nigeria oil industry has contributed to the country's strong economic growth (Ite et al., 2013) and also responsible for the generation of up to 80% of the country's fiscal revenues (Abdul-Rahamoh, et al., 2013), certain challenges have, however, hindered the government's desire for optimisation of potential benefits from the industry. These challenges have collectively combined as a curse on the country's main revenue and economic base.

This research focuses on the failure of natural and extractive resource endowment to translate into economic viability, instead bringing to mind Sachs and Warner's resource curse or the Paradox of Plenty which also depicts the disappointment of resource endowed economies where its citizens live in abject poverty amidst resource abundance (Karl 1997).



Given the magnitude of the challenges inhibiting the generation of potential revenue from the Nigerian oil industry, several policy measures were adopted, in response, by the Nigerian government. The original policy developed for the Nigerian oil sector dates back to 1971, with policy formulated for different aspects of the oil industry including: nationalisation and speedy technology transfer; petroleum products subsidy; co-ordinated national policy on energy; special petroleum price to other African nations; and oil pollution and counter trade (Uche, 2010).

In order to develop robust policies for the regulation and management of the Nigerian oil industry, several acts serving as legal instruments and regulatory framework which transformed into policies have been formulated thus guiding the operation of the industry prior to 1971. For example, oil in the Navigable Waters Act 1968 which aimed to minimise the incidence of pollution into inland water, the Petroleum Act 1969 which stipulates the guidelines for the exploration of oil from terrestrial water in Nigeria, and Petroleum (Drilling and Production) Regulation 1969 amended in 1973, 1979, 1995, and 1996 which aim to protect marine life especially fish, and pay compensation to the owner of such fishing right, Minerals Oil (Safety) Regulations 1963 which is concerned with the safe dislodgement of inflammable gases as well as the stipulation of penalties for violation and non-compliance with its provision, Oil Pipeline Acts 1956 as amended in 1965 which grant right to build and oil pipeline, Petroleum Profit Tax Act (PPTA) 1959 amended in 1967, 1970, 1973 and 1979 which enhanced the amount of government rent in the industry.

Other acts that followed included: the Nigerian National Petroleum Corporation (NNPC) Act 1977 which increased government control on the entire industry, particularly as it relates to oil exploration and production. The Associated Gas Re-injection Act 1979 (as amended) in 1985 which prohibits gas flare except with permission from the petroleum minister. Violation leads to suspension of all rights by the oil company. The Environmental Impact Assessment Act 1992 which mandated the imposition of appropriate mitigation measures for development projects in order to address environmental related problems. The Deep Offshore and Inland Basin Production Sharing Contract Act 1999 which encourage

exploration in deep water by offering attractive terms, The Deep Water Block Allocation to Companies (Backing Rights) Regulations 2003 which encourage active petroleum exploration activities in deep water acreage in Nigeria. The Oil Prospecting Licences (Conversion to Oil Mining Leases, etc.), Regulations 2004 which make provision for the granting of OPL license by the Minister of petroleum, the National Oil Spills Detection and Response Agency (NOSDRA) Act 2006 which aim to ensure compliance with the international convention concerning preparedness for oil pollution, cooperation and preparedness, and the National Energy Policy Applicable to Oil and Gas 2003 which encourage and promote the optimum utilisation of Nigeria's energy resources.

Recently, however, and as a strategic response to the contemporary key challenges facing the industry, two policy measures have been adopted: transparency initiatives championed by the Nigerian Extractive Industry Initiative (NEITI, 2005) and the amnesty initiatives championed by the Presidential Amnesty Programme (PAP, 2009). The amnesty programme was a policy effort of the federal government which granted an unconditional pardon to all persons or group of persons who were directly or indirectly involved in the commission of offences related to militant activities in the Niger Delta region based on their readiness and willingness to give up all illegal arms in their custody and denounce militant activities in all ramifications (Oluduro, and Oluduro 2012).

It is argued in the literature (Agbibo 2014) that governmental desire to maintain optimal (potential) crude oil production (which by extension improves revenue generation from the industry) is arguably the cardinal motive for the amnesty programme as crude oil production almost flattened at the peak of the crises in 2008 and 2009 in the oil producing region (IEA, 2010). This posed dire economic consequences for the Nigerian economy in view of the role played by crude oil (NNPC 2010).

This assertion was also supported by Adejumobi (2009) who succinctly added that the amnesty initiative was a policy strategy of the central government specifically geared towards diplomatically and deceitfully unarming the militants, confining them in designated centres, so that the oil-rich Niger delta region would remain peaceful and calm for unhindered and steady oil exploitation by foreign oil

corporations to the detriment of the host community of the Niger delta. The consequences of this had negatively affected and threatened the economy of Nigeria (IMF, 2011), with an extension of similar effects onto the global economy in view of the contribution of Nigeria to the global oil market (Inokoba and Imbua 2010).

Similarly, it is also argued in the literature (Okpanachi, 2011) that the transparency initiative is specifically aimed at fashioning a practical and effective strategy for addressing corruption in the Nigerian oil industry (NEITI, 2005). The question of how effective these policy interventions are in addressing the issues they were intended for, still requires an answer. This creates the desire for a means capable of addressing this question.

SD is a powerful methodological tool applicable to obtaining useful insights into areas of policy resistance and dynamic complexity (Sterman 2000). It is a suitable method for studies of a dynamic nature and policy analysis and has been applied as one of the most reliable methodologies in strategic research and application in the energy sector (Kiani, Mirzamohammadi et al. 2010). In this research, the five steps advocated by Sterman (2000) for developing models within the framework of System Dynamics are adopted.

This research therefore, provides a platform from which to study the interactions between all aspects of crude oil activities (including exploration, development, exploitation and production) and eventually, revenue as well as the associated challenges associated with these activities. This is done with a view to investigating and developing an understanding of the behaviour of factors responsible for this puzzling financial challenge through the development of a holistic SD model. This then poses the question of whether SD can be used to holistically represent the economic challenges facing the Nigerian petroleum industry. SD emphasises holism where everything is connected to everything else (Sterman, 2000) and has proved suitable for studying problems that have resisted policy intervention (Sterman, 2000).

The operations of the Nigerian oil sector are mainly carried out by multi-national oil companies operating under various contractual arrangements and agreements

with the government owned oil company, the Nigerian National Petroleum Corporation (NNPC) discharging the representative role with a wholly derivative authority from the federal government. Initially, joint venture operations were the main contractual arrangements in the Nigerian petroleum sector, but contemporary trends have witnessed the advent and prominence of another contractual agreement, the production sharing contract (NNPC, 2010). Nevertheless, there have been other contractual arrangements within the industry, particularly in its infancy stage, such as concessionaire contracts even though these are not very prominent nowadays (NNPC, 2010).

## **1.2. Research Scope and Focus**

Prior to selecting a methodology for research, it was deemed prudent to clarify the extent and focus of the study at an early stage. The rationale is to ensure that results of the research will be suitable to the applied context. The scope of this research is limited to Nigeria, as data collection and case studies have been extracted from the Nigerian oil industry, though findings from the research might be applied and adapted to other extractive resource-dependent economies facing similar challenges. The definition of extractive resources has been highlighted above. In particular the research is concerned with the challenges facing the upstream sector of the Nigerian oil industry value chain. The oil value chain comprises a host of interrelated activities including the exploration and discovery of the resources, decisions regarding the exploitation of the resources, the main exploitation of the resources, development activities, and production of the resources as well as the generation of revenue. For the purpose of this research and the sake of simplicity, downstream activities and the upstream gas sub-sector are completely excluded from this research.

This research focuses on the oil sub-sector notwithstanding the contribution of the gas sector within the Nigerian petroleum (oil and gas) industry.

## **1.3. Definition of the Problem**

While researchers have studied challenges facing the Nigerian oil sector (Inokoba and Imbua 2010; Oshwofasa, Anuta, and Aiyedogbon 2012; Paki and Ebienna 2011; Asgill, 2012), yet there is no any comprehensive model previously developed

to explain challenges facing the industry in terms of revenue generation. Although system dynamics-based models have been used for a variety of studies in the energy sector (Naill, 1976; Sterman and Richardson, 1985; Ford, 2011; Ansari and Seifi 2012; Prambudia and Nakano 2012; Aslani and Helo 2014), its application in Nigeria energy sector in general and Nigerian oil industry in particular is rare. A review of government document (Nigerian National Petroleum Corporation, 2011) reveal that one of the key issues facing the industry is lack of any structural tool for policy evaluation that can also give insight to stakeholders on factors influencing revenue generation in the Nigerian oil industry. The only applicable tools that have been in use in energy issues in the country are the MAED3, WASP4 and IAEA2 (Sambo et al., 2006). Although these models offer valuable insights into energy matters, yet they are not able to account for other dynamics, since they are mainly based on a ‘static economic’ modelling approach.

#### **1.4. Research Aim**

This research aims to develop an SD model to capture and quantify the various potential revenue streams to the Nigerian government from the oil (petroleum) industry with the objective of providing an explanatory model of the causal factors and then using the model to construct policy experiments in order to evaluate policies that may optimise these revenues.

#### **1.5. Research Objectives**

The objectives of this research are to:

1. Investigate challenges facing revenue generation in the Nigerian oil industry using the Causal Loop Diagram (CLD).
2. Construct a qualitative CLD documenting the causal relationships discovered in objective 1.
3. Construct a quantified SD model based on the causal relationships documented in the revised CLD.
4. Assess the impact of the two current policy interventions aimed at improving revenue generation in the Nigerian oil industry.

5. Utilise the SD model developed in objective 3 for policy evaluation.

This will be accomplished by developing a policy experiment programme to evaluate (within an SD framework) the alternative policies for enhancing an economy by optimising revenue generation from extractive industries, using the case study of the Nigerian petroleum industry.

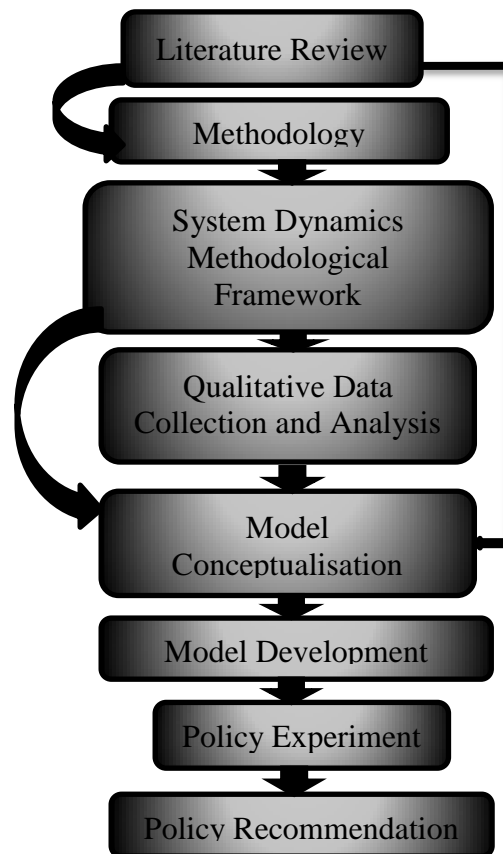
### **1.6. Research Questions**

1. What are the factors responsible for the challenges facing revenue generation in the Nigerian oil industry?
2. What are the relationship and behaviour over time of key variables responsible for challenges inhibiting potential revenue from the Nigerian petroleum industry?
3. How effective are the policy measures aimed at addressing challenges inhibiting potential revenues from the Nigerian petroleum industry?
4. What alternative policy/policies if any can be applied in order to enhance optimisation of revenue from the Nigerian petroleum industry?

## 1.7. The Research Process

Figure 1.1 represents the overall process in conducting this research work. As the ultimate goal of this research is to develop a system dynamics model of Nigerian oil industry, several linked research activities were carried out. The process commences with review of relevant literature. This is followed by the methodology which justified the adoption of System Dynamics methodological framework. In particular, findings from the literature and results from qualitative data analysis, interviews and focus groups are used for the conceptualisation of the model that warrants the development of SD model for this research. The model was used for policy experiments with some policy recommendations.

**Figure 1.1: Research process**



Sources: Author's work and Synthesis from relevant literature

## 1.8. Significance of the Study

Recent developments in Nigeria and other resource endowed economies have heightened concern for effective management of the resources as well as the

provision of effective and efficient remedies to poor natural resource management. Given the key role played by these resources with respect to government and the position of Nigeria in the global oil market as the 10th largest reserve holder in the world (IMF, 2012), the need to address challenges facing the industry and providing answers/solutions will have a major impact on both the country and the global energy security and economy. Presently, there is an overwhelming clamour for greater value from the Nigerian oil industry-the Petroleum Industry Bill (PIB, 2008).

In an attempt to proffer a solution, certain strategic policy interventions were employed (Energy Information Administration, 2013), thus the need to evaluate this intervention and also devise further strategies for the ultimate aim of realising maximum value from this gift of nature. For instance, strategies for optimal revenue generation from the Nigerian petroleum industry, notably, transparency initiatives and the amnesty programme have evolved over time, yet the industry is not generating the benefit of its worth (EIA 2013), hence the need to generate robust solutions in order to address these problems.

This research will be useful for policy makers in the Nigerian oil industry who are confronted with challenges such as corruption, oil theft, vandalism (NEITI, 2005) and other sector-specific challenges such as project delay, and shortfall in investment (NNPC, 2010). It will, therefore be able to make use of the findings of research study precisely via understanding the dynamic behaviour of the system they are dealing with. In addition, the research will extend the application of SD to energy-related issues particularly in the oil sector and also in an emerging economy like Nigeria where its application is scarce (Oyedepo 2012). It will also bridge the existing knowledge gap and further enhance the application of SD in solving real world problems (Sterman, 2000).

## **1.9. Organisation of the Thesis**

This research is organised in four parts and comprises of twelve chapters. The first three chapters, including this introduction, constitute the overall introductory phase of the thesis. Chapter 2 focuses extensively on the review of literature exploring the main issues therein and highlighting the departure point for this research. This is



followed by Chapter 3 which highlights case studies background of this research work. Chapter 4 presents the research design and methodology for this research and also describes various research methods, theories employed as well as the various classes of research approach before describing the approach employed in this research.

The second part of this thesis contains chapters 5, 6 and 7 which dwell extensively on the system dynamics modelling methodology. Chapter 5 presents brief description of models, mental models as well as some available modelling techniques and finally the justification for the selection of SD in this research. In complementing this, Chapter 6 presents the steps involved in developing models within the framework of SD and model conceptualisation. The chapter also describes system dynamics and its modelling tools and also highlights all principles of system dynamics. The chapter also describes source of information for developing the SD model. Chapter 7 focuses on the techniques adopted for data collection and also presents the analysis of the collected data. The chapter also extensively highlights the activities carried out as well as the challenges encountered in the course of field trip.

The third part of this thesis consists of chapters 8, 9 and 10 which focuses on the description of the model, techniques employed in developing the model, model outputs as well as the tests carried out for the sake of validating the model. Chapter 8 in particular, presents an extensive description of the procedures adopted in the development of the SD model for this research. The chapter also describes the model structure in an elaborate detail. Chapter 9 presents baseline run of the model. It specifically presents the model behaviour devoid of any intervention and hence the documented the output of the model. Finally, Chapter 10 presents various tests carried out in order to validate the model developed and also developed confidence on the model.

The fourth and final part of this thesis is made up of chapters 11 and 12. Chapter 11 presents policy analysis and evaluation as well as policy analysis using various scenarios. Specifically, the analysis and evaluation focuses on the two policies aimed at improving revenue generation from the industry: transparency and amnesty measures as well as experiments of other policy scenarios. Chapter 12 is

dedicated to the conclusions, limitations and recommendations for this research work.

## **CHAPTER TWO: LITERATURE REVIEW**

### **2. Introduction**

This chapter presents the intellectual foundation for this research study drawing on both industrial practice and academic literature. Since the statement of problem of this research is multidisciplinary in nature, the review of the literature in this thesis reflects this multidisciplinary perspective and has, therefore, been drawn from diverse domains: Systems Dynamics (SD), and social and economic domain. The chapter comprises of two distinct but interrelated streams and sets of literature reflective of the aim of the research. First is the historical background of System Dynamics. This is followed by literature on System Dynamics work which examines studies conducted utilising SD methodology. In specific terms, the review of this literature focuses on academic works in the energy sector and other relevant areas that adopts SD framework and hence establishes the gap for this research. Finally, a review of previous research works on the Nigerian oil industry is conducted and presented in this chapter.

#### **2.1 Historical Background to System Dynamics**

The history of SD dates back to the 1950s as industrial dynamics, which focused on problems emanating from the corporate entity (Richardson and Pugh, 1981). The term industrial dynamics immediately gave rise to the more general name of System Dynamics (Richardson and Pugh, 1981), which when applied to economic entities becomes business dynamics (Sterman, 2000). Stated differently, SD emerged in a bid to address problems of a complex and dynamic nature as well as policy resistance possessing numerous variables and nonlinearities (Vennix 1996) as an idea rooted in the intellectual integrity of control theory originally developed for dynamic industrial and mechanical systems where delays, feedbacks, stocks and flows play a crucial role in the behaviour of systems by J. W Forrester at the Massachusetts Technology Institute (MIT) in the second half of the 1950s (Forrester, 1961).

Forrester (1961) also observed that, several human, social and economic systems: cities, economic sectors, companies or even the entire universe could be modelled and analysed using the technique. SD was mainly applied to industrial issues during the early years of its inception (Forrester, 1961). Its application later cut across a variety of areas as earlier indicated. For instance, SD was applied to urban activities to analyse issues such as migration, unemployment or housing programmes and its associated policies (Forrester, 1969).

In its developmental progress, the subject was later broadened (Forrester, 1968) leading to the emergence of several global and other high profile studies (Forrester, 1969, 1971; Meadows, et al., 1972), thus extended to managing projects relating to research and development, combating urban decay and stagnation, studying the implications of the exponential pattern of growth in a society characterised by declining and finite natural resources, and even testing theories concerning diabetics (Richardson and Pugh 1981). As expressed by Richardson and Pugh (1981), the pioneering work in the field relates to management problems such as production and employment instabilities, inconsistency in corporate governance or slack, and declining of the share of market. SD presents a distinct potentials contribution to a variety of disciplines ranging from economics, political science or social science modes of analysis. As a profound and unprecedented feat, the technique was also applied to develop a complete world model where population dynamics increase, thus representing the use of resources and population production (Forrester, 1971). This eventually resulted in the WORLD 3 model, referred to as the limit to Growth (Meadows, et al., 1974).

Similarly, the System Dynamics group at MIT has in addition extended its application to the energy sector and has also followed the significant energy transitions in the United States of America for the past four decades. An M.Sc. thesis was supervised by Professor Meadows which, using the framework of SD developed a model of the process of the discovery and production of natural gas in the United States of America thus concluded that Hubbert's peak theory applies to this case (Naill, 1972). In the same vein, during his PhD work, Roger Naill developed the COAL 1 model, thus expanding his original model through the incorporation of all sources of energy in the United States which then transformed

into COAL 2 (Naill, 1977) and later into the FOSSIL1 model. The FOSSIL1 model was transformed into the FOSSIL2 model *via* expansion through incorporating feedbacks from the economy that is evidently absent in FOSSIL1. In the late 1970s and 1980s the level of individual studies within the framework of SD has been scaled down but the magnitude of application of the technique has become exceptionally wide, encompassing a majority of traditional academic areas of study but with a strong focus on socioeconomic areas. Later in the 1990s, the scholarly endeavour of Peter Senge's publication *The Fifth Discipline* resulted in a re-birth of the discipline (Dooley 2002), highlighting the significance of feedback loops and delays in contemporary management decision making (Senge, 2006). Since then SD, has further been applied to a variety of studies: in socio-economic, environmental, as well as energy issues.

## **2.2 Literature Review on System Dynamics Work**

The literature review has identified a gap in the development of models within System Dynamics (SD) modelling framework. The utilisation of the SD framework for the study of energy has been considered a valid approach by many researchers (Ford, 2002; Samii and Teekasap, 2009; Nail and Belanger, 1989; Prambudia and Nakano, 2010; Ford, 2011; Ansari and Seifi 2012; Prambudia and Nakano 2012; Qudrat-Ullah 2013; Aslani and Helo 2014; Aslani and Wong 2014; Kiani et al., 2009; Naill, 1973; Naill, 1976; Budaik and Nail, 1976; Sterman, 1980; Sterman and Richardson, 1985, Kiani and Pourfakhrael, 2010) and also in developing and developed economies.

The approaches to the development of SD models in the energy sector have quite often been considerable. It was first applied by Forrester (1971) with the development of "Limits to growth", referred to as the WORLD models. Similarly, Naill (1972) developed one of the earliest disaggregated models of the discovery and production processes of natural gas. His model was specifically based on the life cycle theory proposed by Hubberts (1956), an American geologist who holds the belief that, due to the finite attributes of natural resources, their production can be depicted as increasing gradually to a highest output, then a long plateau and eventually a slow decline. Sterman and Richardson (1985) adopted Naill's model and developed a model of the US and world oil industry. The model was used at

finding the accurate forecasting method of the ultimately recoverable oil supply. A synthetic data experiment was used by them and a comparison made between a USGS geologic analogy method and the Hubbert life cycle. The simulation results found the most accurate method to be that of Hubbert.

Kiani et al. (2009) developed a model and investigated the Hubbert peak of the crude oil production in Iran. The model was used in evaluating a variety of scenarios which gave useful and informative forecasts pertaining to the value and time of the Hubbert peak in a variety of conditions. Similarly, Tao and Li (2007) developed an SD model which tests the Hubbert Peak, for the oil production in China.

While Sterman and Richardson (1985) aimed at finding accurate means of forecasting the world's ultimate recoverable oil supply and finding Hubbert's method to be the most accurate, Kiani, et al., (2009) and Tao and Li (2007) investigated the Hubbert's peak of crude oil production in Iran and China respectively. Their model was, however, used in the evaluation of a variety of scenarios.

In the same vein, Naill (1976) develop a model, referred to as COAL1 in an effort to answer the question of whether US economic growth is influenced by the limitations of energy like the "Limits to growth" earlier highlighted in WORLD models. The COAL1 model was later transformed to COAL2 model (Naill 1977).

Besides energy models that focuses on Hubbert peak and oil and gas issues, several other energy models within SD frame work have been developed. For example, Ford (2002) developed a model of Californian electricity system and demonstrated how bust and boom might appear; arguing that the same cycle of boom and bust prevalent in specialized sectors such as real estate and commodity markets also applies in competitive electricity markets.

In the same vein, drawing on System Dynamics framework and Ford's mode, Qudrat-Ullah (2013) developed a model to understand the dynamic and highly complex nature of Canada's electricity system. The model considers the causal relationships among the system's large quantity of variables and the patterns that exist in the country's electricity system as essential for systematic and sustainable

policy decisions. While Nail (1976) investigated whether US economic growth is influenced by energy limitation, both Ford (2002) and Qudrat-Ullah (2013) modelled electricity systems, albeit Ford (2002) focuses on the possibility of price spikes and decline in reserve margins as a result of boom in construction while Qudrat-Ullah (2013) emphasise on the need for considerable new investments in the generation capacity of electricity and efficiency enhancements to attain sustainable and balance electricity demand and supply. `

On the other hand Ansari and Seifi (2012) using an integrated framework develops an SD model to analyse steel production, demand and energy consumption. The model used a co-flow structure to depict the long run effects of subsidy reform on energy consumption. The model estimated consumption of energy in steel industry under various steel export and production scenarios while considering new prices of energy to see the pattern of likely demand of energy in steel sector over next 20 years.

Similarly, Prambudia and Nakano (2010) developed a model of energy related policies of Indonesia using SD approach. Their study considers the energy import sector and found energy security to be very high and also exerts overdependence on the import of energy in 2020 under the scenario of business as usual.

In the same vein and in view of the position of Malaysia as a major crude oil-exporting country as well as the future expectation of the country to become a net oil importing nation which led to concerns regarding Malaysia's energy security, especially on the aspect of oil import dependency due to heavy dependent of its industrial and transportation sectors on crude oil, Prambudia and Nakano (2012) develop an SD model simulating dynamic interplays between Malaysian economic sectors and developments in its oil sector, thus explores the degree to which it will depend on oil import and the likely years of the transformation. In their model, four scenarios associated to exploration and production investment, enhanced oil recovery, technology advances and subsidy elimination are considered for the simulation.

Both Prambudia and Nakano, (2010) and Prambudia and Nakano (2012) considered energy security yet the two models differ on the fact that while

Prambudia & Nakano, (2010) looked at Indonesian energy security in terms of supply and demand, Prambudia and Nakano (2012) Malaysian energy security in terms of aspect of oil import dependency.

Samii and Teekasap (2009) developed a model of energy policies impact on the market energy price. The interactions among the following factors were considered by the model: demand of oil, supply of oil by OPEC and non OPEC producers, price of oil, energy conservation, economic growth, new oil fields development and alternative energy sources.

Badzik and Nail (1976) developed FOSSIL used for US energy policy analysis and design. The interactions between prices of energy, depletion of resources, financial markets, government regulations, and changes of technology and the behaviour of the customer determine the patterns of energy production and consumption in the future. The structure of the model is similar to COAL. The sources of energy in FOSSIL were, however, expanded to incorporate hydropower, oil shale, fusion, and geothermal besides natural gas, crude oil, solar energy, nuclear and coal. The whole process for resource transformation and fuel delivery for the satisfaction of end user demand is simulated by the model.

Nail and Belanger (1989) illustrated the conceptual development of a model referred to as FOSSIL 2 used by the United States as a tool for the analysis of issues relating to national energy policy. The model was used under three different scenarios based on the national energy policy plan which developed three world oil price scenarios from different assumptions about the growth of the economy: the behaviour of OPEC, oil supply by non-OPEC as well as other factors. The model was used in the analysis of the policies relating to US energy issues.

Sterman (1980) developed a US energy-economy model in his PhD dissertation. The model was based on the interaction and feedback between the energy and the economic sectors of the US. The influencing interactions between US energy and economic sector were endogenously modelled against factors which had previously not been seen at all or considered endogenous. Extending the application of SD on energy issues, Aslani and Helo (2014) developed an SD model focusing on the role of renewable energy resources on the energy dependency of Finland.



Similarly, In view of the small role that has historically been played by renewable energy resource in the generation of electricity in the US which encouraged US policy makers to debate and think about strategy for diversification in the promotion of renewables and energy supply based on concerns such as security of energy supply, price fluctuations of fossil fuels and limitations, and threats of climate changes in the same vein, Aslani and Wong (2014) developed a System Dynamics model to evaluate various costs of utilisation of renewable energy by 2030. Their findings show that while a market with close to \$10 billion (in the costs levels) in 2030 will be created by renewable, the aggregate worth of renewable energy utilisation and promotion in the United States will be above \$170 billion (in the costs level) in the periods 2010-2030.

Although all these studies focused on, energy security, policy evaluation on energy issues with emphases on energy-economy considering interaction and feedback among different variables for policy analysis, none of these studies sought to evaluate policies that may enhance an economy through revenue generation from the energy sector. The nearest attempt was by Kiani and Pourkhranal (2010).

Kiani and Pourfakhraei (2010) developed a model considering the interaction between demand and supply and revenue from oil of the existing Iranian system considering various economic sectors. This model presented oil surplus export, gas surplus injection into the reservoir of oil by establishing a balance between demand and supply, the existing system feedback and counter effects between demand and supply and revenue from oil which can be seen as considering various sectors of the economy. Consequently, the impact of alternative scenarios for various economic sectors of Iran together with oil revenue and the counter effect of consumption of energy are examined. Three scenarios which indicated cases of worst, base and ideal situations were considered to examine future trends of key variables such as seasonal injected gas in oil reservoir, seasonal gas consumption in power plant, economic growth in the industrial sector, oil consumption in the transport sector, exported gas and industrial gas consumption. Findings indicated that gas export would shoot up to between 500-6205 million cubic meters per day under various scenarios and revenues from export can shoot up to \$500 billion by the year 2025.

While Kiani and Pourfakhrael (2010) investigated the interaction between demand, supply and revenue considering various sectors of the economy and finding exports shooting up resulting in higher revenues, this research is concerned with revenue generation, precisely the evaluation of policies that may optimise revenues generation from the Nigerian petroleum industry.

Regarding the ultimate goal of this research, academic disciplines and policy makers have examined challenges facing the Nigerian oil industry from various perspectives: social, economic, Law, political science, and development studies, and development economics. There have however been no attempts to examine this challenge and problem (challenges facing Nigerian oil industry) in a holistic manner. This model incorporated all the challenges rather than treating them individually.

### **2.3 Previous Research on the Nigerian Oil Industry**

In view of the importance of the Nigerian oil industry to the country's and the global economy, the sector has attracted several pieces of scholarly research. The pioneering scholarly work on the Nigerian oil (petroleum) industry was conducted by Schatcl (1969) concentrating on the operational development of the sector, given the crucial role of crude oil as it relates to the country's energy needs. In the same vein, Pearson (1970) conducted a study that focused on the effects of the Nigerian petroleum industry on the country's economic development. These studies were however preceded by a substantial amount of other scholarly work mostly dealing with investment and economic issues, thus ignoring completely other challenges facing the industry (Odofin, 1979; Onoh, 1983).

For example, Ayadi (2005) investigated the effects of crude oil production shocks in the country. Other research by Ihonvbere and Shaw (1988) and Turner (1977) focused on the effect of oil on the country's political development. Khan (1994) presented the background for the economy of Nigeria. The study provides detailed political institutions and the downstream and the upstream sector of the petroleum industry.

Similarly, a study on the negative effects of natural resources is also not an unexplored area. For example, Ogunleye (2008) conducted a study that focused on

the long term effect of massive crude oil incomes accruing to Nigeria on the development of its economy utilising quantifiable indicators for development such as private consumption, growth of GDP, infrastructural delivery (electricity) and diversification of manufacturing and agriculture. The findings of the study indicate that a substantial positive long term effects of per capital crude oil income on per capital consumption of household and generation of electricity existed while an undesirable relationship was discovered for GDP, agriculture and manufacturing.

Collier (1988) continued to study the Dutch disease model (the malfunction of the economy with an overvalued exchange rate which seriously harms and crowds out the manufacturing and agricultural sub sectors of the economy) albeit using the non-tradable food industry decline with the burst of oil releasing fewer individuals into agriculture with a decline in the price of oil than the ones taken by the oil boom.

On the other hand, Budina, Pang and Van Wijnbergen (2007) asserted that Nigeria's policies have promoted price volatility and that it is not precisely Dutch disease but negative policies that hamper the non-oil sector.

Aliyu (2011) studied the impacts of crude oil price shocks in Nigeria focusing on the real macroeconomic activity. The study carried out multivariate VAR analysis and Granger causality tests utilising both non-linear and linear specifications. Finding shows evidence of both non-linear and linear effect of the shock of crude oil price on real GDP.

Bearing the negative and non-linear effects exerts by some extractive resources (especially oil and minerals) on growth through their deleterious effects on institutional quality, Sala-i-Martin and Subramanian (2013) conducted a study on Nigerian experience thus showing a robust result which confirmed the negative effect of extractive resources on economic growth.

Besides this, the study of the Nigerian oil industry using System Dynamics (SD) has remained an unexplored area even though there were small studies that focused on the energy sector of Nigeria using the framework of System Dynamics (SD). To the best of the researcher's knowledge there has, however, never been a single

piece of research that explores the challenges facing the Nigerian oil industry through the development of a model within the framework of System Dynamics.

## **2.4 Summary and Conclusion**

The above literature reviewed highlighted the historical background of SD as well as studies conducted using SD framework. In particular, the utilisation of the SD framework for the study of energy by many researchers had extensively been discussed in this section. The literature review strongly supports the desire to develop SD model for Nigerian oil industry. It is argued that it SD model would improve understanding and address challenges facing Nigerian oil industry, thereby improving the outcome of resource abundance. Developing SD model for Nigerian oil industry would address the gap identified from the review of studies conducted on the Nigerian oil industry.

SD has been demonstrated to be a good methodology for providing solutions in problem orientated situations (Wolstenholme, 1983) and has proved suitable for studying problems that have resisted policy intervention (Sterman, 2000). Although the importance of the Nigerian oil industry to the country's and the global economy has been established as evident from several pieces of scholarly research attracted by the sector, yet none of the study develop an SD model in the sector thus a gap in the research findings was established.

## CHAPTER THREE: CASE STUDY BACKGROUND

### 3. An Overview of Nigeria

Nigeria is one of the richest nations in Africa by virtue of its abundant mineral and human resources (Sulaiman and Azeez, 2012). With a population of about 167 million, Nigeria is the most populous Black African Country (African Development Bank, 2012). Figure 3.1 presents the map of Nigeria.

**Figure 3.1: Map of Nigeria**



**Source: US Central Intelligence Agency (1993)**

Historically, it has been documented that, prior to the discovery of oil in a commercial quantity, agriculture had maintained the position of Nigerian main stay of the economy and the major source of foreign exchange (Oguntade and Mafimisebi, 2011). Nigerian has extensive and large extractive industry, with oil and playing a dominant role (Van der Ploeg 2011; Akinlo2012) due to its unrivalled contribution to the country's economy (Okpanachi 2011). The following section discusses the Nigerian oil industry.

#### 3.1 Nigerian Oil Industry

Since the first crude oil discovery in Pennsylvania, United States, in 1859 by Edwin Drake, the industry has remained a major player in the global economy (Olah et al., 2011). In Nigeria, the evolution and search for crude oil is traced to the

year 1938, with the granting of licence to a major joint venture involving two oil companies Shell and BP to explore for crude oil across the entire Nigerian territory (NNPC, 2010). This, therefore, accorded them a monopoly for the exploration of hydrocarbon in the entire nation (Obi 1997). This monopoly remained in place until the country gained independence from its British colonial masters in the 1960s and thus Nigeria's oil industry became more open to other operators (Ihonvbere and Falola 1987). Drilling work began in 1951 and 450 crude oil barrels per day were discovered in 1953 at the Akata-1 Well (Scheatzl 1969) with discovery of crude oil in commercial quantities in 1958 which led the industry becoming the economic nerve centre of the country (Oguntade and Mafimisebi 2011; Abdul-Rahamoh et al., 2013).

In May 1971, the Nigerian National Petroleum Corporation (NNPC) was established as a government agency empowered to engage in all aspects of the oil sector ranging from crude oil exploration to marketing and, in July of the same year, Nigeria became a full member of the Organisation of Petroleum Exporting Countries (OPEC) making it the eleventh member of the organisation (Edo, 2013).

On 1<sup>st</sup> April 1977, the Nigerian National Oil Corporation was amalgamated with the petroleum ministry thus forming the Nigerian National Petroleum Corporation (NNPC) (Etikerentse, 2004). The two bodies merged together to form a more virile oil entity and optimised infrastructures and human resources available to government. In January, 1988 the then government announced the commercialisation and the reorganisation of the corporation. A high aspect of this exercise was the establishment of eleven subsidiary companies. The following subsections present oil and gas operations.

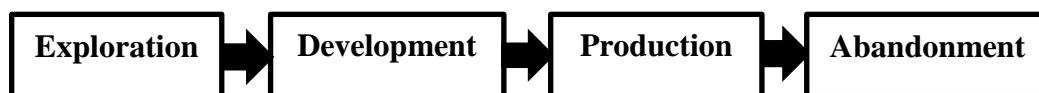
### **3.1.1 Oil and Gas Operations**

In an analytical sense, the Nigerian oil and gas just like other oil industry in the world is usually described in terms of upstream and downstream activities (John, 2011). The upstream sector of the industry explores, produces, and processes oil and gas (Petroleum Communications Foundation, 2001) while the downstream oil operations involves supply, delivery and retailing of petroleum products to the final consumers in a cost-efficient manner (Fernandes, et al., 2013).

Nonetheless, upstream oil activities involve four districts but interrelated stages: exploration, development, production and abandonment. Exploration involves search for oil or gas which may be exploited if discovered in commercial quantities (Al-Kasim et al., 2013). The second stage involves construction of facilities such as well and related facilities enabled the production of oil or gas (Maricic et al., 2012). The third stage is production of oil and gas while abandonment constitute the final stage in which the developed well proved to be no longer productive or produces oil and gas so poorly that it became liability to its owner and hence abandoned thereby reducing number of available wells (Craft and Hawkins 1959).

Figure 3.2 illustrates a generic lifecycle phases of upstream oil and gas projects which comprises exploration, development and production project. It involves series of interrelated activities ranging from exploration to abandonment of a project.

**Figure 3.2: Upstream oil and gas value chain**



**Source: Author and synthesis from literature on oil and gas life cycle.**

### **3.1.1.1 Exploration**

This is the first stage in the upstream sector of the oil and gas industry which comprises a set of activities to search beneath the earth for the purpose of discovery of oil and gas. In the exploration stage, government aimed to investigate all possible commercial reserves under the ground (Al-Kasim et al., 2013). Reserves are the quantities of oil expected to be derived from known fields, under defined levels of probability (Bentley 2002) which can be economically feasible and technically possible to produce under defined conditions (Sorrell, 2012). Because of the inherent uncertainty of reserve estimates, they are therefore commonly considered into two degrees of confidence, namely proved reserves and unproved reserves (Sorrell et al., 2012).

Proved reserves refer to those quantities of oil and gas that possesses reasonable certainty of being discovered, signifying a high level of confidence which may be undeveloped or developed (Bentley 2002) which rises as a result of rate of

discovery from unproved reserves (Fagan 1997; Watkins 2006). Nigeria has the largest reserves holder and highest oil and gas in the African continent has an estimated 35 billion barrels of crude oil reserves respectively (Kadafa 2012; Akinlo 2012). Table 3.1 presents Nigeria's crude oil reserves from 2000-2011.

**Table 3.1: Nigerian proven oil reserves (2000-2011)**

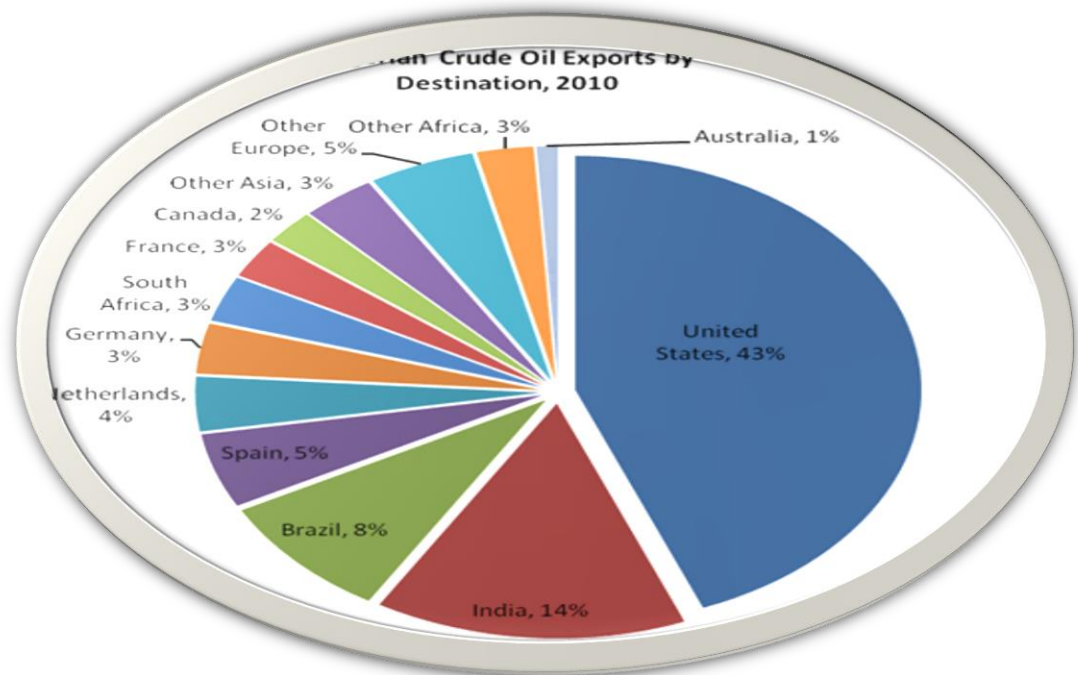
<b>Year</b>	<b>Reserves (billion barrels)</b>	<b>Reserves as a % share of world total</b>	<b>Reserves/ production ratio (years)</b>
2000	21.7	2.1	23.7
2001	29.5	2.2	24.6
2002	31.7	2.5	26.5
2003	32.7	2.5	24.8
2004	33.5	2.6	25.7
2005	35.8	2.6	27.6
2006	33.9	2.7	28.2
2007	33.6	2.8	29.1
2008	35.7	2.9	32.3
2009	36.8	3.0	33.7
2010	37.0	3.1	36.8
2011	37.2	3.2	38.9

**Sources: BP statistical review.**

The table includes Nigerian crude oil reserves as a percentage of a total world crude oil reserves as well as production reserve ratio. With the above Nigerian crude oil reserves, the contribution of the country among crude oil producers in the world is therefore considerable (Akinlo 2012). Among the leading importers of Nigerian crude oil in 2012 include the USA (43 %), India (14 %), Brazil (8 %), Canada (2 %), Europe (5 %), Other Asia (3%), France (3%), Australia (1%), Germany (3%), the Netherlands (4%), Spain (5%) and South Africa (3 %) (EIA, 2012). This crude oil is mainly exported to Western Europe and the USA as shown in Figure 3.3.



**Figure 3.3: Nigerian crude oil exports and destination**



**Source: Energy Information Administration 2012**

The Figure shows the leading importers of Nigerian crude oil in 2012 which includes various countries all over the world with US as the major consumer of Nigerian crude oil.

Nigeria's strategic location (which is outside the crisis ridden Persian Gulf and its high quality crude oil) indicate that global demand for its crude oil resources will continue to be high long into the future (ADB, 2000) as demonstrated by the incessant dispute between Iran and the United States over the former's nuclear ambitions (Cheon and Urpelainen 2014). In the context of this analysis, it can be argued that Nigeria is positioned as an important determiner of global energy supply and security. Any effort, therefore, aimed at addressing challenges facing the Nigerian petroleum industry is not only critical to the Nigerian economy but also crucial to the global energy supply and security.

### **3.1.1.2 Development**

The second stage is development which involves the process that lead to construction of necessary facilities aimed to produce the resources after the evaluation of the oil and gas reservoir as well as their reserves volume (Maricic et

al., 2012). Predominant activities at this stage include construction of crude oil drilling and extraction wells, as well as laying of pipeline and other facilities. A major facility at this stage is development well drilled to extract a portion of previously discovered crude oil (Maricic et al., 2012). In Nigeria, the first oil well was drilled in Oloibiri in 1958 (Akinosho 1998) Since then, the number of oil wells has continued to rise. For example, in 2006, number of oil wells in the country stood at 1,481 (Kadafa2012). By the end of 2008 Nigeria has 5,284 oil wells and oil and gas pipelines facilities covering about 7,000km (Kadafa, 2012).

### **3.1.1.3 Production**

The production of crude oil and gas precedes the completion of the construction of facilities at the development stage. It is targeted at producing the well fluids up the surface for sale or use in refinery. Nigeria has a crude oil production capacity of about 2.9 million barrels per day (bbl/d) (US EIA, 2011) despite OPEC countries agreed to the quota share production system stipulation (Dibooglu and AlGudhea 2007) and produces an average of 710 million barrels annually within its current crude oil reserve of about 37.2 billion barrels which is estimated to last for close to 40 years based on the current production rate and if no new and additional reserve is discovered (OPEC, 2011). Table 3.2 presents Nigerian crude oil production from 2000 to 2013.

**Table 3.2: Nigerian crude oil production (Barrels) 2000-2013**

<b>YEAR</b>	<b>TOTAL PRODUCTION</b>
2000	828,198,163
2001	859,627,242
2002	725,859,986
2003	844,150,929
2004	910,156,489
2005	918,966,736
2006	869,196,506
2007	803,000,708
2008	768,745,932
2009	780,347,940
2010	896,043,406
2011	866,245,232
2012	852,776,653
2013	887,020,111

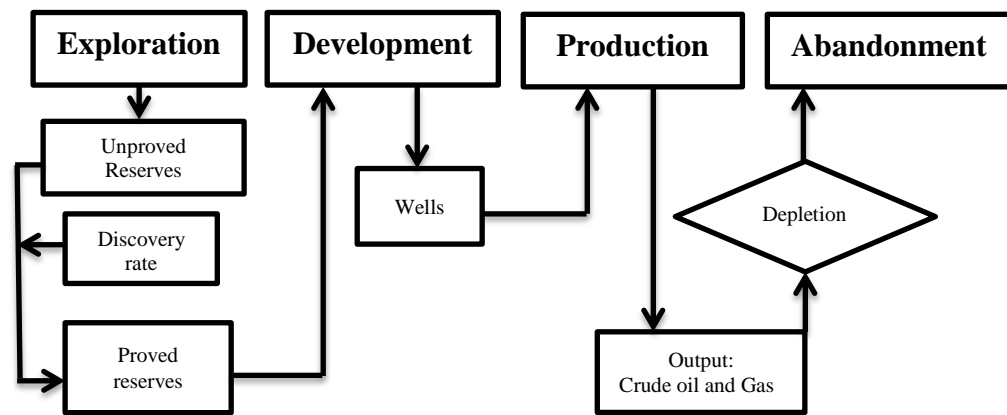
**Source: NNPC statistical bulletin 2009 and 2013**

The Table shows Nigerian crude oil production from year 2000 to 2013. It could be observed from the table that crude oil production had been fluctuating.

#### **3.1.1.4 Abandonment**

This is the final stage in the oil and gas lifecycle, where the developed well proved to be no longer productive or produces oil and gas so poorly that it became liability to its owner and hence abandoned. It signifies the end of the life cycle of a crude oil producing well as it is no longer safe and proved commercially uneconomical to extract crude hence accompanied by a closing down of all operations in the field (Craft and Hawkins 1959). The abandonment of oil wells affects production of crude oil as a result of reduction in number of producing oil wells (Jahn, Cook and Graham 2008). On the other hand crude oil production leads to abandonment of oil wells as a result of its effects on the life of oil well (Höök et al., 2014). Figure 3.4 presents the upstream oil and gas operations and its related output.

**Figure 3.4: upstream oil and gas operations and its related output.**



**Source: Author and synthesis from literature on oil and gas life cycle.**

The Figure presents the upstream oil and gas operations and its related output. It comprises the resultant output arises from each stage of the life cycle of oil operations from exploration to abandonment.

### **3.2 Role of the Nigerian oil industry**

The most important role of Nigerian oil industry is revenue provision to the government because about 80 % of the country's foreign exchange earning comes from oil (CBN, 2008; Igbatayo, 2011; Taiwo et al., 2012; Abdul-Rahamoh et al., 2013). This perhaps explains why Nafziger (2008) asserts that the country had realised about \$500 billion as oil revenue between 1960 and 2006. The revenue generation potential of oil enables Nigeria to utilise the proceeds accrued in executing national economic development programmes and plans and also offers opportunity for increased investment and expenditure (Akinlo 2012).

Stressing its role in economic development, Mcphail (2000) notes that crude oil makes an important contribution to the economic prosperity of the blessed country due to its ability to generate sizeable revenues, create business and employment opportunities, and provide access to water, new roads and power to distant rural areas where the greatest demand is typically situated. The following section presents Nigerian oil curse.

### **3.3. Challenges facing the Nigerian oil industry**

In general, the more a country relies on exports of mineral resources (primary products), the higher it tends to be affected by social, economic and political challenges. Since Nigeria is an economy considerably dependent on oil, it has, at the same time, been considerably susceptible to this myriad of tribulations. Preliminary discussions with key actors in the Nigerian oil industry (Nigerian National Petroleum Corporation, 2011; Federal Inland Revenue Services, 2011; Nigerian Extractive Industries Transparency Initiatives, 2011; Department of Petroleum Resources, 2011), indicated that the most serious challenges militating against optimal revenue generation leading to a shortfall in government revenue to meet its budgetary expenditure include: illegal bunkering (oil theft), vandalism of operational facilities, community unrest, project failures, and cash call related challenges.

In order to address these challenges with a view to realising government objectives, understanding not only the challenges but the industry as a whole becomes indispensable (Sterman, 2000).

Although there are numerous efforts by the government aimed at tackling the aforementioned challenges which includes the provisions of policy measures aimed at instilling stability for sustainable operation of the industry as well as addressing theft of the commodity, the promotion of transparency measures to counteract corruption: all these policy measures are by extension geared towards realising potential revenue for the government.

According to the proposed Petroleum Industry Bill, Nigeria should promote beneficial investments aimed at realising maximum value and benefits from nature's gift.

The proposed legislation also emphasises enhanced crude oil production, according to it, if Nigeria is to maintain its growth trend and enhance its economic position (which is strongly attached to oil revenues) the need to ensure improved and sustained production becomes paramount. It is on this basis that experts in the industry have observed that, as a developing country, Nigeria's journey to one of the top 20 economies in the world will remain an illusion, given the myriad of

challenges facing its main economic base. The overall effect of this is an extension to the revenue due to government from the industry. The inability of the country to optimally generate revenue from the oil resources, to improve and enhance the economic and wellbeing of its citizens is attributable to a range of challenges.

### **3.3 .1 Nigerian Oil Curse**

With the gaining of economic prominence of the oil sector in the late 1960s, Nigeria just like other natural resource endowed economies has also been afflicted with the ‘Dutch disease’ a phenomenon characterised by the malfunction of the economy with an overvalued exchange rate which seriously harms and crowds out the manufacturing and agricultural sub sectors of the economy (Otaha 2012) as experienced after the discovery of crude oil in the North sea (Gary and Karl, 2003). Nigeria is a classical and extreme example of a rentier nation where the whole of the country relies heavily on revenues from crude oil for entire functioning (Ebohon 2013) consistent with Beblawi and Luciani (1987) assertion that, a rentier state is that with at least 40 per cent of the entire government revenue comprises of economic rents.

#### **3.3.1.1 Corruption in the Nigerian oil industry**

The oil sector in Nigeria has been marred by excessive corruption and the absence of good governance thereby militating against the judicious application and utilisation of the proceeds from oil wealth for national development by successive leadership (Broad Street Journal, October 15, 2010). Nigeria possesses a status as one of the most corrupt nations in the world, a reputation that is to some extent based on oil-related scandals (African Development Bank, 2009).

In his view, Hanson (2007) argues that about 80% of crude oil proceeds in Nigeria are in the hands of 1% of the country’s population when the population stood at about 140 million people (The Nation Newspaper of 15th September, 2006). The mismanagement of the wealth from oil proceeds by past Nigerian leaders and regimes, as well as the illusion created, has launched Nigeria among the team of poor nations (Tribune, July 5, 2010).

According to Ogundele and Unachukwu (2012) from independence in 1960 Nigeria has witnessed several cases of mismanagement of oil revenue. They estimated that Nigeria lost about US \$400 billion of its oil revenue from 1960 to 2010. Among the series of notable corruption cases in the Nigerian oil industry is the 12.5 billion dollars oil windfall embezzled from government treasury under the then military regime of General Babangida (Apter, 2005). Similarly, the 2005 audit report released on 11 August 2009 by NEITI discovered over US\$800m of unresolved discrepancies between what oil companies claimed to have paid in to government treasury and what the federal governments acknowledged to have received from sale of oil. Out of this unresolved differences, US\$560m was discovered as shortfalls in royalties and taxes and owed to the federal government and about US\$300m in payment differences relating to payments of dividends, signature bonuses, loan and interest repayments. In quantifying the extent of corruption on the industry, Lubeck, Watts and Lipschutz (2007) argues that an estimates revenue loss to corruption in the industry in the last three decades to be between US\$50 to US\$100. In support of this estimates, a news report by Global Financial Integrity puts the figure for illicit financial outflows from Nigeria oil industry between 1970 and 2008 at US\$58.5 billion (Kar and Cartwright-Smith 2010). In 2012 an investigative panel discovered that while the federal government was paying for 59 million litres of refined crude oil daily in 2011 only about 35 million litres of the products were being consumed daily in the country with subsidy balance for 24 million litres costing an excess payment of N600 billion stolen (Agande and Ovuakporie, 2012). Others corruption cases in the industry include when the former Governor of Central Bank of Nigeria, exposed a high profile corruption in a letter to the country's President exposing a difference between the monetary value of crude oil lifted by NNPC amounting to US\$ 65 billion between January, 2012 and July, 2013, while the amount repatriated to the Federation Account was US \$50 billion (Nnaa, and Nwibor 2015). These and other corruption cases in the industry had earned the industry a reputation of the most corrupt institution in the country reflective of the series of ranking of the country by Transparency International (TI, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, and 2014).

### 3.3.1.2 Crude oil theft

The term bunkering was originally coined in describing the process involve in filling up a vessel with coal or crude oil, but its illegality, which according to Human Rights Watch (2003), is a euphemism for coal or crude oil theft, based on the constitutional provision which states that the total control, custody, title and ownership of all natural resources in any part of Nigeria irrespective of the geographical features are exclusively vested in the power(s) of the federal government (see section 44(3) of the 1999 Constitution of the Federal Republic of Nigeria with its origin in the 1946 Mineral Ordinance). According to the IEA (2012), organised and large-scale oil theft results in the loss of estimated \$7 billion annually by Nigerian government. The quantity of crude oil being stolen in the Niger Delta region is at an industrial scale with the vast quantity of the stolen crude oil sold internationally as well as the emergence of illegal refineries in the region for local refining (Premium Times Newspapers 2013). Figure 3.5 present illegal refinery for stolen crude oil

**Figure 3.5: Illegal Refinery**



**Source: Premium Times Newspapers (Ogala Emmanuel, 2013)**

The International Centre for Reconciliation (ICR), Coventry Cathedral (2008), in another study that conducted, the total estimated crude oil value lost to the Nigerian economy as a result of the disruption of operations and production of crude oil and illegal crude oil bunkering within the period 2003-2008 was one hundred (100) billion dollars translating to approximately fourteen (N14) trillion Naira. On the other hand an estimate made in a report on the Niger delta region by the Technical



Committee led by Ledum Mitee, indicated that about N8.84 trillion or \$61.6 billion dollars was lost by Nigeria as a result of sabotage and illegal bunkering in the volatile oil rich Niger delta region within the period 2006-2008 (Vanguard, July 6, 2009). This report presented a clear and detailed picture which indicated that in the year 2006 alone, the total quantity of crude oil lost as a result of militant activities was \$272 billion translating to 2.45 trillion Naira, while an additional \$1.9 billion translating to 283 billion Naira was lost to illegal oil bunkering. The table 3.3 presents Nigeria's stolen crude oil from 2000 to 2013.

**Table 3.3: Estimated volume of Nigeria's stolen from 2000 to 2013 in millions barrels**

Year	Crude oil	Year	Crude oil	Year	Crude oil	Year	Crude oil	Year	Crude oil
2000	51.5	2003	109.5	2006	36.5	2009	53.0	2012	-
2001	264.3	2004	109.5	2007	36.5	2010	-	2013	36
2002	255.4	2005	91.2	2008	54.7	2011	-		

**Source: Judith (2009), NNPC (2005, 2010, 2014)**

The figures in Table 3.3 represent available estimate which is the best, given the fact that the Nigerian Government neither maintains accurate records nor statistics that distinguish between stolen crude oil or losses occasioned from forged bills of lading and shut-in production (Asuni, 2009). In view of the above, it is a fact that there is a serious challenge to arriving at acceptable figures of what is the actual monetary value of illegal oil bunkering. Arguably, the figures provided by Coventry Cathedral have proved to be more valid as it represents the results and findings of an extensive and scientific research exercise and, hence, is considered acceptable for the purpose of this research study.

According to Asuni (2009), illegal crude oil bunkering fuels conflicts and militancy as a consequence of the proliferation of arms and ammunitions thereby creating instability in the oil rich Niger delta region. This necessitates the discussion on militants presented in the next chapter.

### **3.3.1.3 Militancy**

The term militancy refers to an aggressive and active tendency embarked upon towards the support and/or defence of a given cause (usually political) mostly to an

extreme extent (Inokoba and Inbua, 2010). The negative effect of militants in the Niger Delta region is enormous. For example, the attacks by aggrieved militants in June, 2009 as retaliation against the massive onslaught carried out by the Nigerian Military in Gbaramatu Kingdom, Delta State, resulted in crude oil output hovering between 800,000 barrels of crude oil per day and 1.2 million barrels of crude oil per day up to November, 2009 (The week, 2009). Available records indicate that, from a maximum crude oil production averaging 2.1 million barrels of crude oil per day, witnessed in March 2008, the country's oil output declined drastically to 1.7 million barrels of crude oil per day by May, 2009 (NNPC, 2009). Figure 3.6 shows militants in the Niger Delta region of Nigeria.

**Figure 3.6: Niger Delta Militants**



**Source: Telegraph Newspaper (Leah Hyslop, 2012)**

According to Human Rights Watch (1999), (2002) and (2005), the conflict in the oil rich Niger delta has substantially affected crude oil production and, by extension, revenue generation. Among the effect of militant activities as stated above include vandalism of oil facilities. The following section discusses vandalism.

### 3.3.1.4 Vandalism

Another source of concern not only to policy makers and peace lovers but also to scholars, are the consistent and incessant attacks meted out to oil facilities by militants in the Niger Delta. According to the International Energy Agency (2011), vandalism in the oil region of Nigeria mostly resulted in the destruction of pipelines has forced production to be shut down by the multinational oil corporations. The economic and environmental impact of the destruction of oil facilities is immeasurable. For example, the country lost an estimated revenue amounting to about 2.97 trillion Naira to the destruction of oil facilities and installations as a result of spillages and shut downs in the first three quarters of 2008 (Ajaero, 2009). Figure 3.7 shows vandalised crude oil facility in the Niger Delta of Nigeria.

**Figure 3.7: Vandalised crude oil facility**



**Source: Punch Newspapers (Mike Odiegwu, 2012)**

The situation was succinctly captured by Obi (2010:220) as follows.

“Between late 2005 and mid-2009, attacks against oil installations forced the shutdown of between 25% and 40% of Nigerian’s oil production and exports, leading to substantial loss of revenues and profits by the state-oil multinationals alliance. These militia attacks (in addition to oil theft) have largely accounted for a drop in oil production from about 2.6 million barrels in 2005 to 1.3 million barrels in June 2009. The resultant loss of revenue is estimated in billions of Dollars. The transformation of initially uncoordinated, non-violent protests into a full-blown pan-Delta insurgency and the attendant insecurity in the region has continued to occupy the

attention of strategic and policy analysts and oil multinationals, whose multibillion dollar investments are at grave risks. Also at stake are the energy security and strategic interests of oil-dependent Western powers, which back the oil multinationals and rely on oil imports from the Niger delta.”

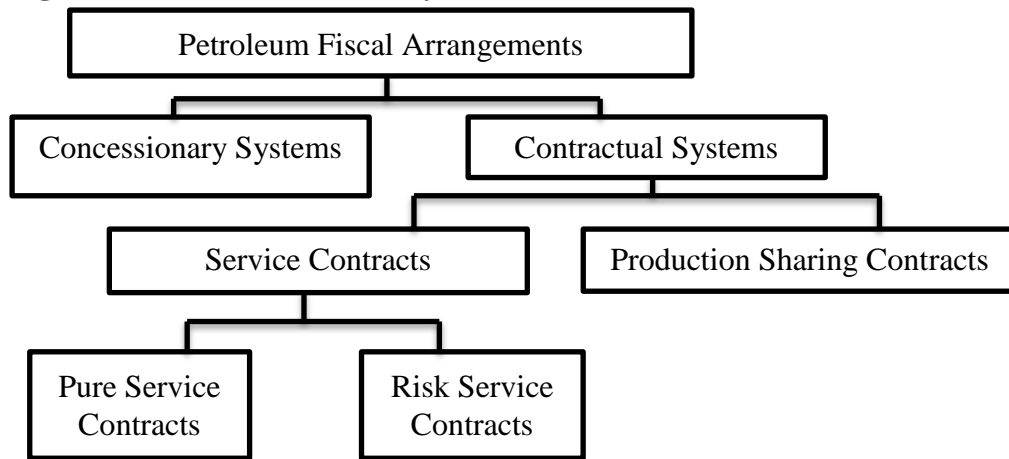
### **3.3.1.5 Community unrest**

According to Ibaba (2011), the country’s exports of crude oil rose considerably in the 1970s, despite a series of community agitations and unrest against the multinational oil companies. In the year 2005, the country witnessed a great increase in unrest and conflicts between the multinational oil corporations and oil producing (Oluduro & Oluduro 2012). This phenomenon in the Niger Delta degenerated into an environment characterised by general insecurity, perpetual agitation, insurgency and overall youth restiveness (Oluduro and Oluduro 2012). Kashubsky (2011) presents a vivid picture of restive acts by aggrieved oil host communities leading to heavy destructions.

### **3.3.1.6 Sector--specific problems**

The prevailing mental model in the Nigerian oil industry is that instability in the Niger delta and corruption are the main challenges inhibiting the generation of optimal revenue in the industry. However, there are additional as well as other sector specific challenges emanated from discussions with key stakeholders in the industry. In particular, a major source of concern is the fiscal arrangement which, according to Isehunwa and Ifeoma (2011), is the framework employed by the authorities of oil producing economies in regulating, managing and sharing the accrued revenues from all the stages. Figure 3.8 presents the petroleum fiscal systems.

**Figure 3.8: Petroleum Fiscal Systems**



**Source: Johnston (1994a. Pp. 25)**

The Figure describes the various fiscal arrangements in oil industry. The first two classes of petroleum fiscal system include concessionary and contractual systems of arrangements. The contractual system is also classified into sub categories of service and production sharing contracts. The service contract is further classified into pure and risk service contracts.

In highlighting the existing fiscal arrangements in Nigeria, Okoye and Mbonu (2005) indicted that there are three main ways in which the Nigerian government participates in upstream petroleum activities: traditional joint venture, production sharing contract and service contract. These perspectives have redefined the scope of this research study. The result is the incorporation of the perspectives of the stakeholders in the research and hence resulting in a holistic and wider view of the challenges inhibiting the realisation of potential revenue from the industry. Below are the highlights of the main fiscal arrangements and their individual challenges.

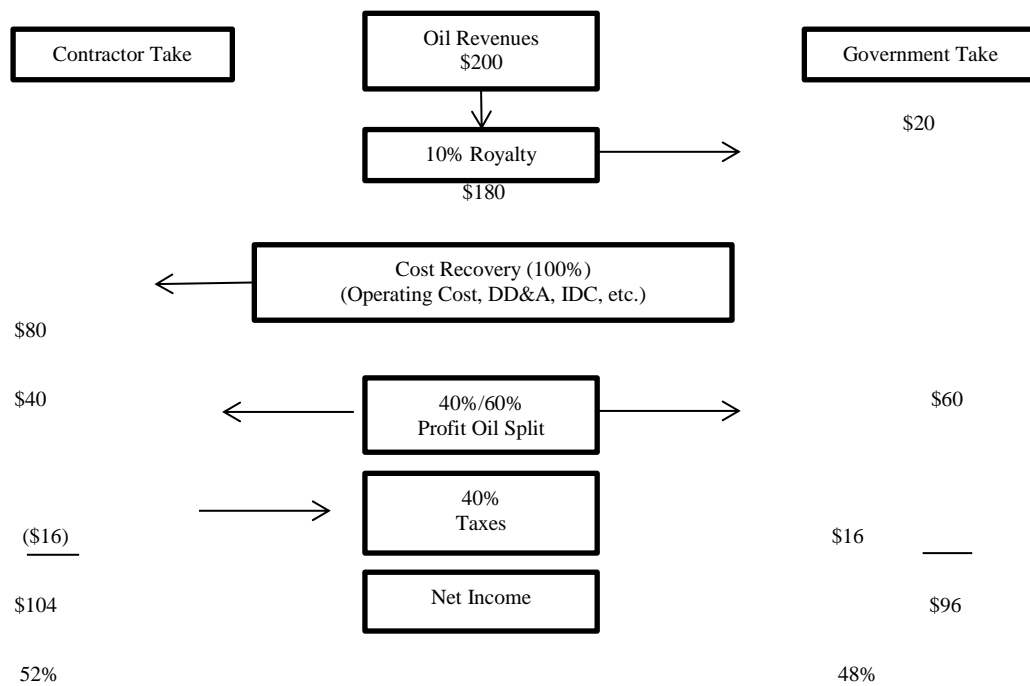
### **Production Sharing Contract (PSC)**

A production sharing contract (PSC) is the commonest form of contractual agreement in the oil and gas business (Pongsiri, 2004). In Nigeria, this policy strategy falls within the regulatory framework of the Deep Offshore and Inland Basin Production Sharing Contract Act, Laws of the Federal Republic of Nigeria. Under the production sharing contract (PSC), the state owned oil company (NNPC)

engages a highly competent contractor (MNO) duly registered in the country to embark on petroleum operations in the country. It is a form of contract which presents to international oil companies the means of acquiring, exploring for and production rights of oil through an agreement (Atsegbua, 1993).

Production sharing contracts originated in Indonesia in the 1960s as an emerging legal instrument that stipulates the contractual relationship between host countries and international oil companies (Atsegbua, 1993; Pongsiri, 2004), This assertion was corroborated by Aghion and Quesada (2009) noting that Indonesia was the first country to introduce production sharing contracts in 1966 and has since then become a significant class of contractual agreement particularly in developing countries. Figure 3.9 presents an overview of a production sharing contract.

**Figure 3.9: Production sharing contract**



**Sources: Adopted from Johnston (1994b Pp. 43)**

The Figure highlights the individual entitlements of the participating partners in production sharing agreement. It shows government share of revenue from the arrangement which includes royalty (10% of oil revenues), profit oil share (60% after deduction operating cost incurred by the contractor, and finally taxes paid by the multinational oil company to the government (40% from IOCs share of profits).

On the other hand, the contractors share is 40% before tax of profit oil aside from its cost recovery amount.

### **Challenges Facing Production Sharing Contract (PSC)**

With the growth of the Nigerian oil and gas industry in the wake of the unique challenges of Joint venture agreement in terms of funding and technical complexity, further allocations of acreages in the shallow and deep offshore compelled a different regime leading to the introduction of a PSC (Frynas, 2010). In order to enhance Nigeria's crude oil reserves as well as improve the country's economy, the introduction of production sharing (PS) as a policy strategy for the exploration of oil in Nigeria became imperative, thus gradually assuming prominence in the entire industry (NNPC, 2010). Initially, it appears that this policy is highly rewarding to both the contractor and Nigeria. The arrangement is also flexible, particularly as it relates to the management of Nigeria's crude oil production in view of the fact that it has lifted the financial burden associated with a JVA.

As a consequence, the Nigerian National Petroleum Corporation (NNPC) and major multinational oil companies in Nigeria embarked on gigantic capital investments in deep water project portfolios during the period 1999 to 2005, under a production sharing contract arrangement, amounting to over \$6 billion (NNPC, 2010). Despite the fact that these projects are pioneering, the first of their kind in the Nigerian offshore, a significant proportion of the project portfolios encountered project management challenges resulting in massive schedule delays and cost overruns. The concept of project duration is vital in assessing the viability or success of a project. Several scholars agree that exceeding the delivery date of a project as originally agreed will result in project time overruns and variation orders (Chan and Yeong, 1995; Toor and Ogunlana, 2008). Project delays lead to cost overruns, greater disputes and poor quality.

## **Joint Venture Agreement (JVA)**

According to Madhok (2006) the convergence of a group of companies holding a production licence, sharing exploration and development costs of a field and the revenue thereof in the ratio to the venture, constitutes a joint venture arrangement. In a typical joint venture arrangement, one or more companies are usually operating members and participate directly in the physical exploration and production while the non-operators are just financial members (Okoye and Mbonu, 2005).

Aghion and Quesada (2009) argue that in most instances, exploration costs are borne by the international oil companies and the participation of government in the venture is dependent on the commercial discovery of oil.

## **Challenges Facing Joint Venture Agreement (JVA)**

The joint venture presents an agreement whereby the host government of Nigeria provide its counterpart funds (cash obligation) for the operation of the joint venture projects (African Development Bank, 2009). The inability of Nigerian government to sufficient financial resources to meet its counterpart funding renders the oil sector not funded to satisfaction (African Development Bank, 2009). The failure to meet cash call obligations as and when due is a continuous challenge as the JVA still constitutes over 90% of both revenue and production (Mbendi, 2000). This creates a funding gap leading to constant cash call shortfall (Nlerun 2010) since cash call payment also lowers funding gap (Nlerun, 2010). This cash call shortfall accumulates thus necessitating alternative funding which reduces the accumulated cash call shortfall provides the needed development investment in the sector (NNPC, 2010). Accumulation of cash call shortfall results to project delay leading to cost overrun and therefore affects the cost of a particular project (Baloi and Price 2003). The overall effects of cash call payment are increase in available funds for investment which has direct effect on rate of government investment in the industry (Odularu2008). Investment generally focuses on number of oil wells and other projects such as pipelines which has significant impacts on crude oil production (Nlerum 2010).



### **3.4 Background of Policy in the Nigerian Oil Industry**

According to Obi and Soremekun (1996) policies in the Nigerian oil industry can be classified into three categories: these can be divided on the basis of historical phases. The initial phase is an extension from the colonial era until the tail end of the 1960s and it was characterised by little participation of the state in the industry. Notably among these policies include: Minerals Oil (Safety) Regulations 1963 Act aimed at ensuring best practice in the activities of the industry, the Petroleum Profit Tax Act (PPTA) 1959 which aimed to boost government take in the industry. Additionally, in order to ensure adherence to safety standards, the Oil Pipeline Acts 1956 was promulgated.

This was followed by the second phase which commenced in 1967 as a response to changes in the political scenario during the 1967-1970 civil war in the country; this phase featured a remarkable state participation in the industry up to the period end 1970s to mid-1980s. In their view, Obi and Soremekeun (1995) assert that in this phase, Nigeria rose from rent collection to direct involvement and participation in the running of the affairs of the oil industry. In 1967, the Petroleum Profit Tax (PPT) amended Decree No. 1, was introduced by the government in an effort to improve its financial receipts from the sector. This decree based the calculation of petroleum profit tax and royalty on posted prices and made provision for expensing of royalty (Ayadi, 2005). In the same period and in what appears to be a move for the prevention of sea pollution, the industry witnessed the promulgation of oil in Navigable Waters Act 1968 (NNPC 2010).

Besides this, other policies were also employed to reposition the industry, for example, the Petroleum (Drilling and Production) Regulation Act 1969. This was followed by the Petroleum Decree of 1969 which was fashioned in full recognition of the relevance to force the multinational oil companies to develop Nigerians to man the sector.

According to the second national development plan, the 1970-1974 Nigerian government should participate in the exploitation and exploration of the national mineral wealth (Akpan, 2012). Pursuant to this policy, in 1971, the government acquired one-third equity interest in the National Agip oil company based on its

concession agreement and 35% in Elf. Since then the Nigerian government has been a major player in the industry as represented by its organ known as the Nigerian National Petroleum Corporation (NNPC) (Saheed, 2010). This policy of indigenisation has been successful, given the fact that Nigeria now has indigenous oil companies that operate in both the upstream and downstream sector of the industry (Asiodu, 1979). The act establishing the state owned oil industry was promulgated by the government as a policy strategy to ensure participation, involvement and control. Thus, the Nigerian National Petroleum Corporation (NNPC) was established under the NNPC Act 1977 (NNPC, 2010). As a consequence, the inspectorate wing of the NNPC embarked on remedial actions to curtail oil pollution such as the enforcement of the reporting of oil spillage on multinational oil companies, under a new arrangement with a view to recording all oil spillages (NNPC, 2010).

The third, which is the last phase, emerged as a reaction to the economic depression of the late 80s and the consequent imposition of the government policy of the structural adjustment programme in the year 1986 (NNPC 2010). It is however worth noting that policy issues dramatically changed and diverted to addressing specific issues bothering the industry as well as the host oil communities. With the rapid expansion of the sector and as it continued to play a dominant role in the economic scene of the country, certain policy interventions became imperative (Akpan, 2012). For example, as a response to a variety of challenges specific to the industry, a variety of policy interventions and initiatives geared towards addressing specific issues such as underdevelopment and conflict were adopted in order to improve the state of affairs as well as the country's economy (Ohswofasa, Anuya and Aiyedogbon 2012 and Inokoba & Inbua 2010). This includes the Environmental Impact Assessment Act 1992 to assess the environment as well as the establishment of Associated Gas Re-injection Act 1979 in order to address gas flare (Okonta and Douglas 2001).

In an effort to address at least some of the demands for faster social development, the federal government scrapped the highly criticized Oil and Minerals Producing Areas Development Commission (OMPADEC) in 1999 (ADB, 2009). The return of civilian administration in 1999 under the stewardship of President Olusegun

Obasanjo replaced OMPADEC with the establishment of the Niger Delta Development Commission (NNDC) (Aghalino, 2004). All these were aimed at instilling human and capital development in the oil producing region as a measure to address the curse of resources. Other policy measures that emerged during this period include Production Sharing Contract (Deep offshore and Inland Basin Production Sharing Contract Act 1999, Deep Water Block Allocation to Companies Regulations 2003. Safety and detection of oil spillage witnessed the promulgation of National Oil Spills Detection and Response Agency Act 2006. Utilisation of the country's energy witnessed the National Energy Policy Applicable to Oil and Gas 2003 and, lastly, instilling stable condition in the oil producing area witnessed Amnesty Initiative of 2009. Below is brief summary policy measures aimed at improving revenue generation in the industry.

### **3.5 Policies Aimed at Addressing Challenges Facing Revenue Generation**

As a response to myriads of challenges facing the industry particularly as it affects government potential to generate optimal revenue benefit from the petroleum industry, two major policy initiatives were employed in the Nigerian oil sector: the transparency initiative (NEITI 2004) championed by the Nigerian Extractive Industries Transparency Initiatives and the amnesty initiative (2009) piloted by the Presidential Committee on Amnesty programme. While the previous initiatives were largely aimed at alleviating the predicaments and responding to the grievances and agitations of the host communities, it is however argued that the transparency and amnesty initiatives were aimed at improving government revenue from the industry.

#### **3.5.1 Presidential Amnesty Programme (PAP)**

Concern about the security and economic challenges as a result of the series of violent agitations occasioned by militant activities, the federal government of Nigeria (under the late President Yar'adua) embarked on the amnesty initiative as a panacea for warring militants (Ogege, 2011). This was intended to serve as a means towards addressing the general insecurity through the creation of a conducive, peaceful and stable environment to address the endemic crises in the region thereby

warranting hitch free operations for the multinational oil companies (Olatoke and Olokoba, 2012).

The government's desire to maintain optimal crude oil production which, by extension, improves revenue generation from the industry is arguably the main motive for the amnesty programme, as crude oil production almost flattened at the peak of the crises in 2008 and 2009 (US IEA, 2010), posing dire economic consequences for the Nigerian economy in view of the role of crude in the prosperity of Nigerian economy (NNPC 2010). The declaration of amnesty towards the end of 2009 resulted in a pact between the militants and the government whereby weapons were handed over in exchange for training opportunities and cash payments. It is argued that the rise in crude oil production after 2009 was apparently as a result of a reduction in destruction of oil facilities resulting from the implementation of the amnesty programme, which afforded time for multinational oil companies to repair some of the destroyed infrastructure thus bringing some supplies back online (EIA, 2012).

On the 25<sup>th</sup> day of June 2009, the central government of Nigeria proclaimed the amnesty programme, thus extending a 60 days period (commencing from August 3 and ending October 4, 2009) to violent militia groups in the oil rich Niger delta to surrender their arms in acceptance of the offer. Champions of amnesty initiatives attributed it to the extreme desire for the restoration of environmental security, peace and human development in the Niger delta in order to create a friendly and conducive environment for speedy and sustainable development (Ogege 2011): thus the setting up of a committee on amnesty to fashion a befitting framework for the exercise. The on-going reforms can be assessed in this context. A temporary cessation of hostilities was witnessed in the region as a result of the amnesty exercise (Babatunde 2011) with some of the ex-militants engaged in a variety of training programmes overseas in an effort to instil human capital development thereby creating stability in the region (Ogege, 2011).

Designated points for collection of arms and withholding camps were however provided and established across the Niger delta region. At the terminal end of the period, in excess of 20,000 armed militants were successfully disarmed and hence surrendered a large quantity of arms and ammunition, including the hardware of

war: pump action guns, rocket launchers, gun boats, AK 47 rifles and machine guns (Okogun and Okeneye, 2009). Overall, a total of 20,192 militants comprised of 20,049 and 133 men and women respectively from all the nine oil endowed states of the Niger delta enrolled for the amnesty programme having renounced their hitherto militant status between the period 6<sup>th</sup> August 2009 at the commencement of the programme and October 4<sup>th</sup>, 2009 the termination date of the programme (Ogege 2011).

Adejumbi (2009) argues that the amnesty initiative was a policy strategy of the central government specifically geared towards diplomatically and deceitfully disarming the militants, confining them in the designated centres so that the oil endowed Niger delta region could remain peaceful and calm for unhindered and steady oil exploitation by the foreign oil corporations to the detriment of the host community of the Niger delta. According to Ibaba (2011), the present policies are not realistically addressing these problems, citing environmental degradation occasioned by oil exploration activities and its socio-economic consequences, as well as corruption in governance and its negative effects on the people.

Nigeria's crude oil production sharply rebounded after the 2009 amnesty programme for the militants in the volatile Niger delta region occasioned by years of violent unrest which had affected crude oil production by around half of the production capacity (EIA, 2012).

### **3.5.2 Nigeria Extractive Industries Transparency Initiatives (NEITI)**

Emerging developments, particularly in resource endowed economies, have escalated global concern for effective remedies to poor management of resource wealth (EITI, 2002). Concern about the impact of the resource curse on a significant number of countries resulted in the promulgation of a foreign policy initiative known as Extractive Industries Transparency Initiatives (EITI) by former British Prime Minister, Tony Blair, at the world summit on sustainable development of the OECD in Johannesburg, South Africa in 2002. As a consequence and in compliance with this, the Nigerian Extractive Industry Transparency Initiative (NEITI) was launched in 2004. It is a home body of EITI. The main objective of this initiative is to explore a competent policy mechanism

that can improve governance generally in the sector with the sole aim of addressing the said failures through the introduction of transparency and accountability measures (NEITI, 2004). Several studies have documented the effect of transparency in reducing corruption (Bac, 2001; Kolstad, and Wiig, 2009). A transparent system connotes system that is open thus guarantees access to reliable, relevant and understandable information at ease (Thurber et al., 2011). Since corrupt practices have thrived in the Nigerian oil industry partly as a result of the secrecy that surrounds its operation (NEITI 2011), it can be argued that transparent efforts can offer the needed solution to address corrupt practices in the industry. On the basis of this, the government now publishes some information concerning revenues received from the industry which hitherto remained secret. The effect of this according to (NEITI 2011) is a reduction in corruption in the industry as is evident from the realisation of some revenue which were hitherto not accounted for.

### **3.6 Summary and Conclusion.**

The above analysis has presented an exposition of case study background. The chapter highlights crude oil discovery in Nigeria as well as economic importance of oil sector globally and in Nigeria. A good insight on the operation of oil and gas industry in Nigeria emphasising its similitude to that of other oil industry globally is also presented in this chapter. Specifically, the chapter described oil and gas industry in terms of upstream and downstream sectors before focusing on an extensive review of the upstream operation of the industry leading to a discussion of the oil and gas value chain from exploration to abandonment.

The Nigerian oil industry structure and dynamics, historically and up to the present has also been provided in this chapter. The chapter also highlights the role of Nigerian oil industry thus establishing the important role the industry serves as revenue provision to the government. The Nigerian 'oil curse' is also discussed in this chapter. Specifically it presented challenges facing Nigerian oil industry on which the modelling effort focuses on which includes corruption, militant activities, vandalism etc. The chapter also discusses the two main policies aimed at addressing the challenges facing revenue generation in the Nigerian oil industry as a response to myriads of challenges facing the industry particularly as it affects

government potential to generate optimal revenue benefit from the petroleum industry.

## **CHAPTER FOUR: METHODOLOGY AND RESEARCH DESIGN**

### **4. Introduction**

Research is generally based on certain philosophical assumptions concerning what constitutes valid research and the research method(s) that is or are suitable for knowledge development in a particular study. In order to execute and evaluate any research work, it is therefore imperative to understand what these assumptions are (Hirschheim, 1992). The aim of this chapter is to highlight the philosophical assumptions and the scientific methodology or procedure which has been adopted in this research. Commonly used philosophical assumptions were evaluated and presented; the positivist and interpretive traditions were evaluated for the framework of this research. Following this is the second section, the research strategy; section three describes the research methodology. Theories employed in this research are presented in section four. Section five highlights the research approach used while the mode of analysis in this research is presented in section six. Section 7 highlights mixed method research and finally the conclusion of this chapter is presented in section 8.

#### **4.1 Overview of Research Methods**

There are different kinds of research studies conducted such as exploratory, descriptive, analytical, quantitative, qualitative, predictive, inductive and deductive (Hussey and Hussey 1997; Crotty 1998). The selection of a particular type of research depends on the methods and methodologies used in the research as well as the justification for the choice. Additionally, the use of methodologies is the assumptions regarding the reality that the investigator brings to her or his task (Hussey and Hussey; Crotty, 1998).

The selection of the methods and methodology for this research has been undertaken to achieve the objectives of the thesis, hence this chapter aims to present the justifications for choice. The rationale will be explained and discussed as it relates to research design, process, and justification of the selected methodology.



## **4.2 Research Paradigm and Philosophy**

According to TerreBlanche and Durrheim (1999), the research paradigm is a comprehensive system of interconnected thinking and practice which defines the nature of investigation along three key dimensions. These three key dimensions are ontology, epistemology and methodology (Saunders et al. 2009). Conversely, the research philosophy is a framework that serves as guidance to the conduct of scientific research (Collins and Hussey, 2009). The research philosophy applied in a piece of research embeds significant assumptions regarding the world view of the researcher (Saunders, et al., 2009). These assumptions underpin the methodology (strategy) of research as well as the methods of research employed by an investigator as a part of that methodology (Myers and Avison 1997).

The history of the term paradigm may be traced to the Greek word *Paradeigma* referring to pattern, as originally applied by Thomas Kuhn (1962) to refer to a conceptual framework adopted by a group of scientist which accorded them with a befitting model for assessing problems and finding solutions. In addition, Kuhn (1962) described a research paradigm as a research culture possessing a composition of assumptions, values and beliefs that a group of researchers possess in common concerning the conduct and nature of research.

Ontological and epistemological issues concern what is generally regarded as a person's worldview (Myers and Avison 1997). The two possible world views include: constructivist and objectivist (Denzin and Lincoln 2003). These divergent ways of viewing the world have effects in a majority of academic fields but yet neither of these views is regarded as superior to the other (Myers and Avison 1997). The two may be appropriate for some aspects and deficient for other purpose (Banister, et al., 2011). Additionally, an individual may alter his or her own view on the basis of a particular situation (Myers and Avison 1997). For instance, this research work adopts elements from the two views and hence regards them as complementary. Individual views regarding the world we want to live in and the world we actually live in are inherently reflected in a research paradigm (Lather 1986).

Gephart (1999) classified research paradigms into three philosophically distinct groups: interpretivist, positivist and critical traditions. This view was also supported by Chua (1986) who argued that the three main philosophical paradigms which have been developed in research are classified as positivist, interpretive and critical traditions and have equally been accepted and view supported by Klein and Myers (1999) and Myers and Avison (2002). The two research traditions commonly adopted to carry out research and construct knowledge in the field of social and management sciences are the positivist and interpretivist (Collins and Hussey 2003). These two main traditions stand as the two extremes of a range of research traditions and along this range, there exist several other paradigms possessing various philosophical assumptions (Collins and Hussey 2003). There exists no agreement, however, regarding whether these paradigms can be considered as contributing distinct roles or are necessarily opposed in the same study (Myers and Avison 2002).

#### **4.2.1 Positivist Paradigm**

This refers to an epistemological stand that supports the utilisation of the methods of the natural sciences to the investigation of social reality and beyond (Bell and Bryman 2007). The underlying assumption of positivist philosophy is that the researcher is independent from reality (Collins and Hussey 2003). Hence, knowledge is gained through the gathering of facts that accord the bases for laws. The essence of theory is to develop hypotheses that are testable (Bell and Bryman 2007).

According to Saunders et al., (2009), the positivist tradition is commonly associated with the application of the deductive approach, where hypotheses and theories are generated and data collected later to test the hypotheses. Positivists proponents tend to apply a methodology that is greatly organised to support verification and replication of their research (Gill and Johnson 2010).

#### **4.2.2 Critical Paradigm**

The philosophical assumptions concerning critical research traditions is that social reality is historically created, hence shaped and reshaped by individuals (Myers and Avison, 2002). Researchers are of the opinion that although individuals can

consciously take an action to alter their individual socioeconomic circumstance yet their capability to do so is limited by several classes of cultural, political and social domination. The main purpose of critical research is to uplift individuals for the sake of creating a befitting environment for themselves (Cavana, Delahaye, and Sekaran 2001).

The major task of researchers under this tradition is that of presenting a social critique within the alienating and restrictive circumstance of the status quo (Myers and Avison, 2002). To achieve this, Klein and Myers (1999) point out that the critical researcher assumes that although the individuals concerned may attempt to alter their socioeconomic circumstance, they are however, constrained by different forms of cultural, political, and social domination such as resource limitations and natural laws. A classical attribute of the critical researcher is the specific attention to evaluation (Cavana, et al., 2001). While the two main research traditions, i.e., interpretive and positivist, are content to explain or predict the status quo (Bernstein 1978), the critical tradition is concerned with the analysis of existing social arrangements and highlighting any conflicts present in the structure. Although there exist several similarities to the interpretive tradition there are, however, three major criticisms outlined by the critical researcher (Chua 1986). Firstly, the degree of agreement of the actor when rationalising results is hence perceived as fragile. There exists no evaluation because of the absence of attention concerning power. Finally, the assumptions of social and physical reality for the interpretive researcher assume that social order is in control and is in line with the method of interpretivism.

### **4.2.3 Interpretive Paradigm**

This philosophy believes that it is significant for the investigator to recognise the distinction relating to individuals and objects that calls for the investigator to hold the non-objective nature of human act (Bryman and Bell, 2007). The underlying assumption for this tradition is non-objective social reality mapped by the perception of the researcher (Collins and Hussey, 2009). Saunders et al., were of the view that as opposed to positivists, interpretivist argue that the human system is too highly complex in nature to warrant theorising based on established laws, as in the natural sciences.

Unlike the positivist philosophy which attaches importance on quantifying human phenomena, the interpretivist approach concentrates on exploring the complex nature of social phenomena to acquire interpretive interpretation (Collins and Hussey, 2009). Rather than adopting quantitative methods employed by positivists for the identification of the occurrence of rate of events in the human environment, interpretivist tends to apply a set of procedures to interpret and describe these phenomena (Collins and Hussey, 2009). The interpretivist approach is usually associated with the application of the inductive technique, where information is gathered and applied in theory development (Saunders, et al., 2009). As a result, theory is the outcome of research and induction processes that involve deriving general conclusions out of observations (Bryman and Bell, 2007).

Conversely, it is imperative to note that there is no philosophy that is superior to the other and the selection or choice of one philosophy depends on the study objectives and problem or the tradition in a particular discipline (Collins and Hussey 2009). This research is about a complex situation and involves quantitative and qualitative variables. In effect, a balanced approach is required for this as being more realistic. Remenyi, Money and Swartz (1998), conclude that it is logical to see these two approaches as complementing each other instead of as two opposites or opposite extremes. The research objectives were formulated in order to direct empirical fieldwork relevant to the causes and effects of challenges facing revenue generation in the Nigerian petroleum industry.

Additionally the quantitative analysis in this research sheds light on various measures for an objective analysis of the effects of a variety of policy options. This situates the ontological perspective of this research study close to a positivist paradigm. An approach that is purely positivist cannot, however, meet the expectations of this research study. Specifically, the manner in which data is collected for this research study and how concepts such as challenges are perceived or are interpreted by individuals imposed a mixture between an interpretivist and a positivist approach.

In order to further elaborate on this, explanation is provided below as to how challenges facing revenue generation are defined in this research work. The research defines challenges facing revenue generation as a term used in the industry

to refer to challenges that extend exploration, development, production to revenue issues in the industry which the industry faces in achieving the potential benefits from the industry. In the same vein, these two methodological strands exhibit potential synergies. It is imperative to combine quantitative and qualitative modelling and research design. The methodological synergies are to develop upon the duo of positivist and interpretivist paradigms, traditions and philosophies. The contribution of the two methodologies brings together the strengths of the positivist and interpretivist paradigms towards modelling this complex situation. The individual complementarities are therefore collectively combined into a framework.

Based upon the combined views of Checkland (1981) and Lane and Oliva (1998), concerning the systems philosophical perspectives, this research work deduced that building a System Dynamics model of the Nigerian oil industry could not be achieved without engaging System actors in whose heads the relevant information resides. This research therefore employed the SD philosophy of modelling with the contribution of the clients through the elicitation of knowledge from their mental model via interviews and used it to enhance the conceptual model developed from the textual data base. This is because as Forrester (1970) asserts that SD inquiry evolves from an epistemology that is developed around the centrality of the knowledge that resides on the head of the system actors (mental models). Therefore interpretive paradigm constitutes one of the ontological assumptions of this research as knowledge is subjective and not independent of the researcher.

On the other hand the epistemological stand of this research involves interaction between the researcher and the research participants thus warrants open communication which resulted in socially constructed knowledge. This allows a deeper understanding and interpretation of phenomena by the research participants. The utilisation of the theoretical (textual data base) and empirical (interviews) information resulted in inductively developing the qualitative model (Causal Loop Diagram) which serves as the dynamic hypothesis (theory) for this research work thus situating this research within the interpretive paradigm.

Converting the qualitative model into a quantitative model (stock and flow diagram), which used a numerical data base, estimation and assigning of numerical values on model parameters, constitute the quantitative realm of this research work.

Furthermore, the theory is deductively tested via simulation experiments which are associated with experimental and scientific approaches and finally results are generated via graphs and other forms of quantifications resulted in situating the research within a positivistic paradigm.

The combination of the interpretive and the positivistic paradigm therefore situate this research within a pragmatic perspective. Both positivism and interpretivism co-exist in this research to achieve the research objectives.

### **4.3 Research Strategy**

The research strategy sets a procedure or logic that paves the way to addressing the research questions. A research strategy should define the epistemological, ontological and methodological setting of the research (Myers 1997). Decisions concerning how to investigate the social world usually lead to a number of significant philosophical debates (Collins and Hussey, 2009). This debate centres on ontology which refers to belief regarding what is to be known concerning the world (Ritchie and Lewis, 2006). The relationship between that reality and the researcher is referred to as epistemology, where a methodology is comprised of the techniques adopted by the investigator to search and discover that reality (Healy and Perry, 2000). As the epistemological position focuses on what can be known regarding the world and the way it can be studied, the ontological position, on the other hand, demonstrates the investigator's view regarding the nature of social reality (Collins and Hussey, 2009).

Epistemology relates to how the world is perceived and the relationship existing between the researcher and the known (Naslund 2002). In their view Burrell and Morgan (1979) conclude that epistemology is concerned with the manner in which one might comprehend the world and transmit this as knowledge to others. The methodology of the research determines, however, how the research will be conducted (Blaikie 2000). Familiarity with the philosophical underpinning of a research study at the initial stage is useful in helping the investigator clarify alternative methods and designs for executing the study, and identify those that are more likely to be suitable in practice.

The most appropriate way to classify and understand the ontological position *vis-a-vis* epistemology is to note the distinction between interpretivist and positivist positions. The debates concerning this divergent dichotomy centres on the scientific nature of various epistemological positions. Understanding this divergent epistemology, ontologically coupled with their accompanying philosophical traditions (interpretivism and positivism) serves as a pointer for directing the process for good research work. The two philosophical traditions can be differentiated by the various methods adopted in data collection and interpretation as well as in arriving at conclusions. These philosophical traditions are interpretivism and positivism as examined in sections 4.2.1 and 4.2.3.

#### **4.4 Research Methodology**

Research methodology refers to guided rules for reasoning assisting the investigator in arriving at the inferences to be drawn. Developing a research project does, however, entail rigorous scientific methods so as to ensure the accuracy of the research result. Indeed, the validity of any research work is dependent on the credibility of the scientific process applied in that study (Selltiz et al. 1959). Research methods refer to an enquiry strategy which extends from the underlying assumptions to the design of the research, and the collection of data (Myersa 2009). The choice of the appropriate method of research begins with the identification of the proposed problem to be investigated and the general review of its likely consequences (Hair et al. 2010).

In view of the existence of other classifications in the research modes, the most conventional categorisation of research method is into qualitative and quantitative forms (Bernard and Bernard 2013). At a practical level, quantitative and qualitative implies a classification concerning the nature of knowledge; the world viewpoint and the ultimate research purpose (Johnston and Henry, 2009). On another discourse level, the terms imply the method of research; the manner for data collection and analysis and the type of representations and generalisations derived from the data.

It is worth noting that there no standard way for research methods (Eldabi et al. 2002). There has, however, been the equivalent of a paradigm war between the

two methods of research, i.e., qualitative and quantitative methods in social sciences. Holliday (2007) highlighted the differences between the activities of the two paradigms. Table 4.1 presents major comparison between qualitative approach and quantitative approach emphasising on the position of each of the approach.

**Table 4.1: Major comparison between qualitative approach and quantitative approach**

<b>Qualitative research</b>	<b>Quantitative research</b>
Looks inwards into the standard of social life	Counts occurrences on a huge population
Situates the research within a particular set up which presents opportunities for applying all possible factors and setting reasonable boundaries	Utilises replicability and statistics to validate generalisation from experiments and survey samples
Preliminary foray into setting results to further more informed exploration as focuses and themes emerge	Attempts to minimise contaminating social factors

**Source: Holliday (2007 Pp. 5)**

#### **4.4.1 Qualitative Methods**

The main feature of the qualitative method is it supports an enquiry from inside (Johnston and Henry 2009). There have been attempts to understand differences between people by using the qualitative method and also in applying flexibility in studying the real world (Colin, 2002). Qualitative methods are phenomenological in nature and have given rise to deep, meaningful and rich data (Creswell 2012). The application of the qualitative method has enjoyed considerable acceptance in the field of education, history and, more generally, in other forms of research (Colin, 2002). Qualitative research is composed of a variety of methods for data collection including interviews, documents, and observations (Holland 2007).

In comparison to quantitative techniques, the investigator collecting qualitative information exploits the data gathering context to increase the value of the data (Kidder and Judd 1986). The approach to qualitative research is generally concerned with a subjective review of behaviour, opinions and attitudes (Creswell, 2012). Research in this type of circumstance is the function of impressions and insight into the research (Colin, 2002). This type of research generates outputs



either in a non-quantitative manner or in a manner which is never subjected to highly quantitative analysis (Holland, 2007). Generally, in-depth interviews and focus group interviews are used (Kothari, 1997).

#### **4.4.2 Quantitative Methods**

This method is termed positivist (Bernard and Bernard 2013). Quantitative methods are enquiries from outside and are used in a number of different situations such as during policy making (Creswell, 2003). These methods give rise to hard generalizable data (Amaratunga et al, 2002). Quantitative methods possess the advantage of strong internal validity since similar results may be obtained from repeated experiments (Bernard and Bernard 2013). The data gathered can be subjected to statistical analysis with clear statements made regarding interdependent and causal relationships between variables (Creswell, 2003). The advantages derived from quantitative methods are highly appropriate for testing a significant population where a sample which represents the entire population can be obtained (Creswell, 2003). Once the data are quantifiable, the data may undergo quantitative analysis that relies on quantifying variables thus leading to structured, explicit and concise data (Bernard and Bernard 2013).

In the case of the required information being of a non-measurable nature these advantages are, however, reduced (Bernard and Bernard 2013). Conversely if the data are related to a qualitative phenomenon the analysis may be qualitative in nature (Creswell, 2003). The qualitative approach requires the analysis of complex descriptive information in which the investigator may enhance his or her probing and involvement to acquire additional information (Bernard and Bernard 2013). The methods of research used are usually testing for the presence of variables as opposed to their frequency and this approach usually generates huge volumes of rich information derived from a limited number of subjects (Bernard and Bernard 2013). At the onset of the field work, five research approaches were reviewed by the researcher.

#### **4.5 Theories Employed in this Research**

All researchers base their research work on a particular philosophical viewpoint. This could be on one or more research paradigms based on the nature of the

research they are conducting. In view of the discussion above, the research philosophy underlying this research work comes largely from interpretivism. The interpretive tradition allows the investigator to acquire an in depth understanding of the subject under investigation since subjective meanings assigned to it by participants are discovered (Easterby-Smith, et al., 2002). This allows the researcher to gain a comprehensive and detailed understanding of the topic under study by discovering the subjective meanings attached to it by various participants. As the investigator is attempting to determine the participants' understanding of the challenges facing the Nigerian oil industry in terms of revenue generation, an interpretive approach provides the opportunity to unveil the various challenges facing the industry in the context of revenue generation (Easterby-Smith, et al., 2002).

The research has, however, elements of positivism. The interpretive approach accords the researcher a wider scope to address issues of impact and influence. Thus, the researcher employs a subjective or interactional position concerning the reality being investigated. The interpretivist tradition often addresses important features of shared understanding and meaning whereas the positivist tradition seeks objectivity and applies a consistently logical and rational research approach (Bernard and Bernard 2013). In addition, a mathematical and statistical technique is critical in the method of research applied by positivist researchers. In this research context, knowledge is being constructed by individuals within the social context influenced by prior understanding, thus the investigator positions himself as an investigator around the parameters of interpretivist epistemological discourse.

In view of the fact that the emphasis is based on the nature of reality being socially constructed, the environment needs to be developed in such a way that there exists a strong relationship between the researcher and what is being investigated thus warranting individuals expressing their unique experiences. Such a situation provides the investigator with the opportunity to investigate, understand and gather documents as well as sufficient information via strategies such as in-depth semi-structured interviews, focus group interviews as well as textual data in a socio-cultural context in which the challenges occur. More so, quantitative data is also collected in this research resulting in quantitative and graphical presentation and

analysis of research findings and result thus in the adoption of a positivist approach for this aspect of the research.

#### **4.6 Mixed Methods Research**

According to Creswell (2009) mixed method is a research approach that combines both qualitative and quantitative forms. It mixes and combines the philosophical assumptions underlying the two methods (Myers 1997). The data collection and analysis comprises the use of the two approaches so that the study's strength is enhanced as opposed to the use of qualitative or quantitative research (Creswell 2009).

The choice of either of the two models of qualitative or quantitative research depends on the research objective and several researchers are of the view that the findings are more beneficial when both methods are mixed (Miles and Huberman, 1994).

The mixed research mode has a long history in the practice of research because active researchers have frequently skipped what was documented by the methodologist when they realised that a mixed mode approach would best assist them in addressing their research questions (Johnson, et al., 2004). According to Johnson et al. (2004), their practice can be linked to the five main rational purposes for conducting mixed mode research:

- a) Triangulation which refers to corroboration and seeking convergence of findings from various designs and methods investigating the same phenomenon;
- b) Initiatives which refers to discovering contradictions and paradoxes that results to a modification of the research questions;
- c) Complementarities which refers to seeking enhancement, clarification and elaboration of the findings from one method with findings from other methods; and,
- d) Expansion which refers to expanding the range and breadth of research by applying various methods for various components of enquiry.

## **4.7 Case Studies**

In order to generate information for use in developing the SD model, a series of qualitative interviews were carried out with the relevant stakeholders in the industry. This section presents the summary of the revenue related issues in the Nigerian oil industry based on interviews with:

- Nigerian National Petroleum corporation (NNPC)
- Department of Petroleum Resources (DPR)
- Federal Inland Revenue Services (FIRS)
- Nigerian Extractive Industries Transparency Initiatives (NEITI)
- Presidential Committee on Amnesty Program (PAP)

### **4.7.1 Case Study Analysis**

On the basis of the information generated from the interviews conducted and extensive review of relevant documents and literature, causal loop diagrams were produced to depict a summary of the key variables relevant to the generation of potential revenue from the Nigerian oil industry.

### **4.7.2 Revenue Generation Model Summary**

The model is made up of four sub views: in developing the cause and effect relationship model for the challenges facing revenue generation in the industry, the four sub views described below were considered:

#### **4.7.2.1 Exploration sub-view**

In terms of the operation and activities of petroleum entity leading to the production of crude oil, exploration serves as the first step in the entire life cycle. Important decisions concerning the viability of the project are considered at this stage. Issues of proven, unproven, recoverable and ultimate recoverable are also determined at this stage of the project. The development of exploration sub view of the model for this research is presented in chapter 8, section 10.

#### **4.7.2.2 Development sub-view**

This sub view relates to investment issues in the industry. At the core of the development sub view is a focus on investment in the industry and its associated challenges. Specifically, this sub view is concern with those challenges which according to stakeholders in the industry, are most deeply concern about. It is a common practice in joint venture operations that the respective partners contribute to the capital on the basis of their respective interest in the venture for smooth operations of the venture. In the case of Nigerian government which is a co-partner to the venture, its persistent failure in meeting its cash call obligation has resulted to delay in project completion thus leading to sourcing alternative funding for sustainable operation. This failure had resulted to reduction in government revenue as occasioned by accrued interest from the loan (alternative funding) sourced. The development sub view of the model for this research is presented in section Chapter 8, Section 11.

#### **4.7.2.4 Production sub-view**

Generally this sub view depicts profound challenges facing the Nigerian oil industry. The view encompasses the challenges that have denied the Nigerian government potential revenue from this natural gift. These challenges as earlier stated in chapter 2 section 3 include bunkering (crude oil theft), vandalism, militancy, community unrest and other sector specific challenges. The production sub view of the model for this research is presented in Chapter 8, section 12.

#### **4.7.2.4 Revenue sub-view**

This is from the research focus of this research most important sub view as it relates to the government take from the industry. Specifically, corruption is considered as the main challenge facing a ‘successful’ outcome in this sub view. The Revenue sub view of the model for this research is presented in Chapter 8, section 13.

## **4.8 Summary and Conclusion**

The chapter introduces the philosophical assumptions concerning what implies as a valid research and the research methods suitable for the development of knowledge in a given study. Specifically, the nature of investigation along three key dimensions including ontology, epistemology and methodology are highlighted in this chapter. The chapter also discusses three research paradigms: positivist, critical and Interpretive. Overview of various research methods were also highlighted in this chapter. The chapter also highlights research strategies which set a procedure or logic that paves the way to addressing the research questions, research methodology which refers to guided rules for reasoning assisting the investigator in arriving at the inferences to be drawn and also the theories employed in this research work. In addition, Case study and case studies analysis are also explained in the chapter. The chapter also brief discusses on revenue generation model in this research work. Finally, the summary and conclusion of the chapter is presented.

## **CHAPTER FIVE: SYSTEM DYNAMICS MODELLING METHODOLOGY**

### **5. Introduction**

This chapter sets the foundation for the conceptual framework of the current research. Specifically, the research draws from the intellectual integrity of System Dynamics (SD) which also draws from control theory and non-linear dynamics originally developed for dynamic industrial and mechanical systems where delays, feedbacks, stocks and flows play a crucial role in the behaviour of complex systems. The methodological aim is, therefore, to present SD and its related simulation approaches as an analytical technique whose strength in analysis of systems is not only feasible but increasingly beneficial for those systems of a complex nature. This approach emphasises the holistic and dynamic view point of a system of interest. Specifically, the researcher employed SD as a modelling approach in order to understand the behaviour of factors inhibiting the realisation of optimal government revenue from the Nigerian oil industry.

Given the fact that crude oil activities are comprised of several interrelated processes, the research combines these segments together in order to acquire a holistic and insightful view of the whole system. The ultimate purpose of the chapter is to help in developing a theoretical framework which can be applied to investigate the research problem. The chapter also serves as the intellectual integrity upon which this research work is based. Since the research intends to develop a model within System Dynamics paradigm, the need to present a brief highlight of models in general and System Dynamics model in particular need not to be overemphasised.

#### **5.1 Model**

A model is an imitation or mimicking of reality which can be theoretical, logical or physical (Ackoff and Sasinieni 1968). It is a substitute for a system or an object (Forrester, 1968) which offers a unique capability for clarification and communication (Saeed, 1994). This view was strengthened by Richardson and Pugh (1981) who described a model as a simplification of a portion of reality. In

view of the fact that the real world is in reality complex and exhibits a variety of interacting elements, models are therefore rendered to be absolutely deficient in replicating this reality in its entirety. In this case, a model must therefore mimic the real world devoid of elements that are essentially not important in the mind of the modeller (Forrester and Senge, 1980), thus yielding information at a reasonable cost (Forrester, 1961).

The selection of a proper or appropriate degree of details of a model is daunting and can even be controversial. This implies that modelling is more an art than a method (Chick 2006). As expressed by Forrester (1961), the value of a model arises as a consequence of its ability in improving human understanding of unclear behaviour more effectively than could be conducted through the observation of the real system. Sterman (2000) concluded, therefore, that human thinking processes depend on models *via* which the world around us is conceptualised and organised. Sterman (2000) further added that a significant amount of such conceptualisation is automatically performed in the human mind which is the essence of the human mental model. This, therefore, brings mental models to a fore.

## **5.2 Mental Model**

From the description of models in the previous section, it is understood that human thinking depends on a model and this model is known as the mental model. This section, therefore, builds upon the previous section in describing a core aspect of system thinking-mental model. Vennix (1996) describe mental model as a conceptual representation of social conditions and/or problems which can be externalised through the use of a causal loop diagram. The mental model involves opinions, ideas, generalisations, assumptions, concerning policy problems and similar issues (Vennix 1990). Sterman (2000) offered two definitions of the mental model: a narrow one in which he defines the mental model as the set of information and assumptions embedded in individuals' minds concerning an aspect of interest. This is accompanied by a broader one in which he defines the mental model as an accessible and enduring, but confined, inner conceptual symbol of an exogenous system whose structure retains the system's perceived structure.



In all cases these mental models are very simple, of necessity in comparison with the real system from which they are abstracted (Forrester, 1972). Human mental models determine the way they take action in addition to the way they make sense of the world (Senge, 2006). To quote Senge (2006):

“Mental models can be simple generalisation such as “people are untrustworthy”, or they can be complex theories, such as my assumptions about why members of my family interact as they do (Senge, 2006 pp-164).”

Sterman (2000) explains that a fundamental deficiency in individual mental models is the tendency to consider cause and effect as immediate and local. Sterman (2000) went further to emphasise that in a complex system that is dynamic in nature, causal relationships are distanced both in time and space. In this case, the mapping of a mental model, while essential, is far from being adequate. On the basis of this, the need for an explicit model needs not to be overemphasised. It is not surprising, therefore, for Richardson and Pugh (1981) to state that a formal model possesses 2 advantages over human informal models on the basis of which human decisions rest. The fact that formal models are explicit makes them communicable as opposed to the non-communicable nature of most mental models. In the next section more discussion is provided on the benefits of modelling especially for research purpose

### **5.3 Benefit of Modelling**

Modelling permits the incorporation of information, process, organisation, systems, and data (Davies 2001) within a research study. According to Bonabeau, (2002) modelling provides a natural description of a system that assists in developing an understanding of the system. Therefore modelling facilitates analysis, multiple view points and viewing of relationships (Davis 2001) which thus provides information to assist decision makers in selecting appropriate and suitable strategies (Bennett 1992) for the exploration of options for improvement (Bonabeau, 2002). According to Davies (2000) modelling offers an ideal avenue for the evaluation of “what if”? Scenarios. In terms of SD modelling, it is increasingly considered as a practical way of facilitating the translation of decisions into action by decision-makers. According to Stave (2002), System dynamics provides five key benefits including a problem focus, seeking causes of problem in

the system structure, documentation of processes, provision of an enhanced public participation framework, and finally serving as a tool for policy design and learning. Managers can therefore utilise System dynamics models as “flight simulators” thus serving as a practice environment. System dynamics offers the opportunity for experimentation and reflection thus warranting decision makers to more fully grasp the complex system in which they work (Stave 2002). Model based research such as SD allows the involvements of stake holders in the process thus result in the incorporation of their inputs (Voinov and Bousquet, 2010).

#### **5.4 Choice of Modelling Technique**

In selecting a modelling technique befitting the circumstances, the purpose and nature of the research was considered. For example, according to Richardson and Pugh (1981), a model is constructed to address a particular set of questions from the SD view point; therefore, it is problems that are being modelled as opposed to systems. On the basis of this, and the nature of the problems this research work intends to address, the following considerations were made before arriving at an acceptable and suitable modelling approach.

##### **5.4.1 System Dynamics vs Discrete Events Simulation**

In the view of Forrester (1961), social and management scientists commonly model discrete events and depend on discrete modelling methods. In contrast, SD modellers use differential equations and continuous modelling. The most vital function of a SD computer model is to warrant experiment and hence to develop system strategies and structures for improving the behaviour of a system (Wolstenholme 1990). At this stage, it is crucial to establish the appropriate modelling method to examine the problem. Specifically, this research is about the Nigerian oil industry, precisely those challenges facing the industry in terms of revenue generation. These challenges are complicated, complex, and interrelated, involving numerous variables possessing causal relations and feedback. Consequently, the need for a dynamic framework with which these variables are allowed to act on each other over a period of time as they operate in the real world need not be over emphasised. This also accords the opportunity to examine the

interdependence and foresee the impacts of a variety of policies via the dynamic based model. A befitting methodology for this case is SD modelling methodology.

On the basis of this specifically, the researcher decided to employ the SD modelling paradigm in this research. SD provides the opportunity to evaluate the problem more elaborately through the consideration of a dynamic feedback. It enables all the variables within the system to be connected to each other. On the basis of this, SD computer models are resorted to due to their ability to assist human mental procedures to deal with such systems. The majority of the side effects of decisions resulting in policy resistance comprise feedback involving long delays, far detached from the decision or the symptom of the problem (Sterman 2000). On the basis of this, the need for a dynamically sufficient model cannot be overemphasised.

## **5.5 System Dynamics**

SD is a computer assisted approach for solving and analysing problems of a complex nature (Sterman 2000). A more succinct definition was offered by the SD society as a computer-assisted technique for policy design and analysis which applies to problems of a dynamic nature arising in complex economic, managerial, social, or ecological systems and any dynamic systems which are characterized by mutual interaction, interdependence, circular causality and information feedback. The utility of SD as a powerful method with a set of tools for analysing and modelling situations of a complicated nature is therefore not contestable. To quote Wolstenholme: SD refers to:

“A rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes , information, organisational boundaries and strategies; which facilitate quantitative simulation modelling and analysis for the design of system structure and control.” (Wolstenholme, 1990, pp 3).

SD's application may not necessarily generate a strategy for an evolutionary improvement, albeit that it may easily develop models which sufficiently offer scientific clarification of observed phenomena (Saeed 1994). SD focuses on the utilisation of diagrams as a means of communicating mental models providing for the discussion of change (Wolstenholme 1990). This form of medium is valuable

since it provides a more compressed and relatively clear form of communication than a textual description (Wolstenholme 1990). Although Forrester (1961) noted SD as a methodology, grounded in the modern theories of non-linear dynamics and control theory, it is in all cases concerned with the representation of real systems or developing models of all kinds and investigating their dynamic behaviour with the improvement (control) of problematic behaviour (Wolstenholme 1990).

The literature in SD states two common features characterised by the problems addressed from an SD point of view. Firstly, they are comprised of quantities that change over time: they are dynamic; these can be represented in terms of over time graphs of variables; and, secondly, with respect to the features of the problems addressed by SD the notion of feedback is evident (Richardson and Pugh 1981; Saeed 1994; Vennix, 1996; Wolstenholme 1996; Sterman, 2000; Senge, 2006). In all cases it is obvious that the SD process is based on the principle that systems are comprised of two fundamental components; information structure and process structure (Wolstenholme, 1990). Or, as Wolsteholme (1990) and Saeed (1994) state, it strongly emphasises the endogenous functioning of an entity. The rationale behind the internal characterisation of problems within an SD framework is to provide policy makers with the opportunity to influence systems for the sake of their behaving in an anticipated and desired pattern (Sterman, 2000). The fundamental of the modelling approach is the representation of the system structure in relation to stocks and flows. In this regard, feedback loops constitute the necessary building blocks for the articulation of the dynamics of the models; hence their interactions can explain system behaviour after it has been adequately represented (Chaucri, et al., 2006).

This discussion is in line with Vennix (1996) who pointed out that it affords a means for capturing feedback effects and complex relationships within a set of interacting processes and activities. It is clearly obvious that it has a user friendly interface in terms of presentations which encourages non-academics to understand and internalise the underlying nature of its logic. Similar views have been shared by Sterman (2000) concluding that, the approach warrants the utilisation of both qualitative and quantitative data, consequently, it is not limited in its application when qualitative data is not available. Most of the art of SD modelling are

detecting and representing the feedback structures which along with level and rate structures, delays, and nonlinearities define the dynamics of a system (Sterman, 2000).

SD can specifically be described as an exercise involving these steps: (a) developing an understanding and clarifying knowledge of the system based on a feedback approach; (b) using causal loop diagrams (CLD) in capturing and modelling of the feedback; and, (c) developing an SD simulation model based on mathematical equations and stock and flow structures. An SD framework is a method which can be used to model process structures in order to analyse their behaviour *via* the examination of how resources flow and accumulate as well as interact in a system over time in a dynamic independent feedback (Vanderminde 2006). SD methodology develops models of selected system aspects to examine specific behaviour as a way of investigating problems that are of a systemic and dynamic feedback nature (Sterman 2000).

## **5.6 Application of System Dynamics in Current Research**

The operations involved in crude oil production are interrelated: the exploration of crude oil, the development of facilities, the production of crude oil up to the sales leading to the realisation of revenue and reinvestment of the revenue constitute a highly iterative exercise. Although the exploration of crude oil may be separated from other phases such as development and production, yet there is a continuing and an intimate link between all the phases involved in crude oil operations. The challenges facing this leading to failure in realising full economic benefit from the industry (as stated in chapter 2) formed the focus of the scholarly work presented in this research. The literature describes each phase of crude oil activities with its own associated challenges. But what is more visible is that all the challenges ultimately impact negatively on the overall revenue generation of the industry. This again affects investment decisions in the industry and thereby affects overall performance of the industry. SD has established itself as a powerful methodology with its own paradigm (Mohapatra and Mandal 1989) as well as an emphasis on a holistic view of a system (Sterman 2000).

The process of modelling using SD is iterative, albeit the steps to be taken may appear to be not chronological. Examining causal relationships between elements in a system is the fundamental focus in SD (Sherwood 2002). As a modelling methodology, SD can be applied to identify factors that need to be improved in order to address challenges inhibiting the realisation of potential revenue from the Nigerian oil industry. The utilisation of SD in this research work for the purpose of developing the model has therefore been further justified based on the following:

- Crude oil production is extremely complex and is comprised of multiple interacting components. The interactions complicate analysis beyond the abilities of mental models since a change in one aspect of the system could have possible implications in other distance aspects. For example, cash call short fall in the development sub-view might result in the scaling down of production in the production sub-view of the industry. On the other hand, providing alternative financing might address the issue but again negatively affect the revenue generation profile in the industry. The research investigates the challenges facing revenue generation in the oil industry in the process of crude oil exploration up to revenue generation which may be as a consequence of several components interacting in a complex relationship. SD presents a suitable model of multiple interrelationships. Certainly, one of the fundamental applications of SD is to capture such interrelationships so that the cause and effect may be traced along the system (Sterman 1992). Additionally, System Dynamics has been applied in a variety of areas in the energy sector (Naill, 1973; Naill, 1976; Sterman, 1980).

- Challenges facing revenue generation in the Nigerian oil industry are highly dynamic. The process of crude oil production is naturally dynamic. In addition, the occurrence of some kinds of challenges will result in the occurrence of other challenges leading to the occurrence of other challenges while attempting to address these challenges. There are several time delays evident in embarking on remedial actions and in responding to unanticipated challenges in the industry. Such dynamic elements imply that the short-term remedial action to a system to perturbation might be different from the long-term remedy. SD as a methodology was developed to address dynamic issues. Accordingly, Sterman (1992) concludes that SD has extensive procedures for the accurate presentation, explanation, and

analysis of the dynamic managerial and complex systems of all the types of formal modelling techniques.

- Crude oil production and challenges facing revenue generation involves a multiple feedback process. A system of a complex nature such as crude oil production and the occurrence of challenges across the entire phases of the industry contain a multiple interrelating feedback process. These feedbacks can either be the self-reinforcing or self-correcting side effects of decisions. Feedback relationships are important to the dynamics of technical, managerial, and other systems. According to Sterman (1992), SD modelling is a suitable technique whenever there are important feedback relationships.

- Challenges facing revenue generation in the industry involves non-linear relationships. Nonlinearity implies that causes and effect relationships do not have proportional, simple relationships. SD, beyond the ability of other modelling methods, emphasises the significance of non-linearity in the formulation of a model (Sterman, 2000; Wolstenholme 1990).

- Crude oil activities as well as challenges facing the industry comprise both soft and hard variables. An oil industry is not purely a matter of technical and engineering aspects alone. It also comprises humans as stakeholders, and thus cannot be understood exclusively in terms of technical interdependencies among components. Most of the important data required to understand the challenges militating against the realisation of potential revenue from the Nigerian oil industry will concern soft variables. Forrester's argument regarding the inclusion of soft variables into models is explicit. If relying on only hard variables, the model would unavoidably exclude important data and implicitly assume that those data are irrelevant.

The majority of the data are qualitative and descriptive albeit the numerical information involves a significant portion of the data in the numerical database, which in turn is minimal in comparison with the information, embedded the mental models of system actors (Sterman 2000). Mental information comprises all the information embedded in the heads of the system actors, including the stories narrated by them, impressions, their knowledge of the system and the manner in

which decisions are actually undertaken, for example. SD utilises multiple information sources including interview, observation, numerical data, and other methods to elicit the decision rules, goals, organizational structures, and other significant managerial aspects of the system. All these sources of information are utilised for the specification of relationships in the model (Sterman 2000).

- The goal of models within the framework of SD is to depict as closely the unbiased and real picture of real system, including accurate estimates of all the parameters. The depicted picture might not necessarily be elegant but it constitutes the truth, comprising several imperfections of the real system. Presumably, a model within the modelling framework of SD will unify, organize, and clarify understanding (Forrester 1991). On the basis of the above justifications, the suitability of system dynamics as a modelling methodology could assist in addressing the problems of the current research.

## **5.7 System Dynamics Modelling Tools**

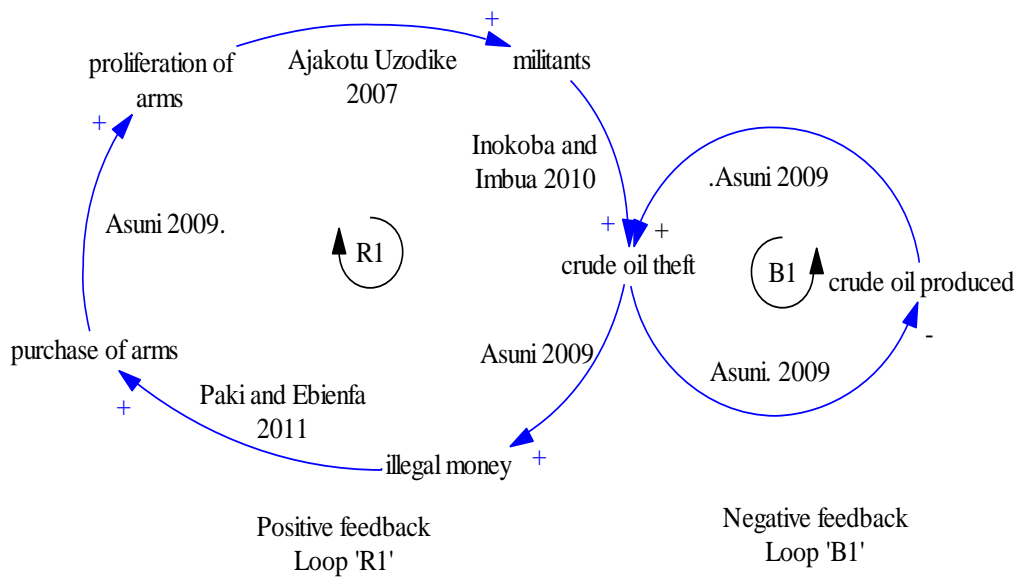
Numerous of the SD tools are specifically designed to aid in developing beneficial, effective and reliable models to serve as virtual worlds to assist in learning and policy design. These tools include the following.

### **5.7.1 Causal Loop Diagram (CLD)**

A causal loop diagram (CLD) is a visual diagram depicting the relationships of interest in a particular system (Sterman 2000). It portray cause and effects in relationships, in a way that emphasises the complete, highly interconnected nature of the problem of interest, thus capturing the way everything is connected to everything else (Sherwood 2002). In order to conceptualise a system under study, emphases is focused by System Dynamicists on the structure and dynamic behaviour of the system based on multiple feedback loops. It is a close path of information and action, close sequence of cause and effect relationships (Richardson and Pugh 1981). These feedback structures are graphically presented using a causal loop diagram in Figure 5.1 which is a section of the main causal loop diagram of the research.



**Figure 5.1: Simple Causal Loop Diagram.**



**Source: Author’s work and synthesis from literature**

A causal loop diagram is a SD tool employed to depict a feedback loop in an explicit diagram (As shown in Figure 5.1). A loop refers to a closed system composed of a number of variables and causality. A high level means of model conceptualisation with regards to their feedback loop structure is provided by the causal loop diagrams as shown in Figure 5.1 Formal procedure for depicting and presenting causal relationship is by the use of arrows and signs at the end of the arrows (Sherwood 2002) as represented in Figure 5.1. The variable at the head of the arrow is logically affected by the variable at the tail (Sterman 2000). The causal effect and relationship is however depicted by the sign at the head of the arrow under an ideal situation, i.e., when other variables remain constant. The signs i.e plus and minus entail the following meanings (Sherwood 2002):

The positive sign (“+”) indicates that both the causing and the affected variables move in the same direction or way when the causing variables change (see Figure 5.2).



The negative (“-”) sign indicates that both the causing and the affected variables move in opposite directions and ways when there exists a change in the causing variable (see Figure 5.1).



In addition to the respective sign in individual links, there is also feedback loop which according to Sterman (2000) is the flow and return of information within a system.

### 5.7.1.1 Feedback loop

A feedback loop constitutes the basic building block of all systems (Forrester 1969) which can be balancing (negative) or reinforcing (positive) feedback (Senge 2006). Additionally, the entire loop is marked with a sign.

According to Sherwood (2002), the determination of balancing and the reinforcing loops can also be conducted by counting minus (-) signs presents on all links that constitutes the loop. Specifically,


A feedback loop is considered reinforcing (indicated by  or  sign), if it comprises an even quantity of negative links as indicated in feedback loop 'R1' in Figure 5.1.

A feedback loop is considered balancing (indicated by  or  sign), if it comprises an odd quantity of negative links as indicated in feedback loop 'B1' in Figure 5.1.

Therefore, the sign of a loop imply the algebraic result of the sign of its own links. In order to enhance the understanding of the feedback loop, an interpretation of a reinforcing feedback loop R1 between 'militant', 'crude oil theft', 'illegal money', 'purchase of arms', and 'proliferation of arms', is explained in details below (see Figure 5.1).

An increase in 'militants' has the potential to increase the rate of 'crude oil theft' (depicting a positive influence, '+' sign) (Inokoba and Imbua 2010). A higher rate of 'crude oil theft' will tend to increase 'illegal money' (depicting a positive influence, '+' sign) leading to an increase in the 'purchase of arms' (the increase in illegal money increases the purchase of arms; this depict a positive influence, '+' sign) (Paki and Ebienfa 2011).

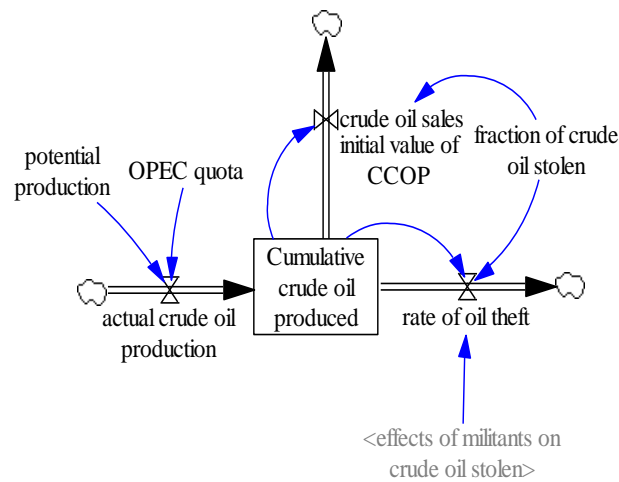
An increased 'purchase of arms' will lead to 'proliferation of arms' (depicting a positive influence, '+' sign) (Asuni, 2009), which, in turn, will enhanced the number of, militants' (the higher the proliferation of arms, the higher the number of militants; this depicts a positive influence, '+' sign) (Ajakotu and Uzudike 2007). Positively enhancing militants closes the loop. Therefore the feedback loop linking 'militant', 'crude oil theft', 'illegal money', 'purchase of arms', and 'proliferation of arms' depict a reinforcing loop as indicated by the R sign (see Figure 5.1).

A balancing loop B1 between 'crude oil produced' and 'crude oil theft' can also be described as follows (See Figure 5.1). An increased in 'crude oil theft' will tend to decrease 'crude oil produced' (depicting a negative influence, '-' sign) (Asuni 2009). On the other hand, as 'crude oil produced' increases, rate of 'crude oil theft' increases (depicting a positive influence, '+' sign) (Asuni 2009) thus closing the loop. Therefore the feedback loop linking 'crude oil produced' and 'crude oil theft' depict a balancing loop as indicated by  sign (see Figure 5.1) (Detailed discussion for causal loop diagram for this research is presented in chapter 8)

### **5.7.2 Stock and Flow Diagram (SFD)**

While a causal loop diagram emphasises the feedback processes of a system, stock and flow diagrams (SFD) emphasise the underlying physical structure of a system (Sterman, 2000). Stock (level) and flow (rate) track accumulations of information, material, and money as they move through a system (Sterman, 2000). Stocks include population, inventories and financial items, such as debts and cash (Sterman, 2000). Flows are the rate of increase or decrease in stock, such as production and shipment, births and deaths, receipt and expenditures (Sterman, 2000). Stocks characterise the state of the system and produce the information on the basis of which decisions are made. Figure 5.2 presents a stock and flow diagram which is a section of the main stock and flow diagram of the research.

**Figure 5.2: illustration of a stock and flow diagram**



**Source: Researcher' own work and synthesis from Sterman (2000)**

In Figure 5.2 the variable actual crude oil production (inflow) accumulate the stock cumulative crude oil produced which is depleted by variables (out flow) rate of oil theft.

In SD modelling, stocks are measured in units (therefore the cumulative crude oil produced which is a stock is measured in Barrels) and flows are measured in units/time (therefore the actual crude oil production and rate of oil theft which represents inflow and outflow respectively are measured in Barrels/year). Stocks are structurally represented in a rectangular form whereas flows are represented by an arrow like shape with a tap signifying that it can be adjusted and regulated (Vennix, 1996) as presented in Figure 5.2.

Flows can be bi- or uni-flows. In the case of bi flows, the flow can be in either way or direction while the latter flows in only one way and direction. The sinks and sources of the flows are depicted and represented by a cloud (see Figure 5.3). A source signifies the stocks from where a flow originating outside the model boundary arises; sinks represent the stocks into which flows exiting the model boundary drain (Sterman, 2000) (see Figure 5.3).

The stock and flow diagram comprises nodes for each of the model parameters and, because of this, it is therefore more complex than the causal loop diagrams. It is

used for the development of a set of equations which is utilised in a numerical simulator to derive the system behaviour (see Figure 5.3).

Usually, understanding the dynamics of a system entails connecting the feedback loop with the stock and flow structure. The determinants of rates include any constant and exogenous variables. Constants and exogenous variables are stocks. The rates of flow represent activities, while the resulting level to which the system has been occasioned by the events is measured by the stocks (Forrester 1961).

## **5.8 System Dynamics Modelling Approach and Process**

SD models attempt to identify the underlying feedback processes generating the system's problems and thus search for the dynamic process underlying the behaviour of the system (Vennix, 1996). The SD approach combines two distinct but interrelated approaches that work separately in research design: the quantitative approach and the qualitative approach. According to Vennix (1996), qualitative SD involves problem articulation and conceptualisation stages, whereas quantitative modelling extends to development of a complete SD model comprising its simulation. Both serve as the methodology for the development of both the conceptual and formal models in this research.

These two should therefore be understood before the commencement of the modelling exercise. The structures create a forum for converting barely perceived assumptions and thoughts regarding the system by respective key actors into meaningful ideas worthy of communication to others (Richardson and Pugh, 1981).

A similar view was shared by Vennix (1999), thus pointing out that SD comprises two separate aspects which can be applied in response to the recognition of a problem or cause for concern. These, according to him, are qualitative and quantitative SD. This method (Qualitative and Quantitative) is in practice both within and between phases and stages is an iterative process (Richardson and Pugh, 1981). Table 5.1 presents a highlight of the features of the individual aspects

**Table 5.1: Qualitative vs Quantitative System Dynamics**

<b>Qualitative System Dynamics</b>	<b>Quantitative system Dynamics</b>	
Diagram creation and analysis stage	Simulation stage	
	Stage 1	Stage 2
To develop and assess feedback structure of systems utilising resource flows depicted by stock and rate variables flows of information, denoted by auxiliary variables.	To investigate the quantitative behaviour of the entire system variables over time.	To develop alternative system control strategies and structures on the basis of (a) intuitive ideas (b) control theory analogies (c) control theory algorithms in relations to non-optimising robust policy design
To offer a qualitative evaluation of the relationship between system processes (such delays), strategy, information, and organisational boundaries	To investigate the sensitivity and validity of the behaviour of system to changes in (a) information structure (b) strategies (c) uncertainties/delays	To optimise the behaviour of particular system variables
To estimate the behaviour of system and to postulate strategy, design, and changes to improve behaviour		

**Wolstenholme (1990, pp. 4)**

### **5.8.1 Qualitative System Dynamics**

This aspect of the method is concerned with developing a cause and effect diagram which is referred to as a causal loop diagram based on rigorous and precise guidelines and applying this to analyse and explore the system (Wolstenholme, 1990). Coyle (2000) stresses that qualitative dynamic modelling can be beneficial in its own right and that simulation may be unwise once it is pressed beyond rational limits. This view is shared by Wolstenholme (1999), thus explaining that a model can in some instances be completely qualitative, comprising only a causal diagram. The formulation stage culminates via model operationalization by converting the initial conceptual validated causal diagrams into a full SD model (a

detailed discussion is presented in chapter 8). To quote Wolstenholme (1990), further extends the claim that the phase of diagramming and analysis could itself be regarded as a qualitative aspect of SD.

This research intends to extend the qualitative aspect of the modelling exercise to the quantitative phase and hence propose the development of an SD simulation model.

These structures are created with the relevant stakeholders to warrant their mental model regarding system strategies and structures to be made explicit. The term structure is used to describe the information process and the process of a system and is termed as the information feedback process of the system (Wolstenholme, 1990). On the basis of this, SD models are usually considered as structuring the feedback processes of a situation. It is a cardinal principle of SD that the feedback processes of a system constitute the major determinant of its behaviour over time (Sterman, 2000). The structures provide a platform for translating perceived assumptions and thoughts regarding the system by respective actors into beneficial ideas that can be transmitted to others. Once developed, the structures can be applied to qualitatively discover alternative strategies and structures both endogenously and exogenously, which might be beneficial to the system (Sherwood, 2002). Despite the fact that comprehensive simulation is not recommended at this stage, it is feasible from the feedback processes of the structures to ascertain their potentially general behavioural direction (such as growth or decline).

### **5.8.2 Quantitative System Dynamics**

This is the second aspect of the method and is supported by the use of specialised quantitative simulation software. The strength of quantitative SD modelling has been enhanced significantly in recent years through the development of computers and related software (Wolstenholme, 1990). It is a more traditional and conventional aspect and involves a joint effort with system actors in deriving relationships between the entire variables within the maps, the derivation of simulation equations, parameter calibration and experiments (Wolstenholme, 1990). The procedure for this quantitative modelling will initially comprise

systematic calibrations of the model with historical time series data (Sterman, 2000). This, according to Sterman (2000), is to achieve congruency with known real behaviour. Despite the facts that numerical values are attached to variables at this stage, it should be stated that the method is not geared towards accurate solutions or predictions (Richardson and Pugh, 1981). Additionally, through the application of some of the experiences out of the outcome of the quantitative simulation modelling in other systems, it is feasible to apply guidelines for restructuring of system strategies and structures to enhance behaviour of the system (Wolstenholme, 1990).

It is feasible to provide accurate behaviour predictions and design specific strategies for control in quantitative SD (Richardson and Pugh, 1981). This implies that the approach affords an advanced technique to support the assessment and design of the information pattern of the systems (Richardson and Pugh 1981). It should be noted that the first step in constructing a computer simulation model is to make an attempt in quantifying the relationships defined by the links of a causal diagrammatic model (Wolstenholme 1990).

### **5.9 Pattern of Behaviour**

System Dynamics, quantitative or qualitative, is applied to distinguish among alternative strategies by exploring model dominant feedback mechanisms, sensitivity, and pressure points. To start considering the structure of a system, it is imperative to generalize from the particular events related to the problem to the consideration of the behavioural pattern that characterizes the situation. This normally requires study into how variable(s) of interest change over time, i.e., what pattern of behaviour is exhibited by these variables? A system approach develops much of its strength as a problem-solving technique out of the fact that related patterns of behaviour manifest in a number of different circumstances, and the pattern of behaviour is known to be caused by the underlying system structure (Senge 2006). Through finding and adjusting the system structure, there is a tendency towards completely eradicating the problem behaviour pattern (Craig 1998). The behavioural pattern of the variables will be presented while highlighting the model in Chapter 8. The patterns of behaviour that follow are the acceptable patterns of behaviour (Sterman 2000):



### 1- Exponential growth

This type of growth manifests from positive (self-reinforcing) feedback loop. The greater the quantity the higher its net increase, further enhancing the quantity and resulting in ever-faster growth. This implies that an initial quantity of a particular variable starts to grow, and the growth rate increases. It is worth stating that the growth may not exactly follow this feature, but the fundamental idea of growth acceleration persists. A typical example of this includes the total cash call shortfall that had continued to accumulate.

### 2- Goal seeking

This pattern of behaviour seeks equilibrium: balance, and equilibrium. It is negative (goal-seeking) behaviour, where the quantities of interest begin either below or above time and goal level time moves towards the goals (Azar, 2012). A typical example of this can be obtained from government expected revenue to fill a gap and for action to reduce corruption back to government expected revenue.

### 3- Oscillation

This constitutes the third fundamental behaviour mode experienced in dynamic systems. It is worth mentioning that initially oscillation exhibits exponential growth, and later turns to an s-shaped growth before finally reversing direction.

## **5.9 Delays**

Not all causal relationships arise instantaneously. According to Senge (2006), delay refers to interruptions between human actions and their eventual consequence. Most of the time, the effect of decision or an action are not noticed until several days, weeks, months, and sometimes even years after the occurrence of an event (Sternan, 2000). More often than not, the causal relationship is obscured by time and space. Understanding a system is extremely difficult when the consequences cannot be observed in close proximity to the system behaviour. Several decisions and actions have outcomes that remain unknown for years and may not be related to early mistakes. Delays are ubiquitous in the real world. A funding of joint venture obligations may, for instance, have negative side effects when alternative

funding is delayed. Unrecognised delay can give rise to breakdown and instability particularly when they are long (Senge 2006).

Delays can generate complex and interesting behaviour in systems, even in situations where those systems possess no feedback and insignificant cause and effect complexity. Delay factor will be explained while description is being made at the formulation stage of the model in Chapter 8.

### **5.10 Summary and Conclusion**

This chapter has presented a brief overview of the framework adopted in the current research. Specifically, the chapter begins with an introduction which is followed by a brief description of model and choice of modelling technique. The rationale for adopting SD in the current research work is also highlighted, thus justifying its adoption as a suitable technique for addressing the issues earlier highlighted. The chapter also focused on the historical development of SD. This therefore made a remarkable reference on the application of SD particularly in the energy sector and other complex problems in general. The chapter progressed by articulating the application of SD in the current research work. Causal loops and stock and flow structures as the basic modelling tools in SD were briefly discussed in this chapter. Qualitative and quantitative SD as the two complementing phases, as well as the technique employed in diagramming causal loop diagrams for the current research work were also highlighted before finally concluding this chapter.

## **CHAPTER SIX: SYSTEM DYNAMICS MODELLING FRAMEWORK**

### **6. Introduction**

The previous chapter introduces the intellectual foundation for the theoretical framework of this research highlighting the background as well as the application of SD. This chapter builds upon the previous chapter by describing the requirement and steps for successful modelling within the framework of SD. Specifically, the chapter focuses on steps involved in developing SD models and the approach adopted in developing the model as well as the source of information utilised by the researcher for the development of the model. Finally, the conclusion of the chapter will be presented.

#### **6.1 Steps in Developing Model within System Dynamics Framework**

In describing the process of modelling, experts in SD have arranged the main activities of the modeller using a variety of arrangements, ranging from three to seven distinct strata. At one point, Wolstenholme (1990) is noted to have recognised the process in three distinct strata. Conversely, Richardson and Pugh (1981) viewed the modelling exercise as a process involving seven distinct steps. In related but distinct views, Randers (1980), Roberts et al., 1983 and Sterman (2000) have categorised the modelling activities in four, six and five stages respectively. Although the patterns of categorising the exercises differ among the various authors, yet the respective activities considered among the various phases remain fairly the same across them, warranting the making of a contrast like the one presented in the following table (table 6.1). Randers' (1980) stage of conceptualisation or Wolstenholme's (1990) diagram development and analysis regards processes that can be diagrammed into the stages of definition of problem and conceptualisation of system from Roberts, et al. (1983) and Richardson and Pugh (1981). The stage of dynamic hypothesis in Sterman (2000) comprises involves the same processes outlined in the conceptualisation stage of Richardson and Pugh (1981) and Roberts, et al. (1983). In the same vein, model evaluation and model behaviour analysis (Richardson and Pugh, 1999; Roberts, et al., 1983) involve the same activities regarded in the testing phase (Sterman, 2000; Randers,

1980). Table 6.1 below illustrates the classification of steps and processes involved in the developments of model within the framework of System Dynamics.

**Table 6.1: Categorisation of System Dynamics modelling steps**

Sterman 2000	Wolstenholme 1990	Robbert et al 1983	Richardson and Pugh 1981	Randers 1980
Problem articulation	Diagram construction and analysis	Problem definition	Problem definition	Conceptualisation
Dynamic hypothesis	Simulation (stage 1)	System conceptualisation	System conceptualisation	Formulation
Formulation	Simulation (stage 2)	Model presentation	Model formulation	Testing
Testing		Model behaviour	Analysis of model behaviour	Implementation
Policy formulation and evaluation		Model evaluation	Model evaluation	
		Policy analyses and model use	Policy analysis	
			Model use	

**Source: Luna-Reyes and Anderson, 2003**

The table shows the various classifications of steps and processes involved from different system dynamics modellers. This ranges from three to seven depending on individual authors.

On the basis of the above categorisation, it can be deduced that the majority of the mainstream authors share similar views regarding modelling within an SD framework. The slight differences of views among classical authors are more on the categorisation of the stages as highlighted above. Luna-Reyes and Anderson (2003) present an extensive work by conducting a thorough comparison of how various classical authors present their respective processes of modelling within System Dynamics framework. They argue that while the techniques of grouping the processes vary among diverse authors, the processes considered along the diverse stages remain fairly constant across them, warranting the building of a comparison (Chapter 5 section 2).

Developing a model within the framework of SD can assume several differing styles as stated above. The approach adopted in this research work centres, however, on the modelling processes along the steps describes by Sterman (2000).

Five steps are involved in developing the model. These steps were advocated by Forrester (1961) and also described in literature on the SD process (Sterman 2000). Several model interactions must be undertaken before arriving at an acceptable structure (Saeed 1994). According to Sterman (2000), the modelling process within an SD framework involves five (5) basic distinct steps:

### **6.1.1 Problem Definition (Selection of boundary)**

As it is firmly established, all SD modelling efforts start with the articulation of a problem as the first and the most crucial step (Sterman 2000), with the expected conclusion leading to implementation of policy in the real world as a solution to the problem of interest (Saeed 1994). In the view of Forrester (1961) identifying the problem to be explored and questions to be addressed constitute the first step in a study of a system. This in effect implied that from a SD point of view, a model is constructed to address a particular set of problems (Richardson and Pugh 1981). Focus on modelling problems as opposed to focusing on modelling systems, therefore, forms an important issue (Vennix 1996). The purpose of a model serves as a guide to its formulation (a detailed discussion is presented in chapter 8). Several important issues are considered at this stage including reference mode, time horizon, dynamic hypothesis and most importantly, the model boundary.

#### **6.1.1.1 System boundary**

In establishing the system boundary, consideration is made concerning what system variables are necessary to produce behaviour of interest, eliminating where possible, and aggregating where convenient for simplicity (Richardson and Pugh 1981). Concepts situated external to the system boundary are placed externally from the model of the system (Richardson and Pugh, 1981). From a SD point of view, closing feedback loops in the system constitute paramount criteria for an accurately drawn system boundary (Richardson and Pugh, 1981). The content of the model is determined by the questions to be answered (Forrester, 1961).

Accordingly, Richardson and Pugh (1981) offered three questions as a further guide to choices of what to incorporate within the system boundary.

1. What constitutes the physical processes in the systems that are important to the problem?
2. How those processes generated and what are their perceptions?
3. How do those perceptions merge together to develop pressures that influence the physical processes?

The modeller should therefore select factors s/he considers pertinent to the problem based on her/his knowledge and experience of the situation (Forrester, 1961).

#### **6.1.1.2 Reference mode**

Reference mode represents a graph(s) of relevant qualitative data depicting the development(s) of the problem over time (Vennix 1996). It helps dynamically in characterizing important variables relevant to the problem, i.e., as a behaviour pattern, unfolding over a period of time, showing how far distant lies the root cause of the problem and its inferred future development (Sterman 2000). As expressed by Saeed (1994), the foremost requirements for the development of a model within the framework of SD are to organise historical data into what is regarded in the jargon as reference mode. This reference mode leads to a dynamic hypothesis formulation, expressed in relation to the important feedback loops underlying the decision aspects in the system that generate the specific time variant pattern in reference mode (Saeed 1994).

To map out a reference mode, it is significant to define a time horizon relevant to the problem and identify important variables and concepts for understanding the problem (Sterman 2000). Besides specifying explicitly the problematic behaviour of the system of interest, the reference mode specifies the time frame over which the model must run. The basis for reference mode for a modelling effort is actual numerical data Richardson and Pugh (1981). In circumstances where, however, there is an absence of numerical data, the modeller proceeds to deduce what the patterns overtime would have to fit with: other known shapes from the contributions of people highly conversant with the problem of interest (Richardson and Pugh 1981). Each of the variables is plotted on a separate vertical scale.

### **6.1.1.3 Time horizon**

Closely to the criticality of reference mode in modelling within the framework of SD is the time horizon. On the basis of this, Sterman (2000) emphasised stating the time horizon at this stage which should cover previous development of the problem indicating its emergence thus extending into the future so as to capture indirect effects of potential policies and delays. In the view of Saeed (1994), the future must be inferred *via* an intelligent projection of the past patterns. According to Sterman (2000), the time horizon should elongate deep into the future to capture indirect consequences of potential policies and delays. To determine which time horizon is relevant for the system being modelled, it is necessary to go back to the model purpose (Saeed 1994).

### **6.1.2 Dynamic Hypothesis Formulation**

A dynamic hypothesis from an SD perspective is a statement of the structure of a system that appears to possess the potential to exhibit the problem behaviour (Richardson and Pugh, 1981). This view was articulated by Sterman (2000) stating that a dynamic hypothesis involves the consideration of crucial theories of the problematic behaviour first; with a dynamic hypothesis endogenously developed as well as the development of causal structure maps such as model boundary chart, subsystem diagram, causal loop structures, stocks and flows maps and policy structure diagrams.

This dynamic hypothesis must integrate causality on the basis of information concerning the decision rules applied by the system actors as opposed to on correlations between observed variables in the historical data (Saeed 1994). In the view of Randers (1980), dynamic hypotheses represent the reference modes accompanying the fundamental mechanisms of a problem.

### **6.1.3 Simulation Model Formulation Stage**

This stage is comprised of an elaborate structure, parameter values, and elements of quantitative data. It entails aspects that are relevant to the construction of the simulation model. According to Sterman (2000), this step involves transforming from the conceptual realms of diagrams to a complete model comprising

parameters, equations and initial conditions. A Systems Dynamicist employs a variety of well-articulated styles in accomplishing this phase. Some modellers proceed by generating the proposed structures such as flows, stocks and constants, developing the model, testing as well as modifying it (Randers 1980).

#### **6.1.4 Model Testing**

This step involves carrying out some assurance tests to ensure that the model is working correctly and effectively. Testing commences as soon as the first equation is generated (Sterman 2000). In the view of Sterman (2000), testing goes beyond the replication of the past behaviour. Each variable in the model must correspond to a meaningful concept in reality, i.e., in the real world (Sterman 2000). All equations must be examined for dimensional consistency, the policy recommendation as well as the sensitivity of the model behaviour must be examined on the basis of the uncertainty in the assumptions, both structural and parametric (Sterman 2000). Models must also be subjected to test under conditions that are of an extreme nature (Sterman 2000). Lyneis (1980) offers an illustration of developing a core model on the basis of a few feedback loops, performing rigorous model tests, specifically policy tests and then revising formulations and further adding more feedback loops and finally testing the effect on model behaviour. The parameters, initial conditions, decision rules and others should consistently be determined at this crucial stage of modelling effort. For instance, in the test regarding structure-verification the model should be consistent with the structure of the system in reality.

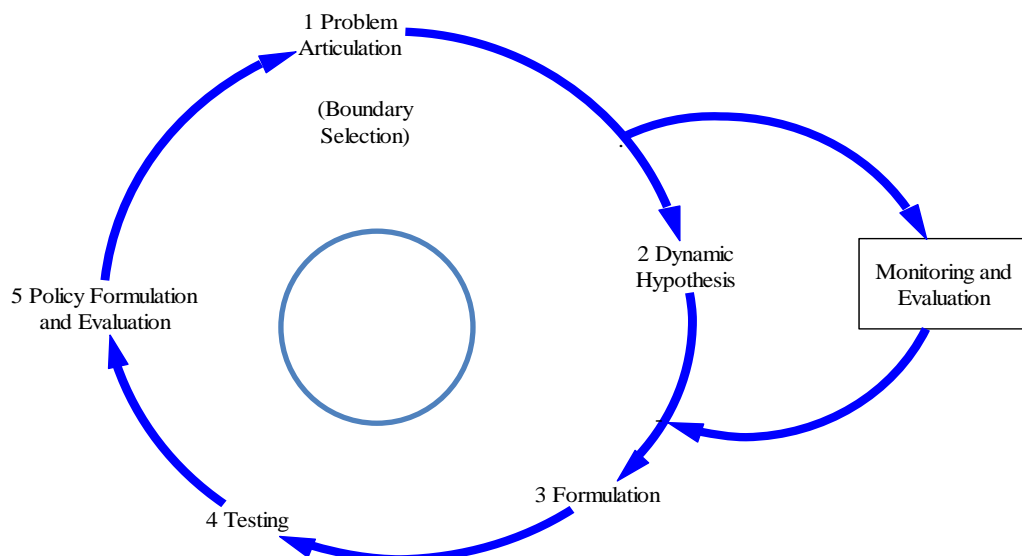
In verifying model structure Forrester and Senge's (1980) recommendations include a review of the assumptions of the model by system actors regarding corresponding aspects of the real system. In most cases, the test for structure verification is first performed based on personal knowledge of the modeller and further extended to incorporate criticisms by key system actors (a discussion of the full proposed model testing is presented in chapter 8 as well as a discussion of the validation and verification of the model).



### 6.1.5 Design and Evaluation of Policy Stage

This is the last step in the modelling steps as outlined by Sterman and thus involves changes in the conditions of the environment (scenarios), policy alternatives and their interactions, as well as the examination of sensitivities of policies under a variety of scenarios (Sterman, 2000). At this stage, a transfer of the study to the user and owner of the model is performed. It is argued to be a qualitative exercise which requires discussion more than equation formulation and examination of parameter values. According to Sterman (2000), designing policy is far more than altering the values of parameters, pointing that policy design involves the development of completely new structures, strategies and decision rules. Figure 6.1 presents the five steps steps involved in modelling as outlined by Professor Sterman (Sterman, 2000).

**Figure 6.1: Steps in Developing System Dynamics Model**



**Source: Sterman (2000 pp. 87)**

### 6.2 Creating Causal Loop Diagram

SD models can be built in either way: by starting with the presentation of the basic mechanisms in terms of CLD and transforming to SFD or starting with SFD and used CLD in explaining the underlying feedbacks structure. According to Sherwood (2002), CLDs can offer a good start for SD modelling. However, SD modelling process can

also start with SFD because the pioneer model developed by Forrester (1961) was completely quantified simulation model and utilise CLD near the end of the modelling exercise to visualise and summarise the dominant loops of the model. In this research, the development of the model commenced with CLD which was transformed into a quantified simulation model (see Chapter 8, section 7).

Sherwood (2002) has conducted an interesting exercise in the field of causal relationships. Sherwood applied the concept of the causal loop to depict why a specific process and patterns develop overtime, hence theorizing the existence of patterns of causal behaviour that explain the rationale for the occurrence of some events. The technique for diagramming influence (causal loop) diagrams used for this thesis (Details is presented in Chapter 8) are synthesised from the guidelines by Sherwood (2002) and Vennix (1996).

Several authors (Sterman, 2000; Sherwood 2002; Vennix, 1996; Wolstenholme, 1999; Richardson and Pugh, 1981) provide technical suggestions and guidelines in diagramming causal structure. This research draws from the 12 golden rules (Sherwood, 2002) five suggestions (Richardson and Pugh 1981) and the approach by Vennix (Vennix, 1996). The research also applied the approach suggested by Wolstenholme (1999) in diagramming the causal relations for the current research work.

### **6.3 Approach to Developing the Model in this Research**

In developing a System Dynamics model, Wolstenholme (1990) presented an extensive work. Accordingly Wolstenholme (1990), points out that System Dynamics models can be developed in two simple ways, which practically tend to be utilised together: the modular or feedback loop approach. The feedback loop method can proceed with the identification of feedback loops (or structure) which is responsible for the system's reference mode of behaviour or by identification of specific examples of information, process, strategy, delay or organisation associated with the problem (the modular approach) (Wolstenholme, 1990). In the case of the modular approach, the type of the system and the aim of the investigation determine which of the elements is used as the point of start in the modular approach (Wolstenholme 1990). On the other hand, the feedback loops

approach obviously necessitates a reference mode of behaviour as the point of starting and the developing of proper feedback loops, almost from nowhere, is often extremely difficult, especially for the beginner (Wolstenholme 1990).

A very structured technique which results to the early variables identification as well as the development of feedback structures and hence warrants the development of simulation (quantitative) models is provided by the modular approach (Wolstenholme, 1990). It is essential to start with one or two essential variables related with the problem in the absence of the reference mode and to attempt to relate examples of information, process, strategy, delay, or organisation to these (Wolstenholme, 1990). This research work adopted the modular approach to model development.

The formulation of the initial model relationships was based on the empirical and theoretical evidence obtained in literature (documents) highlighting challenges facing the Nigerian oil industry thus developing the initial causal diagrams. The conceptual formulation was refined using information elicited from 15 interviews and focus group interviews. This model should be empirically valid and internally consistent from the onset (Saeed 1994). Since it is essential to disaggregate the complex problem into sub sectors whose behaviour can easily be comprehended, four separate sub model views representing various challenges facing revenue generation in the Nigerian oil industry were developed. (Detailed discussion is presented in chapter eight).

#### **6.4 Rational for Adopting the Modular Approach to Model Construction**

Generally, the modular approach to model development has the potential to explore the system as well as its environment. The approach to modelling using modular technique is iterative and directed to focusing attention on the best trade-off between the size of the model and its level of resolution. This usually involves initially the expansion of the model's boundaries and then gradually contradicting them. A model which incorporates all the underlying characteristics of factors influencing the source of concern in the most compact and simplest way constitutes the ideal result of the conceptualisation activities.

## **6.5 Steps in Constructing the Model**

Important causal influence/relationships among the four different sectors and their respective challenges were listed thus culminating at tracing the feedback loop structure (Meadows, 1972). This was achieved through extensive literature review and wider consultation (semi structured interviews and focus group interviews) of system actors (Meadows, 1972). This resulted to the formulation of the most basic structure that reflected the main interaction between the four sub views on the basis of concepts and themes that emanated from the analysis of qualitative data gathered (details is presented in chapter 7). Each relationship is then quantified as accurately as possible using available data and expert judgements.

In view of the fact that new information emerges from a later step lead to a revisit of the previous structure and alter the fundamental feedback loop structure, imply that these steps were not serially adhered to (Meadows, 1972).

**Table 6.2: Steps Involved in the Modular Approach to System Dynamics model**

STEPS	PROCESSES
1.	Identify the important (key) variables relevant to the perceived problem and obtain data where possible regarding the dynamic behaviour of these variables and state a reference mode for the underlying system behaviour over a suitable time frame.
2.	Recognition of some of the initial system resources related to the important (key) variables
3.	Recognition of some of the initial levels (states) of individual resource. The definition of this initial state should be made at an appreciable high degree of aggregation.
4.	Create resource flows for individual resource, containing the state identified and their relevant rate of conversion. Incorporate any important process delays in the flow of resources. (A flow of resource must comprise at least one resource flow and one resource).
5.	In cases where more than one state of individual resource is involved the resource flow is cascaded together to generate a chain of resource transfer or conversion, alternating the rates and levels.
6.	Within each flow of resource identify behavioural information flows, strategies and organisational boundaries by which the levels (states) influence the rates. Incorporate any important delays associated with the information flows.
7.	Identify similar behavioural/information flows, organisational boundaries, and strategies between various resource flows. For situations that are complex this should be conducted for small sets of resources at a time within a specific (define) theme and the resultant structures reduced to generate the simplest structure possible, consistent with linking the important (key) variables of the problem.
8	Identify any emerging (new) states of underlying resources, or emerging (new) resources, which affects the variable developed, then add this to those identified in step one and two.
9	Repeat if necessary.

**Source: Wolstenholme (1990. p30)**

System Dynamics framework entails that, where possible and on the basis of the availability of data, demonstration of the dynamic behaviour of the important variables that generate the problem of interest over some time frame, termed reference mode, equally, an initial description of the causes of the reference mode is termed dynamic hypothesis. The endogenous description of the under root causes should be presented. The following section presents details of how data can be elicited from a variety of sources.

## **6.6 Sources of Information in System Dynamics**

Although models built within System Dynamics (SD) framework represent mathematical representations of complex problems and policy options, it is recognized that majority of the data and information available to the modeller is qualitative in nature as opposed to numerical (Sterman, 2000). For example, while highlighting information sources for the process of model development, Forrester (1994) pointed out that this qualitative data and information resides in the heads of the system actors (mental database), and the textual form (written database). Forrester further pointed out the tapping of the vast information residing in the heads of the system actors as the first step in modelling endeavour.

On the basis of this, the importance of knowledge elicitation from the system actors cannot be overemphasised. (Detailed discussion of data elicitation from system actors is provided in chapter 7).

Overall qualitative data constitutes the key source of information in the modelling process (Forrester, 1975). On the same vein, this position and view point is shared among leading authors in the field (Richardson and Pugh, 1981; Randers, 1980; Sterman, 2000; Roberts et al., 1983; Wolstenholme, 1990). Developing models within the framework of System Dynamics mainly rely on three source of information as earlier indicated: mental data base (i.e. the knowledge elicited from key system actors), the textual data base (operations manual, company reports, etc) and the numerical data base. According to Sterman (2000), the numerical data base is considered very small in relation to the textual data base which is relatively large, and the knowledge elicited from the system actors is also vast.

### **6.6.1 The Mental Data Base**

The mental data base is derived from experts, employees and workers of an organisation or company (i.e. decision makers). It provides the richest form of information which provides the knowledge that offers the opportunity to reconstruct the policies governing decisions that influence our problem (Sterman 2000). The extraction of information from the mental database can be in the form of interviews, discussions, from the business magazines, newspapers and the media (Detailed discussion is presented in chapter 7). Therefore the utmost step in the

modelling process is working clients to articulate the problem—the real problem, not the symptoms of the problem (Sterman 2000). In this research, a close working relationship was established with individual that has sufficient knowledge of the system.

### **6.6.2 The Textual Data Base**

The textual data base is sourced upon long-term experience synthesized into general theories which are expressed in textbooks and journal papers (Sterman 2000). The majority of the theories may not conform to the problem of particular interest, but are on the other hand more generally applicable (Sterman 2000). Less information is derived from this source of information compared to what is obtained from the mental database, because of the fact that theoretical descriptions have to be simplification of reality (Sterman 2000). The review of the literature (C.f. chapter 2) has indicated a variety of perspectives from which a general problem affecting extractive industries in general and oil industry in particular arises.

### **6.6.3 The Numerical Data Base**

The numerical data base comprises minimal information compared to the other two mentioned sources of information available to a system dynamics modeller (Sterman 2000). Statistics and measurements constitute the contents of this database, but no information is provided about the relationships of the data points.

## **6.7 Summary and Conclusion**

This chapter has presented the steps for developing a successful model within the framework of System Dynamics. In particular, the chapter highlighted different views of the mainstream authors in System Dynamics before ultimately settling on the steps advocated by Sterman (2000). Problems articulation: system boundary; reference mode; time horizon, dynamic hypothesis, simulation model, testing and design are the main features as enumerated by Sterman (2000). Others issues highlighted includes creating causal loop diagram as proposed system dynamicists, approach to developing the model in this research using as well as the rational for adopting the approach, steps in constructing the model using the modular approach

and sources of information available to System Dynamics Modellers are also highlighted in this chapter. This highlight serves as a compass in mapping a suitable approach to collection of information necessary for the successful conduct of this research work. Finally, the summary and conclusion of the chapter is presented



## **CHAPTER SEVEN: DATA COLLECTION AND ANALYSIS**

### **7. Introduction**

This chapter is made up of two sections. On the one hand, it explores the data collection techniques in this research. On the other hand it describes the methods utilised in the analysis of the data collected in this research. Yet both are so intertwined and interwoven that separating one from the other is extremely difficult or at best impossible. The first section describes the data collection techniques and procedures employed in this research. It also provides justifications for the decisions employed concerning data collection sources (interviews, focus groups, documents and questionnaires). The chapter also described the field trip undertaken in the course of the research highlighting the challenges encountered as well as the successes recorded. This is followed by the section that highlights the procedure used in analysing data for this research work. The chapter specifically highlights the technique adopted in the analysis of the data used as part of the model development process.

In particular, grounded theory technique for qualitative data analysis was employed for the analysis of the semi structured interviews conducted in this research. It also describes the analysis of the focus group interviews that have been employed for the enhancement and validation of the preliminary model in this research. Finally, the summary of the chapter is presented.

#### **7.1 Data Collection Procedures and Techniques**

Since this research intends to develop a System Dynamics model and based on Forrester (1961) assertion that three types of information are available for building SD model including mental, textual and numerical data bases with qualitative information constituting the largest, the need for a technique for gathering the required data becomes necessary. Forrester (1994) asserts that, the qualitative information resides in the heads of the system actors (mental database) and in textual form (written database). Therefore in order to obtain the textual data base as well as the mental data, the wealth of information residing on the heads of the

relevant stakeholders in the Nigerian oil industry must be tapped. These stakeholders are the clients and owners of the model with vested interest and are involved in providing the needed modelling data for four main reasons: to identify relevant problems to provide information required for the development of the model, to validate the structure of the model, and as the owners and implementers of the results of the model. In terms of ways of collecting qualitative data, Wolcott (1994), view observations, interviews and examining materials prepared by third party as the three main ways qualitative researchers adopt to collect data. According to (Ghuri and Gronhaug, 2010), interviews are regarded as one of the best methods for qualitative data collection. On the other hand, Saunders et al., (2009), points questionnaire as a very important instrument employed by quantitative researchers in collecting data

In this research, both qualitative (mental and written) and quantitative data are collected through both primary and secondary sources. The primary qualitative data was collected mainly through semi structured interviews and focus group interviews while the secondary qualitative data was mainly collected from documentary evidence such as annual reports and internet sources, local and International Newspapers, World Bank reports, OPEC reports, IMF reports, books and journal articles. Quantitative data (time series historical information) and parameter values for model calibration forms part of the quantitative data collected. The following section discusses the processes for the qualitative data collection in this research.

### **7.1.1 Qualitative data collection**

In order to collect the needed data for the development of the model in this research, the researcher adopts the qualitative data collection techniques devised by social scientist because while Forrester (1972) asserts that the information available to the modeller is largely qualitative, several scholars (Wolcott, 1994; Ghauri and Gronhaug, 2010), noted observations, document reviews, Delphi studies, interviews and focus groups as the series of data collection techniques developed and employed by social scientist. As Forrester identified that the most crucial source, both in quantity and importance for the System Dynamicists, is the mental database and (Ghuri and Gronhaug, 2010) noted interviews as one of the best

methods for qualitative data collection hence the use of semi structured interviews in this research and focus groups to enhance the model developed from the textual data base. The following section describes the technique used in collecting qualitative data for the study. Each of the research objectives has been achieved using two or more methods as presented below in table 7.1.

**Table 7.1: Research Objectives vs Research Methods**

<b>Research Objectives</b>	<b>Research Methods</b>
Investigate challenges facing revenue generation in the Nigerian oil industry using the CLD.	Literature review, Documents and Semi structured interviews.
Construct an SD model based on the causal relationships documented in the CLD and calibrate the model initially (contribute) to assessing the validity of the initial SD model by comparing it to the reference mode	Case studies, Semi structured interviews and Focus group with key stakeholders.
Assess the impact of the two policy interventions aimed at improving revenue generation in the Nigerian petroleum industry.	Construction of a simulation model
Utilise the SD model developed in 3 (above) for policy evaluation. This will be accomplished by developing a policy experiment programme to evaluate (within an SD framework) the alternative policies for enhancing an economy by optimising revenue generation from extractive industries, using the case study of the Nigerian petroleum industry.	Simulation experiments

The table presents the research objectives and the associated research methods. The table lists each of the methods utilised in order to achieve the related research objective. Specifically, the research methods have been combined to meet the requirements of any situation on which this research work is based and encompasses the previous case study and scrutiny of the current challenges facing the Nigerian oil industry. The research was facilitated by this to embark on a series of experiments to evaluate potential and practical changes and solutions. The choice for multiple sources of data collection has accorded the researcher an opportunity to confirm triangulation of data and also confirm the results to achieve the objective of the research.

### **7.1.1.1 Interviews**

In this research work, the open ended semi structured interviews have been adopted to obtain required data to confirm and refine initial understanding developed from the review of literature at the onset of the research work. In order to enhance the data collection exercise, the interview instrument was piloted because Chenail (2009) asserts that a number of mock exercises are recommended for the researcher in order to address potential biases and improve their research instruments. Piloting assist the interviewer in verifying and checking any limitations, flaws or other shortcomings within the design of the interview and hence allow the researcher to effect necessary amendments before the study implementation (Kvale 2009).

### **7.1.1.2 Pilot Study**

In order to make the interviews schedule an effective data collection instrument for research, the research questions underwent some processes with the aim of uncovering any ambiguity in relation to questions or statements so as to make it effective instrument for the collection of data in this study.

The pilot testing was conducted in the University of Bedfordshire based on the general context of both the design of the interview schedule as an instrument of research for data collection as well as the area of study in order to achieve the target objectives. Research students of university of Bedfordshire under the same sponsorship i.e. Petroleum Technology Development Fund, Nigeria (PTDF) with the researcher and also with experience and background knowledge in Nigerian oil and gas industry were involved in the exercise. They are also conversant and have experience of using interview schedule as an instrument for data collection in research. The participants (PTDF Scholars) offered their suggestions on the structure of the interview schedule. They recommended that, the questions should be amended to reflect the diversity of the interview participants. They also recommended simplifying the questions further for easy understanding by the entire participant as well as ensuring that the interview schedule captured sufficient material issues regarding Nigerian oil industry in terms of challenges facing revenue generation. After receiving feedback from them, the interview schedule

was amended where necessary and employed as a basis for the exploratory interviews with purposeful number of research participants.

### **7.1.2 Selecting Participants**

The importance of choosing the appropriate subjects for a research study was stressed by Creswell (2007) asserting that the interviewer should apply one of the several forms of sampling approaches in order to get suitable candidates who will give the most reliable information to the investigation. Similarly Creswell (2007) also pointed out the importance of acquiring respondents who would be willing to be honest and open to share knowledge or their story. On the basis of this the judgemental sampling approach was adopted. This feature is based on the selection of the research participants on the strength of their knowledge and experience of the phenomenon (Hussey and Hussey 1997).

In particular, interview participants in this research were operational personnel of relevant government agencies charged with revenue related matters in the industry. Their selection was also based on their roles and expertise in the operations of Nigerian oil industry. According to NEITI (2005), the following agencies are responsible for the collection of government revenue from the Nigerian oil industry: Nigerian National Petroleum Corporation, Department of Petroleum Resources and Federal Inland Revenue Services. In addition other agencies that assist in the realisation of potential revenue from the industry were included: the Nigerian Extractive Industry Transparency Initiative (NEITI) and Presidential Amnesty Programme (PAP). It should be noted that the later was not involved in the exploratory study but incorporated in the main interview, a development that was informed by the exploratory study so that participants comprises all stakeholders that contribute directly or indirectly towards enhancing government revenue in the industry. Although involving stakeholders in the modelling effort in it warrants the provision of the necessary data, the construction of the preliminary model that serves as basis for the engagement of stakeholders in order to acquire additional information would be impossible without acquiring a better understanding of challenges facing the industry. Based on this, the first research objectives (Investigate challenges facing revenue generation in the Nigerian oil

industry using the CLD) was formulated. In order to achieve this objective, in-depth literature review was conducted.

### **7.1.3 Exploratory Study**

Phase one of the research interviews involved an exploratory study with relevant respondents. These respondents as earlier noted represent key system actors (stakeholders) in the industry who are highly knowledgeable about the area of concern. They however, informed the researcher's further understanding of some of the issues and concerns related to challenges facing the industry in terms of revenue generation. The rationale for exploratory study is to gain insights into the practical operation in the industry (Forrester 1960), enhanced understanding of the problem, and investigation of the possibility of future research as well as problem elaboration (Hart 2006). The exploratory study provided direction for the rest of the data collection exercise.

In particular, the outcome of the exploratory study indicated the need to expand the instrument further in order to incorporate participants from other agencies that contributed directly or indirectly to revenue related issues in the industry hence the incorporation of personnel from the Presidential Committee on Amnesty Programme (PAP). Without the exploratory study, the interviewer wouldn't have identified other relevant participants. Table 7.2 presents the number of participants in the exploratory study, their individual organisation as well as role in the industry.

**Table 7.2: The Exploratory Study: Interviewees**

S/No	Participants	Organisation	Department	Role in the industry
1	EIP_A	NNPC	Crude oil Marketing Department	State owned oil company.
2	EIP_B	DPR	Strategy Department	Regulator of the Industry
3	EIP_C	FIRS	Multinational Corporation Department	Tax collector in the Industry
4	EIP_D	NEITI	Evaluation and Technical Department	Promoting Transparency and conduct of periodic audit in the Industry

Table 7.2 presents the list of participants involved in the exploratory interview. The participant's names were withheld and hence coded using EIP which is an acronym that implies exploratory interview participants and A-D indicates alphabetical order assigned to each participant for identity purpose. The characteristics of the four research participants involved in the exploratory interviewees and the respondent's backgrounds such as their respective organisations, department as well as role played in the industry were presented in the table.

Before the interview, an interview information sheet (see Appendix A) was sent via email to four potential respondents introducing the topic as well as soliciting their cooperation and all responded and consented to the request. After receiving their individual consent, the interview schedule was also sent via email to each of the participant to allow for adequate preparation so that the respondents would be conversant with the questions. In all four telephone interviews were conducted in this exploratory study, this is because Ghauri and Gronhaug, (2010) noted that the technological revolution facilitates the utilisation of equipment such as web cameras and mobile phones with recording facilities such as video recorder thus promotes the popularity of telephone interviews for management and business research and hence address the loss of non-verbal data.

Telephone interview was considered more suitable in this research than face to face based on several reasons. This includes geographical spread of the participants, as according to Vennix (1996), the interview may be extremely difficult in a situation

where the participants are geographically dispersed. Telephone interviews also warrants verbal contact with the respondents where face-to-face interview would be impractical because of the distance, prohibitive cost and time constraints (Saunders et al., 2012) thus facilitates verbal interaction between the researcher and the interviewee (Maylor and Blackmon 2005). Others reasons that further influence the choice of telephone interview include the speed of collection of data and easy access to the research participants.

At the commencement of the interview, the participants were assured of confidentiality as part of the ethical requirement for conducting interview because Ghauri and Gronhaug, (2010), suggest that the investigator requests for permission to record and document the proceeding, and also anonymously quotes the participant in the written reports. The interviewees were also requested for permission to record the interviews. The entire participants agreed and the proceeding of the interview was recorded. Each interview lasted for an average of one hour. The researcher was able to pose probe questions because of the semi structured nature of the instrument since Ghauri and Gronhaug (2010) argues that some issues relating to semi-structured interviews differentiate them from both unstructured and structured interviews because it provides opportunity to pose probe questions such as why and how. This question of why and how generates causal arguments which is at the heart of system dynamics.

The exploratory interview helped in providing a basis for the development of the research scope and orientation. It also provided a basis for a wider context in which to view challenges facing the Nigerian oil industry in terms of the generation of revenue. After transcribing the recorded interviews, the interviewer contacted the interviewees to ask if they are interested to go through the transcribed document in order to verify the contents of the document, but all of them declined.

#### **7.1.4 The Main Study Interviews**

Phase two of data collection involves the main interviews of the study. The interviews assisted in ratifying the causal diagrams developed from document review, adding more perspective to challenges facing the industry that were not obtained from the review of the literature, as well as eliciting more details from the participants that were not obtained from the exploratory study. The interview



schedule (appendix B) was carefully crafted and expanded with core stakeholders (from Nigerian oil industry) in mind but also included other categories of stakeholders such as those assisting the industry in achieving its objective: Amnesty programme officials and staff of the Nigerian extractive industry transparency initiatives. The interview format was devised based on general qualitative research guidelines (Kvale, 2009). In view of the semi-structured pattern of the study interviews, the interviewees were however frequently prompted to provide more information, clarification and explanation.

Table 7.3 present details of the interviewees for the main study interviews. The table include organisation of respective participants, the number of participants from each organisation, and the pattern of questions asked from the interview schedule.

**Table 7.3: Main Interviewees of the Study**

No	Participant	Agency	Department	Role in the industry	Notes
1	MIP_A	NNPC	Crude oil Marketing Department	State owned oil company	Interview followed planned questions
2	MIP_B	NNPC	Crude oil Marketing Department	State owned oil company	Interview followed planned questions
3	MIP_C	NNPC	Crude oil Marketing Department	State owned oil company	Interview followed planned questions
4	MIP_D	DPR	Strategy Department	Regulator of the Industry	Interview followed planned questions
5	MIP_E	DPR	Strategy Department	Regulator of the Industry	Interview followed planned questions
6	MIP_F	DPR	Strategy Department	Regulator of the Industry	Interview followed planned questions

7	MIP_G	FIRS	Multinational Corporation Department	Tax collector in the Industry	Interview did not follow planned questions
8	MIP_H	FIRS	Multinational Corporation Department	Tax collector in the Industry	Interview did not follow planned questions
9	MIP_I	FIRS	Multinational Corporation Department	Tax collector in the Industry	Interview did not follow planned questions
10	MIP_J	NEITI	Evaluation and Technical Department	Promoting Transparency and conduct of periodic audit in the Industry	Interview did not follow planned questions
11	MIP_K	NEITI	Evaluation and Technical Department	Promoting Transparency and conduct of periodic audit in the Industry	Interview did not follow planned questions
12	MIP_L	NEITI	Evaluation and Technical Department	Promoting Transparency and conduct of periodic audit in the Industry	Interview did not follow planned questions
13	MIP_M	PAP	Monitoring Department	Coordination of Federal Government Amnesty Programme	Interview did not follow planned questions
14	MIP_N	PAP	Monitoring Department	Coordination of Federal Government Amnesty Programme	Interview did not follow planned questions
15	MIP_O	PAP	Monitoring Department	Coordination of Federal Government Amnesty Programme	Interview did not follow planned questions

Table 7.3 highlights details of all the interviewees. In particular, the backgrounds of the participants were presented including, the code assigned to each participant using MIP as an acronym that implies main interview participants and A-O

indicates alphabetical order assigned participant for identity purpose and the pattern adopted in posing the research questions to individual participants during the conduct of the research interview. In particular, it could be observed from the table that some interviews did not follow planned questions in the interview schedule because the participants were drawn from various agencies within the industry hence their varying roles in the industry was considered in designing the interview schedule as well as in conducting the interview. In particular, participants 1 to 6 were asked all the questions in the interview schedule where as participants 7 to 15 were not asked all the questions in the interview schedule.

Preparatory to the interview, an email was sent to the respondents attached with the interview information sheet (see Appendix A) which introduced the aim of the interview to them and emphasised the significance of their contribution to the research. This was achieved because of the personal rapport between the researcher and the interview participants given the position of the researcher as a stakeholder in the industry as well as the exploratory interview with some of the participants. All the interviewees responded positively and agreed to participate in the interviews. The interview schedule was equally sent to each of the respondents in order to acquaint themselves with the questions and adequately prepare for the interview. All the respondents in the exploratory interview also participated in the main interview.

In all, 15 participants were involved and a total of 15 telephone interviews were successfully conducted. The semi-structured interview schedule consisted of twenty three questions to cover for each category of participants, with slight deviations for each set of interviewers (see Appendix B). The same questions were not asked by the interviewer each time. The questions were however adjusted based on the interviewees' response to specific questions and this trend guided the pattern of the questions asked. Each of the interviews lasted an average of about an hour. At the onset and before the commencement of the interview, the investigator requests for permission to record and document the proceeding, and also anonymously quotes the participant in the written reports. The majority of the participants agreed to the interview to be recorded while 2 of the participants declined being recorded based on personal grounds.

For those that consented to recording the interviews, the interview was accordingly recorded using voice recorder and notes were also made in the course of the interviews which were followed by a detailed report after each of the interview session. On the other hand only notes were taken from those that declined recording the interviews.

Also full details of the participants were withheld in compliance with the ethical provision guiding the study. The semi-structured interview was conducted to complement the exploratory interview and the documentary evidence. Additionally, the questions in the interview schedule were selected to keep the interviewees interested (Schein 1999) and providing important information regarding the situation in the Nigerian oil industry. The responses extended into lengthy passages of text. After transcribing the recorded interviews, the interviewer contacted the interviewees to ask if they are interested to go through the transcribed document in order to verify the contents of the document, but all of them declined.

#### **7.1.5 Focus Groups Interviews**

In phase three of data collection, the researcher conducted a focus group interview during field trip to Nigeria. This was aimed to confirm, reinforce, add depth to the researcher's findings from both interview and literature review and also validate the model. One of the major challenges faced by the researcher was how to bring together the relevant participants (who are also stakeholders in the industry) given their geographical spread. The Nigerian oil and gas conference which took place on the 23<sup>rd</sup> day of September 2013 in Abuja, Nigeria, presented a good opportunity for the researcher. The forum provided a suitable platform for the conduct of the focus group interviews as the major stakeholders in the industry were in attendance and their convergence on one place coupled with the position of the researcher as a stakeholder in the industry was a great advantage for the successful conduct of the focus group discussion.

The focus groups participants were a combination of various key stakeholders in the industry with 3 of those that have participated in the exploratory interviews and the main interviews and one that participated in the main interview only. This participant possesses an in-depth understanding and experience in the industry and

in the area of study. The relevant stakeholders' involvement from whom to elicit information in this regards was supported by several mainstream authors in SD (Vennix, 1996; Sterman, 2000). Before the gathering however, a series of telephone and email correspondence was maintained between the researcher and the individuals considered to be potential participants. In all, 8 participants were in attendance. The participants were not conversant with System Dynamics thus necessitated the presentation of the CLD during the gathering because Vennix (1996) asserts that, it is essential that participants trust and understand the logic used in modelling the system. Therefore the interviewer delivered a short presentation and description of the CLD highlighting the various kinds of variables (stocks, flows and intermediate) to the participant at the gathering in the form of a conference. This resulted in better understanding by the participant as it offered them an opportunity to be conversant with system dynamics. Overall, they were impressed with the logic involved in the modelling process.

The participants in the discussion met for one hour facilitated by the researcher who played the role of moderator to ensure that no single individual dominated the floor (Saunders, et al., 2009). The researcher realise that the manner in which the participants assessed the model and gave their final feedback demonstrates their confidence and acceptance of the model in terms of representing the industry as well as all the challenges facing the industry. Therefore, the findings are highly useful as a basis for the model improvement that will form the overall and final structure of the model. The group proceeding was recorded using a digital recorder and field notes were documented. Off point topics and conversations were however not recorded.

A questionnaire which seeks to obtain the view of the participants based on the clarity, logical structure, practical relevance, comprehensiveness, intelligibility and applicability of the model in the industry (appendix c) together with a list of variables their obtained from literature (see appendix e) involved in the model development was also administered to all the participants.

The use of was supported by Vennix (1996) Questions were asked in the questionnaire for the validation of the model and the desire to obtained additional information where necessary. The questionnaire was filled in by all the 8

participants in the Session. This questionnaire (see appendix D) along with the table of relationships (see appendix e) were then collected and analysed, and causal links were accordingly revised on the basis of the exercise.

### **7.1.6 Questionnaire**

In this research study, the questionnaire used was to validate the model by the stakeholders and further acquire more insight into the current reality of issues under investigation. This is supported by Vennix (1996) who proposed the use of a questionnaire in validating causal structure. It will also accord a collective consensus on both the structure of the model as well as the relationship between constituent's elements of the model.

The questionnaire in this research was designed in three different sections: section one, section two and section three. Section one specifically requests the participants to assess the model based on these assessment criteria: Clarity, Logical structure, Practical relevance, Comprehensiveness, Intelligibility and Applicability. Attached to the section is 7 point Likert scale ranging from (Excellent to Extremely poor) Strongly Excellent =7, Very good =6, Good=5, Neither good nor poor =4, Poor=3, Very poor=2, Extremely poor=1. An additional space is also provided in the section for further clarification in text form. This section specifically aimed to measure the level of acceptance of the model by the respondents with a view to improving an enhancing it where necessary.

Section two contains statements in relation to whether the model depicts an accurate economic representation/description of the Nigerian petroleum industry. It also contains other statements asking whether the participants feel that the stock in the model represents variables that accumulate or deplete over time and the flow represents all the variables that either increase or decrease the stock (level). The section aimed to measure the level of participants' agreement or disagreement concerning the statements in the questionnaire in order to ensure that the model had capture all the necessary issues the research intend to focus on. Attached to the section also is a 7 point likert scale ranging from (Strongly agree to very strongly disagree). Strongly agree =7, agree=6, slightly agree=5, neither agree nor disagree=4, disagree =3, strongly disagree =2, very strongly disagree=1. In addition

to the 7 point likert scale, a space is also provided for additional explanation in the section with a view to enhancing the model.

Finally, Section three which present statement relating to the opinion of the participants as to whether there is any other method that can better used to describe the industry and what are its advantages and disadvantages and finally questions regarding the experience of individual participants in terms of evaluating and managing revenue related issues in the industry. In order to make a questionnaire an effective data collection instrument, the need to subject it to some rigorous procedures, so that the questions or statements contained therein are devoid of any form of bias or ambiguity (Jonker and Pennink, 2010). Based on this, the questionnaire was designed using simple and straightforward questions so that participants feel at ease while answering the questions.

#### **7.1.6.1 Pilot testing**

The pilot testing was conducted in the University of Bedfordshire based on the general context of both the design of questionnaire as an instrument of research for data collection as well as the area of study in order to achieve the target objectives. The questionnaire was administered to the same research students involved in piloting the interview instrument i.e. students of University of Bedfordshire under the same sponsorship with the researcher with experience and background knowledge in oil and gas industry. They are also conversant and have experience of using questionnaire as an instrument for data collection in research.

Although they are not conversant with system dynamics yet the simplicity adopted in designing the questionnaire greatly assisted them in understanding it. The participants suggested that, for ease of answering, the length of the questions should be reduced and also make it easily understandable. The participants also commended the quality of the questionnaire as it captured the general issues reflected in the model. After receiving feedbacks from the participants, the questionnaire was edited, revised and amended where necessary for subsequent exercise.

#### **7.1.1.6.1 Questionnaire Administration**

The questionnaires in this research were administered to participants at the focus group interview during the field trip to Nigeria. The essence as earlier noted was to validate and enhance the CLD with key stakeholders (clients) in the industry. Consequently, a comprehensive list of the major weaknesses and strength of the model was figured out and hence compelled for further model revision. Emphases were placed on the client by the researcher on the strength and the limitations of the model with a view to improve it.

#### **7.2 Field Trip Element of the Research**

The field trip has been utilised by the researcher in order collect additional data, validate the model (through focus group), as well obtain recommendations in the form of feedback from key stakeholders in the industry who constitute the participants.

The focus group interview would not have been possible without embarking on the field trip. The field trip was carried out in Nigeria for a period of one month from September to October, 2013. Travelling to Nigeria for the study trip presented both challenges and opportunities. Although key stakeholders in the Nigerian oil industry are spread across the country, the majority of them were situated in Abuja, the federal capital of Nigeria. The researcher also relied on a number of documents related to the Nigerian oil industry as additional sources for the collection of secondary data during the field trip thus resulted in the collection of vast array of vital documents from the relevant stakeholders at the venue of the conference and other offices visited.

A wide range of documents such as magazine publications and newspaper reports were reviewed by the researcher in order to identify various aspects of the challenges facing the industry. These documents were obtained at the conference venue and some were also retrieved from the archives and libraries of key agencies such as the Nigerian National Petroleum Corporation (NNPC), Nigerian Extractive Industries Transparency Initiatives (NEITI), Department of Petroleum Resources (DPR) and Federal Inland Revenue Services (FIRS). Relevant and vital documents were also retrieved from the websites of Multinational Oil Companies (MNOG)



operating in Nigeria. Another important issue is the visit by the researcher to the Nigerian country office of the Revenue Watch Institute (RWI) which also adds focus to the research work.

Overall, these documents assisted in providing evidence based sources in support of data from the literature. Because as Yin (2003), assert various kind of documentary evidence can assists in terms of augmenting and corroborating other sources source of data. For example, while the research participants enumerated the various challenges facing the industry in terms of revenue generation, they did not provide numerical information needed for other modelling aspects; therefore other documentary evidences were sought, and obtained from documentary sources. Table 7.4 below present list of the locations visited during the field trip,

**Table 7.4: Locations visited during the field trip**

<b>S/No</b>	<b>Organisation</b>	<b>Location (state)</b>	<b>Outcomes</b>
<b>1</b>	NNPC	Abuja	Obtained material documents: Bulletin
<b>2</b>	DPR	Abuja	Obtained material documents: Bulletin
<b>3</b>	NEITI	Abuja	
<b>4</b>	FIRS	Abuja	Obtained material documents: News letters
<b>5</b>	RWI	Abuja	Obtained material documents: Magazine
<b>6</b>	Transcop Hilton	Abuja	Conducted focus group interview and accessed materials presented at the venue

Figure 7.4 presents details of the places visited during the field trip embarked by the research. The table highlights the organisations visited, the official location of each organisation and the results/outcome of the visits.

### **7.3 Data Analysis**

The previous section discussed the techniques and procedure for the collection of data in general and for this research work in particular. The aim of this section is to build upon data collection procedures outlined in the previous section by highlighting the procedures adopted for qualitative data analysis in this research. On the basis of this, details of the analytic and systematic techniques for the

analysis of data and the procedures applied are explained and justified in this chapter. Within the chapter also, the researcher highlights the analysis of the interviews, and the questionnaires administered to participants at the focus group interviews. Finally, the conclusion of the chapter is also discussed this chapter.

#### **7.4 Analysis of Interview data**

The analysis of the interview commences immediately after the first interview was conducted. The following section highlight the processes undertaken in analysing the semi structured interview conducted in this research work.

##### **7.4.1 Transcription and Handling of Interview Data**

The first stage in analysing qualitative data involves the handling and transcription of the data. Immediately after the completion of the recorded interviews, backup copies of the interviews (digital files) were made by the researcher. Each recorded tape was later transcribed into a written file. For those interviews whose participants declined recording the conversation, transcription was made from hand written texts. After completing the transcription of all the interviews, the researcher read and re-read through all the interview transcripts to ensure the correct compilation of data. This gave rise to thorough familiarization with the data by the researcher. The transcripts were later transferred into NVivo 8, software for qualitative data analysis to facilitate the analysis of the data. For the purpose of this, a grounded theory mode of analysing qualitative data was employed. The following section discusses this in detail.

#### **7.5 Grounded Theory**

The initial stage for grounded theory according to Hussey and Hussy (1997) is noted to be coding, thus labelling the codes to enable the separation, compilation and organisation of the qualitative data (Hussey and Hussey, 1997).

##### **7.5.1 Coding of Transcripts**

The transcripts were coded using the technique advocated by Strauss and Corbin (1998). Responses were first grouped (coded) on the basis of the interview questions. Each question stands as a node of information via which answers from

all interviewees for a specific question can be viewed. From this, themes and concepts were identified across the texts. These themes and concepts are comprised of variables which are linked together to generate rich stories, thus forming the basis for the development of the model. Since the study employs grounded theory for data analysis, the need present details of series of coding exercises to reflect on a grounded theory mode, as the coding of data became imperative.

## **7.6 Grounded Theory Analysis of Exploratory Interviews**

The first step which is open coding commences simultaneously with the qualitative interviews by reading the transcribed interviews with a view to discovering and identifying concepts related to the focus of the investigation, that is, challenges facing revenue generation in the Nigerian oil industry, events that result to reduction in government revenue as a result of those challenges, possible categories of these challenges, and also manifestation of these challenges in this case study. Five concepts were initially found, which were placed in fourteenth categories: a) projects costs, b) projects delay, c) government revenue from crude oil, d) government approved budget, e) Cash call default, f) alternative funding, g) development investment, h) Interest i) degradation of vulnerable land, j) destruction of marine resources, k) potential revenue, l) revenue gap, m) curtailing daily production, n) production below optimal level.

The first category- projects delay was created from three basic concepts: elongating life of a project, long gestation periods and delay from implementation of projects. It was these basic concepts that the stakeholders used in describing their views regarding projects delay in the industry.

“With regards to NNPC, it should be open to make the industry more transparent to make contracts very firm to reduce the impact of variation so that you make sure you have detail plan (....) so that if you say you need to spend three years and no more instead of tying that resources by elongating life of a project and nothing to come for the next five years without anything coming to the government hence increasing projects cost through variation of projects costs.”(EIP\_A).

The second category – Government revenue from crude oil - was created from two concepts: government take and government share of revenue. It was these concepts used to describe government earning from the oil industry.

“Government take and government share of revenue is affected by variation as a result of prolong project duration in the industry (...) thus deny government what is potentially due to it. (EIP\_A).

The third category – Government approved budget - was created from two concepts: amount set aside by government and financial ability of government. It was these concepts used to describe a situation where government make provision for its counterpart funding in joint venture operations.

“The amount set aside by the federal government is usually based on its financial ability which is always far less than its agreed share of funding of the joint venture operations. This impact (...) negatively on the smooth operation of the joint venture. (EIP\_A).

The fourth category- projects costs were created from two concepts: amount set aside and approved budget. This category has to do with what the interviews termed costs of the project in relation to what is set aside and what is approved by the government.

“Most of the times the projects costs overshoots as a result of accumulated neglect by the government. In most cases government budgeted and set aside funds far below what is expected and thus extending expected period of completing projects which result to variation.” (EIP\_A).

The fifth category- cash call defaults was created from three basic concepts: government inability to meet its cash call, government failure to meet up its own part of obligation and sourcing money by government to meet up cash call due. It was these basic concepts that the stakeholders used in describing their views regarding cash call challenges in the industry.

“The major issue is that government is unable to meet its cash call obligation which affects investments in the industry and when government is not able to meet its own part of the cash call due, the oil company have to carry it forward and this result to additional interest burden on government because this oil companies normally source this money through loan which attract interest that is attributable to government failure to meet up its own side of the obligation, therefore government have to pay that interest which invariable lowers what is potentially do to government.”(EIP\_B).

The sixth category – Development investment- was created from two concepts: cash call paid and funding of projects. It was these concepts used to describe a situation where the despite the funding efforts in the industry, short fall in funding persisted.

“Cash call and funding of projects remains a serious concern in the industry thus resulting to perennial short fall in the industry. (EIP\_B).

The seventh category- alternative funding, this was created from two concepts: debt financing and borrowed funds. This category is more about the financial means sourced by the multination oil companies in order to meet up with the failure of government to meet its cash call responsibility.

“In most cases the IOC resorts debt financing or going for borrowed funds in order to keep the venture going as a result of government’s persistent failure to meet up with its own contribution in the joint venture agreement which lead to the payment of the cost of the debt plus the actual debt.”(EIP\_B).

The eighth category- interest was created from two basic concepts: cost of debt and compensation. It was these two basic concepts that the stakeholders used in describing their views regarding charges in relation to an alternative source of finances provided by the IOC to meet up with government failure in providing its own share of counterpart funding in the venture.

“The major issue is that government is not able to meet its counterpart funding in the joint venture agreement and so the IOC look for another source which requires serving the cost of debt or a form of compensation which means debt service and the amount borrowed (.....) thus becomes additional burden to the government” (EIP\_B).

The ninth category – degradation of vulnerable land - was created from two concepts: deterioration in land and deterioration in farmland. It was these concepts used in the industry in describing the effects of crude oil production in the oil rich Niger Delta.

“Degradation of land and degradation in farmland are particularly high in oil producing areas. This affects farming activities and is as a result of the operations of the oil companies. The situation is (.....) so bad as it affect means of lively hood generally”. (EIP\_A).

The tenth category – destruction of marine resources - was created from two concepts: deterioration in water and deterioration in rivers. It was these concepts used to describe the extent to which the operations of IOC is affecting their means of livelihood i.e. fishing activities in the oil rich Niger Delta.

“Deterioration in water and deterioration in rivers are source of serious concern in the oil producing region particularly among the fishing community. In fact the effect is just too enormous (.....) and what do you expect in such kind of situation? This destruction affects fishing activities. Also destruction of other lands affects farming activities. These combined and hence exert negative effect on the means of livelihood of the community. (EIP\_A).

The eleventh category- potential revenue was created from two concepts: revenue optimisation and accurate revenue. This category has to do with what the interviews termed as what the government ought to be generating from the industry.

“I think most of the challenges facing the industry ultimately deny government from realising full benefits from the industry. In particular revenue optimisation from the industry is not as suppose and accurate revenue is not been realised as a result of corruption. This therefore calls for the need to devise measure that will ensure revenue optimisation and generation (.....) of accurate revenue in the industry given the vast resource in the oil sector” (EIP\_C).

The twelfth category- revenue gap was created from two concepts: what ought to have been generated and what is generated. This category has to do with what the interviewees termed the revenue shortfall experienced from the industry as a result of corrupt practices.

“Government doesn’t realise what is potentially due to it from the industry. In most cases what is generated is far lower than what is ought to have been generated from the industry as a result of variety of corrupt practices (.....) this has always been the issue in the industry” (EIP\_C).

The thirteenth category – curtailing daily production - was created from two concepts: violence and conflicts. It was these concepts used to describe the circumstance affecting normal crude oil production in the oil rich Niger Delta.

“Violence and conflicts are particularly frequent occurrences in the oil producing region. In many instances the host communities engaged in confrontational means as a way of expressing their dissatisfaction with the operational impacts of the oil producing companies. This usually affects daily operations and production of the oil producing companies”. (EIP\_A).

The fourteenth category – production below optimal level - was created from two concepts: capacity constraint and decline in production. It was these concepts used to describe a situation where the industrial is operating or producing below optimal level.

“Capacity constraints and decline in production constitute is serious threat in the industry thus affecting optimal crude oil production which by extension affects revenue generation in the industry”. (EIP\_A).

The second step of analysis, axial coding implies grouping of relevant and related phenomenon. It is firstly an effort that involves drawing relations between respective concepts and form groups that were again labelled. During this process, it was observed that, one of the concerns expressed by the stakeholders, is a somewhat silence issue in the industry. The four categories that describe these are project delay, government revenue from crude oil, government approved budget and project costs. The new category that emerged on the basis of these two open coding categories was labelled “variation”.

As joint venture operation of the industry progresses, certain challenges which negatively affect the smooth operation of the venture agreement were noticed. In this regards, the stakeholders shares there experience on these issues and how that affects unhindered operation of the industry. These concepts can be discovered in the open coding categories ‘cash call defaults, development investment, interest, and alternative funding’. These categories were reconstructed to the axial coding category of ‘cash call shortfall’. This constitutes challenge that is of serious concern to the stakeholders.

The third axial coding category ‘environmental impacts, was developed based on two open coding categories: ‘degradation of vulnerable land’ and ‘destruction of marine resources’.

The fourth axial coding category ‘corruption, was developed based on two open coding categories: ‘revenue gap’ and ‘potential revenue’. There is always difference between what the government ought to realise and what actually get to government coffers.

The fifth axial coding ‘disruption of operations’ was developed based on two open coding categories: curtailing daily production and production below optimal level’. This is one of the major ways in which huge revenue is lost from the industry as result of epileptic production.



The third step and the final step of analysis, selective coding, and the basic aim was to integrate categories developed at the step of the axial coding. This is relatively similar to the integration earlier conducted when migrating from open coding to axial coding, and really, it is, this integration that is done in the final stage of the analysis, performed in a more abstract level. The central categories form the entire categories discovered in the previous steps were developed and labelled “Challenges facing revenue generation in the Nigerian oil industry”

Grounded theory analysis of the qualitative interview data also revealed challenges facing revenue generation in the Nigerian oil industry: a) variation, b) cash call shortfall c) environmental impacts, d) corruption, and e) disruption of operations. According to this analysis, the Nigerian oil industry is faced by four challenges that impact negatively on revenue generation. Further aspects will be explored more fully in the analysis of data obtained from the main interviews. Figure 7.1 shows the phases of grounded theory and their emerging categories for exploratory interviews.

**Figure 7.1: Phases of grounded theory and their emerging categories for exploratory interviews.**

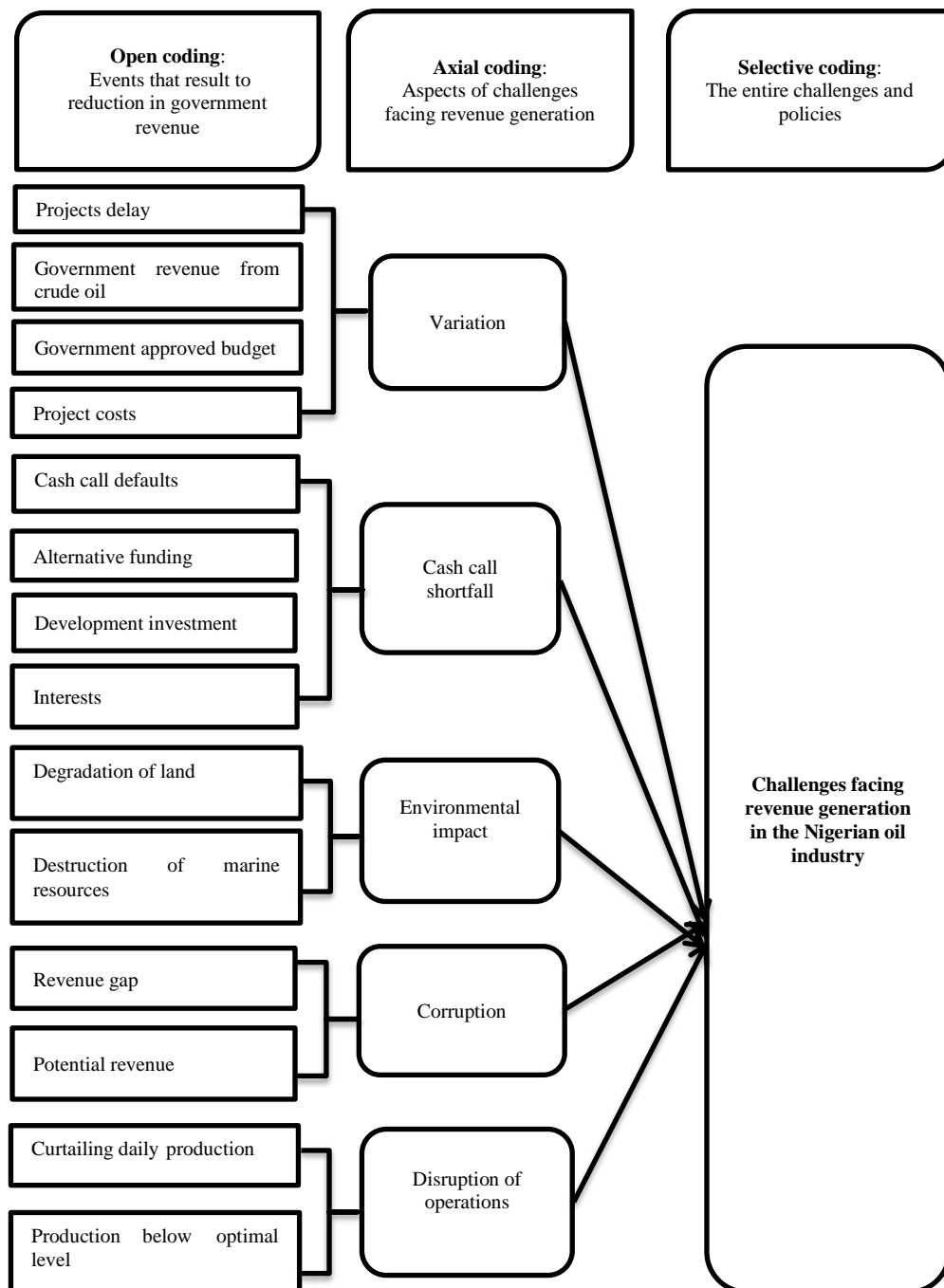


Figure 7.1 presents three classes of coding for the exploratory interviews. This includes: open coding comprising events that result to reduction in government revenue, axial coding comprising aspects of challenges facing revenue generation and finally selective coding comprising the entire challenges thus providing an explanatory theory of challenges facing government revenue in the Nigerian oil. The following section presents grounded theory analysis of main interviews.

## 7.7 Grounded Theory Analysis of Main Interviews

The first step which is open coding commences simultaneously with the qualitative interviews by reading the transcribed interviews with a view to discovering and identifying concepts related to the focus of the investigation, that is, challenges facing revenue generation in the Nigerian oil industry, events that result to reduction in government revenue as a result of those challenges, possible categories of these challenges, and also manifestation of these challenges in this case study. Eight concepts were initially found, which were placed in nineteen categories: a) absent of good governance, b) inaccurate records of crude oil sales, c) inaccurate records of crude oil output, d) potential production, e) production capacity, f) disruption of operations, g) communal unrest, h) potential militants, i) rate of militants, j) unemployed youths, k) illegal bunkering l) siphoning of crude oil, m) interest, n) project delay, o) cash call obligation, p) actual cash call paid, q) relative peace and calm, r) reduction in militant activities, s) openness in operations, and t) conduct of periodic audit.

The first category- absence of governance was created from six basic concepts: fraud, governance challenge, governance structure, institutional weakness, source of personal wealth and corporate governance. It was these basic concepts that the stakeholders used in describing their views regarding corruption in the industry. As the issue of corruption is pervasive throughout the industry, virtually all the stakeholders view it as a serious issue in the industry. Specifically, it constitutes a grave concern to the stakeholders that usually mentioned it first before any other challenge facing the industry. Although some measures were taken to address this monster, the stakeholders did not find these measures helpful. They however recommended more stringent measures both in terms of design and implementation.

“Let me say that the industry have been privatised to the extent that all the institutions that functions along its value chain are weak to the extent that they cannot prevent fraud. In the recent time (.....) there have been serious challenges with governance, a situation where to a large extent, the country itself does not exactly knows how much crude oil it produces, how much really

accrued to government and how much really comes into government coffers. Most of the proceeds from the industry is been diverted” (MIP\_G).

The second category- inaccurate record on crude oil sales was created from two concepts: differences between the amount reported to have been remitted by the responsible agencies and the amount reported to have been received by government. The stakeholders used these two concepts to describe the situation of inaccurate revenue due to government from the sale of crude oil. Some of them have previously worked in various constituted committees set to reconcile such differences.

“It is extremely difficult for both NNPC and CBN to come with the same figures in terms of what NNPC claimed to have remitted to the government and what the CBN claimed to have received on behalf of the government.” (MIP\_H).

The third category, inaccurate records on crude oil output was created from two concepts: contradictory figures between various agencies and poor reports. Inaccurate records have a significant influence on the promotion of corruption in the industry.

“Considering the various conflicting records between various agencies responsible for crude oil administration, it is evidently clear that all the figures provided by them (...) are questionable”. (MIP\_J)

The fourth category- Production capacity - was created from two concepts: maximum production and optimal. It was these concepts used to describe a situation where the produces at maximum or optimal capacity devoid of intermittent hitches in production.

“Maximum level of production and optimal level of production are being negatively affected series of conflicts as a result of agitations by the host community leading to closure of operation which by extension affects revenue generation in the industry”. (MIP\_C)

The fifth category- Potential production - was created from two concepts: possible production and expected production. It was these concepts used to describe the level that can be produced by the industry giving the enabling environment.

“The major issue is that the industry is unable to produce expected production as well as possible production. This is as a result of consisted disruption of operations as a result of communal unrest and attacks on production facilities.” (MIP\_C)

The sixth category- disruption of operations was created from two basic concepts attacks and destructions of facilities. The industry is seriously being attacked. This, of course, rendered the industry to be operationally affected negatively. Also damage to some infrastructures is another way of hampering the operation of the industry.

“Destructions and attacks on of oil pipelines facilities have continued to remain among most serious challenges facing our industry”. (MIP\_M).

The seventh category- communal unrest- this was created from three concepts: agitation conflicts and protest. This category is more about the difficulties experienced by the industry as it relates to its relationship with the host community. One significant issue to note is that the operation of the industry usually results to adverse environmental impact, thus leading to grave loss of means of livelihood of the host community.

“Instability in the oil producing region is relatively a periodic occurrence leading to damaging of crude oil production facilities. More so agitation, conflicts, and protest by the host communities in the region as a result of destruction of means of livelihood of the locals is a common occurrence”. (MIP\_N).

The eighth category- potential militants was created from two concepts: unemployed youths that manifest militant tendencies and youths that felt frustrated as a result of the operations and presence of IOC.

Some youth just developed militant's tendencies due to high rate of unemployment in the region or the feeling of frustration due to pervasive unemployment among the teeming youths in the region". (MIP\_O).

The ninth category – Rate of militants - was created from two concepts: agitators and freedom fighters. It was these concepts used to describe the rate of militants in the Niger delta region.

“Freedom fighters and agitators constitute a serious threat to the rise of militancy in the industry thus leading to vandalism and crude oil theft”. (MIP\_O).

The tenth category – Unemployed youths- was created from two concepts: unskilled youths and domination of oil industry by expatriates. It was these concepts used to describe the circumstance of majority of youths in the oil rich Niger Delta.

“Underemployment and unemployment are particularly high in states with huge revenues from oil and are correlated with restiveness poses by the youth. In many cases, teeming unemployed youth (men in particular), are recruited and trained into militant groups in the Niger Delta.

As oil industry requires technical knowledge for it employees, it is therefore very difficult to employ vast unskilled youths parading in the region. Most of the youths are not educated to warrant the acquisition of any skill that will make them employable in the industry. Moreover, the IOCs are more interested in bringing expatriate workers at the detriment of Nigerians seeking for employment in the sector”. (MIP\_M).

The eleventh category- illegal bunkering was created from two concepts: stealing of crude oil and sabotage. This category has to do with what the interviews termed as the various ways in which crude oil is taken away illegally.

“A lot of illicit activities occur in the creek. You find youths/ militants engaged in sabotaging activities. Stealing crude oil product and selling and transporting it to high sea where they upload on big ships with collaboration foreign national who usually buys the stolen commodity. This is an act of sabotage”. (MIP\_A).

The twelfth category- siphoning of crude oil: was created from two concepts: connivance and overloading of ship. This relates to situation where staff charge with loading crude oil into ship load beyond what is supposed to be load as well as conniving with locals of the area to still crude oil products.

“In most cases, government official connive to load beyond what is on the bill and also connive with the locals to give them opening so that they can be stealing crude oil directly from the point of loading” (MIP\_B).

The thirteenth category – Interest rate – was created from two concepts: cost of alternative (financing) funding and payment of interest. This category has to do with what stakeholders in the industry considered to be a concern they are deeply concerned about as it deprived government from generating potential revenue.

“The funding gap results to the sourcing of alternative means of financing by the IOCs in order to maintain steady operation in the industry. This financing attract certain expenses which is the cost of the debt. The financing is considered as a form of loan to the government and hence the government is expected to repay back the loan including the cost of the loan. On the other hand, the IOCs normally charge 8% as the cost of the loan”. (MIP\_D).

The fourteenth category – project delay – was created from two concepts: time taken to complete a project and the rate at which project come on stream. This according to stakeholders in the industry is of serious concern as it affects maintenance of target production in the industry.

“Most of the projects in the industry go beyond their agreed completion schedules. On the basis of this, you find limited number of completed project against what ordinarily should be. This by implication means continuous funding of the projects by the government”. (MIP\_E).

The fifteenth category – Actual cash call paid - was created from two concepts: funding deficit and funding inability. It was these concepts used to describe the actual cash call paid by the government in the joint venture operation.

“Funding deficit and funding inability are the major issues confronting Nigerian government in funding joint venture operations. Funding inability and deficits constitute is serious threat in the industry thus affecting smooth operation of the joint venture operation since government provides less than its counterpart share of funds”. (MIP\_F)

The sixteenth category – Cash call obligation - was created from two concepts: counterpart funding and funding share. It was these concepts used to describe the government expected contribution for the funding joint venture operation in the industry.

“Counterpart funding and funding share production constitute a serious challenge on the part of government as it always result to funding gap in the industry”. (MIP\_D).

The seventeenth category – relative peace and calm was created from two concepts: reduction in attacks and stability leading to increase in crude oil output, reduction in violent confrontation on oil workers and reduction in the destruction of oil facilities.

The eighteenth category- reduction in militant activities was created from two concepts: stability in the region and uninterrupted operation of the industry.

“I call these operationally related issues. There are challenges here and there leading to the disruption in the activities of the



operating companies and stealing of crude oil as a result of militant's activities but had now been drastically reduced". (MIP\_M).

The nineteenth category – openness of operation was created from two concepts: checks and balance and reduction of opacity in the industry.

“NEITI as an entity goes out to the field, collect information, verify this information through rigorous audit exercise and finally brings out its finding to the general public after reporting its findings to the government”.(MIP\_K).

The twentieth category – conduct of periodic audit was created from two concepts: the role of NEITI to the industry and stakeholders involvements. These two concepts describe the new approach aimed at instilling probity and accountability into the system. It was very evident from the stakeholders narratives that the industry is witnessing an unprecedented efforts aimed at addressing sharp practice prevalent in the sector.

“Before the country is missing a lot of money and some of the money are not even accounted for. For instance, after the conduct of the 1999 – 2005 audit, it was discovered that in excess of 1 billion dollars was owed as shortfall to MOBIL based on the calculation of PPT based on their own assumption using realisable price. So that is once instance and if companies like MOBIL have that kind of shortfall imagine what would happen or what had happened actually when you go to other companies”. (MIP\_L).

The second step of analysis, axial coding implies grouping of relevant and related phenomenon. It is firstly an effort that involves drawing relations between respective concepts and form groups that were again labelled. During this process, it was observed that, at the core of concern expressed by the stakeholders, is a trend in the industry. The three categories that describe this are absence of good governance, inaccurate records on crude oil output and inaccurate records on crude

oil sales. The new category that emerged on the basis of these three open coding categories was labelled “corruption”.

It was observed that, at the core of concern expressed by the stakeholders, is a trend in the industry. The three categories that describe this are production capacity and potential production. The new category that emerged on the basis of these three open coding categories was labelled “production shut down”.

As operation of the industry progresses, in most cases with attendants’ consequences such as pollution, that operation can be interrupted or even partially stopped. In this case, the stakeholders spoke of their experience on certain acts and how that influences the smooth operation of the industry. These concepts can be discovered in the open coding categories ‘disruption of operations’ and ‘communal unrest’. These categories were reconstructed to the axial coding category of ‘vandalism’.

The fourth axial coding category ‘militants, was developed based on three open coding categories: ‘unemployed youths’, ‘rate of militants’ and ‘potential militants’. As most of the youths in the area could not be engage in a meaningful employment, the vast of them roam about in the street. These therefore turn to tools that can be used to cause problems in the area.

The fifth axial coding ‘crude oil theft’ was developed based on two open coding categories: illegal bunkering and siphoning’. This is one of the major ways in which huge revenue is lost from the industry.

The sixth axial coding category cash call shortfall was developed based on two open coding categories: ‘interest’, actual cash call paid, cash call obligation and ‘projects delay’. This constitutes challenge that is of serious concern to the stakeholders.

The seventh axial coding category amnesty measure was developed based on two coding categories relative ‘peace and calm’ and ‘reduction in militants activities’.

The eighth axial coding category transparency measures was developed based on two coding categories ‘openness of operations’ and ‘conduct of periodic audit’

The grounded theory (GT) analysis revealed seven aspects of challenges facing revenue generation in the Nigerian oil industry and two policy measures aimed at addressing those challenges. The first aspect of the challenges is corruption, which highlights its effects on a number of activities in the industry. What portrayed the characteristics to corruption taking place in an environmental setting is the absence of strong institutional structure and lack of probity and accountability in the industry. Even in developed economies, the importance of strong institution needs not to be over emphasised. This is in line with the view of Benhua (2010) who stress the importance of institution quality to the success of resource endowed economies. Inaccurate records of crude oil output and sales also pose challenges which are also institutionally inclined.

The second aspect of the challenge manifested in this research is vandalism of facilities, which describes how some actions resulted to challenges in the industry. Constant attack on production facilities as well as protest by the host community usually disrupts operation in the industry leading to production shut in.

The third aspect is militancy challenge, in which havoc is created in the industry occasioned by anger expressed by the youths in the area as a result of their non-engagement in a meaningful employment or vocation engagement

The fourth aspect of challenge is crude oil theft which is an avenue for loss of crude oil revenue and hence loss of potential revenue due to government.

Crude oil theft has been rising in the Niger Delta leading to massive loss of revenue due to Nigerian government. Militants engage in crude oil theft to finance their operations, buy arms and recruit members

The fifth aspect of the challenge is cash call shortfall in which government counterpart funding for the funding of joint venture operations in the industry faces challenges.

Specific constraints faced by JOA include funding challenges, as a result of the imbalance which usually exists in the financial ability of the respective joint venture partners, particularly the government due to its excessive pressures on its scarce resources thus failing to meet its cash call obligations in different joint

venture agreements with the IOCs and ultimately leading to consequential revenue loss due to reduction of operations. The multinational oil corporations in the existing joint venture operations have persistently protested that government budgetary provisions for cash-call purposes have frequently been below the required amounts over the years. Consequently and as a result in the cash call shortfall, the industry resorted to alternative financing approaches in funding some projects. These alternative financing approaches which are of short-term nature have not offered acceptable stable alternatives to the financing problem and cash-call challenges.

Two policy interventions that were aimed at addressing aforementioned challenges were identified:

The first aspect of the policy intervention is the amnesty measure.

The policy intervention of the government aimed at reducing disruption in the industry had greatly assisted at improving crude oil production to a maximum level. It is a government policy intervention which has instilled peace and stability in the oil industry therefore increased crude oil production.

The second aspect of the policy intervention is the transparency measure.

We have experienced some improvements (...) the industry is gradually becoming more malleable and agreeable allowing the general public to know what is happening in the industry so that alone is an improvement. Secondly, the issue I have raised now prior to this time is not known to majority of Nigerians including those that are supposed to be running the sector such as the government. So there is an improvement from my own perspective but at a very slow pace, not very past but we are hopeful based on the plans we currently have on ground. Overall, the industry is more open now compared to five years to 10 years and 15 years back. The openness is not 100% but I can give it 20% to 30%.

The third step and the final step of analysis, selective coding, and the basic aim was to integrate categories developed at the step of the axial coding. This is relatively similar to the integration earlier conducted when migrating from open coding to axial coding, and really, it is, this integration that is done in the final stage of the

analysis, performed in a more abstract level. The central categories for the entire categories discovered in the previous steps were developed and labelled “Challenges facing revenue generation in the Nigerian oil industry” and “Policies aimed at increasing revenue generation” respectively.

Grounded theory analysis of the qualitative interview data also revealed challenges facing revenue generation in the Nigerian oil industry: a) corruption, b) vandalism, c) militants, d) crude oil theft, e) production shut down, and f) cash call shortfall. According to this research, the Nigerian oil industry is faces by five major challenges that negatively affect the generation of potential revenue from the industry. The effect of each aspects of the challenge depends greatly on individual sectors of the industry, but overall it impacts negatively on the generation of revenue for the government. For example, the need for accurate records for crude oil production is more important to DPR as it serves as the basis for its reports to FIRS that is used for tax purposes. It is worth noting that despite the introduction and analyses of challenges facing revenue generation in the oil industry from multiple perspectives, in reality there could be other unidentified challenges, notwithstanding the view of the stakeholders that this constitutes comprehensive aspects of challenges facing revenue generation in the Nigerian oil industry. While it is useful to analyse the interview data in this research, and explain the process in section using grounded theory (GT) technique, the rational is for analysed data to support the development of well-grounded System Dynamics model. It is also used in supporting the qualitative findings of the research. Figure 7.2 presents the phases of grounded theory and emerging categories for main interviews

**Figure 7.2: Phases of Grounded Theory and Emerging Categories for main interviews**

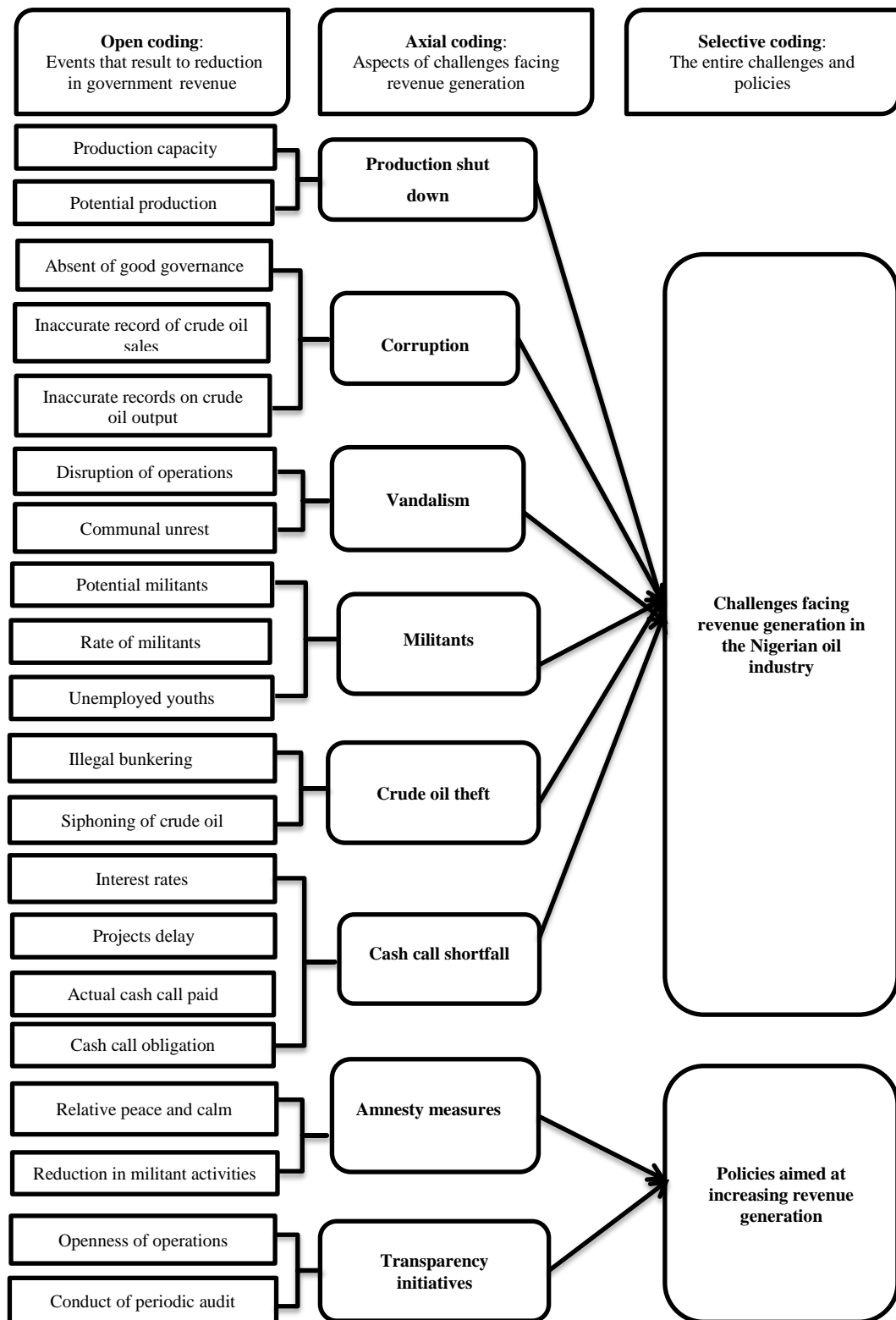


Figure 7.2 shows the phases of grounded theory and their emerging categories. Three classes of coding are presented in the figure. This includes: open coding comprising events that result to reduction in government revenue, axial coding

comprising aspects of challenges facing revenue generation and finally selective coding comprising the entire challenges and policies thus providing an explanatory theory of challenges facing government revenue in the Nigerian oil industry and policies aimed at addressing those challenges. The following presents the respective grounded theory analyses of the interviews data adopted in this research.

## **7.8 Analysis of the Questionnaire**

As described in the previous section this research conducted focus group interviews to refine, acquire additional details and validate the preliminary model. Based on this, the research work emphasises on a number of fundamental attributes for the validation of the model as earlier noted comprising: clarity, practical relevance, logical structure, intelligibility, applicability and comprehensiveness.

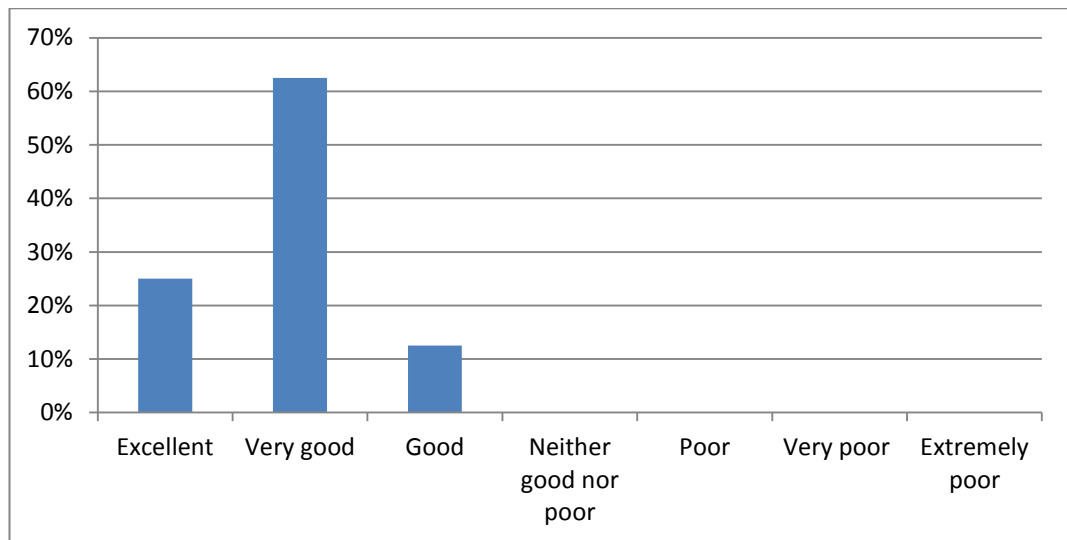
The respondents' responses from the questionnaire administered during the focus group interviews were analysed using descriptive and simple statistics (percentages) because the questionnaire administered were not large but sufficient for the research and the need of the study hence does not necessitate the use of quantitative software such as SPSS. On the basis of the results of the analysis, the model was revised and updated.

The following represent the results obtained from the questionnaires (validation instrument) administered to focus group participants relating to the CLD presented on the basis of the following attributes:

### **7.8.1 Clarity of the CLD**

In relation to the request made to participants to assess the model based on the level of clarity of the CLD using the seven point Likert scale provided in the questionnaire, Figure 7.4 presents the outcome of the responses by the participants.

**Figure 7.4: Clarity of the CLD**



**Source: Author's calculation**

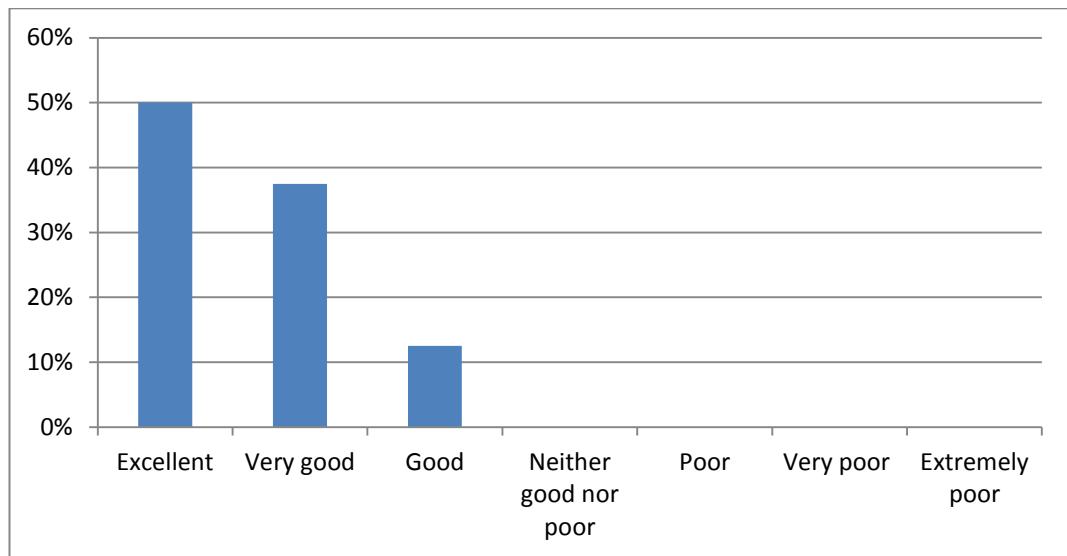
Figure 7.4 indicates the responses of the participants based on their assessments in terms of clarity of the CLD. Twenty five per cent of the participants have indicated the clarity of the CLD as excellent. Sixty three per cent of the participants have expressed the clarity of the CLD as very good while twelve per cent of the participants judged the CLD as good. All the participants assigned a high to highest value (good, very good and excellent) to the representation of CLD's in terms of the relationships among relevant variables based on their knowledge and experience of the system.

### **7.8.2 Logical Structure of the CLD**

In response to a question that requested the participants to assess the level of agreement on the logical structure of the model in the questionnaire, Table 7.5 presents summary of the responses of the participants based on the seven point Likert scale as to the extent of the participants agreement on the logical structure of the CLD.



**Figure 7.5: Logical structure of the CLD**



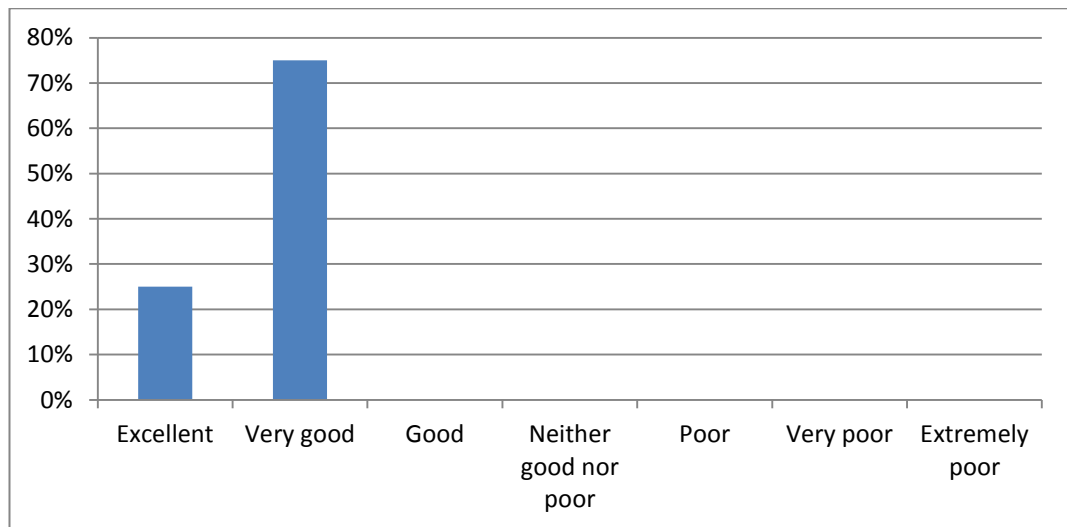
**Source: Author's calculation**

Figure 7.5 presents the responses of the participants. All the participants have agreed and accepted the logic involved in diagramming the CLD. In particular, fifty per cent of the participants have agreed to the logical structure of the CLD as excellent while thirty eight per cent and twelve per cent found the connections of different variables within the model to be very good and good respectively.

### **7.8.3 Practical Relevance of the CLD**

To assess the level of practical relevance of the CLD, the seven point Likert scale in the questionnaire was used and Figure 7.6 presents the responses of the participants in this regards.

**Figure 7.6: Practical relevance of the CLD**



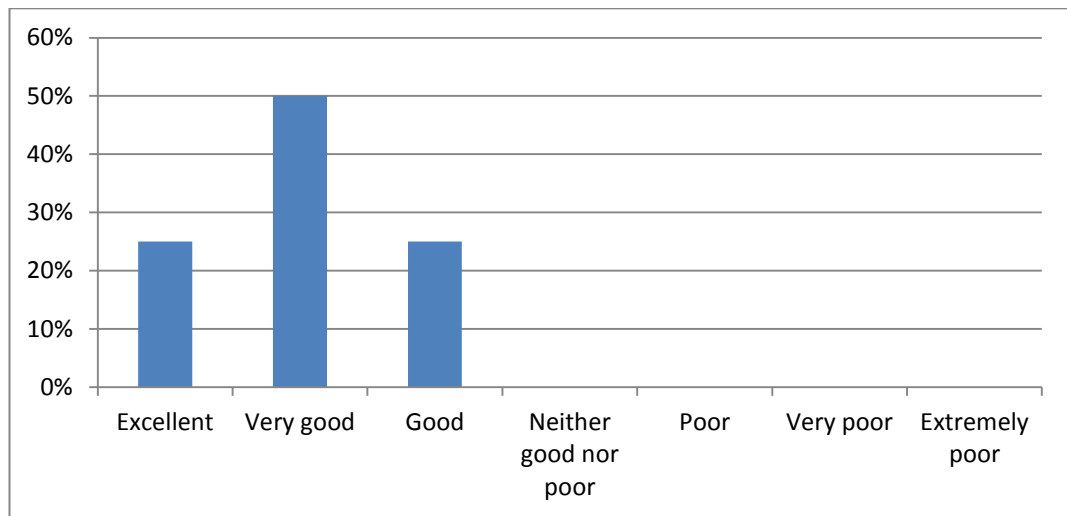
**Source: Author's calculation**

Figure 7.6 presents the views of the participants concerning the degree to which the model is practically relevant. Twenty three per cent of the participants have acknowledged the model as excellent in terms of practical relevance to Nigeria oil industry and sixty seven per cent have given their response as very good.

#### **7.8.4 Comprehensiveness of the model**

The model was validated in terms of comprehensiveness by taking responses from the participants as to the extent of coverage of the entire challenges (economic challenges) facing the industry. Figure 7.7 presents summary of all the responses from the participants in this regards.

**Figure 7.7: Comprehensiveness of the CLD**



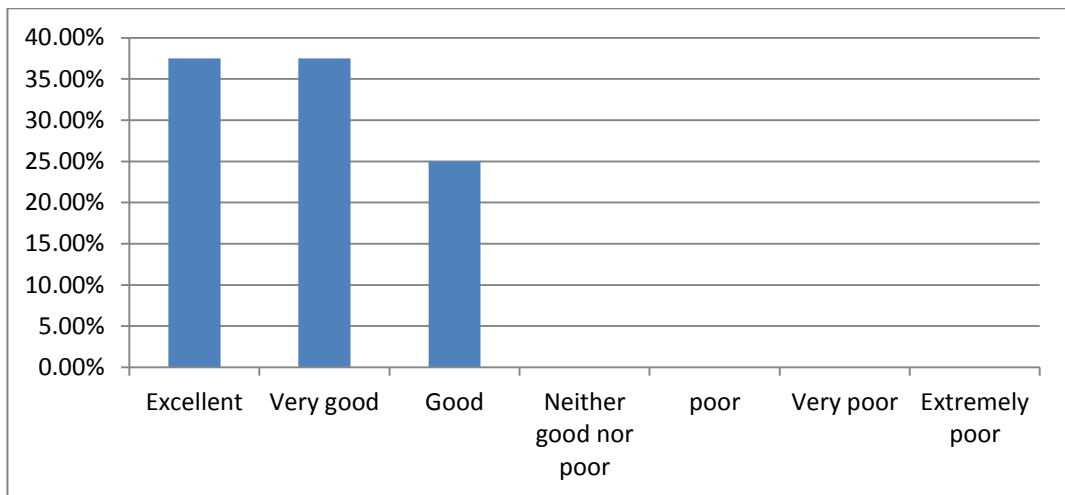
**Source: Author's calculation**

The responses of the participants concerning the extent of coverage of important variables at play in terms of economic challenges in the system are presented in Figure 7.7. All participants have asserted that a wide coverage has been made in order to document challenges facing revenue generation in Nigerian oil industry. In particular, twenty five per cent of the participants have ranked the model as excellent, fifty per cent as very good and the remaining twenty five per cent as good in terms of degree of comprehensiveness.

#### **7.8.5 Intelligibility of the model**

The intelligibility presented in terms of the model has been evaluated using the seven point Likert scale by requesting the participants of the focus group interview to give their respective view. Figure 7.8 shows summary of the responses to which the participants have agreed with the intelligible way in which of the model has been developed.

**Figure 7.7: Intelligibility of the model**



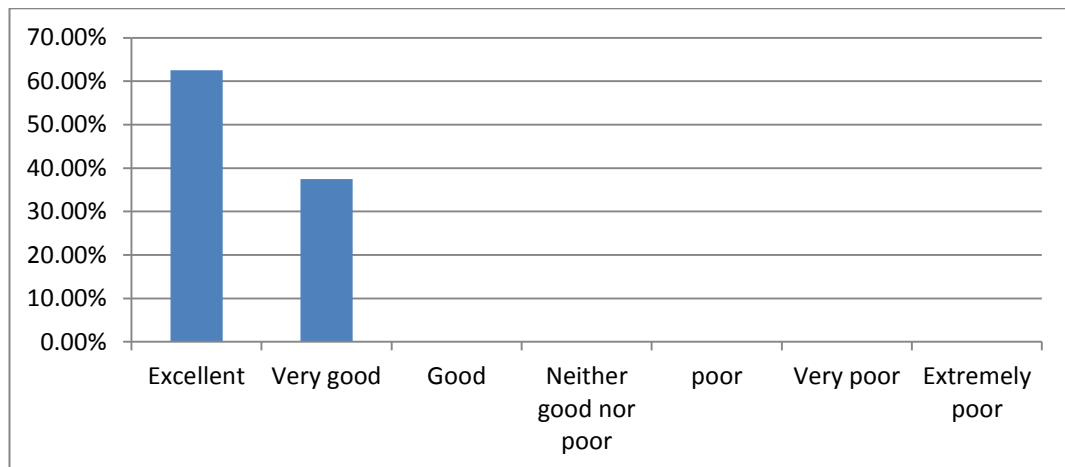
**Source: Author's calculation**

Figure 7.8 presents the responses of the participants regarding the degree to which the model has the ability to simplify a complex system to the understanding of common reader. Thirty seven per cent of the participants indicated that it has excellently achieved that while another set of thirty seven per cent participants found it to be very good in terms of intelligent representation of reality. Finally, twenty four per cent have indicated that the intelligibility of the model as good.

#### **7.8.6 Applicability of the model**

The extent of applicability of the model has been assessed using seven point Likert scale in the questionnaire from the focus group interview participants. A summary of participant's feedbacks as to what extent the participants have acknowledged the applicability of the model in the industry is presented in Figure 7.9.

**Figure 7.9: Applicability of the CLD**



**Source: Author's calculation**

All the responses relating to the extent to which the model is applicable in the real world situation are presented in Figure 7.9. Based on the result a majority of the participants, i.e. sixty two per cent have indicated the applicability of the model as excellent while thirty eight per cent have assessed the model as very good in terms of applicability.

#### **7.8.7 Diagram's Points of Weakness**

Based on the above responses, space is provided in the questionnaire for further clarification in text form from the focus group participants requesting them to identify any weakness/weaknesses observed from the model in order to obtain the reason behind their individual responses. The aim was to serve as the basis for model revision and enhancement. On the basis of this, few unimpressive points of the model were highlighted. These were used to revise and update the CLD with a view to perfecting any imperfection observed by the participants thereby enhancing the degree of acceptability and robustness of the model. The following presents the areas pointed out by individual participants.

The participant P\_1 has indicated that, *“Alternative funding/financing” is the general name given to finance sourced by oil companies to finance NNPC shortfall. Similarly, “Decommission wells” is what is now generally used in the industry and not “abandoned wells” after oil is depleted”.*

The participant P\_2 has pointed out that, *“annual inflation rates” and “annual incremental cost of a project” are the two main factors used in the determination of variation of a project. Also discovery coefficient is the main factor used in the determination of rate of crude oil discovery.*

The participant P\_3 indicates that *“depletion rate”* is highly considered in determining remaining proven crude oil reserves. *So it is recommended that this should be incorporated into the model. He further states that “rate of government crude oil revenue” accumulates to form “actual government cumulative crude oil revenue” and “actual government cumulative crude oil revenue” has direct effect on “rate of government investment” in the industry which in turn reduces “actual government cumulative crude oil revenue”.*

The participant P\_4 pointed out that *“average time taken for repairs” of vandalised facilities is very important in assessing the quantity of vandalised facilities in the industry and hence recommended that it should be taken into consideration. He also pointed the role of “youth’s population” in the oil producing region in the rise of militant activities as well as how it is being affected by “population”. He also highlighted “prevalence of poverty” among the inhabitants as contributing to communal unrest as well as it is also being enhanced by the population. In addition p\_4 also stated that there exists “revenue gap” i.e. the difference between cumulative potential crude oil revenue and actual cumulative government potential crude oil revenue*

The participant P\_5 pointed out that *“The model concentrated on government revenue alone without considering the major operators in the industry although everything is working well for them”. He also recommended the consideration of “average project completion periods”. He further asserts that “actual crude oil revenue” in the oil industry determines “rate of government crude oil revenue” from the industry.*

The participant P\_6 shares the same view with P\_1 and P\_2 thus asserts that, *the model should use “decommissioned wells” instead of the “abandoned wells”.*

The participant P\_7 pointed out that *“the use of “corruption in the oil industry” as against “corruption” in general seems to be more realistic. He further stated that*

*“corruption” in the society shapes “corruption in the oil industry”. The participant also stressed how corruption breeds as a result of increase in corruption.*

On the basis of the above, the following areas have been identified as the main weaknesses of the model during the data analysis of the focus group interviews. Decommission wells: Most of the participants recommended that abandoned wells presented in the model should be replaced with decommissioned wells.

Annual inflation rates and annual incremental cost of a project: The participants have agreed with the recommendation of one of the participants that annual inflation rates and annual incremental cost of a project are the two main factors used in the determination of variation of a project as well as discovery coefficient as the main determinant of rate of crude oil discovery.

Alternative funding/financing: The participants have agreed with the recommendation of one of the participants to harmonise all forms of funding available and be represented by the generic name in the industry i.e. alternative funding.

Average time taken for repairs and average project completion periods: The participants have agreed with the recommendation of one of the participants that average time taken for repairs of vandalised facilities and average project completion periods are very important in assessing the quantity of vandalised facilities in the industry and normal period for completing projects respectively and hence recommended that they should be taken into consideration.

Actual crude oil revenue, rate of government crude oil revenue, revenue gap, rate of investment and government revenue from crude oil: All the participants unanimously agreed that these items should be explicitly incorporated into the model so as to enhance the clarity of the model as each item represent different thing at different stage.

Youth population: The participants have agreed with the recommendation: that youth in the oil producing region contributes to the rise of militant activities. He also highlighted “prevalence of poverty” among the inhabitants as contributing to communal unrest.

Corruption in oil industry: The participants have agreed with the recommendation that the use of corruption in the oil industry as against corruption in general seems to be more realistic and that it is a reflection of corruption in the larger society.

Finally, some of the participants raise an issue that the model concentrated on government revenue alone without considering the major operators in the industry although everything is working well for them.

### **7.8.8 Diagram's Points of Strength**

On the other hand, another open ended question was provided in the questionnaire to assess the model's points of strength. Several positive remarks were obtained from the participants concerning this model in this regards.

The participant P\_1 remarked, "*it provided a clear diagram in a simple format for any level of person to understand.*"

The participant P\_3 concludes, "*The model has sufficiently represented major challenges facing the industry.*"

The participant P\_4 pointed out that, "*The major point of strength of this model is project variation analysis. Variation will always have significant impact on the project cost.*"

**Accurate economic representation of the Nigerian petroleum industry:** 75% of the participants strongly agree that the diagram depicts accurate economic representation of/description of the Nigerian petroleum industry while 25% agree in that regard. However, the following observations were made by the participants. P\_2 asserts "*need to add other variables to take care of impact generated by community agitation.*"

**Whether the model has adequately captured the major challenges facing revenue generation in the Nigerian oil industry:** 62.55 per cent of the participants strongly agree while 37.5 per cent agree that the model has adequately captured the major challenges facing revenue generation in the Nigerian oil industry. However, the following points were raised by the participants. P\_1 asserts that "*The model is addressing only the government of Nigeria participation in the*



*petroleum industry. P\_2 asserts that “Not all. Need to talk at effects of current legislations that are not adhered to.”*

**Whether the model has suitably indicates all the causes and the effects relationship between variable.** 75 per cent of the participants strongly agree while 25 per cent agree that the model has suitably indicates all the causes and the effects relationship between variable.

**Whether the stock in the model represents all variables that accumulates or deplete over time and the flows represents all the variables that either increases or decreases the stocks:** 75 per cent of the participants strongly agree while 25 per cent of the participants agree that the stock in the model represents all variables that accumulates or deplete over time and the flows represents all the variables that either increases or decreases the stocks

**Whether there is any other method they feel can better used to describe the industry and what are its advantages and disadvantages:** the participants have unanimously indicated that there is no any method as comprehensive as system dynamics that can incorporate all challenges facing revenue generation in the Nigeria oil industry and this is indeed the first of its kind.

The outcome showed the percentage of response in terms of each of the criteria listed: clarity, practical relevance, applicability, comprehensiveness and intelligibility and participants were directed to indicate their level of agreement on each of the above. In term of the provisions made for further comments on the questionnaire, the comments were considered as suggestions by the participants towards enhancing and improving identified weaknesses of the model and hence utilised to revise the model. (See section 8.6). The implication is that the revision of the model on the bases of the responses received from the participants have helped to address the weaknesses of the model from the clients (stakeholders) point of view thus enhancing the value of the model and its acceptance by the stakeholders. Specific issues raised are ensuring that contemporary issues in the industry were adequately captured in the development of the model. (See section 8.3) for model improvement based on the result of analysis of the questionnaire

## **7.9 Summary and Conclusion**

In this chapter a detailed description of the available data collection techniques used in this research, i.e., interview techniques, focus groups discussions and document reviews have been discussed along with the techniques that have been used for data analysis. Based on the aim of the research, justification was provided on the choice of data collection technique employed by the research relying on Foresters assertion on essential data necessary in building SD model. Semi structured interviews was elaborately discussed as the main qualitative data collection technique. In particular, the semi structure interviews were conducted in two different phases: through an exploratory interviews and main interviews. Additionally, field trip aspect of this research was also discussed in this chapter focusing on challenges as well as successes recorded during the exercise.

In terms of data analysis, the chapter extensively describe Grounded theory as a technique for the analysis of qualitative data in this research stressing the steps involve: open, axial and selective coding. The chapter also described the methods used in analysing the questionnaire used as an instrument of validation during the focus group interviews as a way of validating the model with relevant stakeholders and finally the summary of the chapter.

## **CHAPTER EIGHT: MODEL DEVELOPMENT AND DESCRIPTION**

### **8. Introduction**

In the previous chapters, the background and motivation for this research, the necessary literature for building the model and the technique employed for that purpose were presented. This chapter presents the model development and description through the adoption of the System Dynamics methodological framework proposed in chapter four and the modelling steps outlined in chapter five. In this chapter, a detailed description of the features and structures of the System Dynamics model is presented that could be utilised to promote and enhance comprehension of the economic challenges facing the Nigerian oil industry.

The model was developed in order to explain the challenges facing revenue generation in the Nigerian oil industry since 2000 and portrays a possible future through to 2035. It is an effort to bring together the immense body of existing knowledge regarding cause and effect relationships concerning the economic challenges facing the industry in four model sub views including exploration, development, production, and revenue sectors and to present that knowledge in terms of interconnected feedback loops (Meadows 1972).

By combining socio economic and System Dynamics literature, a broader understanding of economic challenges facing the Nigerian oil industry has been constructed (c.f section 2.1). This multidisciplinary approach is in line with Samii and Teekasap's (2009) proposal for the application of System Dynamics in a variety of areas. Given this connection, a satisfactory solution will be found in focusing not just on a single aspect of the overall challenges facing the industry - such as crude oil theft, vandalism, cash call shortfall, project delays, and militants, amongst others, but rather all these challenges collectively as a system. In order to realise this objective, the chapter is organised as follows. Firstly, the approach to model design and development is presented, starting with the development of the qualitative model utilising the modular approach expressed by Wolstenholme (1990) as well as the guidelines offered by Vennix (1996) and Sherwood (2002)

(c.f chapter four and chapter five). This process, steps, and guidelines are operationalized below in order to facilitate the development of the model for this research.

In order to conduct a more elaborate quantitative simulation analysis, the influence diagram (CLD) of the various parts of the of the model given in figures 8.13 to 8.16 below are converted and transformed to stock and flow diagrams. These structures reflect the entire challenges facing revenue generation in the Nigerian oil industry which, as earlier indicated, are grounded from diverse social, economic and conflict literature (section 3.1.: oil and gas operations) and (see section 3.3.1: challenges facing Nigerian oil industry), as well as in-depth enquiry data (see section 7.6 and 7.7 for grounded theory analysis of exploratory and main interviews respectively and figures 7.3 and 7.4 for phases of grounded theory analysis for exploratory and main interviews respectively). A detailed System Dynamics model is presented in sub views by defining important variables and depicting key relationships linking the relevant levels and rates using SFD.

Finally, the overall model fully evolved through collaborative engagements with system actors, the guidance of the director of studies as well as frequent reviews by experts in both qualitative and quantitative aspects of System Dynamics. For System Dynamics simulation modelling, this research used Vensim DSS software which supported the construction of the model in stock and flow diagrams, reflecting the same relationship of the causal loop diagram.

## **8.1 The Problem**

Socio-economic and political challenges are common occurrences in some natural resource endowed economies (c.f. section 1.1). Several natural resource endowed economies were noted to have experienced an increased risk of civil conflicts, economic deterioration, and corruption (c.f section 2.1 and 2.2). These challenges negatively affect the revenue generation potentials of the industry thus affecting the government revenue profile in view of the role of the sector to the country's economy (for an elaboration of the literature, refer to the literature review in section 2.2). As noted earlier, this study intends to develop a System Dynamics model in order to investigate this problem.

Three powerful tools are involved at this stage of the modelling exercise. These include: reference modes, time horizon and model boundary.

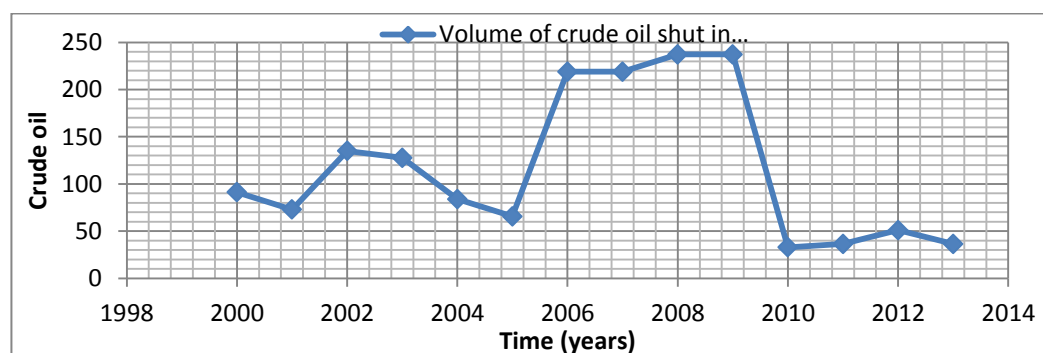
### 8.1.1 Reference Modes

The reference mode in this research describes challenges facing revenue generation in the Nigerian oil industry via graphical representation of important variables depicting the behavioural pattern that dynamically characterised the problem: evolving over time; exhibiting the genesis of the problem and inferring the future behaviour of the problem. The term reference mode serves as a reference source: i.e., the modeller refers back to them in the process of modelling, thus helping the client and the modeller to avoid the narrow event orientated world view common to many people from a broader and holistic viewpoint and to events that are detached in space and time (Sterman 2000).

The behaviour pattern of certain important variables was obtained from literature and the decision-makers. Those variables are: actual crude oil revenue, actual crude oil production, corruption, illegal crude oil theft, and vandalism. Examples of the graphical representations of the reference modes of behaviour for these key variables are depicted below in Figures 8.1a through to 8.1f.

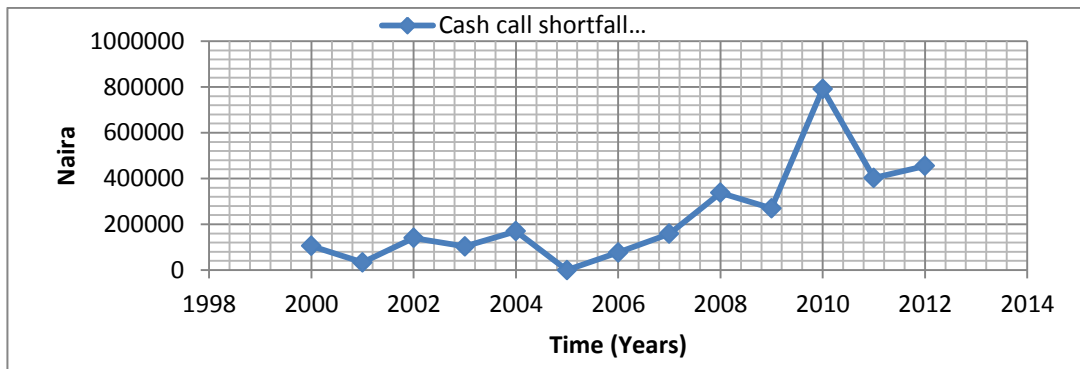
#### Reference modes (graphs)

**Figure 8.1a: Production shut in**



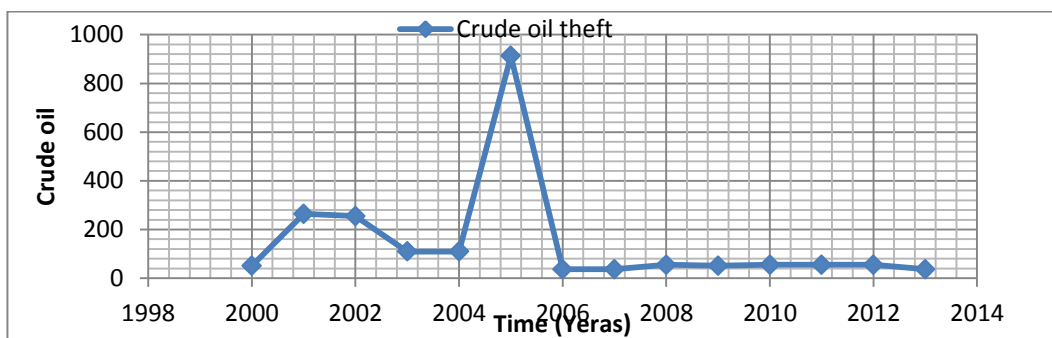
**Reference mode for production shut in (NNPC 2010, 2014 NEITI 2006 and 2013)**

**Figure 8.1b: Cash call shortfall**



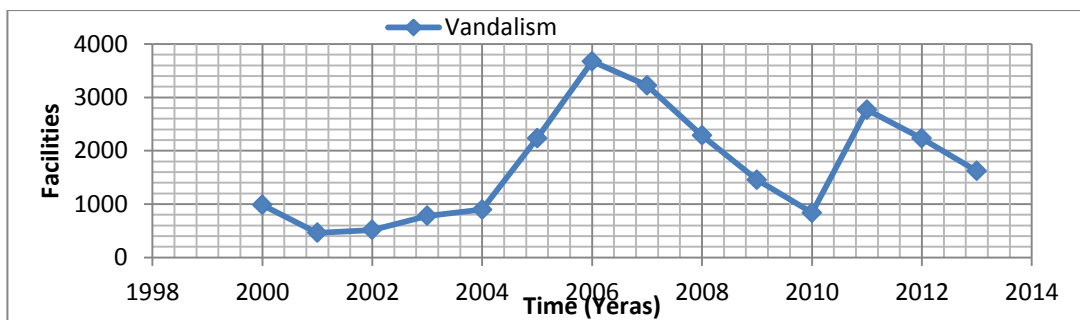
Reference mode for cash call shortfall (NNPC 2010, 2014 NEITI 2006 and 2013)

**Figure 8.1c: Crude oil theft**



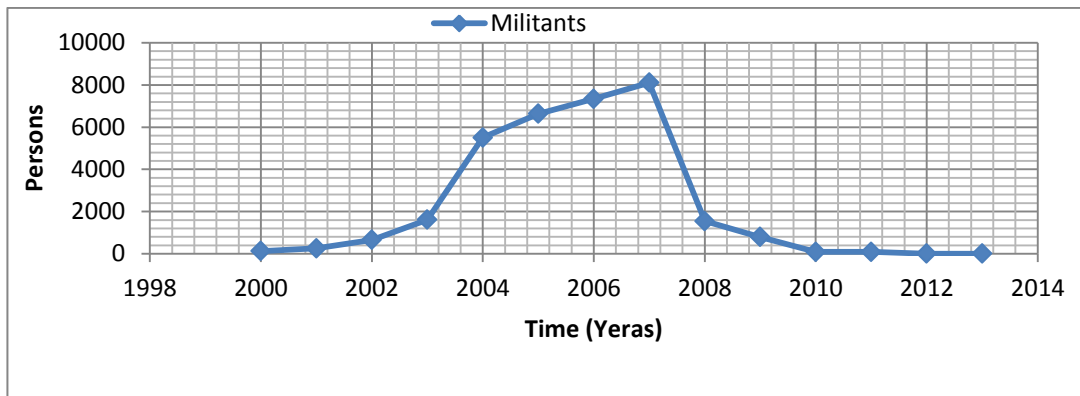
Reference mode for crud e oil theft (stolen in Nigeria (NNPC 2010, 2014 NEITI 2006 and 2013)

**Figure 8.1d: Vandalism**



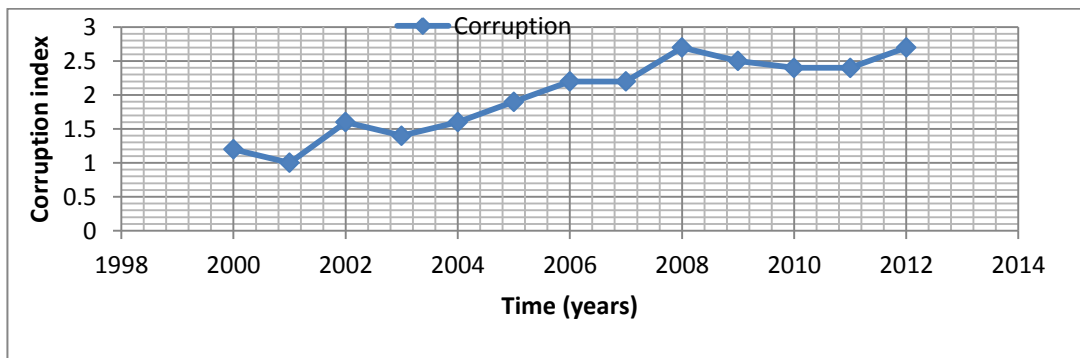
Reference mode for vandalism in Nigeria (NNPC 2010, 2014 NEITI 2006 and 2013)

**Figure 8.1e: Militants**



Reference mode for militants in Nigeria (NNPC 2010, 2014 NEITI 2013)

**Figure 8.1f: Corruptions**



Reference mode for corruption in Nigeria (TI 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 2014)

### 8.1.2 Time horizon

The need to view the problems from their origins entails looking back over a long time considering previous policies, actions and inactions: the fact that these might have given rise to effects that are far displaced in space and time is not contestable in SD. This view was strengthened by Saeed, (1994) in noting that the time horizon of the reference mode is dependent on the goal of the model, further stressing that it would usually be longer than the historical information on which it is based since it would also involve information concerning the inferred future. On the basis of this, the selection of an adequately long time frame is crucial.

The time for this research is determined as 35 years covering the period between 2000 and 2035 with the base year of 2000. Selecting this time period was based on several reasons including the estimated time for which the Nigerian crude oil reserve is estimated to last; 35 years. It is also considered a suitable time frame for

the modelling approach warranting exploratory activities and experimentation regarding a variety of possible policy implications. The time allotted also accommodates and allows the need for studying the effect of changes in various parameters, alternative policy decisions and for devising solutions to deal with the various existent and potential problems.

### **8.1.3 System Boundary**

The boundary of the model reflects the challenges facing revenue generation in the Nigerian oil industry. A boundary chart is used to communicate the model boundary and also highlights its causal relationships. A summary of the model scope by classifying and listing key variables into three classes is presented in Figure 8.2. The model developed in this research was configured to comprise four views. The first view depicts the basis and starting point for all crude oil activities (exploration sub view) while the remaining sub views portray the five major challenges facing revenue generation in the industry.

This model was designed in such a way that all the sub views interact dynamically. Since systems do not exist in isolation, the presence therefore of some elements external to the system that directly or indirectly affect system behaviour is imperative. Based on this, it is important to clearly state the boundary of the system. Bank (1994) defined a system boundary on the objective of the study conducted. On the basis of this, the modeller needs to define the system boundary as a prelude to building a model. Accordingly, Forrester (1961) stressed that factors that must be considered for inclusion when building a model emerge directly from the questions to be addressed. With the emergence of new questions, any particular model needs, therefore, be altered and extended (Forrester, 1961). Figure 8.2 represent the model boundary chart for this research work. The model variables where specifically drawn from the literature: oil and gas operations (section 3.1.1), challenges facing Nigerian oil industry (see section 3.3.1) grounded theory analysis for exploratory interviews (see section 7.6), main interviews (see section 7.7), as well as their accompanied Figures 3.2 for upstream oil and gas operations and its related input, 7.3 for grounded theory analysis of exploratory interviews and 7.4 for grounded theory analysis of main interview.



**Figure 8.2: Model boundary chart**

**EXCLUDED VARIABLES**

**Degradation of land, destruction of marine resources, curtailing daily production, production below optimal level, absence of good governance, conduct of periodic audit, openness of operations, inaccurate crude oil output, inaccurate records of crude oil sales, siphoning of crude oil, cash call default, loan, relative peace and calmness and reduction in militants.**

**EXOGENOUS VARIABLES**

corruption, transparency, amnesty initiatives, interest rate, rate of repairs, average project completion periods. Discovery coefficient, average depletion rate, crude oil price, average cost of a single arm, rate of repairs, average time taken for repairs, compensation, average cost of a single well,

**ENDOGENOUS VARIABLES**

Cumulative crude oil produced, actual crude oil production, vandalism, rate of vandalism, communal unrest, militants, rate of militants, potential production, rate of crude oil theft, illegal money, money used to purchase arms, proliferation of arms, actual cumulative government, rate of government investment, cash call shortfall, cumulative cash call shortfall, alternative funding,, interest, oil wells available for production, decommission wells, oil spill, oil theft, proved crude oil reserves, rate of crude oil discovery, depletion, rate of investment, project delay, decommission wells, variation, actual cash call paid, oil spill, rate of investment, oil spill, rate of investment, average oil well life, crude oil sales, potential crude oil revenue, cumulative government potential crude oil revenue, crude oil revenue, development investment, cash call obligation, interest incurred, interest paid.

fraction of unemployed youths that turn to militants, rate of unemployed youths, rate of unemployed youths, rate of investment, average cost of a single oil well, average time taken to pay interest, reserve production ratio and OPEC quota.

The model chart consists of three classes of variables: excluded, endogenous and external variable. The following sub section gives a brief highlight on each class of variable.

### **8.1.3.1 Endogenous variables**

Endogenous variables are those variables whose behaviour arises as a result of the interaction(s) within the model (system). “System dynamics seeks endogenous explanations for phenomenon” (Sterman, 2000, p.95). Variables contained in the box compartment for endogenous variables are modelled as endogenous variables in the model. These numbers of variables are operationalized and described further in the process of model development as presented in Figure 8.2 in Chapter 8 section 3.1.1, Figure 8.3 in Chapter 8 section 3.1.2, Figure 8.4 in Chapter 8 section 3.1.3, Figure 8.5 in Chapter 8 section 3.1.4, Figure 8.7 in Chapter 8 section 3.2.2, Figure 8.8 in Chapter 3.2.3, Figure 8.9 in Chapter 8 section 3.2.4, Figure 8.11 in Chapter 8 section 4.2, Figure 8.12 in Chapter 8 section 4.3, Figure 8.13 in Chapter 8 section 4.4, Figure 8.15 in Chapter 8 section 5.2, Figure 8.16 in Chapter 8 section 5.3, and Figure 8.17 in Chapter 8 section 5.4 as well as equations presentation.

### **8.1.3.2 Exogenous variables**

Exogenous variables are those variables considered outside the system boundary but yet exert influence on the system in some ways. The behaviour of the system is being explained by the exogenous variables as being triggered by external variables. These are hence not modelled explicitly; the influence of exogenous variable(s) is/are considered to be unidirectional and devoid of any important feedbacks expected (Sterman, 2000). On the basis of this understanding variable in the compartment labelled "exogenous variables" in table 7.2 are considered and treated as external variables in the process of model development as presented in Figure 8.4 in Chapter 8 section 3.1.3, Figure 8.5 in Chapter 8 section 3.1.4, Figure 8.7 in Chapter 8 section 3.2.2, Figure 8.8 in Chapter 3.2.3, Figure 8.11 in Chapter 8 section 4.2, Figure 8.12 in Chapter 8 section 4.3, Figure 8.13 in Chapter 8 section 4.4, Figure 8.14 in Chapter 8 section 5.1, Figure 8.15 in Chapter 8 section 5.2, Figure 8.16 in Chapter 8 section 5.3, and Figure 8.17 in Chapter 8 section 5.4 as well as equations presentation.

### **8.1.3.3 Excluded variables**

Excluded variables are treated outside the boundary of the system and thus excluded and ignored. The variables: degradation of land, destruction of marine

resources, curtailing daily production, production below optimal level, absence of good governance, inaccurate records of crude oil sales, siphoning of crude oil, criminal activities, and country's economy are being excluded and ignored in the model because the model is only concerned with challenges facing government revenue in the industry and other issues that affect the economy are beyond the scope of this research.

## **8.2 Formulating Dynamic Hypotheses**

The working theory is constructed for the purpose of explaining the problem at hand. This is comprised of the structure of the system that possesses the potential to reveal problem behaviour. Forrester (1968) pointed out that if the model perfectly depicts an actual situation, it therefore implies the theory of the manner in which that aspect of the real system operates. In the presentation of the dynamic hypotheses for this research work, the challenges facing revenue generation in the Nigerian oil industry is explained by a complex relationship which involves: illegal bunkering (crude oil theft), vandalism, militancy, community unrest, cash call shortfall leading to incurring interest and project delay. Overall, the dynamic hypothesis behind this research's model is highlighted via causal loop structure (see section 8.3).

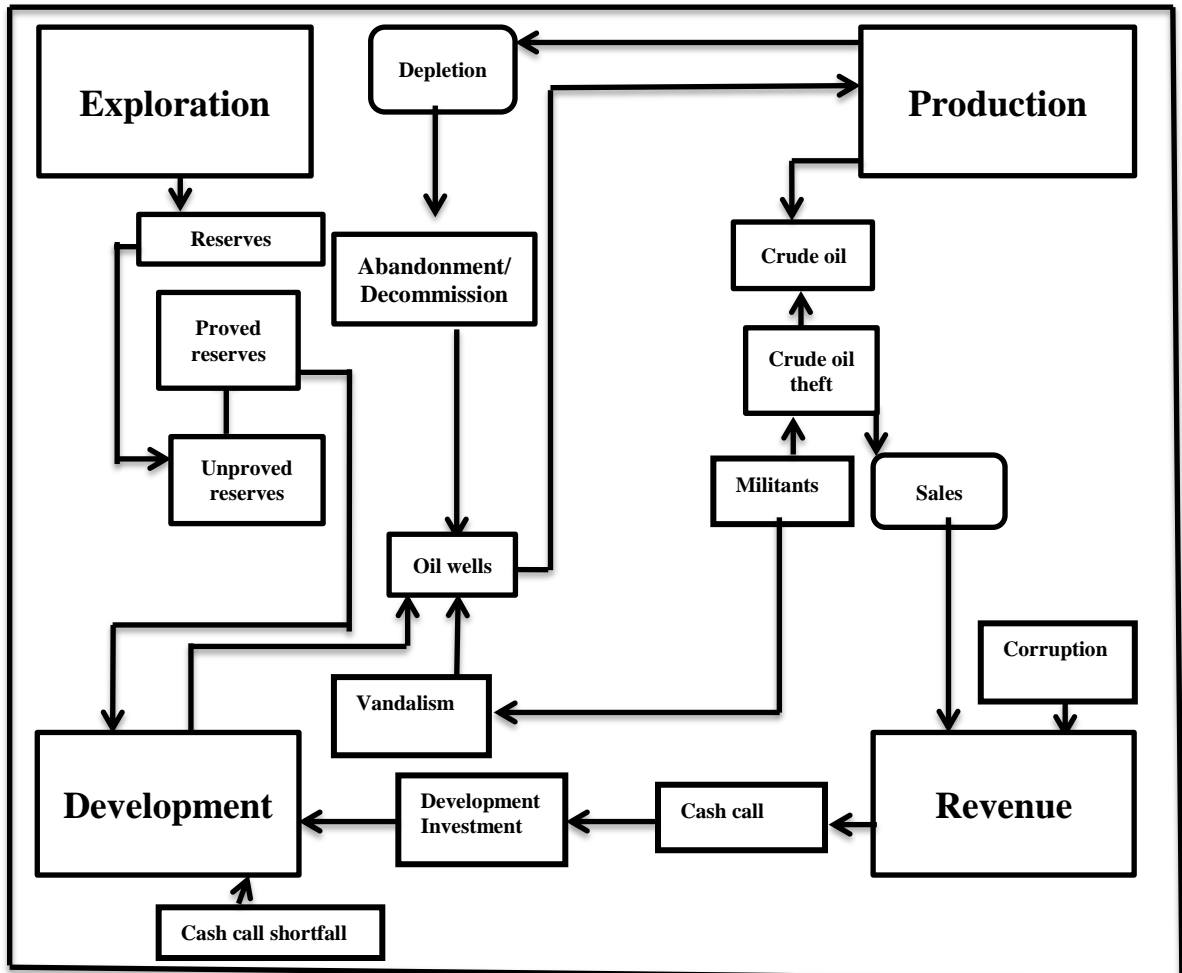
### **8.2.1 Sub System Diagram**

The basic model characterising challenges facing revenue generation in the Nigerian oil industry is specifically developed for a 35 years' timescale, from 2000 to 2035. The sub system diagram represents the sector map for this research work. There are four sectors in this sector map: exploration, development, production and revenue. The investment decision is crucial in the 2 model sectors of development and production and solely relies on the revenue sector for proper financing. The availability of oil as well as its associated revenue is the major determinant of the possibility of investment or not including the accurate size as well as befitting the environment for investment.

Overall, the figure represents the architecture of the model for this research which is built around. Figure 8.3 represents the overall model architecture for this

research. This helped in achieving clarity and easy navigation. Figure 8.3 represent the sub system diagram of the mode for this research work.

**Figure 8.3 Sub system diagram**



**Source: Author's work and synthesis from literature**

Figure 8.1 represents a sub system diagram configured specifically to capture the overall structure of the model for the study. The sub system diagram serves as a dynamical hypothesis as well, thus guides the construction of the final model. The sub system diagram consists of four sectors: exploration, development, production and revenue.

As shown above, these sectors are connected together. The first three sectors (as well as abandonment/ decommissions) represents the crude oil value chain and the last sector constituting revenue as a resulting from sales of the crude oil. As illustrated in the sub system diagram, exploration (upper left corner) which is the first phase towards ensuring flow of oil from reserves, development (lower left

corner) is the second phase towards ensuring the extraction of the reserves through construction of wells and related facilities. The third phase (upper right corner) ensures the production of the reserves through the available facilities and finally the revenue phase (lower right corner) is concerned with the revenue resulting from the sales of the crude oil. In each case identified challenges relevant to each sector is presented in the diagram. An elaborate diagram comprising all relevant variables is presented in respective CLDs and SFDs.

### **8.2.2 Major assumptions.**

1. The model assumes that crude oil reserves is sufficiently large enough provide 35 to 40 years of crude oil at an average production rate of 2 million barrels/day to as reported by OPEC (2011) (See section 3.1.1.3)
2. A short fall in funding reduces government potential revenue as a loan is sourced to augment the short fall occasioned by the government attitude, thereby incurring interest which reduces revenue due to government as reported by Nlerun (2010) (See section 3.3.1.6). This allows interest to be represented in the model as what is potentially supposed to be additional revenue to the government if not for the cash call shortfall.
3. The model assumes that corruption is constant. This allows corruption in oil industry to be represented in the model based on the opinion of the stakeholders interviewed in the industry.
4. The model assumes the total number of militants to be between 25,000 and 30,000 as reported by (Okogun and Okeneye, 2009). This allows this rise of the militants to be represented in the model.
5. The model assumes 10 years as the average oil well life based on the opinion of the interviewees and allows rate of well decomposition to be estimated.
6. The model assumes only one operator in the industry. This allows the research to concentrate on challenges facing government in the industry and also limit the boundary of the model.

7. The model assumes only crude oil is produced. This allow the boundary of the model to be control as incorporating gas sub sector will take another aspect of the industry and also expand the scope of the model.

8. Although the downstream sector of the industry is also of high significance, it has not been included in the current model. This allows the research to draw a good model boundary.

9. The average project completion period globally is 5 years but projects in Nigeria are about 10 years before completion due to project delay (USA Energy Information Administration, 2013). This allows delay in project completion to be incorporated in the model.

10. The model assumed that crude oil theft is mainly responsible by militants. This allows government policy (amnesty measures) to be perfectly represented in the model and also limit the boundary of the model.

11. The model assumed there was no significant provision of employment by the government. This allows effect of employment to unemployed youths to be measured in the model.

### **8.3 Model Development**

The second step of Sterman (2000) modelling framework comprises the identification of the key interrelationships operating within a system. System dynamics model is mainly conceptualised through the development of causal loop diagrams. The CLD in this research followed Figure 3.4 developed from literature on background of oil and gas industry (upstream oil and gas operation and its related output) described in section 3.1, literature on challenges facing Nigerian oil industry where list of variable and their relationships where obtained and documented in table form. (see tables 8.3, 8.4. 8.5 and 8.6), the effort of the researcher, the guidance of his supervisor as well as a series of interactions with experts in the field of both qualitative and quantitative system dynamics. The model is further refined and modified through the engagement of the system actors in semi structured interviews and focus group discussions.

In particular, a modular approach to model development was adopted in this research using the steps advocated by Wolstenholme (1990) which involves commencing the construction of the model from central problem of the research. The modular approach breaks down the complex research problem into small entities and studies them more closely separately in order to gradually gain an understanding of the whole central research problem. To this end, the central problem is broken down in the three sub views: development, production and revenue sub views. However, the fourth sub view, i.e. exploration sub view is also linked to the other sub views because of its importance in crude oil value chain notwithstanding the fact that no problem is identified to be associated to it. The following variables: corruption, crude oil theft, vandalism, funding gap and production shut down are recognised to be associated with the perceived cause(s) of concern, therefore, relevant historical data on their behaviour over time were obtained hence facilitates defining a reference (see Figures 8.1a to 8.1e).

In the various sub views, system's process structure are firstly developed thus identified the resources of system associated with the important variables (see Figures 8.22, 8.23, 8.24 and 8.25). This is followed by the identification of the initial state of individual resources and finally the resource flow for individual resource, comprising relevant resource states and their respective rates of conversion is created (Wolstenholme, 1990) (see Figures 8.22, 8.23, 8.24 and 8.25). Essentially, the complex problem was disaggregated into sub sectors whose behaviour can easily be comprehended. This resulted to the development of four sub model views representing various challenges facing revenue generation in the Nigerian oil industry. The following section further describes the gradual development of the model based on a number of qualitative exercises

### **8.3.1 Developing Structures from textual data bases**

The starting point of the research was the development of the model from the documents obtained and literature on oil and gas operations as well as challenges facing Nigerian oil industry from previous research work as stated in section 3.3. The table of relationships was obtained from thorough document and literature reviews where the texts were reread sentence by sentence documenting relationships subsisting between variables on a sheet of paper in a diagram form

thus forming a list of variables and their respective relationships (see tables 8.3, 8.4, 8.5 and 8.6). Due diligence was employed in selecting only relevant variables in this regards. By building on the modular approach to model building (Wolstenholme 1990), causal loop diagramming technique (Sherwood 2002; Sterman 2000), the five recommendations by Vennix (1996), the respective CLDs were developed. Figure 8.2 represent the exploration CLD for this research. The following section presents exploration, development, production and revenue CLDs.

### 8.3.1.1 Exploration Sector CLD

The exploration CLD was specifically developed to link it to other sectors of the model in order to represents the complete upstream value chain since there is no any challenge is identified with the sector. Table 8.3 present the variables used in developing the CLD for exploration sector.

**Table 8.3: Variables and relationship for exploration CLD**

No	Variable	Sources
1	unproved crude reserves → rate of oil discovery	(Fagan, 1997; Watkins 2006)
2	proved crude oil reserves → rate of depletion	(Sorrell et al., 2012).
3	rate of depletion → proved crude oil reserves	(Sorrell et al., 2012).
4	Proved crude reserves → unproved crude reserves	(Fagan, 1997; Watkins 2006)
5	Rate of oil discovery → proved crude reserves	(Fagan, 1997; Watkins 2006)

Table 8.3 represent the variables used in developing CLD for exploration sector of the model. The variables were presented with their respective causal relationships as extracted from section 3.3. This provides the basis for the development of the exploration CLD which is presented in Figure 8.2.



**Figure 8.2: Exploration sector CLD developed from the textual data base**

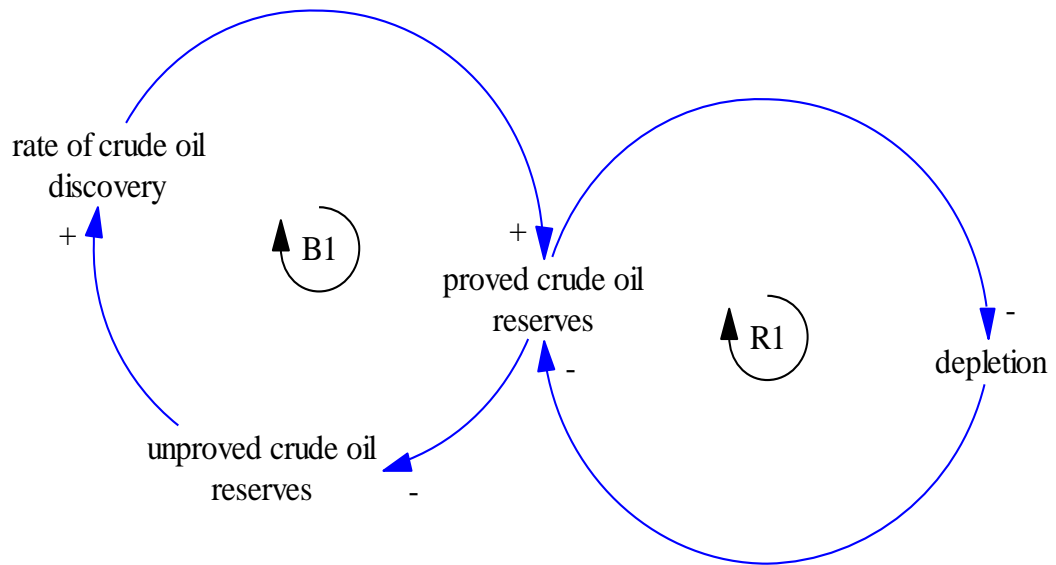


Figure 8.2 was developed from the literature on oil and gas industry. It is made up of two feedback loops including: Balancing and reinforcing feedback loops. Detailed discussion is also provided in the section for description and structural verification (see section 8.5.1.1).

### **8.3.1.2 The Development Sector CLD**

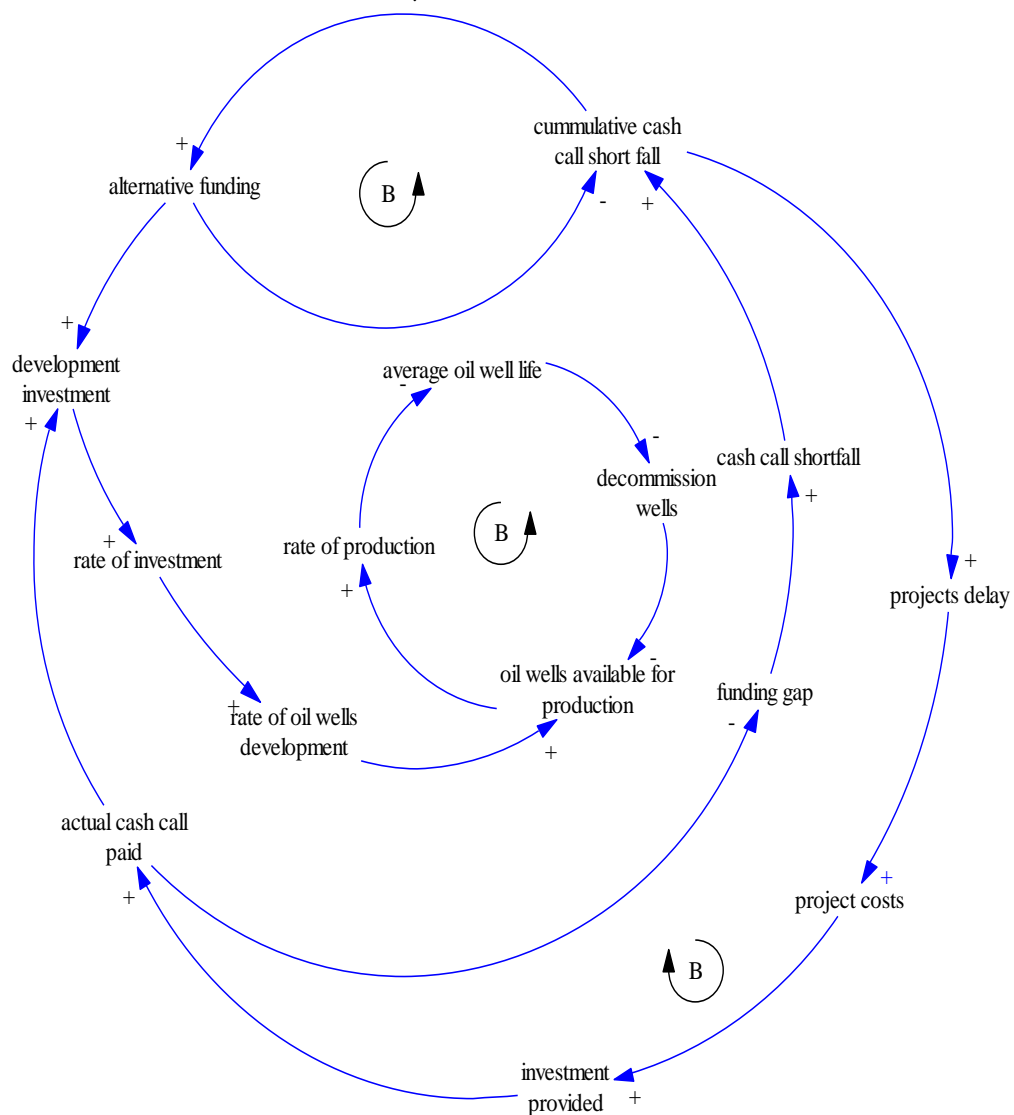
The Development CLD also draws from the upstream value chain of oil and gas operation as well as challenges facing Nigerian oil industry from previous research work as stated in section 3.3. Table 8.4 present the variables used in developing the CLD for development sector.

**Table 8.4: Variables and relationship for development CLD**

No	Variable	Sources
1	Cash call shortfall → C/cash shortfall	ABD 2009; NNPC 2010
2	Production → Oil well life	Hook et al., 2014
3	Oil well life → Abandonment	Hook et al., 2014
4	A/funding → C/cash call shortfall	NNPC 2010
5	C/cash shortfall → A/funding	NNPC 2010
6	Abandonment → Oil wells	Jahn, Cook and Graham, 2008
7	Oil wells → production	Hook et al., 2014; Craft & Hawkins 1959
8	Funding gap → cash call short fall	Nlerun 2010.
9	Cash call obligation → Funding gap	Mbendi, 2000
10	Actual cash call paid → Funding gap	Nlerun 2010
11	C/cash call shortfall → Project delay	Baloi and Price 2003
12	Investment provided → Actual cash call paid	NNPC 2010
13	Rate of oil wells development → Oil wells available for production	Nlerun 2010
14	Alternative funding → Development Investment	NNPC 2010
15	Development investment → Rate of investment	Odularu2008
16	Project delay → Project costs	Baloi and Price 2003
17	Project costs → Investment provided	Baloi and Price 2003
18	Actual cash call paid → Development Investment	Odularu2008

Table 8.4 represent the variables used in developing CLD for development sector of the model. The variables were presented with their respective causal relationships as extracted from section 3.3. This provides the basis for the development of the development CLD which is presented in Figure 8.3.

**Figure 8.3 Development sector CLD developed from the textual data base**



**Source: Author's work and synthesis from literature**

Figure 8.3 was developed from the literature on oil and gas industry. It is made up of three balancing feedback loops. Detail discussion is also provided in the section for description and structural verification (see section 8.5.1.2).

### 8.3.1.3 The Production Sector CLD

The production CLD also draws from the upstream value chain of oil and gas operation as well as the challenges facing Nigerian oil industry from previous research work as stated in section 3.3. This sub view is the most discussed in the

literature as most of the challenges facing the industry falls under this sub view.

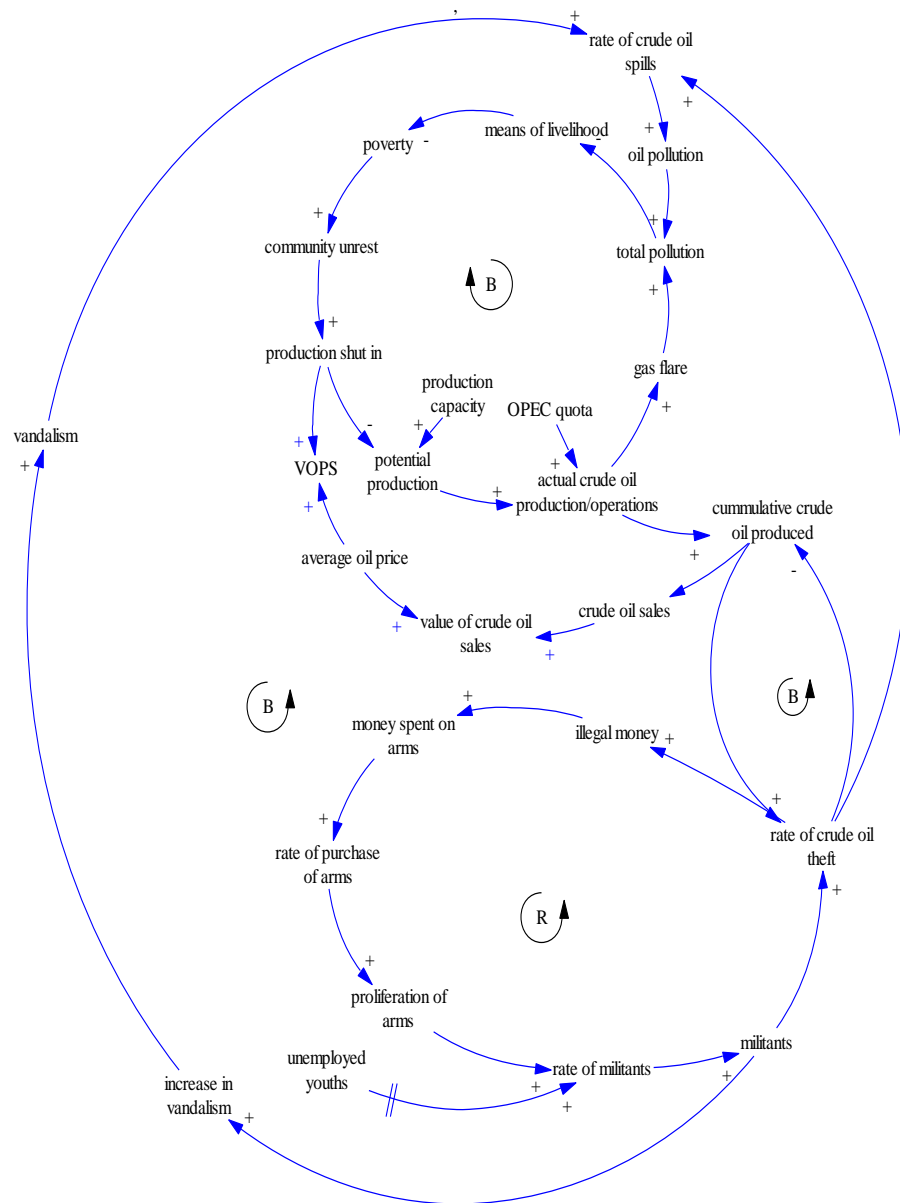
Table 8.5 present the variables used in developing the CLD for exploration sector.

**Table 8.5: Variables and relationship for production CLD**

No	Variable	Sources
1	Means of livelihood → Poverty	Jike 2004
2	Poverty → Community unrest	Okafor 2011
3	Communal unrest → P/shut in	Asgill, 2012.
4	Production/Operations → Gas flare	Inokoba and Imbua 2010
5	Rate of gas flare → Pollution	Afinotan and Ojatorotu 2009
6	Pollution → Means of livelihood	Jike 2004
7	oil-theft → Crude oil produced	Paki and Ebiefa 2011
8	Oil theft → illegal money	Asuni 2009
9	Illegal money → P/ Arms	Paki and Ebiefa 2011
10	Purchase of arms → P/ Arms	Asuni 2009
11	Profilferation of arms → Militants	Ojakotu and Uzodike 2007
12	Militant → Vandalism	Oshwofasa, Anuta, & Aiyedogbon 2012
13	Vandalism → Oil spill	Oshwofasa, Anuta, & Aiyedogbon 2012
14	Oil spill → Pollution	EIA 2012
15	Production → Crude oil	Ebeku 2008
16	P/production → Actual production	UNDP 1996
17	Unemployed youths → Militants	UNDP 2006
18	Production shut in → P/Production	Aiyedogbon 2012
19	Rate of repairs → Vandalism	Ajaero 2009
20	Production capacity → P/Production	NNPC 2010
21	Actual production → C/crude oil	UNDP 1996
22	C/crude oil produced → Oil theft	Paki and Ebiefa 2011
23	Militants → Crude oil theft	Inokoba and Imbua 2010
24	OPEC quota → Actual crude oil production	Dibooglu and AlGudhea 2007
25	Rate of militants → Militants	Innokoba and Imbua 2010
26	Potential militants → Rate of militants	Innokoba and Imbua 2010

Table 8.5 represent the variables used in developing CLD for production sector of the model. The variables were presented with their respective causal relationships as extracted from section 3.3. This provides the basis for the development of the production CLD which is presented in Figure 8.4.

**Figure 8.4: production sector CLD developed from the textual data base**



**Source: Source: Author’s work and synthesis from literature**

Figure 8.4 was developed from the literature on oil and gas industry. It is made up of four feedback loops including: three balancing and a reinforcing feedback loops. Detail discussion is also provided in the section for description and structural verification (see section 8.5.1.3).

### 8.3.1.4 The Revenue Sector CLD

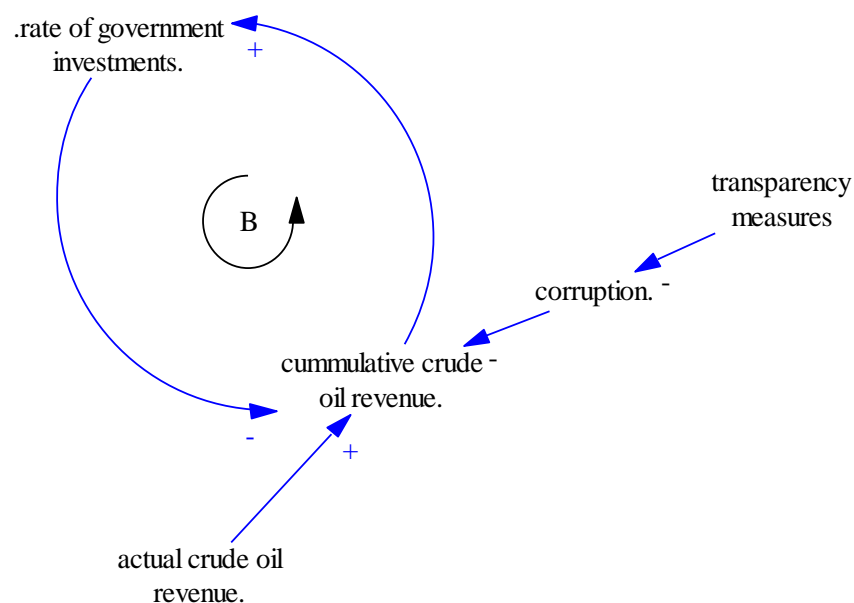
The revenue CLD also draws from the literature on the role of oil and gas industry in section 3.2 as well as challenges facing Nigerian oil industry from previous research work as stated in section 3.3. Table 8.6 present the variables used in developing the CLD for production sector.

**Table 8.6: Variables and relationship for revenue CLD**

No	Variable	Sources
1	Corruption → cumulative crude oil revenue	Mohammed 2013; Hanson 2007
2	C/crude oil revenue → rate of government investment	Akinlo 2012
3	Crate of government investment → C/crude oil revenue	Akinlo 2012
4	Transparency measures → Corruption	NEITI 2011
5	Actual crude oil revenue → C/crude oil revenue	NEITI 2011

Table 8.6 represent the variables used in developing CLD for revenue sector of the model. The variables were presented with their respective causal relationships as extracted from 3.2 and 3.3. This provides the basis for the development of the revenue CLD which is presented in Figure 8.5.

**Figure 8.5: Revenue sector CLD developed from the textual data base**



**Source: Source: Author's work and synthesis from literature**

Figure 8.6 was developed from the literature role of oil industry as well as challenges facing Nigerian oil industry presented in section 3.2 and 3.3.1 respectively. It is made up of a single balancing loop denoted by B. Detail discussion is also provided in the section for description and structural verification (see section 8.5.1.4). The following section presents enhancement of the CLD with information obtained from mental data base.

### **8.3.2 Developing Structures from mental data bases**

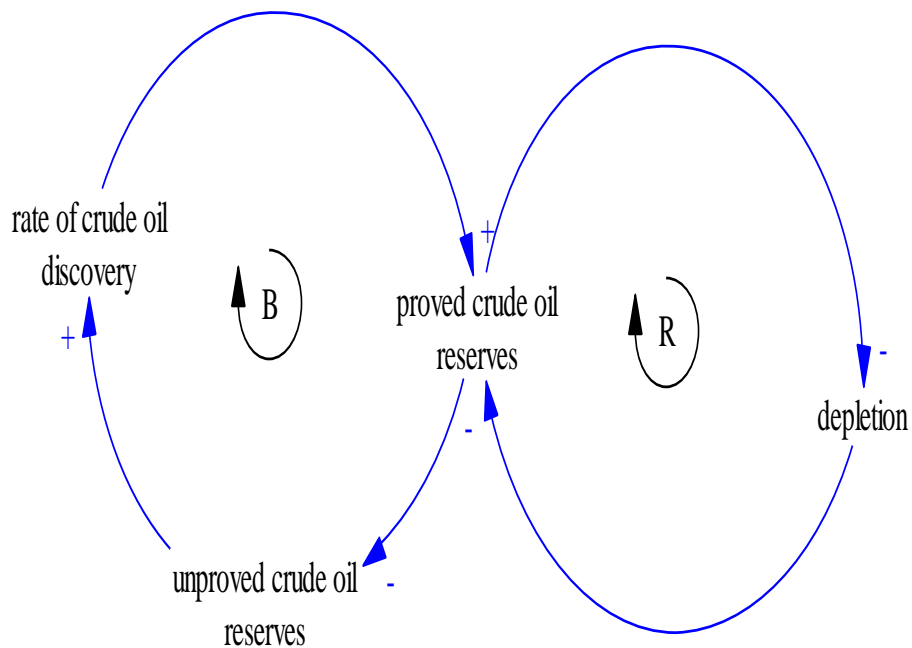
In addition to the earlier structures developed from the textual data base, the results of the analysis of the data elicited from the mental data base were also used to complement these structures. After the analysis of the enquiry data from both exploratory interviews presented in section 7.6 and Figure 7.3 and the main interviews in section 7.7 and Figure 7.4, using a grounded approach advocated by Strauss and Corbin (1998), the variables that emerged were incorporated into the initial respective CLDs developed from the documents and literature. The outcome of this was used in confirming and enriching the initial CLDs developed and also the refinement of conceptual understandings regarding the problem. The new CLDs that emerged from both the exploratory and main interviews were presented commencing with exploratory interviews. Figure 8.6 below presents the exploration CLD; Figure 8.7 presents the development CLD; Figure 8.8 presents the production CLD and figure 8.9 presents revenue CLD based on the outcome of the data obtained from the exploratory interviews.

### **8.3.3 Developing Structures from exploratory interviews**

#### **8.3.3.1. Exploration CLD**

In this section, no new variable relevant to this sub view emerged from the exploratory interviews. Based on this, the exploration CLD in Figure 8.6 at this stage remained as it was in Figure 8.2.

**Figure 8.6: Exploration sector CLD from exploratory interviews**



**Source: Source: Author's work and synthesis from literature**

Figure 8.6 represent the CLD at the stage of exploratory interviews. This CLD remained intact as no new variable relevant to it emerged in the data generated from the exploratory interviews.

### **8.3.3.2. Development Sector CLD**

Based on the data obtained from the exploratory interviews, new variables emerged from the qualitative data. (See section 7.6 for the grounded theory analysis and Figure 7.3 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.7 present the number of new variables relevant to development causal loop diagram that emerged.

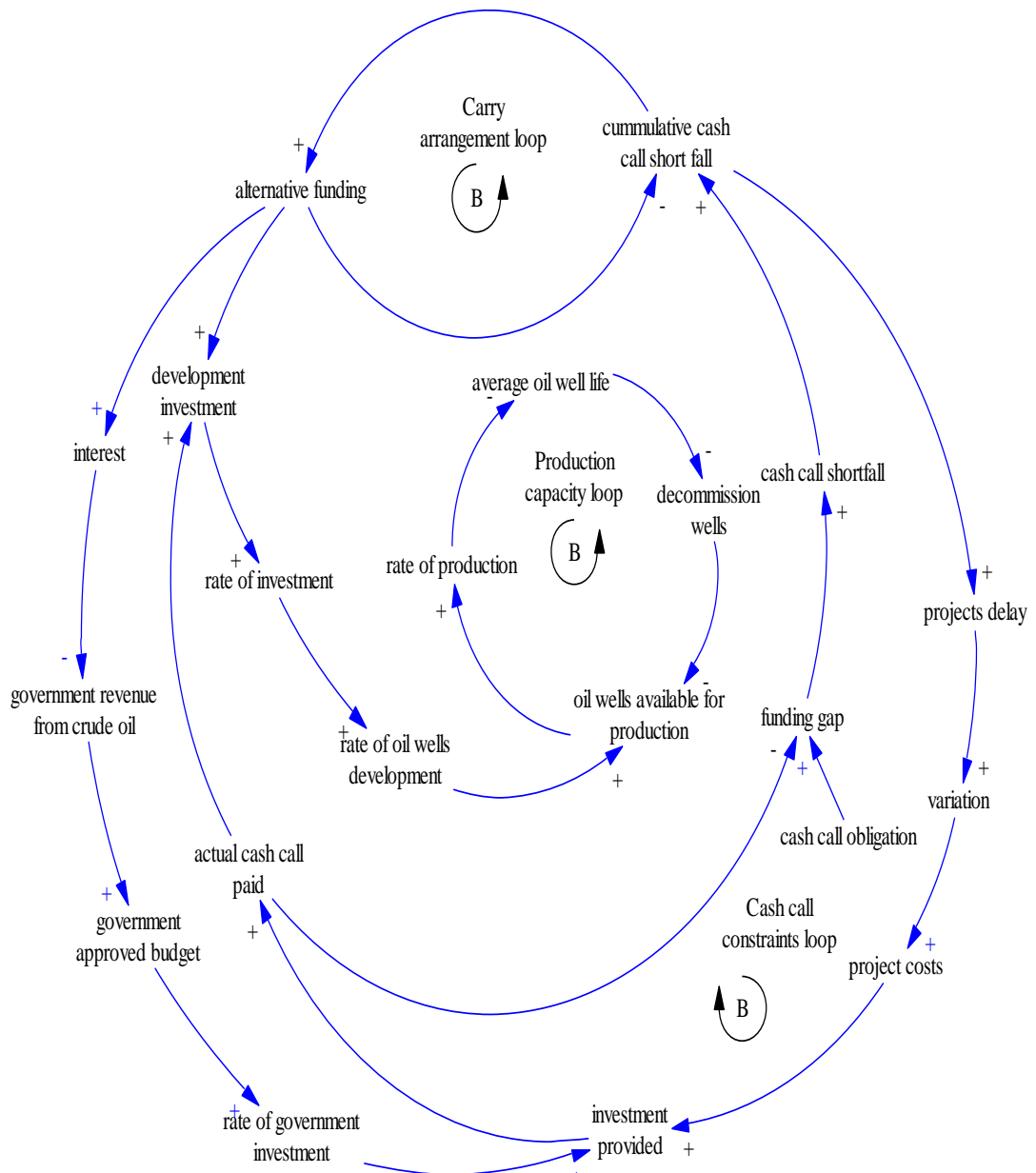


**Table 8.7: Variable relevant to development sub view from exploratory interviews**

No	New variable	Included variable	Excluded variable
1	Cash calls shortfall	Cash call	Cash call defaults
2	Project delay	Interest	Loan
3	Project cost	Variation	
4	Cash call default	Government revenue from crude oil	
5	Loans	Government approved budget	
6	Interest	Project costs	
7	Variation		
8	Government revenue from crude oil		
9	Government approved budget		
<b>Treated variables</b>			
1	Project delay	Also treated in textual data base	
2	Development investment	Also treated in textual data base	

Table 8.7 provides list of new variables relevant to this sub view that emerged from the grounded theory analysis of the exploratory interviews. It can be observed that some of the variables are included while others are excluded from model building process. The variables excluded i.e. loan and cash call defaults and the rationale behind their exclusion is discussed here. Loan is excluded from the CLD as it has been subsumed by alternative funding which referred to a more technical term used in the industry for funds borrowed in form of loans utilised to finance a cash call shortfall occasioned by government. Cash call default is also excluded from the CLD and replaced by and subsumed by cash call shortfall. This is based on the fact that, cash call shortfall constitute what is currently applicable in the industry. Additionally, project delay which also emerged from the analysis of the exploratory interviews has already been incorporated from the variables obtained from textual data bases. Based on this, Figure 8.7 can be further extended and revised with addition of included variables.

**Figure 8.7: Development sector CLD extended from exploratory interviews**



**Source: Source: Author's work and synthesis from exploratory interviews**

Figure 8.7 represent an extended and revised version of Figure 8.3, as some of the variables that emerges from the exploratory interviews were incorporated and hence the CLD is revised

### 8.3.3.3. Production Sector CLD

Based on the data obtained from the exploratory interviews, new variables emerged from the qualitative data. (See section 7.6 for the grounded theory analysis and Figure 7.3 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.8 presents new variables relevant to production sector causal loop diagram that emerged.

**Table 8.8: Variable relevant to production sub view**

No	New variables	Included variables
1	Disruptions of operation	Disruption of operations
2	Environmental impact	Environmental impact
3	Degradation of land	
4	Destruction of marine resource	
5	Curtailing daily production	
6	Production below optimal level	
<b>Treated variables</b>		
1	Potential production	Also treated in textual data base
2	Production capacity	Also treated in textual data base
3	Rate of militants	Also treated in textual data base
4	Potential militants	Also treated in textual data base
5	Production shutdown	Also treated in textual data base
<b>Excluded variables</b>		
1	Degradation of land	
2	Degradation of marine resources	
3	Curtailing daily production	
4	Production below optimal level	

Table 8.8 provides list of new variables relevant to this sub view that emerged from the grounded theory analysis of exploratory interview. It can be observed that some of the variables are included while others are excluded from model building process. The variables excluded i.e. degradation of land, degradation of marine resources and curtailing daily production as well as the rationale behind the exclusion of this variable is discussed below.

Degradation of land and destruction of marine resources are environmental impacts responsible for pollution and are treated under the theme pollution and environmental impacts modelled as the name of the loop. Treating all of them differently in the model would require more data, expand the scope of the model and also lead to deviation from the main focus of this research. Curtailing daily



Figure 8.8 represent an extended and revised version of Figure 8.4, the variables that emerges from the grounded theory analysis of exploratory interviews were incorporated hence the CLD is revised.

### 8.3.3.4. Revenue Sector CLD

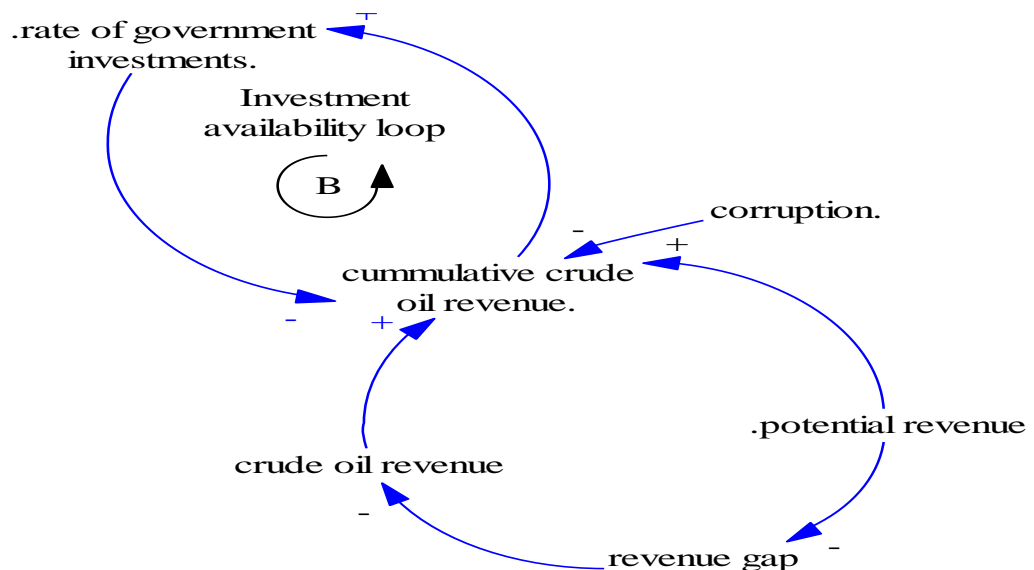
Based on the data obtained from the exploratory interviews, new variables emerged from the qualitative data. (See section 7.6 for the grounded theory analysis and Figure 7.3 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.9 present the number of new variables relevant to revenue sector causal loop diagram that emerged.

**Table 8.9: Variable relevant to revenue sub view**

S/No	New variables	Included variables	Excluded variables
1	Potential revenue	Potential revenue	-
2	Revenue gap	Revenue gap	-

Table 8.9 provides list of new variables relevant to this sub view that emerged from the grounded theory analysis of exploratory interview. Figure 8.9 can be further extended and revised with addition of included variables.

**Figure 8.9: Revenues sector CLD extended from exploratory interviews**



**Source: Author's work and synthesis from exploratory interviews**

Figure 8.9 represents an extended and revised version of Figure 8.5, the variables that emerge from the qualitative interviews were incorporated and hence the CLD is revised.

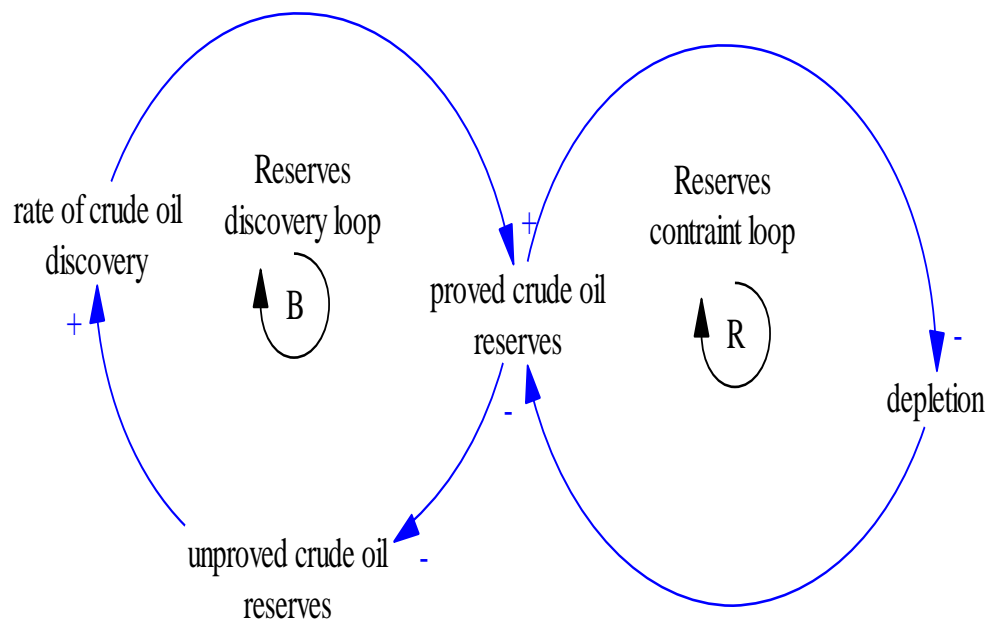
#### 8.4 Developing Structures from Main Interviews

In addition to the CLDs above, the results of the analysis of data elicited from the mental data base were also used to complement these structures. After the analysis of the enquiry data from main interviews using a grounded approach presented in section 7.7 and Figure 7.4. The following section presents the enhancement of the respective CLD.

##### 8.4.1 Exploration Sector CLD

In this section again no new variable relevant to this sub view emerged from the main interviews. Based on this, the exploration CLD in Figure 8.10 at this stage remained as it was in Figure 8.6.

**Figure 8.10: Exploration sector causal loop diagram**



**Source: Author's work and synthesis from literature**

Figure 8.10 represent the CLD at the stage of main interviews. This CLD remained intact as no new variable relevant to it emerged during the main interviews.

#### 8.4.2 Development Sector CLD

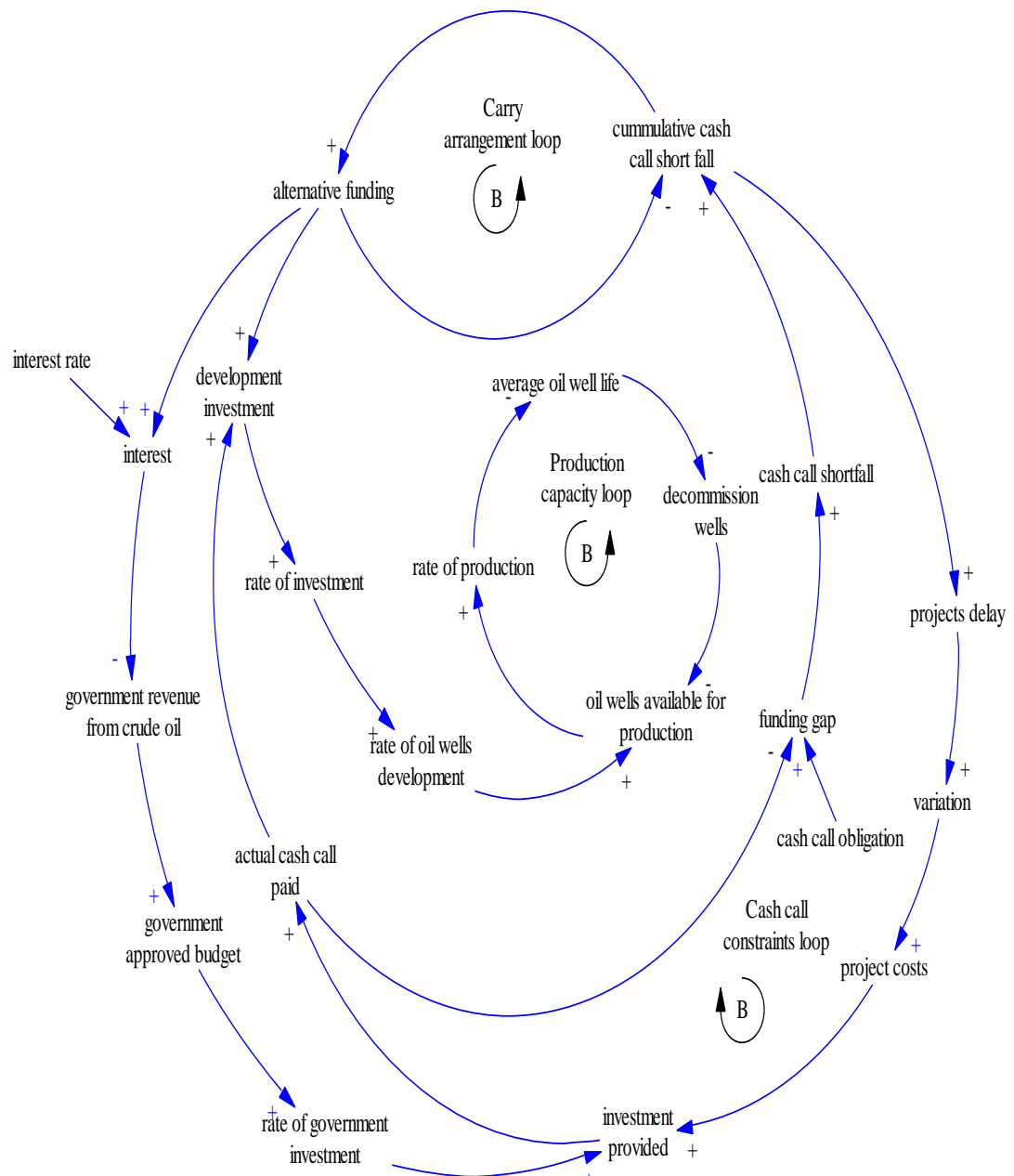
Based on the data obtained from the main interviews, new variables emerged from the qualitative data. (See section 7.7 for the grounded theory analysis and Figure 7.4 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.10 present the number of new variables relevant to development sector causal loop diagram that emerged.

**Table 8.10: Variable relevant to development sub view**

No	New variables	Included variables
1	Cash call obligation	Cash call obligation
2	Interest rates	Interest rates
3	Cash call shortfall	
4	Project delay	
<b>Treated variables</b>		
1	Project delay	Also treated in textual data base and exploratory interview
2	Cash call shortfall	Also treated in textual data base
3	Actual cash call paid	Also treated in textual data base

Table 8.10 provides list of new variables relevant to this sub view that emerged from the grounded theory analysis of main interview. Figure 8.11 can be further extended and revised with addition of included variables. It can be observed that some of the variables are included while others were treated in other sectors of the CLD. Based on this Figure 8.11 can be further extended and revised with addition of included variables.

**Figure 8.11: Development sector CLD extended from main interviews**



**Source: Author's work and synthesis from main interviews**

Figure 8.11 represent an extended and revised version of figure 8.7, the variables that emerges from the qualitative interviews i.e. cash call shortfall, interest rates, project delay and cash call obligation were incorporated and hence the CLD is revised



### 8.4.3 Production CLD

Based on the data obtained from the main interviews, new variables emerged from the qualitative data. (See section 7.7 for the grounded theory analysis and Figure 7.4 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.11 present the number of new variables relevant to production sector causal loop diagram that emerged.

**Table 8.11: Variable relevant to production sub view**

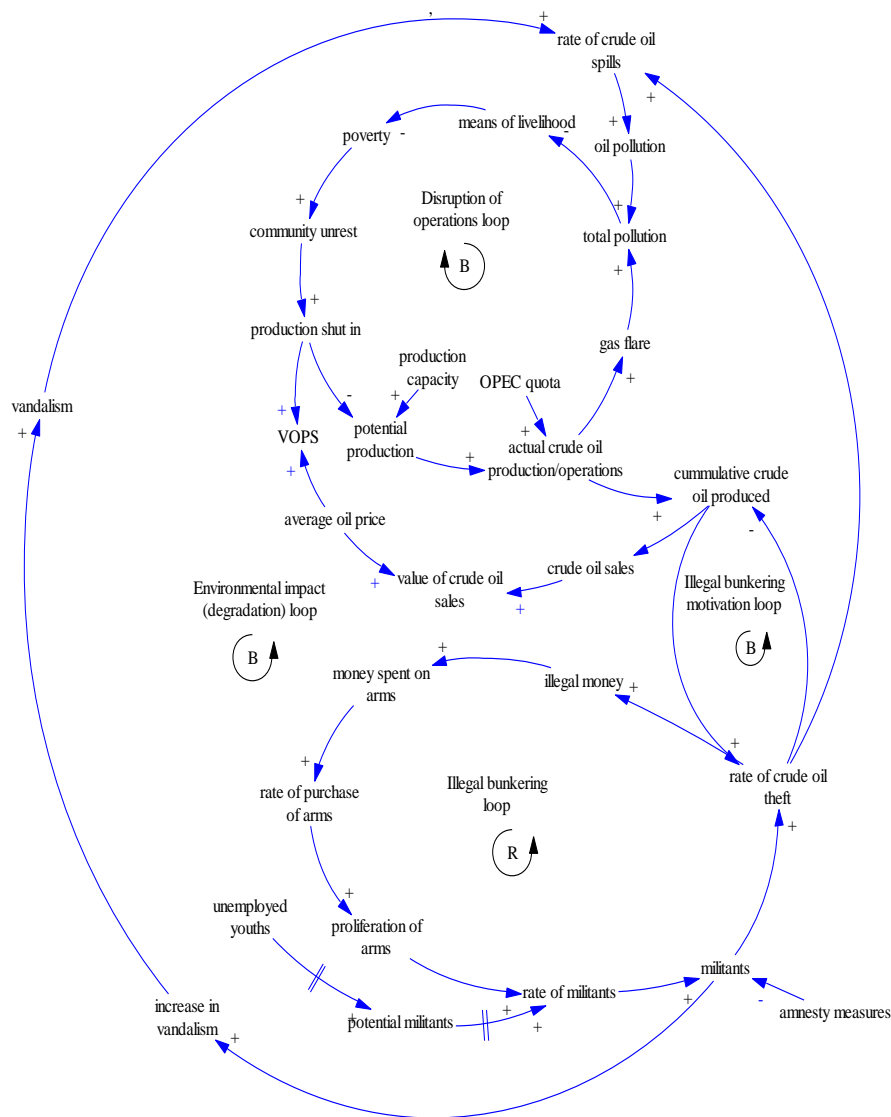
No	New variables	Included variables
1	Crude oil theft	Crude oil theft
2	Amnesty measures	Amnesty measures
3	Illegal bunkering	Illegal bunkering
4	Siphoning of crude oil	Potential militants
5	Relative peace and calmness	
6	Reduction in militants	
7	Potential militants	
8	Disruption of operations	
9	Communal unrest	
10	Vandalism	
11	Unemployed youths	
12	Militants	
<b>Treated variables</b>		
1	Militants	Also treated in textual data base
2	Rate of militants	Also treated in textual data base
3		
<b>Excluded variables</b>		
1	Siphoning of crude oil	
2	Relative peace and calmness	
3	Reduction in militants	

Table 8.5 provides list of new variables relevant to this sub view that emerged from the main interview. It can be observed that some of the variables are included while others are excluded from model building process. The variables excluded i.e. siphoning of crude oil, relative peace and calmness, and reduction in militants as well as the rationale behind the exclusion of this variable is discussed below.

In the case of siphoning of crude oil, variable became a concept represented by crude oil theft. Although the name does not explicitly appear the concept it describes remained preserved in the CLD. In the case of illegal bunkering, it was used to name a loop around crude oil theft since it involves process used to

describe crude oil theft in the industry. Other variables are relative peace and calm and reduction in militants. These variables although used to described the effect of amnesty policy yet they are both excluded from the CLD as they have been subsumed by the amnesty policy intervention which had promote peace in the region as well as addressed militant activities. Based on this Figure 8.12 can be further extended and revised with addition of included variables.

**Figure 8.12: production sector CLD extended from main interviews**



**Source: Author's work and synthesis from main interviews**

Figure 8.12 represent an extended and revised version of figure 8.8, the variables that emerges from the grounded theory analysis of the main interviews was incorporated and hence the CLD is revised.

#### 8.4.4 Revenue CLD

Based on the data obtained from the main interviews, new variables emerged from the qualitative data. (See section 7.7 for the grounded theory analysis and Figure 7.4 for variables that emerged from analysis of exploratory interviews). This therefore necessitates further revision of the model. Table 8.12 present the number of new variables relevant to revenue sector causal loop diagram that emerged.

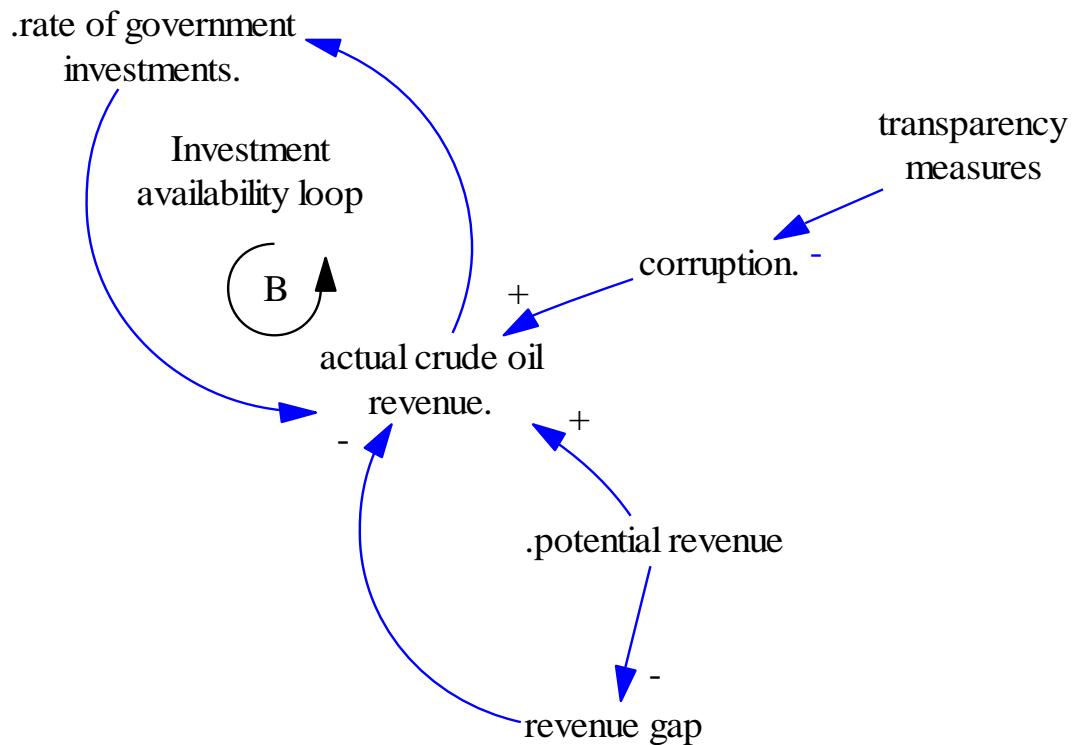
**Table 8.12: Variable relevant to revenue sub view**

No	New variables	Included variables
1	Absence of good governance	Transparency initiatives
2	Inaccurate records of crude oil sales	
3	Inaccurate records of crude oil output	
4	Transparency initiatives	
5	Conduct of periodic audit	
6	Openness of operations	
7	Corruption	
<b>Excluded variables</b>		
1	Conduct of periodic audit	
2	Openness of operations	
3	Absence of good governance	
4	Inaccurate records of crude oil sales	
5	Inaccurate records of crude oil output	
6	Corruption (already used in textual data base)	

Table 8.6 provides list of new variables relevant to this sub view that emerged from the qualitative interview. It can be observed that some of the variables are included while others are excluded from model building process. The variables excluded i.e. siphoning of crude oil, relative peace and calmness, and reduction in militants as well as the rationale behind the exclusion of this variable is discussed below. Openness of operations and conduct of periodic audit have not been reflected explicitly in this CLD. Transparency had subsumed openness of operation and conduct of periodic audit as a policy intervention in the industry. Similarly, absent of good governance, inaccurate records of crude oil sales and inaccurate records of crude oil output are not directly reflected in this CLD because both variables

described corruption and hence been subsumed by corruption in oil industry. Based on this, Figure 8.13 can be further extended and revised with addition of included variables.

**Figure 8.13: revenue sector causal loop diagram extended from main interviews**



**Source: Author’s work and synthesis from main interviews**

Figure 8.13 represents an extended and revised version of Figure 8.9, the variables that emerges from the qualitative interviews was incorporated and hence the CLD is revised.

### 8.5 Developing Structures from Focus group Interviews

In addition to the earlier structures developed from the literature, the exploratory and main interviews, a focus group interview was utilised in order to validate and also enhance these structures. In this case, variables were confirmed by the participants and some new once suggested. This therefore necessitates further revision of the model through the incorporation into the initial respective CLDs. Figure 8.14 presents the exploration CLD; Figure 8.15 presents the development

CLD; Figure 8.16 presents the production CLD and Figure 8.17 presents revenue CLD based on the outcome of the data obtained from the focus group interviews.

### 8.5.1 Exploration sector CLD

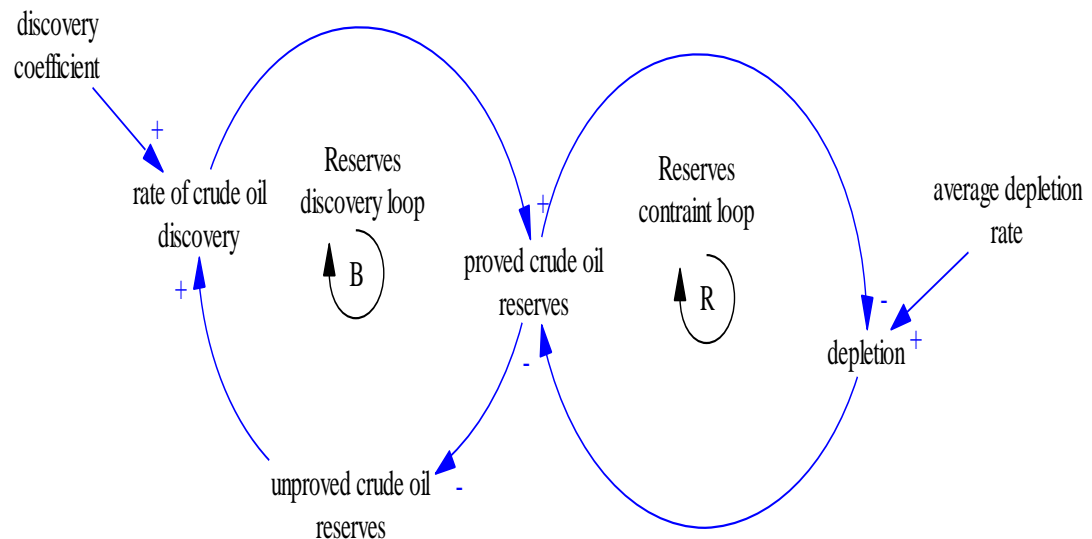
Based on the data obtained from the focus group session new variables emerged from the discussion in section 7.8.7. This therefore necessitates further revision of the model. Table 8.13 present the number of new variables that emerged. The exploration CLD in this case was amended by the participants.

**Table 8.13: Variable relevant to revenue sub view**

No	New variables
1	Average depletion rate
2	Discovery coefficient

Table 8.13 provides variable relevant to the exploration sub view that emerged from the focus group interview. Based on the new variable in table 8.7 that emerged from the focus group interview, Figure 8.14 can be further extended.

**Figure 8.14: Exploration sector CLD extended from focus group interviews**



**Source Author's work and synthesis from focus group interviews**

Figures 8.14 represent an extended and revised version of Figure 8.8, the variables that emerges from the focus group interviews i.e. average depletion rate and discovery coefficients was incorporated and hence the CLD is revised.

### 8.5.2 Development sector CLD

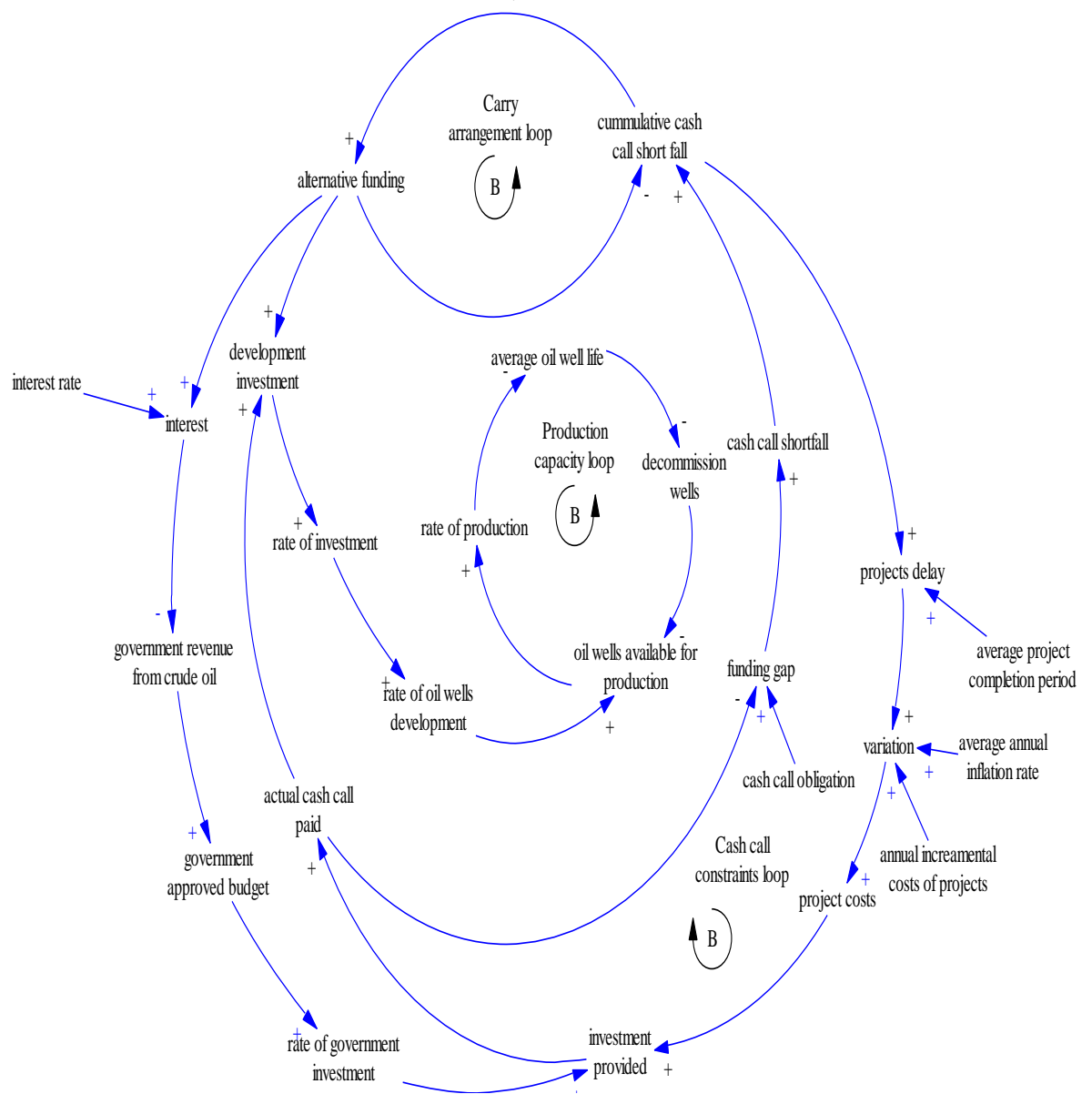
Based on the data obtained from the focus group interviews, new variables emerged in section 7.8.7. This therefore necessitates further revision of the model. Table 8.14 present the number of new variables that emerged.

**Table 8.14: Variable relevant to revenue sub view**

No	New variables
1	Average annual inflation rate
2	Annual incremental cost of projects
3	Decommissioned wells
4	Average project completion period

Table 8.14 provides list of new variables relevant to this sub view that emerged from the focus group interview. Based on the new variables in table 8.7 that emerged from the focus group interview, Figure 8.15 can be further extended.

**Figure 8.15: Development sector CLD extended from focus group interviews**



**Source Author's work and synthesis from focus group interviews**

Figures 8.15 represent an extended and revised version of figure 8.7, the variables that emerges from the focus group interviews i.e. average annual inflation rate, annual incremental cost of a project, average project completion period and decommission wells were incorporated and hence the CLD is revised.

### 8.5.3 Production sub-view

Based on the data obtained from the focus group interviews, new variables emerged in section 7.8.7. This therefore necessitates further revision of the model. Table 8.15 present the number of new variables that emerged.

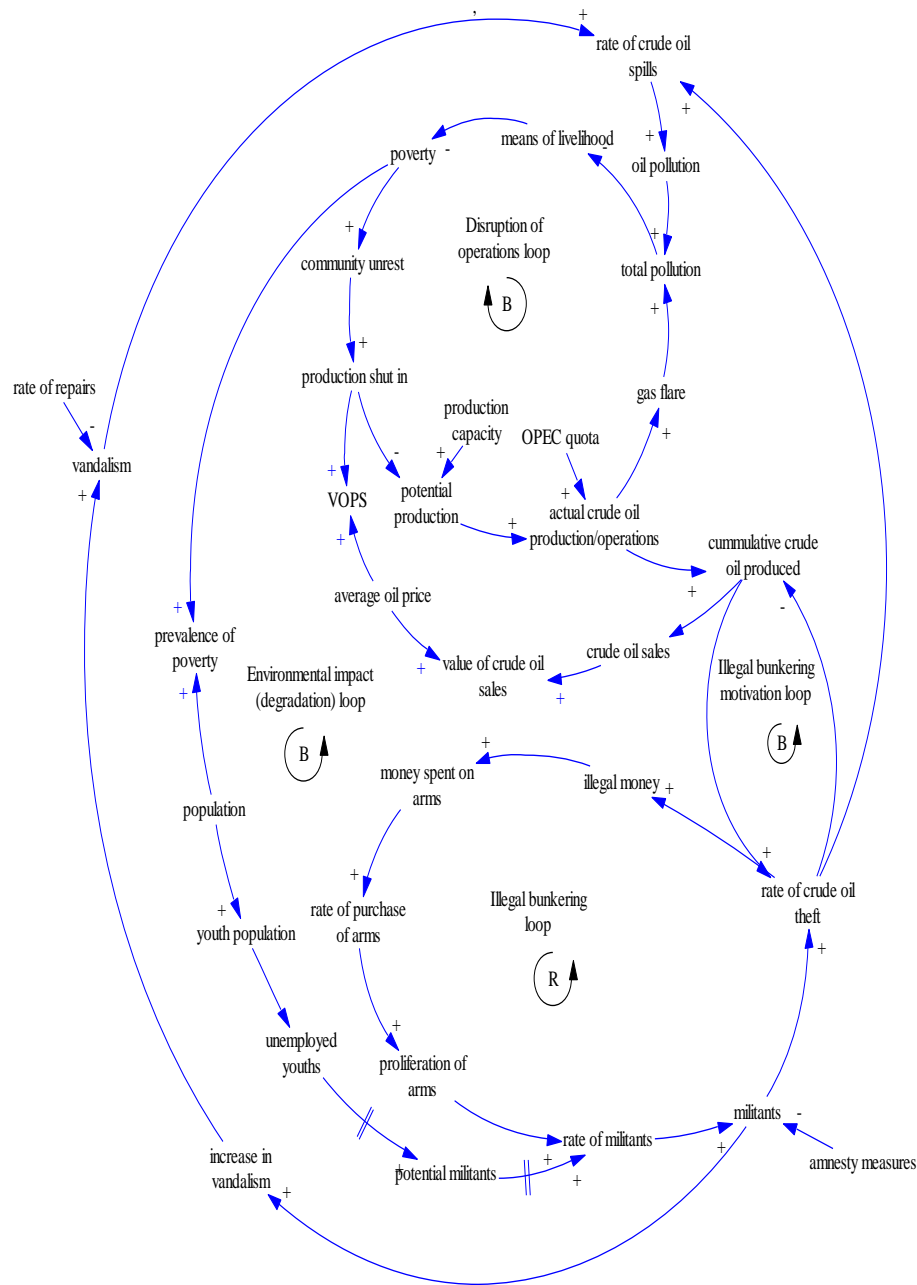
**Table 8.15: Variable relevant to revenue sub-view**

No	New variables
1	Prevalence of poverty
2	Youth population
3	Average time taken for repairs
4	Population

Table 8.8 provides list of new variables relevant to this sub view that emerged from the focus group interview. Based on the new variables in table 8.8 that emerged from the focus group interview, Figure 8.16 can be further extended.



**Figure 8.16: Production sector CLD extended from focus group interviews**



**Source: Author's work and synthesis from focus group interviews**

Figures 8.16 represent an extended and revised version of figure 8.8, the variables that emerges from the focus group interviews i.e. prevalence of poverty, population, youth population, and average times taken for repairs were incorporated and hence the CLD is revised.

### 8.5.4 Revenue sub-view

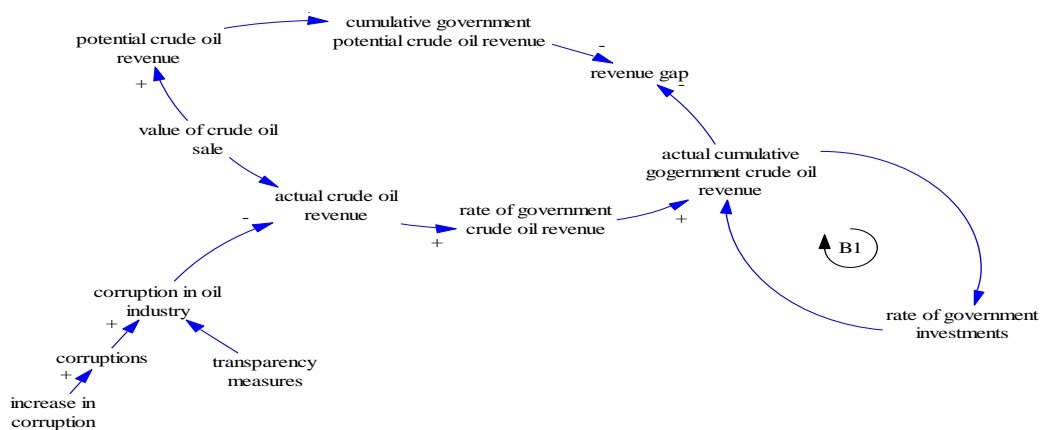
Based on the data obtained from the focus group interviews, new variables emerged in section 7.8.7. This therefore necessitates further revision of the model. Table 8.16 present the number of new variables that emerged.

**Table 8.16: Variable relevant to revenue sub view**

No	New variables
1	Corruption in oil industry
2	Potential crude oil revenue
3	Increase in corruption
4	Cumulative government potential crude oil revenue
5	Actual crude oil revenue
6	Rate of government crude oil revenue
7	Actual cumulative government crude oil revenue

Table 8.16 provides list of new variables relevant to this sub view that emerged from the focus group interview in section 7.8.7. Based on the new variables in table 8.9 that emerged from the focus group interview, Figure 8.17 can be further extended.

**Figure 8.17 Revenue causal loop diagram extended from focus group interviews**



**Source: Author's work and synthesis from focus group interviews**

Based on the outcome of the focus group the interviews, some variables were excluded and based on table 8.9 new variables were incorporated and hence the

CLD is revised. The following section presents the description of the model this research.

## **8.6 Model Description**

In this research, a causal loop diagram was developed to study challenges facing revenue generation in the Nigerian oil industry in a feedback perspective in order to help in understanding the complex behaviour emerging from the feedback structure and also provide an appropriate medium for communicating the model to stakeholders (clients) in the industry. In particular, the causal loop diagram represents the challenges facing the industry as opposed to the whole system.

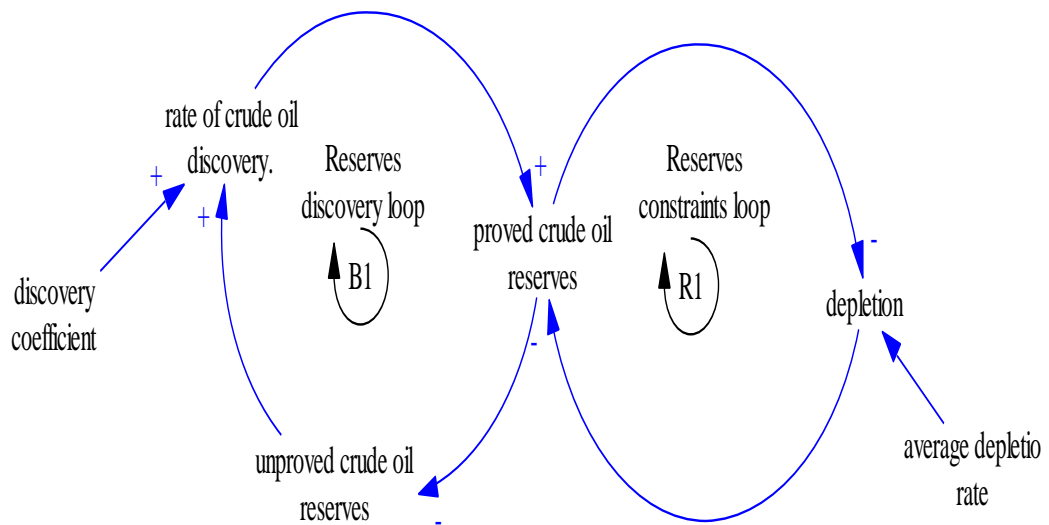
### **8.6.1 Causal loop diagram of challenges facing Nigerian oil industry**

In order to develop a model that reflects the real world, the need to rely on one or more sources of information (mental data base discussed in section 6.6.1, textual data base discussed in section 6.6.2 or numerical data base discussed in section 6.6.3) need not to be overemphasised. In this research, a CLD emanating from textual data base as well as mental data base of people familiar (stakeholders/client) with the issue under study is developed. This CLD required to be verified. According to (Forrester and Senge 1980), the verification of the structure of a SD model involves the comparison of the model structure to that of the real system. The following sub sections discuss the CLD developed in section 8.4 on the basis of this perspective.

#### **8.6.1.1 Exploration causal loop diagram and related concepts**

The concepts in this section are all related to exploration sector of the model. Two feedback loops are identified and presented. These are reserves discovery loop and reserves constraints loop. Figure 8.18 represents the causal loop diagram for the exploration sector of the model.

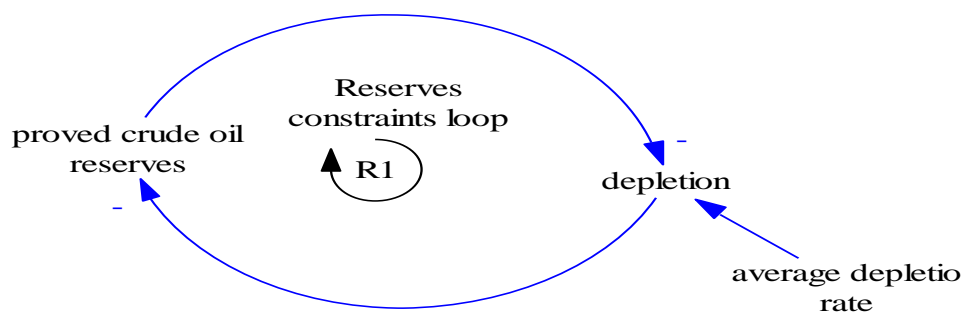
**Figure 8.18: Exploration causal loop diagram**



**Source: Author's work and synthesis from literature and interviews**

Figure 8.18 can be further elaborated based on the causal loops. For example, in Figure 8.18, the two loops comprises of one reinforcing feedback loop R and one balancing feedback loops B. The reinforcing feedback represent reserves constraints loop, while the balancing loops involves reserves discovery loop. In order to enhance the quality of the model, all the feedback loop present in the model needs to be examined in order to verify their causal connections and also offer logical description of their operation. Therefore, the structure and other aspects of the feedback loop will be verified structurally while relying on sources from both mental, textual data bases as well as logical reasoning. Figure 8.18.1 and 8.18.2 provides details of the loops.

**Figure 8.18.1 Reserves Constraint loop**



**Source: Author's work and synthesis from literature and interviews**

### **Loop description**

The reserves constraints loop in figure 8.18.1 shows that if proved crude oil reserves increases depletion decreases. The causal relationship between proved crude oil reserves and depletion is positives. On the other hand the causal relationship between depletion and proved crude oil reserves is also negative because an increase in depletion leads to a decrease in proved crude oil reserves thus closing the loop with a positive feedback loop R. Table 8.17 presents an overview of the meaning and source of variables in Figure 8.18.1.

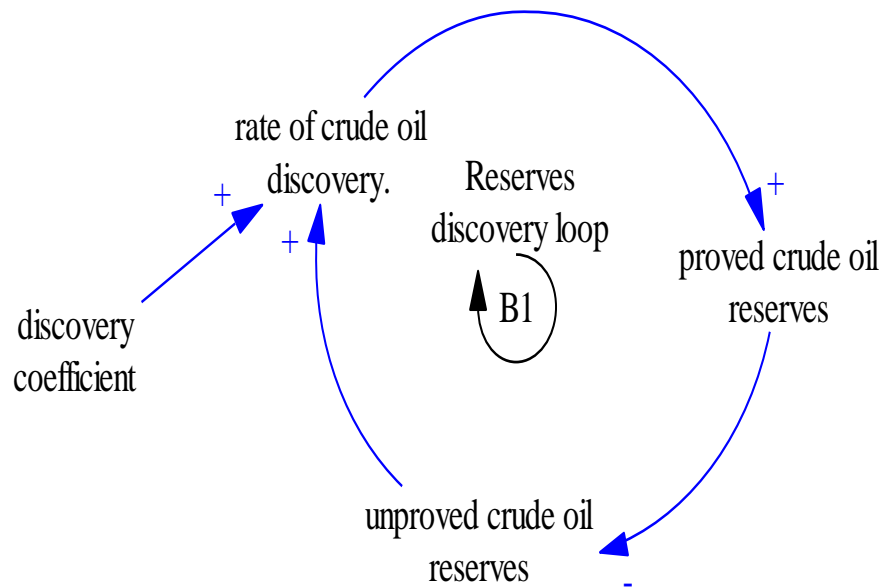
**Table 8.17: Support table for Figure 8.18.1**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Proved crude oil reserves</u> : those quantities of oil and that possesses reasonable certainty of being discovered	Proved crude oil reserves affects depletion	-	Sorrell et al., 2012	
<u>Depletion</u> : is a function of production per annum to some estimate of proved reserves	Depletion affects proved crude oil reserves	-	Sorrell et al., 2012	
<b>Other variable</b>				
<u>Average depletion rate</u> : is the rate of reduction of proved crude oil reserves as a result of production	Average depletion rate is affected by actual crude oil production.	+		P3 Focus group

Table 8.17 presents the summary of variables involved in reserves constraints loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case each causal relationship is justified.

## Reserves constraints loop

Figure 8.18.2 Reserves Discovery Capacity loop



Source: Author's work and synthesis from literature and interviews

### Loop description

The reserves discovery loop in Figure 8.18.2 shows that an increase in the rate of crude oil discovery leads to an increase in proved crude oil reserves. Therefore the causal relationship between rate of crude oil discovery and proved crude oil reserves is positive. The causal relationship between proved crude oil reserves and unproved crude oil reserves is negative because an increase proved crude oil reserves leads to a decrease of unproved crude oil reserves. An increase in unproved crude oil reserves leads to an increase in rate of discovery of crude oil which also depends on discovery coefficient thus depicting a positive causal relationship between unproved crude oil reserves and rate of crude oil discovery and closing the loop with a balancing feedback loop B. Table 8.11 presents an overview of the meaning and source of variables in Figure 8.18.2.

**Table 8.18: Support table for Figure 8.18.2**

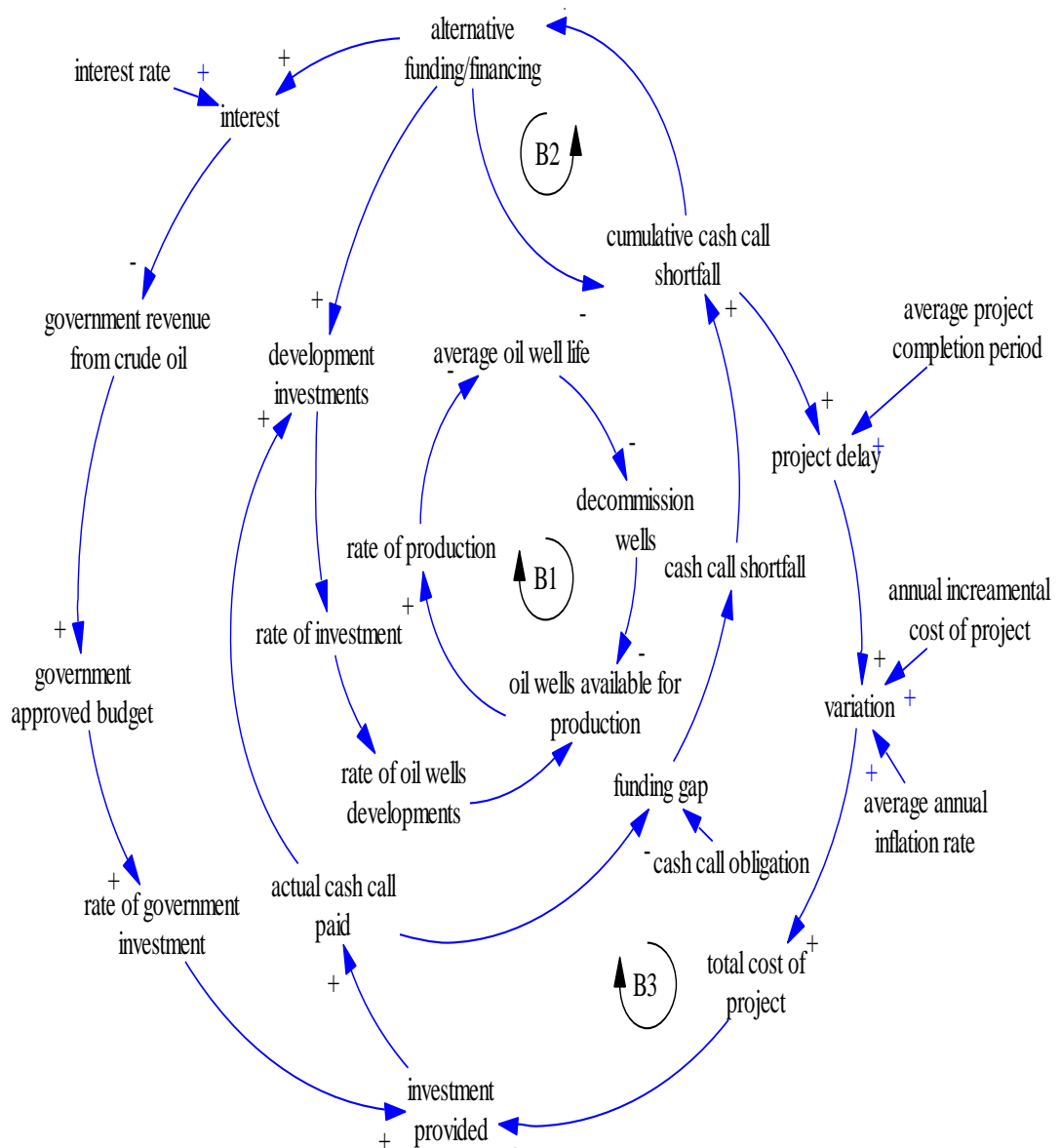
<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Rate of crude oil discovery</u> : this is an addition from unproved reserves to prove reserves	Rate of discovery affects proved crude oil reserves.	+	Fagan 1997; Watkins 2006	
<u>Proved crude oil reserves</u> : those quantities of oil and gas that possesses reasonable certainty of being discovered	Proved crude oil reserves affects unproved crude oil reserves	-	Fagan 1997; Watkins 2006	
<u>Unproved crude oil reserves</u> : is total quantity of crude oil expected to be discovered in the future that is not as a result to growth of prevailing fields.	Un proved crude oil reserves affects rate of crude oil discovery	+	Fagan 1997; Watkins 2006	

Table 8.18 presents the number of variables in reserves discovery loop including definition, individual links, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case each causal relationship is justified.

### **8.6.1.2 Development causal loop diagram and related concepts**

The concepts in this section are all related to development sector of the model. Three feedback loops are identified and presented. Figure 8.19 shows the causal loop diagram for the development sector of the model.

**Figure 8.19: Development causal loop diagram**



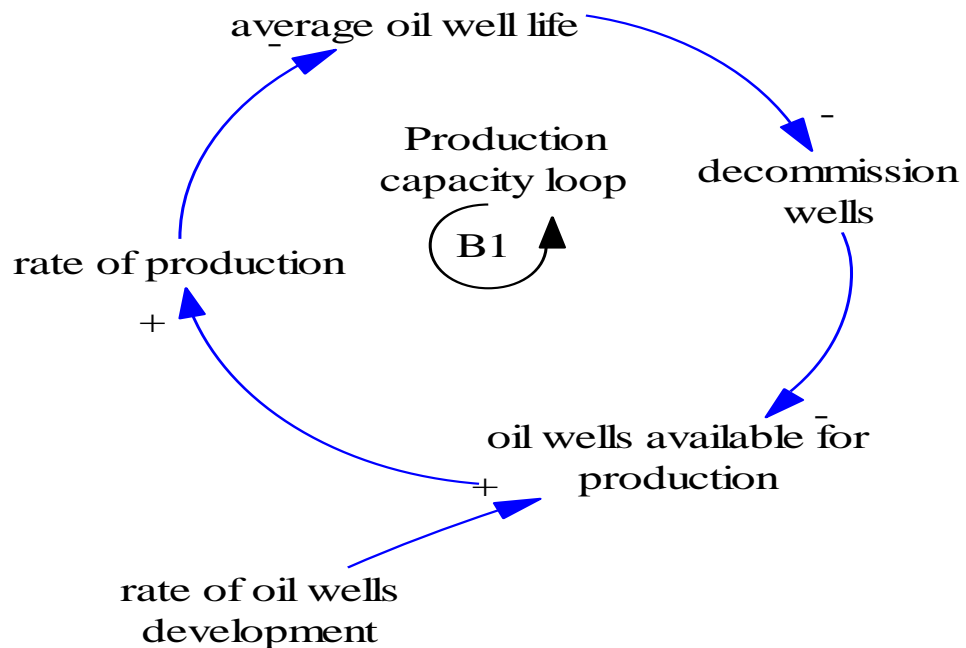
**Source: Author’s work and synthesis from literature and interviews**

Figure 8.19 can be further elaborated based on the causal loops. For example, in Figure 8.19, the three loops comprises of three balancing feedback loops B. These are carry arrangement loop, production capacity loop and cash call constraints loop. In order to enhance the quality of the model, all the feedback loop present in the model needs to be examined in order to verify its causal connections and also offer logical description of its operation. Therefore, the structure and other aspects of the feedback loop will be verified structurally while relying on sources from both mental, textual data bases as well as logical reasoning. Figure 8.19.1 to 8.19.3 provides details of the loops.



## Production capacity loop

Figure 8.19.1: Production capacity loop



Source: Author's work and synthesis from literature and interviews

### Loop description

The production capacity loop in Figure 8.19.1 shows that if rate of production increases, average oil well life decreases, therefore the causal relationship between rates of production and average oil well life is negative. The causal relationship between average oil well life and decommissioned well is negative because an increase in average oil well life leads to a decrease in decommissioned wells. An increase in decommissioned wells leads to a decrease in oil wells available for production which also depends on rate of oil wells development thus depicting a negative causal relationship. The causal relationship between oil wells available for production and rate of production is positive because as oil wells available for production increases, rate of crude oil production also increases thus closing the loop with a balancing feedback loop denoted by B. Table 8.19 presents an overview of the meaning and source of variables in Figure 8.19.1.

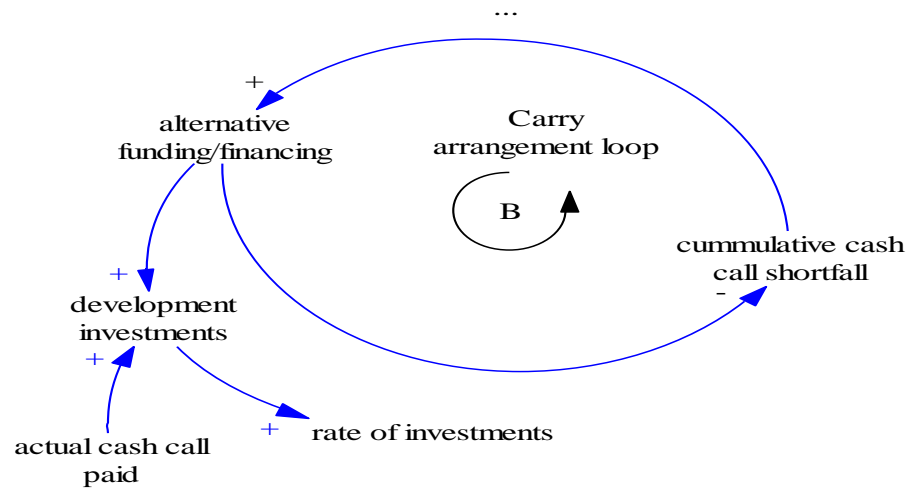
**Table 8.19: Support table for Figure 8.19.1**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Rate of crude oil production</u> : this is the rate at which crude oil is produced	Rate of production affects oil well life	-	Hook et al., 2014).	
<u>Average oil well life</u> : it is the productive period of an oil well	Average oil well life affects decommission (Abandoned) wells	-	Hook et al., 2014	
<u>Decommission (Abandoned) well</u> : it's a well that is either producing crude oil poorly or not producing crude oil	Decommission (Abandoned) wells affects oil wells available for production	-	Jahn, Cook and Graham 2008).	P_6, P_1 and P_2  Focus group
<u>Oil wells available for production</u> : number of well that are producing crude oil	Oil well for production affects production	+	Hook et al., 2014; Craft and Hawkins 1959	
<b>Other variables</b>				
<u>Rate of oil wells development</u> : rates at which oil wells are developed for crude oil production	Rate of oil wells development affects Oil wells available for production	+	Nlerum 2010	

Table 8.19 presents the summary variables involved in production capacity loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case each causal relationship is justified.

## Carry arrangement loop

Figure 8.19.2: Carry arrangement loop



Source: Author's work and synthesis from literature and interviews

### Loop description

Carry Arrangement is a funding arrangement whereby the Multinational Oil Companies (MOC's) sources for advance loan to finance cash call shortfall from NNPC for the purpose augmenting the deficit arising from the shortfall to be used in financing upstream projects.

The carry arrangement loop in Figure 8.19.2 shows a negative causal relationship between alternative funding/financing and cumulative cash call shortfall because an increase in alternative funding/financing leads to a decrease in cumulative cash call shortfall.

The causal relationship between cumulative cash call shortfall and alternative funding/financing is positive because an increase in cumulative cash call shortfall leads to an increase in alternative funding thus closing the loop with a balancing feedback loop denoted by B. Table 8.20 presents an overview of the meaning and source of variables in Figure 8.4.2.

**Table 8.20: Support table for Figure 8.19.2**

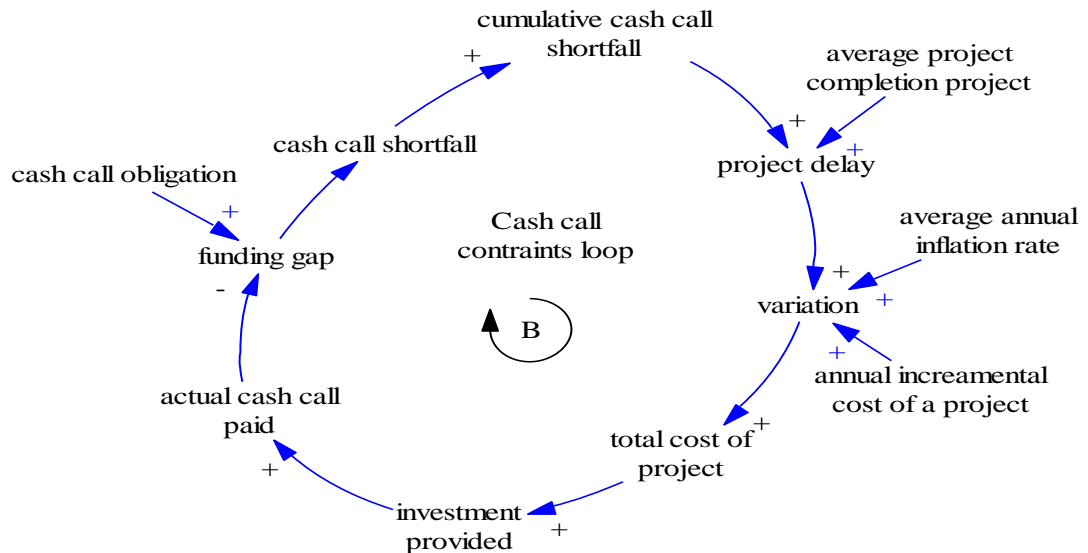
<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Alternative funding/financing</u> : it's a borrowed fund to finance shortfall	Alternative funding affects cumulative cash call shortfall	-	NNPC 2010	EIP_B
<u>Cumulative cash call shortfall</u> : build-up of cash call shortfall	Cumulative cash call shortfall affects alternative funding	+	NNPC 2010	
<b>Other variables</b>				
<u>Alternative funding</u> : it's a borrowed fund to finance shortfall	Alternative funding affects Development Investment and Interest	+	NNPC 2010	EIP_B
<u>Development investment</u> : cash meant for development in the industry	Development investment affects Rate of investment	+	Odularu2008	
<u>Actual cash call paid</u> : it is the actual cash provided by the government for the joint venture operations	Actual cash call paid affects Development Investment	+	Odularu 2008	MIP_F
<u>Government revenue from crude oil</u> : it is the amount due to government from the industry	Government revenue from crude oil affects Government approved budget	+		EIP_A
<u>Government approved budget</u> : it is the amount set aside by government as part of its counterpart funding in the joint venture operations	Government approved budget affects rate of government investments	+		EIP_A
<u>Interest rate</u> : it is the proportion alternative funding charged as interest	Interest rate affects interest	+		MIP_D

Table 8.20 presents the summary of variables involved in carry arrangements loop including links, sign, literature supports from literature review, data support which

refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case causal relationship is justified.

### Cash call constraints loop

**Figure 8.19.3: Cash call constraint loop**



**Source: Author's work and synthesis from literature and interviews**

### Loop description

The cash call constraints loop in Figure 8.19.3 shows that if cash call shortfall increases, cumulative cash call shortfall also increases thus depicting a positive causal relationship between cash call shortfall and cumulative cash call shortfall. An increase in cumulative cash call shortfall affects project delay thus leading to a positive causal relationship between cumulative cash call shortfall and project delay because as cumulative cash call shortfall increases project delay also increases.

The causal relationship between project delay and variation is positive because an increase in projects delay leads to an increase in variation which also depends on average annual inflation rate and annual incremental cost of project. An increase in variation leads to an increase in total project costs thus forming a positive causal relationship between variation and total project costs.

The causal relationship between total projects costs and investment provided is positive because an increase in total projects costs leads to an increase in the

investments provided by the government. An increase in investments provided lead to an increase in actual cash call paid thus depicting a positive causal relationship between investment provided and actual cash call paid.

The causal relationship between actual cash call paid and funding gap is negative because as actual cash call paid increases funding gap decreases. An increase in the funding gap leads to an increase in cash call shortfall thus depicting positive causal relationship between funding gap and cash call shortfall and closing the loop with a balancing feedback loop denoted by B.

Table 8.14 presents an overview of the meaning and source of variables in Figure 8.19.3.

**Table 8.21: Support table for Figure 8.19.3**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Cash call shortfall</u> : is the deficit arising from government's inability to fully meet its cash call obligation	Cash call shortfall accumulates to form cumulative cash call shortfall	+	African Development Bank, 2009; NNPC 2010).	
<u>Cumulative cash call shortfall</u> : build-up of cash call shortfall	Cumulative cash call shortfall affects projects delay	+	Baloi and Price 2003	
<u>Projects delay</u> : is when project exceeds estimated completion time	Projects delay leads to variation	+	Baloi and Price 2003	EIP_A
<u>Variation</u> : additional cost of projects as a result of delay in completion	Variation increase cost of a projects	+		EIP_A
<u>Total cost of projects</u> : it is the overall cost of projects	Total cost of a project affects investment provided	+	Baloi and Price 2003	
<u>Investments provided</u> : is what the government set aside to fund its own part of obligation	Investment provided affects actual cash call paid	+	NNPC, 2010	

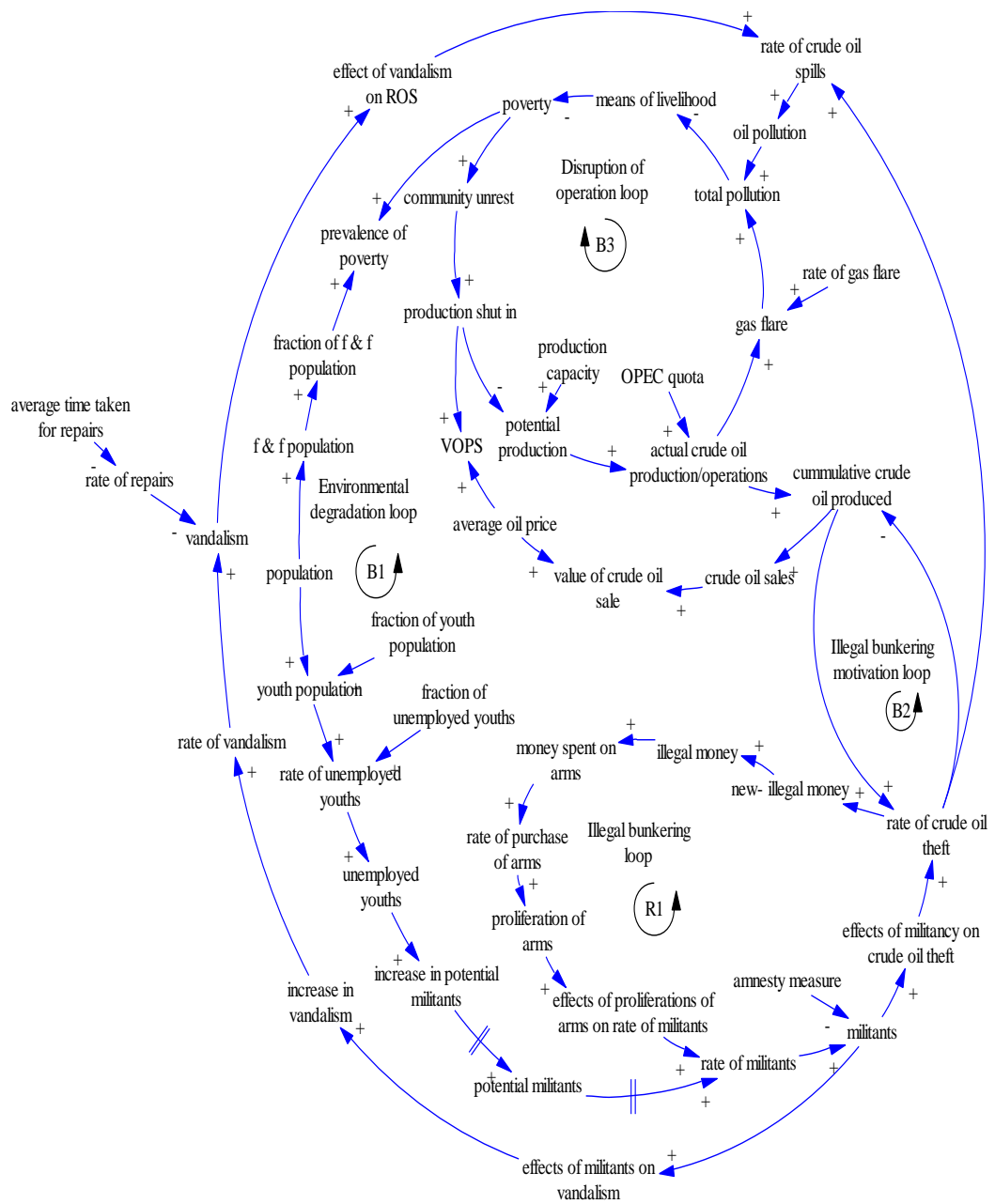
<u>Actual cash call paid:</u> is what was actual paid by government	Actual cash call paid affects funding gap	-	Nlerum, 2010	
<u>Funding gap:</u> is the difference between cash call obligation and actual cash call paid	Funding gap affects cash call shortfall	+	Nlerum, 2010	
<b>Other variables</b>				
<u>Cash call obligation:</u> counterpart funds for the running of joint venture operations	Cash call obligation affects funding gap	+	Mbendi, 2000	
<u>Average project completion period:</u> is the average expected period of completing a project in oil industry	Average project completion period affects project delay	+		P_5 Focus group
<u>Annual incremental cost of project:</u> is the yearly increment in cost of a project	Annual incremental cost of project affects variation	+		P_2 Focus group
<u>Average annual inflation rate:</u> is the annual rate of inflation in the country	Average annual inflation rate affects variation	+		P_2 Focus group

Table 8.21 presents the summary variables involved in cash call constraints loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case attempt is made to justify each causal relationship.

### 8.6.1.3 Production causal loop diagram and related concepts

The concepts in this section are all related to production sector of the model. Four feedback loops are identified and presented. These are illegal bunkering loop, illegal bunkering motivation loop, disruption of operations loop and environmental degradation loop. Figure 8.20 represents the causal loop diagram for the production sector of the model.

**Figure 8.20: Production causal loop diagram**



**Source: Author’s work and synthesis from literature and interviews**

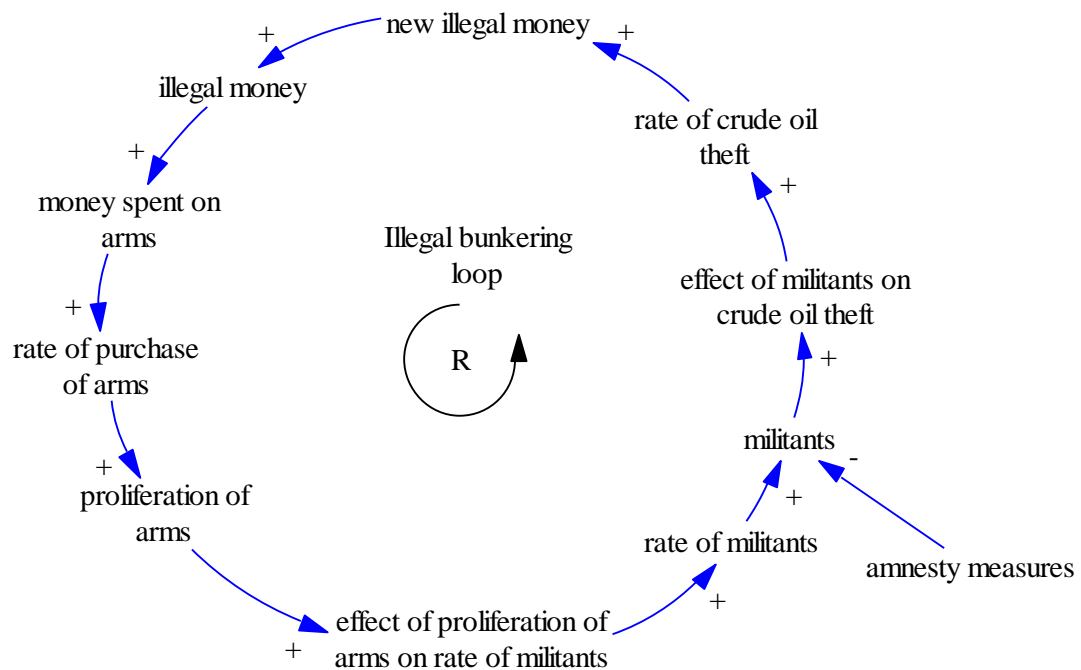
Figure 8.20 can be further elaborated based on the causal loops. For example, in Figure 8.20, the four loops comprises of one reinforcing feedback loop R and three balancing feedback loops B. The reinforcing feedback represent illegal bunkering loop, while the balancing loops includes: environmental degradation loop, illegal bunkering motivation loop and disruption of operation loop. In order to enhance the quality of the model, all the feedback loops present in the model needs to be examined in order to verify their causal connections and also offer a logical



description of the operations. Therefore, the structure and other aspects of the feedback loop will be verified structurally while relying on sources from both mental, textual data bases as well as logical reasoning. Figures 8.20.1 to 8.20.4 provides details of the loops.

### Illegal bunkering loop

**Figure 8.20.1: Illegal bunkering loop**



**Source: Author's work and synthesis from literature and interviews**

### Loop description

The loop description starts with militants and their effect on crude oil theft. It has been shown that the rate of militant's activities affects to crude oil theft since an increase in militants lead to an increase in the rate of crude oil theft thus depicting a positive causal relationship. This is well established in studies on militant activities in the Niger delta area (Inokoba and Imbua 2010). In order to place militants and their activities in proper perspective, the terms proliferation of arms need to be highlighted. Proliferation of arms refers to the infiltration and illegal possession of arms among youths in the oil rich Niger delta region. The causal relationship between crude oil theft and illegal money is positive because an increase in crude oil theft leads to increase in illegal money. Increase in illegal money is often

reflected in the quantity of crude oil stolen and the per barrel sales value of the stolen oil.

As illegal money increases, money spent on arm increases, thus represented by a positive causal relationship, which results to an increase in rate of purchase of arms which also has a positive causal relationship. An increase in rate of purchase of arms leads to an increase in proliferation of arms thus labelled with a positive causal relationship. The causal relationship between the proliferation of arms and the rate of militants is positive because an increase in proliferation of arms leads to an increases rate of militants thus closing the loop with a positive overall polarity and making it a reinforcing feedback loop as represented in Figure 8.20.1 above. Table 8.22 presents an overview of the meaning and source of figure 8.20.1.

**Table 8.22: Support table for Figure 8.20.1**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Rate of militants</u> : rate of freedom agitators that embarks on economic sabotage such as crude oil theft and destruction of crude oil facilities	Rate of militants affects number of militants	+	Innokoba and Imbua 2010	MIP_O
<u>Militants</u> : freedom agitators that embarks on economic sabotage such as crude oil theft and destruction of crude oil facilities	Militants affects vandalism and crude oil theft	+	Oshwofasa , Anuta and Aiyedogbon 2012: Innokoba and Imbua 2010	
<u>Rate of crude oil theft</u> : illegal process of taken away crude oil by militants.	Rate of oil theft affects illegal money	+	Asuni 2009	
<u>Illegal money</u> : this is the money realised by militants from sale stolen crude oil	Illegal money affects money spent on arms	+	Paki and Ebienfa 2011; Asuni 2009	

<u>Money spent on arms:</u> is the percentage of illegal money spent on purchase of arms by the militants	Money spent on arms affects purchase of arms	+	Paki and Ebiefa 2011	
<u>Rate of purchase of arms:</u> is the acquisition of weapons by the militants for their militant activities	Rate of purchase of arms affects proliferation of arms	+	Asuni 2009	
<u>Proliferation of arms:</u> it is the degree of spread of weapons among youths in the region.	Proliferation of arms affects rate of militants	+	Ojakotu and Aiyedogbon 2012	
Other variables				
<u>Amnesty measures:</u> it's a policy measure aimed at addressing the insecurity through the creation of a peaceful environment in the oil producing region for hitch free operations of oil companies	Amnesty measures affects militants	-	(Olatoke and Olokoba, 2012).	MIP_M

Table 8.22 presents the summary variables involved in illegal bunkering loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case attempt is made to justify each causal relationship.



an increase in pollution thus depicting a positive causal relationship. The causal relationship between pollution and means of livelihood is negative because as pollution increases, the means of livelihood decrease. As the means of livelihood decreases, poverty also increases thus depicting a negative causal relationship. The causal relationship between poverty and community unrest is positive because as poverty increases community unrest also increases. As community unrest increases production shutdown also increases thus depicting a positive causal relationship. The relationship between production shut in and potential production is negative because as production shutdown increases, it leads to a decrease in potential production. As potential production increases, actual crude oil production increases thus depicting a positive causal relationship. As actual crude oil production increase, it leads to an increase in cumulative crude oil produced thus making a positive causal relationship between actual crude oil production and cumulative crude oil produced. As cumulative crude oil produced increase, crude oil theft also increases thus depicting a positive causal relationship. The causal relationship between rate of crude oil theft and illegal money is positive because an increase in rate of crude oil theft leads to an increase in illegal money. An increase in illegal money lead to an increase in money used to purchase arms thus depicting a positive causal relationship.

The causal relationship between money used to purchase arms and the purchase of arms is positive because as money used to purchase arms increases, purchase of arms also increases. An increase in purchase of arms leads to an increase in proliferation of arms thus depicting a positive causal relationship because as money used to purchase arms increases proliferation of arms also increases. An increase in proliferation of arms leads to an increase in the number of militants which closes the loop with an overall negative polarity thus forming a balancing feedback loop B. Table 8.23 presents an overview of the meaning and source variables in Figure 8.20.2.

**Table 8.23: Support table for Figure 8.20.2**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Militants</u> : freedom agitators that embarks on economic sabotage such as crude oil theft and destruction of crude oil facilities	Militant affects increase in vandalism	+	Oshwofasa, Anuta and Aiyedogbon 2012	
<u>Vandalism</u> : refers to serial attacks meted out on oil facilities by militants in the Niger Delta.	Vandalism affects rate of oil spill	+	Oshwofasa, Anuta and Aiyedogbon 2012	
<u>Rate of repairs</u> : is the rate at which destroyed oil facilities are replaced	Rate of repairs affects vandalised facilities	+	Ajaero, 2009).	
<u>Rate of oil spill</u> : is the loss of oil as a result of destruction of oil facilities and installations leading to pollution.	Rate of oil spill affects oil pollution	+	EIA 2012	
<u>Pollution</u> : is the destruction of the environment as a result of crude oil spill and gas flare.	Pollution affects means of livelihood	-	Owolabi 2012, UNDP, 2006	
<u>Means of livelihood</u> : this refers to the main occupation of the inhabitants (people) in the oil producing region. The main occupation is farming and fishing	Means of livelihood affects poverty	-	Jike 2004	
<u>Poverty</u> : this refers to the state of lack of basic needs occasioned by the destruction of means of livelihood of the inhabitants of the oil producing region.	Poverty affects communal unrest	+	Okafor 2011	
<u>Community unrest</u> : are the periodic hostilities between oil companies and host communities	Communal unrest affects production shut in	+	Asgill, 2012	
<u>Production shutdown</u> : suspension of operation as a result of vandalism and community unrest.	Production shut in affects potential production	-	Asgill 2012	MIP_C

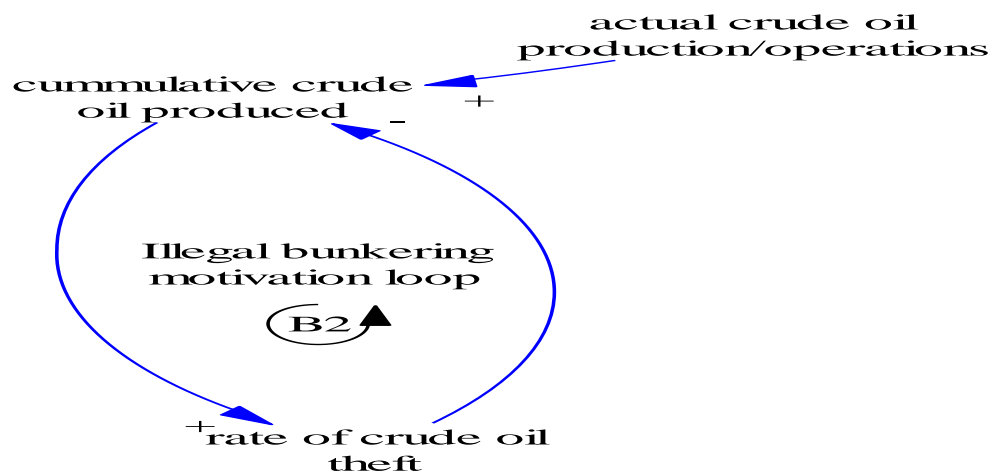
<u>Potential production</u> : this is the quantity of crude oil that can be produced devoid of challenges affecting production	Potential production affects actual production	+	UNDP 1996	MIP_C
<u>Production capacity</u> : this is the installed capacity of oil companies	Production capacity affects potential production	+	NNPC 2010	MIP_C
<u>Actual crude oil production</u> : this is the quantity of crude oil production as a result of challenges affecting what can potentially be produced	Actual production affects cumulative crude oil produced	+	UNDP 1996	
<u>Cumulative crude oil produced</u> : this is the accumulation of actual crude oil production less crude oil theft and crude oil sales	Cumulative crude oil produced affects rate of oil theft	+	Paki and Ebiefa 2011	
<u>Rate of crude oil theft</u> : illegal process of taken away crude oil by militants.	Rate of oil theft affects illegal money	+	Asuni 2009	
<u>Illegal money</u> : this is the money generated from sale of stolen crude oil	Illegal money affects rate of purchase of arms	+	Paki and Ebiefa 2011; Asuni 2009	
<u>Money spent on arms</u> : is the percentage of illegal money spent on purchase of arms by the militants	Money spent on arms affects purchase of arms	+	Paki and Ebiefa 2011	
<u>Rate of purchase of arms</u> : is the acquisition of weapons by the militants for their militant activities	Rate of purchase of arms affects proliferation of arms	+	Paki and Ebiefa 2011	
<u>Rate of militants</u> : rate of freedom agitators that embarks on economic sabotage such as crude oil theft and destruction of crude oil facilities	Rate of militants affects number of militants	+	Innokoba and Imbua 2010	MIP_O
<u>Proliferation of arms</u> : it is the degree of spread of weapons among youths in the region.	Proliferation of arms affects rate of militants	+	Asuni 2009	

Other variables				
Potential militants: refers to unemployed youths that are likely to become militants	Potential militants affects rate of militants	+	Inokoba and Imbua 2010	MIP_O

Table 8.23 presents the summary variables involved in environmental degradation loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case attempt is made to justify each causal relationship.

### Illegal bunkering motivation loop

Figure 8.20.3 Illegal bunkering motivation loop



### Loop description

The illegal bunkering motivation loop in Figure 8.20.3 shows a negative causal relationship between rate of crude oil theft and cumulative crude oil produced because as crude oil theft increases, cumulative crude oil produced decreases. An increase in cumulative crude oil produced leads to an increase in rate of crude oil theft thus depicting a positive causal relationship thereby closing the loop with an overall negative polarity and thus forming a balancing feedback loop B. Table 8.24 presents an overview of the meaning and source of Figure 8.20.3.



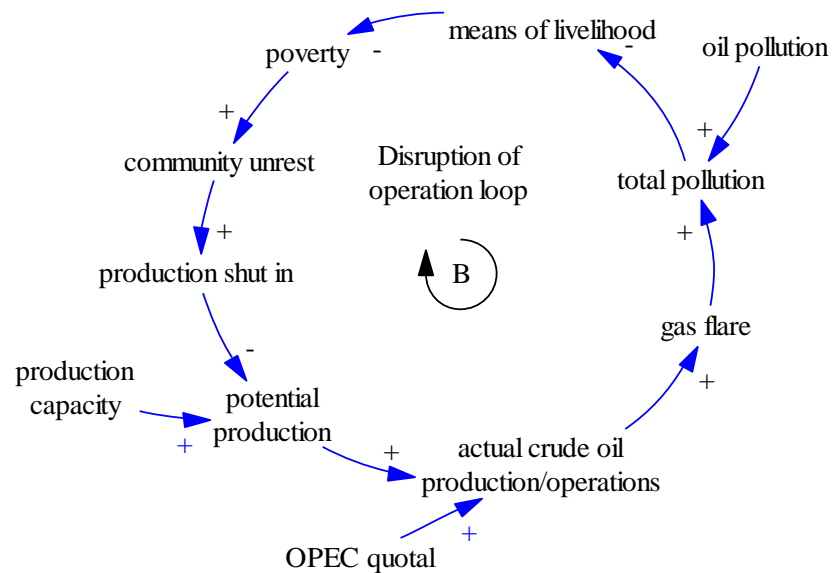
**Table 8.24: Support table for Figure 8.20.3**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Rate of crude oil theft:</u> is the acknowledgement of corruption in regulation and enforcement processes.	Rate of oil theft affects cumulative crude oil produced	+	Paki and Ebienufa 2011	MIP_A
<u>Cumulative crude oil produced:</u> this is the accumulation of actual crude oil production less crude oil theft and crude oil sales	Cumulative crude oil produced affects rate of oil theft, cumulative crude oil produced affects crude oil sales.	+	Paki and Ebienufa 2011	
<u>Actual crude oil production:</u> this is what oil companies are able to produced normally below installed capacity as a result of some challenges	Actual crude oil production affects cumulative crude oil produced	+	Ebiku 2008	

Table 8.24 presents the summary variables involved in illegal bunkering motivation loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case attempt is made to justify each causal relationship.

## Disruption of operation loop

Figure 8.20.4: Disruption of operations loop



Source: Author's work and synthesis from literature and interviews

### Loop description

The Disruption of operations loop in Figure 8.20.4 shows a positive causal relationship between actual crude oil production and gas flare. This is because an increase in actual crude oil production leads to increases in gas flare. The causal relationship between gas flare and pollution is also positive because an increase in gas flare leads to an increase in pollution. As pollution increases, means of livelihood decreases thus depicting a negative causal relationship between pollution and means of livelihood. The causal relationship between means of livelihood and poverty is negative because an increase in means of livelihood leads to decreases in poverty. As poverty increases, community unrest increases thus suggests a positive causal relationship. The causal relationship between community unrest and production shutdown is positive because an increase in community unrest leads to increases in production shut-in. An increase in production shut in leads to decrease

in potential production which imply a negative causal relationship between production shut in and potential production. The causal relationship between potential production and actual production is positive because as potential production increases, actual crude oil production also increases thus forming a balancing feedback loop denoted by B. Table 8.25 present an overview of the meaning and source of figure 8.20.4.

**Table 8.25: Support table for Figure 8.20.4**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Actual crude oil production</u> : this is what oil companies are able to produced normaly below installed capacity as a result of some challenges	Actual crude oil production affects cumulative crude oil produced	+	UNDP 1996	
<u>Rate of gas flare</u> : is the quantity of associated gas discharged into the environment in the process of crude oil production.	Rate of gas flare affects gas flare pollution	+	Afinotan and Ojakorotu 2009 (check d literature)	
<u>Pollution</u> : is the destruction of the environment as a result of crude oil spill and gas flare.	Pollution affects means of livelihood	-	Owolabi 2012, UNDP, 2006	
<u>Means of livelihood</u> : this refers to the main occupation of the inhabitants (people) in the oil producing region. The main occupation is farming and fishing	Means of livelihood affects poverty	+	Jike 2004	
<u>Actual crude oil Production</u> : this is what oil companies are able to produced normaly below installed capacity as a result of some challenges	Actual crude oil production affects Gas flare	+	Inokoba and Imbua 2010	

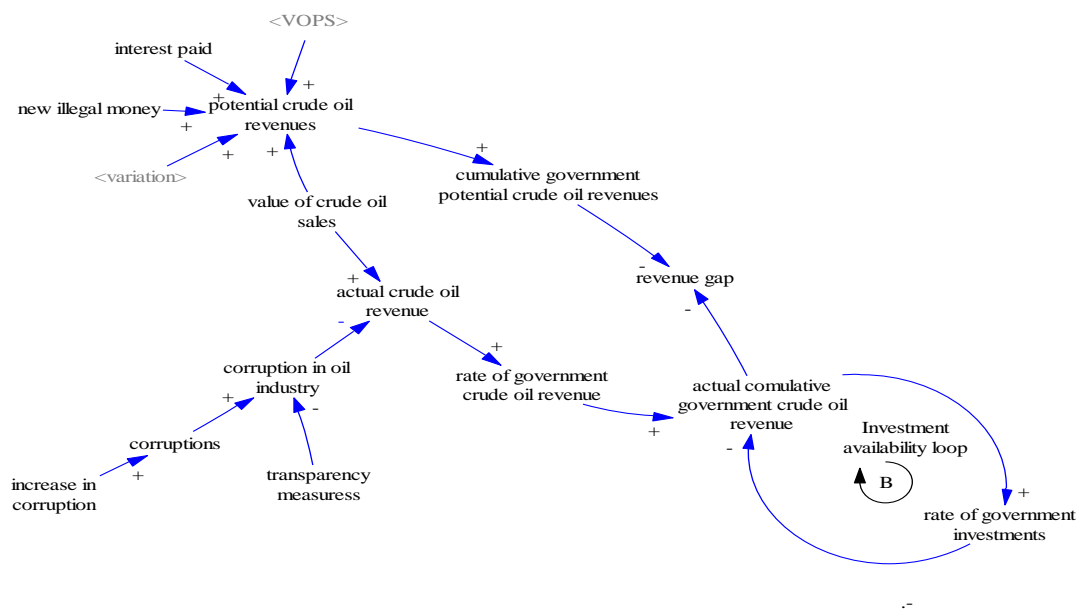
<u>Poverty</u> : this refers to the state of lack of basic needs occasioned by the destruction of means of livelihood of the inhabitants of the oil producing region.	Poverty affects communal unrest	+	Okafor 2011	
<u>Community unrest</u> : the periodic hostilities between oil companies and host communities	Communal unrest affects production shut in	+	Asgill, 2012	
<u>Production shut down</u> : suspension of operation as a result of vandalism and community unrest.	Production shut in affects P/ Production	-	Aiyedogbon 2012	MIP_C
<u>Potential production</u> : this is the quantity of crude oil that can produced devoid of challenges affecting production	Potential production affects actual production	+	UNDP 1996	MIP_C
<u>Rate of gas flare</u> : is the quantity of associated gas discharged into the environment in the process of crude oil production.	Rate of gas flare affects pollution	+	Afinotan and Ojatorotu 2009	
<b>Other variables</b>				
<u>Production capacity</u> : this is the installed capacity of oil companies	Production capacity affects potential production	+	NNPC 2010	MIP_C
<u>Oil pollution</u> : is the destruction of the environment as a result of crude oil spill	Pollution affects means of livelihood	-	Owolabi 2012, UNDP, 2006	

Table 8.25 presents the summary variables involved in disruption of operations loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case attempt is made to justify each causal relationship.

### 8.6.1.4 Revenue causal loop diagram and related concepts

The concepts in this section are all related to revenue sector of the model. It comprises a balancing feedback loop B, Investment availability loop is identified and presented. Figure 8.21 represents the causal loop diagram for the revenue sector of the model.

**Figure 8.21: Revenue causal loop diagram**

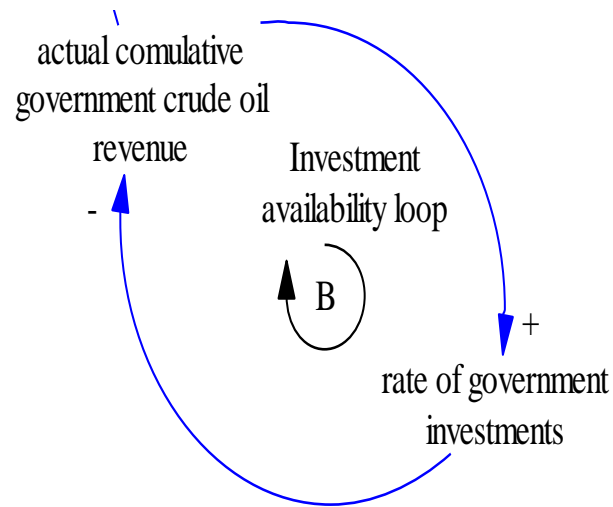


**Source: Author's work and synthesis from literature and interviews**

Figure 8.21.1 can be further elaborated based on the causal loops. For example, in Figure 8.21, the loop comprises balancing feedback loops B. The balancing feedback loop represent investment availability loop. In order to enhance the quality of the model, this feedback loop present in the model needs to be examined in order to verify its causal connections and also offer logical description of its operation. Therefore, the structure and other aspects of the feedback loop will be verified structurally while relying on sources from both mental, textual data bases as well as logical reasoning. Figure 8.21.1 provides details of the loops

## Investment availability loop

Figure 8.21.1 Investment availability loop



Source Author's work and synthesis from literature and interviews

### Loop description

The investment availability loop in Figure 8.21.1 shows that if actual cumulative government crude oil revenue increases, the rate of government investment also increases and if rate of government investment increases actual government cumulative crude oil revenue decreases. The causal relationship between actual cumulative government crude oil revenue and rate of government investment is negative. Table 8.10 present an overview of the meaning and source of Figure 8.21.1.

**Table 8: Support table for Figure 8.21.1**

<b>Definition</b>	<b>Link</b>	<b>Sign</b>	<b>Literature support</b>	<b>Data support</b>
<u>Actual cumulative government crude oil revenue:</u> build-up of government crude oil revenue	Actual cumulative government crude oil revenue affects rate of investment	+	Akinlo 2012	P_3 Focus group
<u>Rate of government investment:</u> government financial provision in the industry	Rate of investment affects actual cumulative government crude oil revenue	+	Akinlo 2012	P_3 Focus group
<u>Rate of government crude oil revenue:</u> it's the amount received by government from the oil industry	Rate of government crude oil revenue affects actual cumulative government crude oil revenue	+		P_3 Focus group
<b>Other variables</b>				
<u>Value of crude oil sales:</u> is amount realised from sale of crude oil	Value of crude oil sales determines actual crude oil revenues	+		P_3 Focus group
<u>Corruption:</u> Diversion of money due to government from oil industry	Corruption affects crude oil revenue	-	Mohammed 2013; Hanson 2007	
<u>Potential crude oil revenues:</u> what is actually supposed to be generated by government from oil industry	Potential crude oil revenues affects cumulative potential crude oil revenue	+		EIP_C.
<u>Cumulative government potential crude oil revenues:</u> build-up of what is actually supposed to be generated by government from oil industry	Cumulative government potential crude oil revenue reduces revenue gap	-		P_4 Focus group

<u>Revenue gap:</u> is the difference between potential revenue and actual revenue	Revenue gap is affected by actual cumulative government crude oil revenue and cumulative government potential crude oil revenue	-		EIP_C
<u>Actual crude oil revenues:</u> is the actual amount realised by government from oil industry	Actual crude oil revenues affects rate of government revenues	+		P_5 Focus group
<u>Transparency measures:</u> is openness of operation in the oil industry	Transparency measures reduces corruption	-	NEITI 2011	MIP_I
<u>Corruption in oil industry:</u> corruption specific to oil industry	Corruption in the oil industry affects actual crude oil revenue	-		P_7 Focus group
<u>Corruption:</u> acts of short-changing government	Corruption influences corruption in oil industry	+		P_7 Focus group

Table 8.18 presents the summary variables involved in the investment availability loop including links, sign, literature supports from literature review, data support which refers to data items derived from the telephone interviews and focus group conducted in the field work. In each case each causal relationship is justified.

The causal loop structure in this research has been verified and justified structurally in the above sections. The next section presents the formulation of the formulation of simulation model in this research.

## 8.7 Formulation of Simulation Model

In modelling within the framework of System Dynamics, the process is supported by computational tools which facilitate the formulation of the model on the basis of the structure (causal loop) diagrams (CLD) earlier developed in the previous stages. To carry out a more comprehensive quantitative analysis, structure (causal loop) diagrams earlier developed are converted to a stock and flow (structure) diagram. According to Forrester (1961), a basic model structure is comprised of four



fundamental features including levels, flow rates, decision functions and information as the bases for decision. This section leads to the quantification of the CLDs in terms of stock and flow structures based on the dynamic hypothesis generated at the qualitative level of the system.

Based on the CLD developed in section 8.6, a Stock and Flow (SFD) structures can be constructed to better characterize system behaviour in terms of accumulation and/or depletion of quantities in the system. The CLD was developed and labelled in an appropriate way in order to simplify the transformation to SFD. In particular, variables which are stocks, flows, auxiliaries and specification of links representing information and flows dependencies were appropriately represented. In terms of feedback loops, it was diagrammed in such a way that it contain at least one stock and one flow throughout while developing the CLD.

Specifically, a more leading SD software is utilised (Ventana, 2007). The Vensim modelling software developed by Ventanna system is utilised in this regards. This choice is based on the fact that Vensim software permits a user friendly and readily available support when learning model construction with it as well as provision of a simulation environment that offers building blocks for constructing quantitative SFD models, devoid of the need for learning programming language that are complex in nature based on its ability to formalise and represent systems of complex nature explicitly in such a way that they can be easily communicated to both laymen and experts.

The researcher found translating the causal loop diagram to a stock and flow diagram in one stage to be practically impossible. This therefore necessitates an adjustment, thus adopted a gradual and incremental process of developing the SFD from the CLD. In particular, an iterative approach where a gradually and progressively process of developing the Stock and flow model in small incremental bits was adopted. Stocks (levels) are identified first at this stage so as to represent the variables that are accumulated or depleted over time by the associated flow or rates, while flows (rates) are identified as variables that change the stocks and are thus measured over time interval.

For example, crude oil produced in the production sub view, cumulative cash call short fall in the development sub view, proved reserves in the exploration sub view are modelled as stocks with their respective inflows and outflows. This is followed by testing and verifying the emerging model including its behaviour to identify possible gaps. This explains the addition of some variables in the SFD which are not present in the CLD. In this case, the reference modes are used to serve as guide for the expected behaviour of the system. The use of the inbuilt unit checks provided by the software also assisted in the process since a unit check failure often implies a wrong combination or missing component of variables. Additionally, the relationship between system parameters with equations is presented and initial condition specified which involves the setting up of a complete model with complete equations, initial conditions and parameters that represent the system.

Finally all the feedback loops that appears in the CLD where traced. For example, all the loops in the exploration sub view including (reserve discovery loop and reserve constrain loop), the development sub view including (carry arrangement loop, production capacity loop and cash call constrain loop), the production sub view including (disruption of operation loop, environmental degradation loop, illegal bunkering loop and illegal bunkering motivation loop) and the revenue sub view including (investment availability loop) are represented in the SFD.

Specifically, the model covers the historical period (2000 to 2013) and projects to 2035. A System Dynamics model of the Nigerian oil industry like other models is not specifically designed for the prediction of the future with certainty but as a tool for policy issues to be utilised as a component in the on-going proposed reforms in the industry. The model is aimed to be utilised as a device for acquiring an increased understanding of the dynamics of challenges facing revenue generation in the Nigerian oil industry and as a means of evaluating the effectiveness of a variety of policy interventions and possibly generating insight for possible policies to be tested.

At the core of the overall model, as earlier noted, are four model sub views collectively depicting economic challenges facing the Nigerian oil industry: exploration sub view, development sub view, production sub view and revenue sub view. The rationale for collectively integrating these various model sub views is at

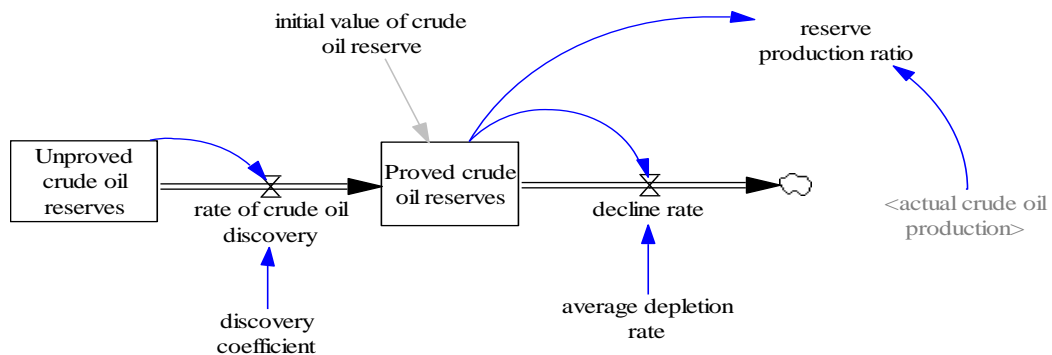
the heart of System Dynamics thus resulting in the representation of comprehensive processes involved in crude oil activities, as well as how respective challenges impact on various sub views within the process. Given the fact that no identified challenge is discovered in the exploration sub view yet incorporated as a sub view of the overall model it remained indispensable, as based on its criticality as the basis and essential stage of any oil activity.

While a causal loop diagram represents a graphical tool which is used to qualitatively capture the mental model of system actors, stock and flow structure depicts a more comprehensive graphical tool to aid in quantifying what has been captured earlier in the causal loop structure. Variables in the causal loop structure are represented in the stock and flow structure (level and rate diagrams). On the basis of this, four model sub views were developed reflective of the earlier developed causal loop diagrams in figures 8.18, 8.19, 8.20 and 8.21. These include exploration, development, production and revenue sub views.

#### **8.7.1 Exploration Sub-view Stock and Flow Diagram**

The exploration sub view is the first model view presented due to its significance in the overall crude oil cycle as: 1) it provides the foundation for crude oil reserves required; and, 2) it directly influences the overall activities in the industry. The sector is linked with the production sub view as issues of proved crude oil reserves is core to operation and production in the oil sector. Figure 8.22 below presents a stock and flow diagram for the exploration sub view.

**Figure 8.22 Exploration stock and flow diagram**



The structure of the exploration stock and flow diagram is displayed in Figure 8.22. Specifically, this sub view depicts the stock of unproved reserves which support the rate of crude oil discovery and rate at which crude oil discovery accumulates proves crude oil reserves which eventually support production. The sub view is also modelled without any new exploration activities. This is based on the fact that for quite some time there have not been any exploration efforts in the Nigerian oil industry and the challenges facing the industry which this research aims to address is not prevalent in the exploration sub sector of the industry. A complete Listing of Model Equations in readable form (Written in the Vensim software of Ventana Systems Inc.) for exploration sub view is presented below and also in Appendix D.

**Exploration sub view equations**

*Unproved\_crude\_oil\_reserve=INTEG (-rate\_of\_crude\_oil\_discovery, initial\_value\_of\_unproved\_crude\_oil\_reserves) and given a unit barrels..... (1)*

Where

*Rate\_of\_crude\_oil\_discovery=discovery\_coefficient\*Unproved\_crude\_oil\_reserves and is given a unit barrels/year*

*Proved\_crude\_oil\_reserves=INTEG(rate\_of\_crude\_oil\_discovery-decline\_rate, initial\_value\_of\_crude\_oil\_reserve)-and\_is\_given\_a\_unit\_barrels..... (2)*

Where

*Rate\_of\_crude\_oil\_discovery=discovery\_coefficient\*Unproved\_crude\_oil\_reserves and is given a unit barrels/year*

*Decline\_rate=average\_depletion rate\*Proved\_crude\_oil\_reserves and is given a units barrels/year.....(3)*

*Reserve\_production\_ratio=Proved\_crude\_oil\_reserves/actual\_crude\_oil\_production and is given a unit year.....(4)*

### **8.7.2 Development Sub-view Stock and Flow Diagram**

In constructing the development sub view, part of the overall model is the stock and flow structure that captures the accumulation of cash call short fall by the integrated flow of cash call short fall which portrays investment shortfall on the side of the government. This cash call short fall accumulates, thus leading to a shortage in joint venture investment within the industry.

In an effort to maintain steady development in order to guarantee unhindered and uninterrupted development projects, the multinational corporations embarked on numerous arrangements (as noted above) in financing the government share of the venture capital. Historical data for cash call obligation, cash call shortfall, alternative funding and government approved budgets for funding of its part of the venture were obtained from NNPC (NPDC 2010, 2012) as well as the audit reports of NEITI (NEITI 2004, 2010, 2013). In order to enable the calibration of the model, these historical data were transformed in order to be able to fit into the model.

This financing arrangement referred to as alternative funding is depicted by an outflow in the model which decreases the flow of cumulative cash call short fall and, hence, is defined as increasing the stock of development investment. The stock of development investment is also increased by a flow of actual cash call paid. The actual cash call paid is the function of investment provided by the government which is mainly determined by the overall government approved budget as part of government counter funding in the sector. In most cases, the government set aside an amount that is much lower than its joint venture share in the industry.

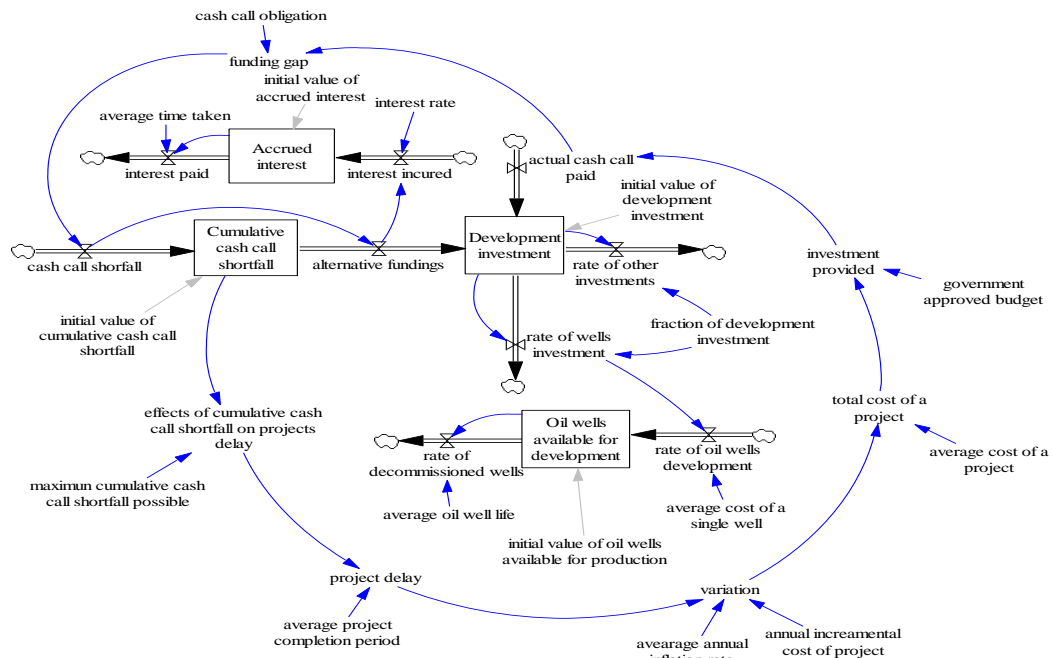
This eventually compiled to accumulate cash call short fall in the industry. The cumulative cash call short fall manifested in a variety of challenges including the accumulation of interest as the multinational companies' resorted to borrowing in order to finance the short fall that arose as a result of government failure to meet its

counter funding, thereby reducing government potential revenue from the industry in the form of debt servicing and cost of capital. Although no organised historical data were obtained regarding interest as a result of borrowing in order to finance funding short fall occasioned by the federal government, the model used the interest rate (cost of financing) alternative funding set by the industry which stands at 8% (NNPC 1999, 2000 and 2009). A delay is introduced into the model to represent the time delay involved between the periods of the short fall and that of sourcing alternative funding. This is a first order delay. On the other hand, this cumulative cash call short fall resulted in project delay leading to variation and ultimately escalating cost of projects which, therefore, increased the cost of running the venture by the government with eventual negative effects on the potential revenue due to the government.

According to US Energy Information Administration (2013), while it took approximately 9 years for petroleum projects to come on board after crude oil discovery, in Nigeria, however, new projects are expected to take an average of 15 years to come online. In arriving at the cost implications of variation, average annual rate of inflation in the country is used.

Historical data for respective annual rate of inflation in Nigeria from 2000 to 2013 was obtained from the data base of the National Bureau for Statistics. This is multiplied by the annual incremental cost of a project as well as the length of project delay. In determining the total cost of a project, variation and average cost of project are summed together. The total cost of a project, therefore, represents government expected financial commitment and here is used as government counterpart funding within the venture. Either of the two, however, total cost of project or government approved budget, represent resources available for cash call. Figure 8.23 below presents a stock and flow diagram for development of the sub vie

**Figure 8.23 Development stock and flow diagram**



The structure of a development stock and flow diagram is displayed in Figure 8.23. Two additional outflows are involved in the stock development investment; these include rate of investment which feeds another in flow (rate of oil well development) which accumulates the stock of oil wells available for production. This stock is, however, depleted by an outflow (rate of decommissioned wells). It is important to stress here that this view captures the aspects of development investment that relates to government alone as the main aim of this research is to capture the various potential revenue due to government from the Nigerian oil industry. Although historical data for the rate of oil well development were obtained, yet data transformation was embarked upon in order to model this relationship in a way that can facilitate model validation. In arriving at the rate of oil well development, a suitable fraction out of stock of development investment was used against average cost of a single well. The cost of a single oil well was obtained in dollar terms and converted to naira value for respective years. This resulted in the accumulation of the stock of oil wells available for production. This stock is also depleted by an outflow which is the rate of decommissioned wells. This flow is calculated using the value of oil wells available for production against the average oil well life which is pegged at 10 years. A complete Listing of Model Equations in readable form (Written in Vensim software of Ventanna Systems Inc.) for development sub view is presented below and also in Appendix D.

**Development sub view equations**

*Cumulative\_cash\_call\_shortfall=INTEG (cash\_call\_shortfall-alternative\_funding, initial\_value\_of\_cumulative\_cash\_call\_shortfall) and is given a unit Naira.....(1)*

Where

*Cash\_call\_shortfall=funding\_gap and is given a unit Naira/year*

*Alternative\_funding =cash\_call\_shortfall is given a unit: Naira/year*

*Development\_investment=INTEG(actual\_cash\_call\_paid + alternative\_funding - rate\_of\_other\_investmentsrate\_of\_wells\_investment,initial\_value\_of\_development\_investment) and is given units Naira.....(2)*

Where

*Actual\_cash\_call\_paid=investment\_provided and is given a units Naira/year*

*Alternative\_funding =cash\_call\_shortfall is given a unit: Naira/year*

*Rate\_of\_other\_investments=(1fraction\_of\_development\_investment)\*Development\_investment and is given a units Naira/year*

*Rate\_of\_wells\_investment=Development\_investment\*fraction\_of\_development\_investment and is given a units Naira/year*

*Accrued\_interest= INTEG (interest\_incurred-interest\_paid, initial\_value\_of\_accrued\_interest) and is given a unit Naira.....(3)*

Where

*Interest\_incurred=alternative\_funding\*interest\_rate and is given a unit Naira/year*

*Interest\_paid=Accrued\_interest/average\_time\_taken and units is given a unit Naira/year*

*Oil\_wells\_available\_for\_development= INTEG (rate-of-oil-wells-development-rate\_of\_decommissioned\_wells, initial\_value\_of\_oil\_wells-available-for-production) and is given a units well.....(4)*

Where

*Rate\_of\_oil\_wells\_development=rate\_of\_wells\_investment/average\_cost\_of\_a\_single\_well and is given a units well/year*

*Rate\_of\_decommissioned\_wells=Oil\_wells\_available\_for\_development/average\_oil\_well\_life and is given a units well/year*



*Investment\_provided=MIN (total\_cost\_of\_a\_project, government\_approved\_budget) and is given a unit Naira/year.....(5)*

Where

*Total\_cost\_of\_a\_project=average\_cost\_of\_a\_project + variation and is given a unit Naira/year*

*Variation=annual\_incremental\_cost\_of\_project\*average\_annual\_inflation\_rate\*project\_delay and is given a unit Naira/year*

*Project\_delay=average\_project\_completion\_period\*effects\_of\_cumulative\_cash\_callshortfall\_on\_projects\_delay and is given a units year*

*Funding-gap=cash-call-obligation-actual-cash-call-paid-and-is-given-a-units Naira/year*

### **8.7.3 Production Sub-view Stock and Flow Diagram**

In all, this view is comprised of nine stocks including cumulative crude oil produced, total vandalism, potential militants, militants, cumulative illegal money, proliferation of arms, population, pollution and unemployed youth stocks. The stock of cumulative crude oil produced is accumulated by the rate of actual crude oil production and this rate of actual crude oil production is determined by two factors including OPEC quota and potential production and this potential production is also determined by two other factors which are production capacity and the effects of disruption on production capacity.

Since there are sufficient and numerous historical data on crude oil production in Nigeria as reported by several organisations including OPEC, USA Energy Information Administration, NEITI, NNPC, amongst others, the research did not rely on a single source of historical data and hence obtained all these records before finally settling on the use of historical data provided by both NEITI and NNPC. In order to calibrate the model, these historical data were transformed in order to be keyed into the model. The stock of cumulative crude oil production is depleted by 2 outflows (crude oil sales and rate of crude oil theft) in the model. Historical data for both were also obtained and transformed in order to be able to mimic the reference mode. Although various organisations maintained records on crude oil stolen using a variety of measuring techniques, effort was made by this study to obtain the most reliable data on crude oil stolen in Nigeria from 2000 to 2013.

The stock of total vandalism is accumulated by the increase in vandalism and also reduced by an outflow of the decrease in vandalism. Historical data for the rate of vandalism in the industry from year 2000 to 2013 was obtained from the records of NNPC (2013) while the rate of the decrease in vandalism was arrived at using rate of repairs, which is a function of vandalism and average time taken for repairs. The average time taken to repair a vandalised facility was obtained from the stakeholders via the researcher's engagement with them. Another stock is cumulative illegal money. This stock is fed by an inflow which is the monetary value of crude oil stolen (theft). This is arrived at after multiplying the crude oil price for respective years by the corresponding quantity of crude oil stolen for that particular year (Coventry Cathedral 2009, NNPC 2013 and CBN 2010, 2012 2014).

Although crude oil price are reported in dollars (\$) and also bearing in mind the volatile nature of crude oil price and the dollar to the naira in terms of the exchange rate (which fluctuates frequently) the study obtained the respective average annual crude oil price from year 2000 to 2013 as well as the equivalent exchange rate (dollar to naira) to be able to arrive at the naira value of crude oil for the periods under review. This is very necessary because the report of this study will be presented to the stakeholders in naira value. An outflow which reduces the stock of cumulative illegal money is the rate of illegal money used to purchase weapons. This rate of outflow is a function of cumulative illegal money and a fraction of illegal money used to purchase weapons. In this research the model assumes that 50% of illegal money is used to finance the purchase of weapons as there is no concrete evidence on the actual amount of money spent by militants for the purchase of weapons. Instead, the study relied on an estimate of the quantity and sophistication of weapons used by the militants.

The rate of money used to purchase weapons and the average cost of a single weapon constitutes an inflow of the rate of weapons purchased which cumulates in the stock of the proliferation of weapons. This stock of the proliferation of weapons is decreased by an outflow which is the rate of weapons reduction representing a function of the proliferation of weapons and a fraction of the proliferation of weapons. Given the quality and sophistication of weapons used by the militants, the study assumes N500, 000 as an average cost of a single weapon. Additionally, the research aggregates all weapons in a single stock irrespective of the type of

weapon. Hence, for the sake of simplicity, it did not distinguish between them. A look up graph was built to represent a nonlinear relationship depicting the effect of the proliferation of weapons on the rate of militants.

In arriving at the rate of militants that accumulates as the stock of militants, demographic data were obtained from the National Bureau of Statistics (NBS) (2011). Using available population figures for 1991 and 2006 census figures in Nigeria, the population of men was used from 2000 to 2013 since over 98% of militants are men. The study specifically utilised historical data on the population of males in the region obtained from the Nigerian National Population Commission. Based on available figures from the Nigerian Bureau of Statistics, (NBS) (2006), youths constitute 62% of the male population in the Niger delta region of Nigeria. This warrants the calculation of the number of youths in the region from 2000 to 2013.

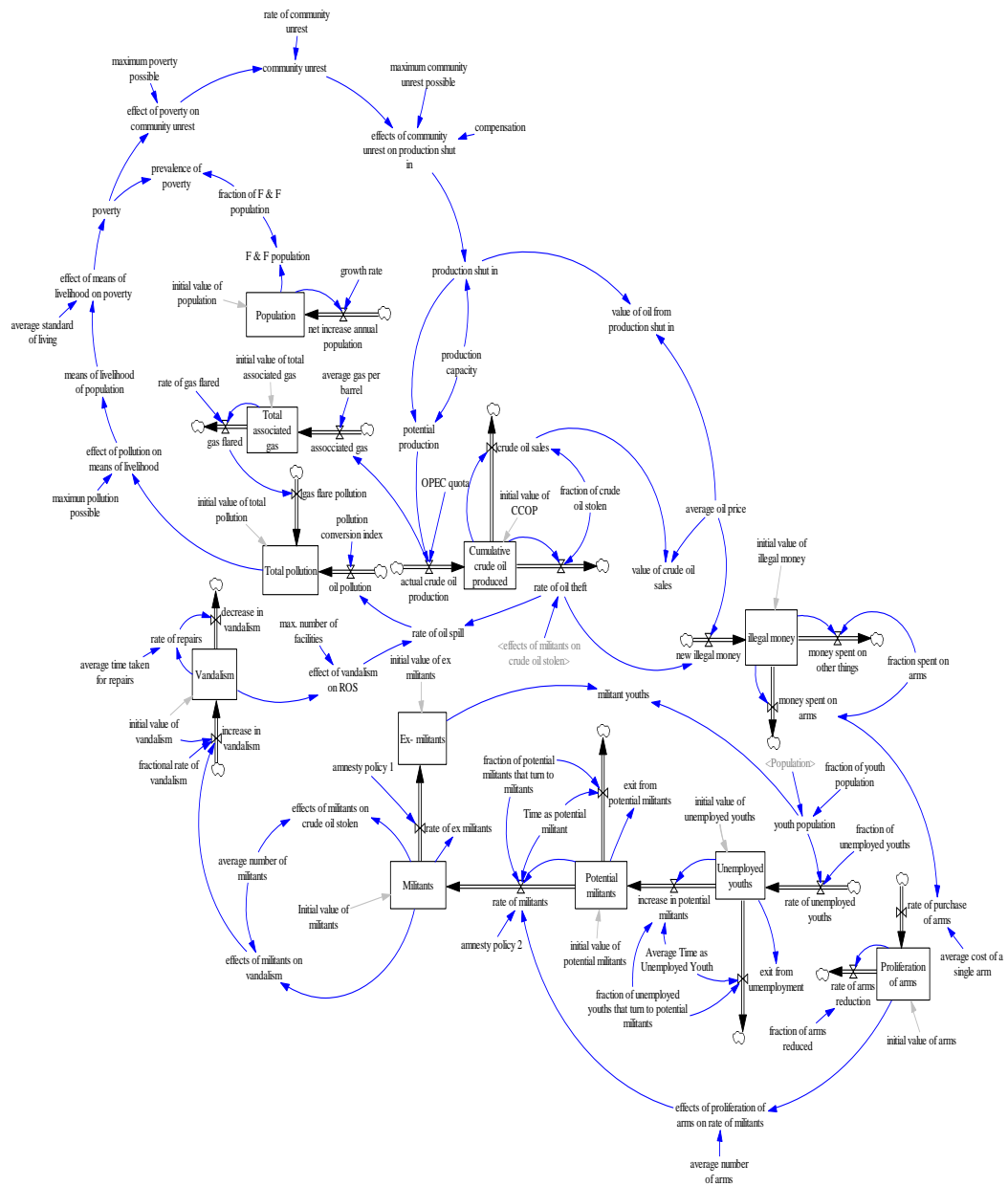
In the same vein, records from the NBS indicated that 50% of youths in the region were unemployed and hence the number of unemployed youths in the region from 2000 to 2013 was arrived at. In using the model data for deriving the model at this end, the growth rate of unemployed youths was utilised for that purpose. To be able to calculate the number of youths susceptible to becoming potential militants, the study assumed that 30% of unemployed youths turned into potential militants. This constituted the basis for arriving at the number of militants in the region.

Since there is no accurate record on the exact number of militants in the region as well as their developmental processes, the study developed a gradual growth process in the population of militants from year 2000 to 2013 with the highest record of growth from year 2004 to 2007. This steady trend of growth of militants from 2000 to 2013 is supported by available literature as well as the number of militants that registered and surrendered their weapons in 2009 after the declaration of amnesty by the then government. For example, various sources estimate the number of militants operating in the creeks at above 25,000 before the commencement of the amnesty initiative (Ibaba, 2011).

On the other hand, a total of 26,358 ex- militants (including about 1,000 female fighters) registered for the post-Amnesty Programme of reintegration and transformation (PAP 2011). On the basis of this, the research assumes that there

were a total of between 25,000 to 30,000 militants at the time of the declaration of the amnesty offer in 2009 by the federal government. Figure 8.24 below represents the stock and flow diagram for the production sub view.

**Figure 8.24: Production stock and flow diagram**



The structure of the production stock and flow diagram is displayed in figure 8.24. Other stocks include the stock of vandalism which was fed by the rate of increase in vandalism that was also determined by the amount of unemployment. The stock is also depleted by the rate of the outflow of repairs and this outflow was determined by the average time taken for repairs and the total vandalism. Historical data for

vandalism from 2000 to 2013 was obtained from the records of NNPC and was modified to enable the calibration of the model. This stock of vandalism affected the rate of oil spill via a look up graph depicting a nonlinear relationship.

This rate of oil spill also affected another rate; i.e. oil pollution. The oil pollution rate accumulated the stock of total pollution together with another inflow to this stock which was the rate of gas flare pollution. In arriving at the oil pollution rate, a pollution conversion index was used in order to convert crude oil spilled to pollution. This conversion index was obtained from NNPC. The rate of gas flare pollution was obtained from the combination of associated gas that is wasted in the process of crude oil production and the average gas *per* barrel of crude oil (Oluduro and Oluduro, 2012). The effect of total pollution in the system was modelled to impact on farming and fishing areas, thus affecting the means of livelihood of the population in the region. According to a report by UNDP (2006), about 70% of the population in the region depended solely on agriculture and fishing for a livelihood.

This, therefore, served as the basis for arriving at the population of farmers and fisher-people in the region. The total population of the region was obtained from the records of the NPC and 70% of this population for respective years was utilised for the purpose of this model effort. On the other hand, as means of livelihood deteriorates average rate of poverty in the area also escalated remarkably; leading to a series of community unrest events by the farming and fishing populations with an eventual effect of community unrest on production shut in (Orogun, 2009). This effect is also modelled in this model using a look up relationship. A complete Listing of Model Equations in readable form (Written in Vensim software of Ventanna Systems Inc.) for production sub view is presented below and also in Appendix D.

**Production sub view equations**

*Cumulative\_crude\_oil\_produced*= INTEG (*actual\_crude\_oil\_production*-*crude\_oil\_sales*-*rate\_of\_oil\_theft*, *initial value of CCOP*) *is given a units barrels.....(1)*

Where

*Actual\_crude\_oil\_production*=MAX (*OPEC\_quota*, *potential\_production*) *is given a units barrels/year*

*Rate\_of\_oil\_theft=IF THEN ELSE (effects\_of\_militants\_on\_crude\_oil\_stolen>0, Cumulative\_crude\_oil\_produced\*fraction\_of\_crude\_oil\_stolen, 0) is given a unit barrels/year*

*Crude\_oil\_sales=(1-fraction\_of\_crude\_oil\_stolen)\*Cumulative\_crude\_oil\_produced and is given a unit barrels/year*

*Unemployed\_youths=INTEG(increase\_in\_potential\_militants-exit\_from\_unemployment-rate\_of\_unemployed\_youths, initial\_value\_of\_unemployed\_youths) is given a units Person.....(2)*

Where

*Increase\_in\_potential\_militants=Unemployed\_youths\*fraction\_of\_unemployed\_youths\_that\_turn\_to\_potential\_militants/Average\_Time\_as\_Unemployed\_Youth and given a unit Person/year*

*Exit\_from\_unemployment=(1-fraction\_of\_unemployed\_youths\_that\_turn\_to\_potential\_militants)\*Unemployed\_youths/Average\_Time\_as\_Unemployed\_Youth and is given a units Person/year*

*Militants= INTEG (rat\_of\_militants-rate\_of\_exit\_militants, Initial\_value\_of\_militants) and is given a unit Person.....(3)*

Where

*Rate\_of\_militants=IF THEN ELSE (effects\_of\_proliferation\_of\_arms\_on\_rate\_of\_militants>0, Potential\_militants\*fraction\_of\_potential\_militants\_that\_turn\_to\_militants/Time\_as\_potential\_militant, 0)\*amnesty\_policy\_2 and is given a unit Person/year*

*Rate\_of\_exit\_militants=Militants\*amnesty\_policy\_1 is given a units Person/year*

*Vandalism= INTEG (increase\_in\_vandalism-decrease\_in\_vandalism, initial\_value\_of\_vandalism) is given a unit Facilities.....(4)*

Where

*Increase\_in\_vandalism=IF THEN ELSE (effects\_of\_militants\_on\_vandalism>0, initial\_value\_of\_vandalism\*fractional\_rate\_of\_vandalism, 0) is given a unit Facilities/year*

*Decrease\_in\_vandalism=rate\_of\_repairs is given a units Facilities/year*

*Potential\_militants= INTEG (increase\_in\_potential\_militants-exit\_from\_potential\_militants-rate\_of\_militants, initial\_value\_of\_potential\_militants) is given a units Person.....(5)*

Where

*Increase\_in\_potential\_militants=Unemployed\_youths\*fraction\_of\_unemployed\_youths\_that\_turn\_to\_potential\_militants/Average\_Time\_as\_Unemployed\_Youth is given a unit Person/year*

*Exit\_from\_potential\_militants=(1-fraction\_of\_potential\_militants\_that\_turn\_to\_militants)\*Potential\_militants/Time\_as\_potential\_militant is given a unit Person/year*

*Rate\_of\_militants=IF (effects\_of\_proliferation\_of\_arms\_on\_rate\_of\_militants>0, Potential\_militants\*fraction\_of\_potential\_militants\_that\_turn\_to\_militants/Time\_as\_potential\_militant, 0)\*amnesty\_policy\_2 is given a unit Person/year.....(6)*

*Proliferation\_of\_arms= INTEG (rate\_of\_purchase\_of\_arms-rate\_of\_arms\_reduction, initial value of arms) Units: arms.....(7)*

Where

*Rate\_of\_arms\_reduction=Proliferation\_of\_arms\*fraction\_of\_arms\_reduced and is given a unit arms/year*

*Rate\_of\_purchase\_of\_arms=money\_spent\_on\_arms/average\_cost\_of\_a\_single\_arm is given a unit arms/year*

*Illegal\_money= INTEG (new\_illegal\_money-money\_spent\_on\_arms-money\_spent\_on\_other\_things, initial\_value\_of\_illegal\_money) and is given a unit Naira.....(8)*

Where

*New\_illegal\_money=average\_oil\_price\*rate\_of\_oil\_theft and is given a units Naira/year*

*Money\_spent\_on\_arms=illegal\_money\*fraction\_spent\_on\_arms and is given a unit Naira/year*

*Money\_spent\_on\_other\_things=(1-fraction\_spent\_on\_arms)\*illegal\_money and is given a unit Naira/year*

*Total\_associated\_gas= INTEG (associated\_gas-gas\_flared, initial\_value\_of\_total\_associated\_gas) Units: tons.....(9)*

Where

*Associated\_gas=actual\_crude\_oil\_production\*average\_gas\_per\_barrel and is given a unit tons/year*

$Gas\_flared = rate\_of\_gas\_flared * Total\_associated\_gas$  and is given a unit tons/year

$Total\_pollution = INTEG (gas\_flare\_pollution + oil\_pollution, initial\_value\_of\_total\_pollution)$  and is given a unit tons.....(10)

Where

$Gas\_flare\_pollution = gas\_flared$  and is given a unit tons/year

$Oil\_pollution = rate\_of\_oil\_spill * pollution\_conversion\_index$  and is given a unit tons/year

$Population = INTEG (net\_increase\_annual\_population, initial\_value\_of\_population)$  and is given a unit Person.....(11)

Where

$Net\_increase\_annual\_population = Population * growth\_rate$  and is given a unit Person/year

$"F\_ \& \_F\_population" = Population * "fraction\_of\_F\_ \& \_F\_population"$  and is given a unit Person.....(12)

Where

$Population = INTEG (net\_increase\_annual\_population, initial\_value\_of\_population)$  and is given a unit Person

$"F\_ \& \_F\_population" = Population * "fraction\_of\_F\_ \& \_F\_population"$  which is given a unit Person

$Potential\_production = production\_capacity - production\_shut\_in$  and is given a unit barrels/year.....(13)

Where

$Production\_shut\_in = production\_capacity * effects\_of\_community\_unrest\_on\_production\_shut\_in$  and is given a unit barrels/year

$Militant\_youths = youth\_population - "Ex- militants"$  and is given a unit Person

Where

$Youth\_population = Population * fraction\_of\_youth\_population$  and is given a unit Person

$"Ex- militants" = INTEG (rate\_of\_ex\_militants, initial\_value\_of\_ex\_militants)$  and is given a Unit Person

$Community\_unrest = effect\_of\_poverty\_on\_community\_unrest + (rate\_of\_community\_unrest)$  and is given a unit Dmnl



Where

*Effect\_of\_poverty\_on\_community\_unrest=poverty/maximum\_poverty\_possible and is given a unit Dmnl*

*Rate\_of\_community\_unrest) is presented as a model variable*

*Rate\_of\_oil\_spill=rate\_of\_oil\_theft\*effect\_of\_vandalism\_on\_ROS and is given a unit barrels/year*

Where

*Effect\_of\_vandalism\_on\_ROS= WITH LOOKUP ("max.\_number\_of\_facilities"/Vandalism,*

*([(0,0)-(6,10)],(0,0),(1,1),(2,4),(4,4),(6,10) )) and is given a unit Dmnl*

*Means\_of\_livelihood\_of\_population=effect\_of\_pollution\_on\_means\_of\_livelihood and is given a unit Dmnl*

Where

*Effect\_of\_pollution\_on\_means\_of\_livelihood= WITH LOOKUP (Total\_pollution/maximum pollution\_possible,([(0,0)-(1,1)],(0.1,0.7),(0.2,0.4),(0.385321,0.197368),(0.568807,0.0964912),(0.8043,0.0438596),(0.9939,0.02193) )) and is given a unit Dmnl*

*Effects\_of\_vandalism\_of\_oil\_facilities(poverty=effect\_of\_means\_of\_livelihood\_on\_poverty and is given a units Dmnl*

Where

*Poverty\_effect\_of\_means\_of\_livelihood\_on\_poverty and is given a unit Dmnl*

*Effect\_of\_means\_of\_livelihood\_onpoverty=average\_standard\_of\_living/means\_of\_livelihood\_of\_population\_and is given a unit Dmnl*

*Prevalence\_of\_poverty=poverty/"fraction\_of F\_& F\_population" and is given a unit Dmnl*

Where

*Poverty\_effect\_of\_means\_of\_livelihood\_on\_poverty and is given a unit Dmnl*

*fraction\_of\_F\_&\_F\_population" which is given a unit Person*

*Rate\_of\_repairs=Vandalism/average\_time\_taken\_for\_repairs and is given a unit Facilities/year*

Where

$Vandalism = INTEG (increase\_in\_vandalism - decrease\_in\_vandalism, initial\_value\_of\_vandalism)$  and is given a unit Facilities

$Average\_time\_taken\_for\_repairs$  and is given a unit year

$Rate\_of\_unemployed\_youths = youth\_population * fraction\_of\_unemployed\_youths$  and is given a unit Person/year

Where

$Youth\_population = Population * fraction\_of\_youth\_population$  and is given a unit Person

$Fraction\_of\_unemployed\_youths$  and is given a unit Person

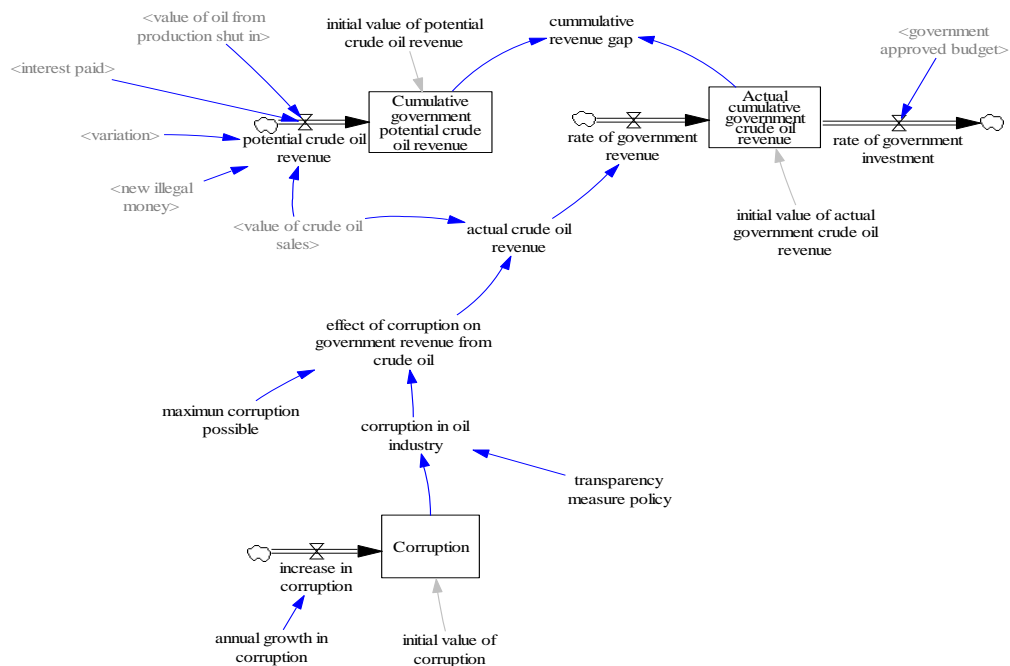
#### **8.7.4 Revenue Sub-view Stock and Flow Diagram**

This model sub view is comprised of three stocks including cumulative government potential crude oil revenue, actual cumulative government crude oil revenue and corruption stocks. The aim here was to demonstrate the potential crude oil revenue due to government from the industry. The sub view is also linked to the rest of the sub views. The first stock cumulative government potential crude oil revenue is accumulated by the inflow rate of potential government crude oil revenue which was determined by five factors: value of crude oil sales, rate of illegal money, value of crude oil loss from production shut in, variation and interest accumulation from alternative funding. This stock constituted what ordinarily ought to be revenue generated by the government. The second stock of actual government crude oil revenue was determined by an inflow rate of government crude oil revenue which is a function of cumulative government potential crude oil revenue and a fraction of cumulative government potential crude oil revenue as well as two outflows; revenue loss determined by actual cumulative government crude oil revenue and a fraction of revenue loss as well as the other outflow which is rate of government investment.

The last stock is corruption which was modelled outside the system in order to show only its effect on some variables within the model. The research takes the corruption perception index in the Nigerian society as a guide in assigning values for both the flow and stock of corruption in this model. Also of note is that

corruption was modelled outside the system as earlier indicated so that it is only the effect of corruption that impacts the system. The stock of corruption is increased by an inflow of the rate of increase in corruption which is determined by a corruption perception index and decreased by an outflow decrease in corruption which is determined by the stock of corruption and transparency measure which is a policy initiative aimed at reducing corruption in the industry. Figure 8.25 below presents a stock and flow diagram for the revenue sub view

**Figure 8.25 Stock and flow diagram for revenue sub view**



A complete Listing of Model Equations in readable form (Written in Vensim software of Ventanna Systems Inc.) for revenue sub view is presented below and also in Appendix D.

**Revenue sub view equation**

*Cumulative\_government\_potential\_crude\_oil\_revenue=INTEG(potential\_crude\_oil\_revenue, initial\_value\_of\_potential\_crude\_oil\_revenue) is given a units Naira.....(1)*

Where

*Potential\_crude\_oil\_revenue=interest\_paid + new\_illegal\_money + value\_of\_oil\_from\_production\_shut\_in + value\_of\_crude\_oil\_sales + variation and is given a units Naira/year*

*Corruption*= *INTEG* (*increase\_in\_corruption*, *initial\_value\_of\_corruption*) and is given a unit *Dmnl*.....(2)

*Increase\_in\_corruption*=*annual\_growth\_in\_corruption* and is given a unit *1/year*

*Actual crude oil revenue*=*value\_of\_crude\_oil sales\*effect\_of\_corruption\_on\_government\_revenue\_from\_crude\_oil* and is given a units *Naira/year*.....(3)

*Actual\_cumulative\_government\_crude\_oil\_revenue*= *INTEG* (*rate\_of\_government\_revenue-rate\_of\_government\_investment*, *initial\_value\_of\_actual\_government\_crude\_oil\_revenue*) and given a units *Naira*.....(4)

*Rate\_of\_government\_revenue*=*actual\_crude\_oil\_revenue* is given a units *Naira/year*

*Rate\_of\_government\_investment*= *government\_approved\_budget* is given a unit *Naira/year*

*Corruption\_in\_oil\_industry*=*Corruption\*(1-transparency measure policy)* is given a unit *Dmnl*.....(5)

*Cumulative\_revenue\_gap*=*Cumulative\_government\_potential\_crude\_oil\_revenue-Actual\_cumulative\_government\_crude\_oil\_revenue* is given a unit *Naira*.....(6)

Where

*Cumulative\_government\_potential\_crude\_oil\_revenue*=*INTEG*(*potential\_crude\_oil\_revenue*, *initial\_value\_of\_potential\_crude\_oil\_revenue*) is given a units *Naira*

*Actual\_cumulative\_government\_crude\_oil\_revenue*= *INTEG* (*rate\_of\_government\_revenue-rate\_of\_government\_investment*, *initial\_value\_of\_actual\_government\_crude\_oil\_revenue*) and given a units *Naira*

*Value\_of\_oil\_from\_production\_shut\_in*=*production\_shut\_in\*average\_oil\_price* and is given a units *Naira/year*.....(7)

*Effect-of-corruption-on-government-revenue-from-crude-oil*= *WITH LOOKUP* (*corruption-in-oil-industry/maximum-corruption-possible*,([(0,0) (5,2)],(0,0),(0.24,0.729481),(0.44,0.669205),(0.448,0.792675),(0.48,1.14795),(0.496,0.6663),(0.52,0.893422),(0.544,0.697639),(0.544,0.551179),(0.56,0.8968),(0.608,0.610394),(0.608,0.5721),(0.608,0.445858),(0.624,0.576568),(0.656,0.694698),(5, 1) )) Units: *Dmnl*

## 8.8 Model Parameterisation and Calibration

In this research, three types of parameter were used in different sectors of the model. These include constants, initial values of the stocks, and table functions. However, there is the need to know whether or not the parameter values used are

consistent with relevant descriptive and numerical knowledge of the system being modelled and, as such, have real world meaning. The model was therefore, parameterised and calibrated in such a way that its output mimics reality. To achieve this, a number of steps were taken to ensure that all the parameter values were assessed and verified. Some of the parameter values were extracted from archival materials as retrieved from NNPC 2000- 2013; NEITI, 2005, 2009, 2011; OPEC, 2010; NPC 1992, 2006; CBN, 2000, 2013). These constants show that they are real values and they make the model to be operational in modelling reality (see Table 10.1 for the list of parameters extracted from archival materials. Additionally, some parameter values were assigned based on expert opinion as part of the interviews and focus groups conducted during the course of the research. Again, this exercise ensured that confidence is built in assigning values to those parameters. See Table 10.1 for the list of parameter values assigned based on expert opinion. Furthermore, the model was calibrated by using partial model tests of different sectors that made up of the model. The data that served as the source of input parameters for this model were all collected in EXCEL spread sheets. These data items were imputed into the model as imported datasets. Specifically, the data sets were carefully organised in order to achieve flexibility in the use of the datasets by distinguishing the spread into initial values, model and calibration datasets. Details of the process were explained under each of the model sub view. (See section 8.7.1 for exploration sub view, section 8.7.2 for development sub view, section 8.7.3 for production sub view and section 8.7.4 for revenue sub view.

## **8.9 Summary and Conclusion**

This chapter serves as the engine room for this research work. It provides the basis for both qualitative and quantitative processes as well as articulating all required steps in the overall development of the model for this research. Specifically, the major assumptions for this research work are also presented in this chapter. The overall outcome was the representation of both the CLD and SFD depicting the challenges facing the Nigerian oil industry. Specifically, four model sub views were developed in this chapter including exploration, development, production and revenue. In particular, the empirical relevance and rigour of the model are tightly

connected to the definition of the problem and conceptualisation of the model (Kopansky and Luna Reyes 2008).

These 2 unique procedures are depicted by problem definition within the modelling efforts and have logically been highlighted in the model construction and development section of this chapter. Model description and structural verification is also discussed in this chapter. Overall, this chapter serves as a foundation for subsequent chapters. Finally, the summary and conclusion of the conclusion is presented.

## CHAPTER NINE: MODEL BASE RUN BEHAVIOUR

### 9. Introduction

As a foundation for policy and scenario analysis, this chapter presents the baseline model behaviour. This behaviour depicts the development of the system if exogenous factors remain unchanged. Specifically, the data for the base run were obtained from relevant historical sources (NNPC 2000- 2013; NEITI, 2005, 2009, 2011; OPEC, 2010; NPC 1992, 2006; CBN, 2000, 2013). Simulation started in 2000 and ran until 2035. The period up to 2013 refers to historical reality, specifically 2005 serves as the first and 2009 as the second periods for policy interventions. Recall that the two policy interventions were both aimed at improving government revenue from the industry albeit implemented at different points in time as stated above.

While transparency policy measures (2005) aimed to address corruption in the industry, the amnesty policy measure (2009) on the other hand aimed to instil stability in the oil producing region through the eradication of militant activities. As a source for the analyses of policy and scenario in the following sections, the behaviour of the model under the base run will be presented. The base run behaviour of the model illustrates and discusses 4 different dynamics of the base model.

The four different dynamics include: the pre-transparency (before 2005) era, the pre-amnesty (before 2009) era and finally the post-transparency (after 2005) and amnesty (after 2009) eras. The pre-transparency and amnesty eras relate to the development of the system devoid of change in external forces, i.e. government policy interventions aimed at improving revenue generation from the industry, whereas the post-transparency and post-amnesty eras relate to periods after the policy interventions. These periods are characterised by different degrees of policy intervention. These periods are categorised into short, medium and long term scales for the purpose of this modelling work. The pre- with no policy interventions and the post- with policy interventions are discussed under the following headings.

## 9.1 Transparency Policy Measure

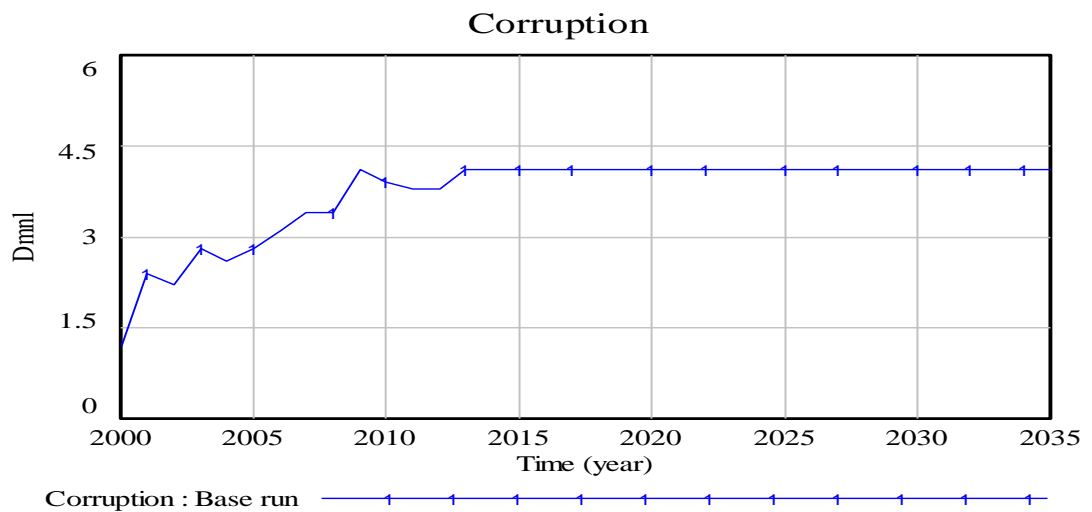
Immediately after the conduct of the initial and first ever audit exercise (financial and physical) it was collectively concluded by the stakeholders in the industry that an erstwhile opaque organisation would henceforth experience a relatively transparent status in the area of its operation. As a result of this, the operation of the industry was brought to the notice of the general public and thereby performance improved in the view of the stakeholders. Although it still remained extremely difficult to quantify the effect of this policy intervention, yet the general consensus among system actors remained that an estimated 20% level of transparency had significantly been attained immediately after the release of the first audit report in year 2006. In this section, the behaviour of several variables (which aimed at being addressed by the transparency policy intervention) will be looked at.

Basically, the behaviour falls into 2 different stages as stated above. The pre-transparency era representing the period before 2005 is chosen as a short term scale of time since historical data on importable variables that relate to these policy interventions (such as crude oil revenue and corruption from 2000, until 2005 and until 2013) are available. The period from 2000 to 2005 corresponds to the 5 years period where there is no policy intervention; 2006 to 2013 relates to the 9 years aftermath of the policy intervention. In particular, the aim of this policy intervention, according to government, is to reduce corruption in the industry in order to enhance government take via blockage of revenue leakages.

On the basis of this, the behaviour of corruption and corruption in the oil industry will firstly be analysed and these analyses will eventually lead to further analysis of other variables that will be impacted directly as a result of the behaviour of these variables. Below are the graphs of the behaviour of corruption in figure 9.1a and corruption in the oil industry in 9.1b with emphasis on the periods from 2000 to 2005, 2006 to 2013 and 2035, representing the short, medium and long term time scales respectively.



**Figure 9.1a Base run – corruption**

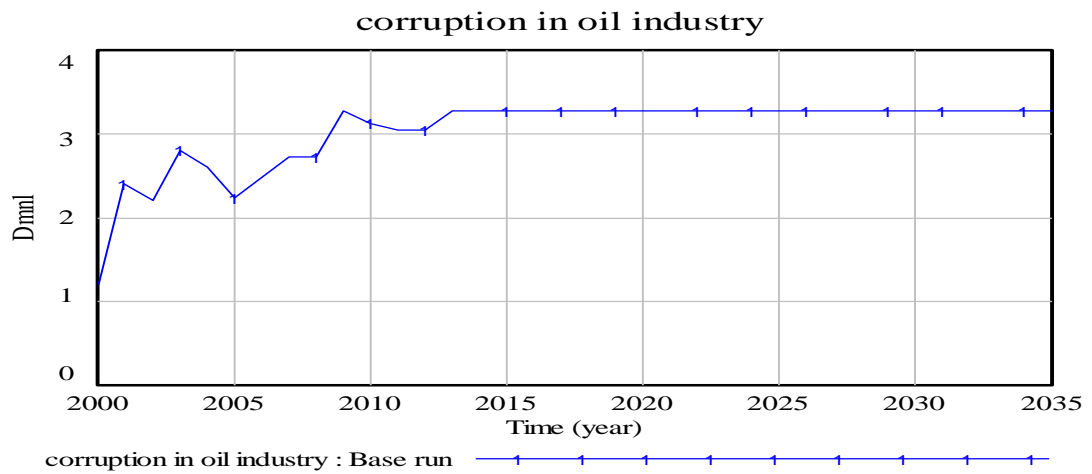


**Source: Author's work**

Upon further scrutiny it was observed that the simulation outputs for corruption have short settling times to equilibrium. This is because there is no reliable and accurate data, so it was based on approximation of the corruption perception index provided by TI. While the settling time might not be exactly like the graph, yet it is an indication that that policy measure may eventually work as it maintains corruption to a stable level.

As stated above, corruption had been prevalent in the Nigerian oil industry and reflected the situation in the entire country. The historical value for corruption from year 2000 to 2013 was obtained from available records of ranking by Transparency International (TI). This serves as a guide in modelling corruption in this research. The graph depicts an exponential growth of corruption in the country. Figure 9.1b represents the base run behaviour of corruption in the Nigerian oil industry.

**Figure 9.1b Base run – corruption in oil industry**

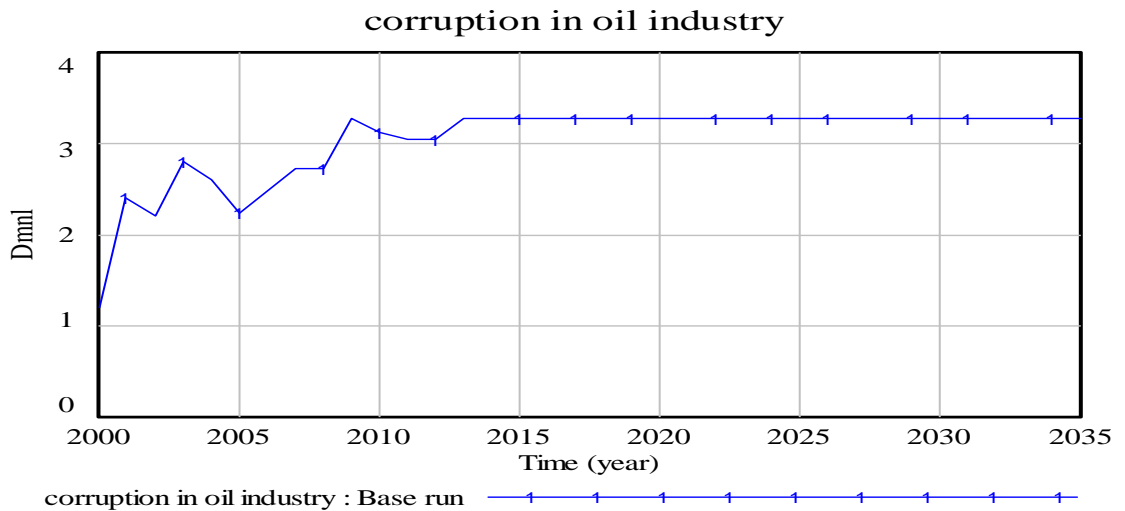


**Source: Author's work**

In representing the effect of this policy (transparency measures) intervention, the research estimated the degree and effect of transparency measures on corruption in the Nigerian oil industry at about 20% as agreed by the stakeholders' collective judgement. On the basis of this, the research used a step function to incorporate the policy intervention that came on board in the year 2005. Transparency policy = 2000 – 2005 = 0% and from year 2006, the effect increases to 20% and remained at that rate up to now according to stakeholders who were, as a result of the increase, hoping to attain a higher level.

It is worth stating that, despite the fact that the model of corruption in the oil industry is reflective of corruption in the larger society, the base run behaviour of corruption in the oil industry takes a slightly different dimension from the corruption in the larger society especially from year 2006 (notwithstanding the exact similarity between the two from year 2000 to 2005). This is attributed to the transparency policy intervention implemented in year 2005 and which became operational in the years following 2005. The resultant effect of this policy intervention can also be observed on the behaviour of the variables that follow in figure 9.1c (representing actual crude oil revenue), figure 9.1d (representing the rate of government revenue) and figure 9.1e (representing cumulative government crude oil revenue).

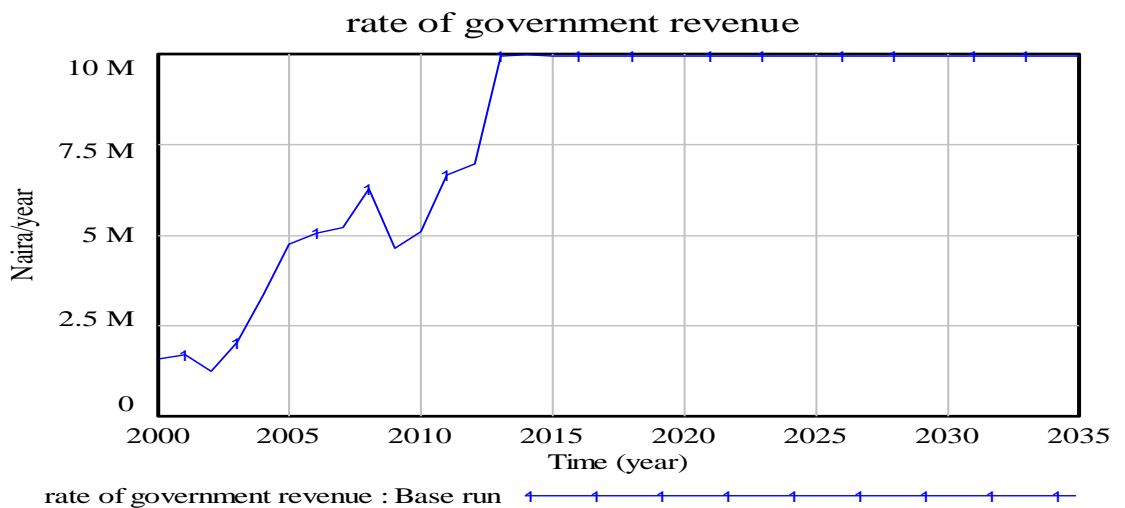
**Figure 9.1c Base run – actual crude oil revenue**



**Source: Author's work**

In the base run of the model just as in all cases, the previous values of crude oil are from the historical data and after that the actual crude oil revenue stayed constant from 2014 to the end of the simulation.

**Figure 9.1d Base run – rate of government crude oil revenue**



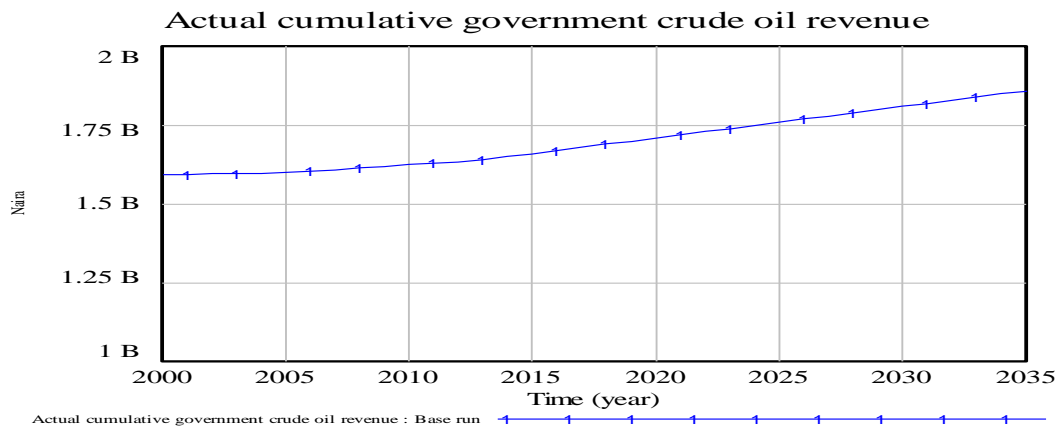
**Source: Author's work**

This follows the same trajectory path with the actual crude oil revenue in the industry. Figure 9.1d is the product of the rate of government crude oil revenue. In the model, the cumulative government crude oil revenue is modelled as an

accumulation of the rate of government crude oil revenue less the rate of government investments.

The graphs show that government crude oil revenue (9.1c) increases gradually, driving the gradual increase of cumulative government crude oil revenue (9.1d) increasing exponentially after 2005 and also deriving an exponential increase in cumulative crude oil revenue in the corresponding period.

**Figure 9.1e: Base run – actual cumulative government crude oil revenue**



**Source: Author's work**

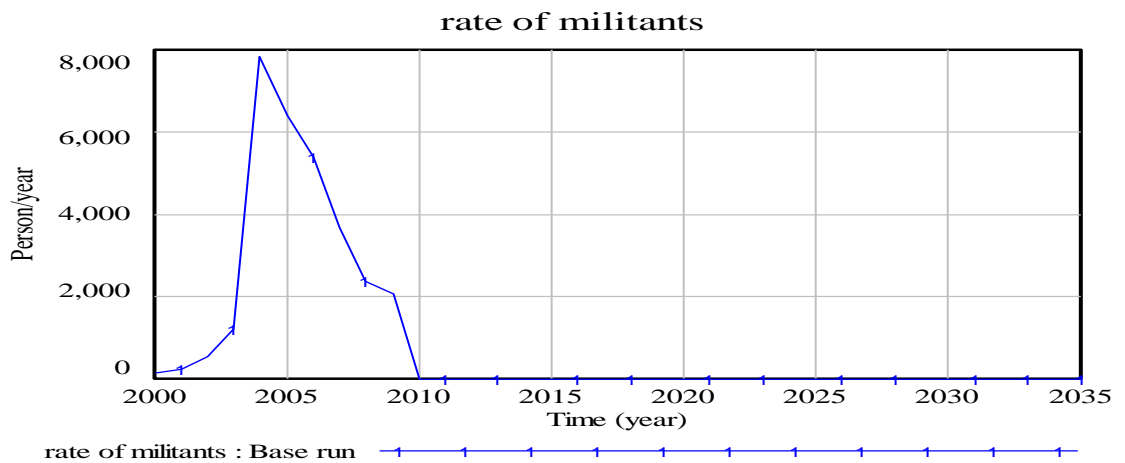
It can be observed that, actual cumulative government crude oil revenue grows gradually from 2000 to 2005 but the growth escalates more rapidly leading to exponential growth from year 2005 up to the end of the simulation. As stated earlier, the observed behaviour of the base run is associated with corruption which the transparency measure seeks to address.

## **9.2 The Amnesty Policy Measures**

In this section the analysis of the base run behaviour of the model focuses on variables whose behaviour is intended to be altered by this policy intervention. Specifically, the aim of this policy, according to stakeholders, was to instil stability in the oil producing area so as to warrant uninterrupted crude oil production, address crude oil theft and vandalism via a reduction of militant activities and, finally, curtail communal unrest. By extension, it was hoped that this would lead to an increase in government revenue from the industry. On the basis of this, the base

run behaviour of the rate of militants was focused upon and this was followed by the base run behaviour of other variables having a direct relationship with militant activities in the industry. The pre-amnesty era represents the period before 2009 and was chosen as the medium term time scale, since historical data on crude oil production from 2000 to 2009 and until 2013 were available. The period from 2000 to 2009 corresponds to about 9 years, and 2009 to 2013 corresponds to 4 years. The periods from 2000 to 2009, 2009 to 2013 are depicted in the graphs in figure 9.2a representing the rate of militants and 9.2b representing number of militants.

**Figure 9.2a Base run – rate of militants**



**Source: Author's work**

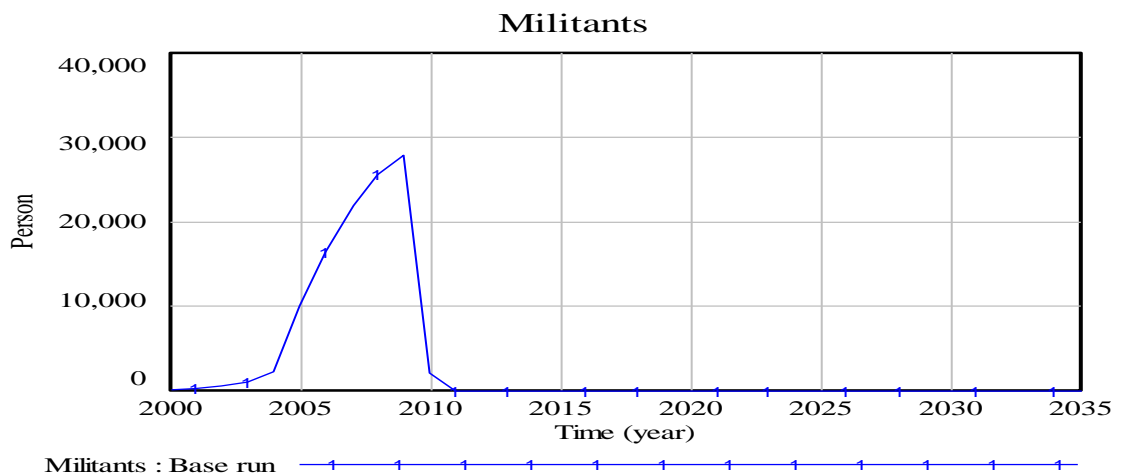
In the base run behaviour of the model, the rate of militants witnessed a steady rise from the base run year 2000 with the most exponential rise in the period between years 2004 to 2006. Although there is no historical data on militants or rate of militants, yet it is evidently clear from the available literature and enquiry data that the highest trend of militancy growth was witnessed between years 2004 to 2006. Additionally, prior to year 2009, there was no amnesty policy but the implementation of the policy in year 2009 brought an abrupt end to militant activities in the region – hence the total collapse of the graph in 2010.

While numerous challenges have militated against the potential level of crude oil production in the Nigerian oil sector, the implementation of this policy measure resulted in the curtailment of challenges such as vandalism, crude oil theft, communal unrest and oil spill via the reduction of militant activities. For example,

vandalism acts were responsible for oil spill that turned to pollution which triggered communal unrest with eventual effects on potential crude oil production. In representing the amnesty policy measure, the research used a time step function to incorporate the policy which came on board in 2009. Prior to 2009, militant activities remained unhindered resulting in serious loss of revenue to the government. It could be observed that immediately after the implementation of the policy measure in 2009, crude oil production started increasing in a gold seeking behaviour.

The effect of this policy was immediate as the activities of militants were brought under control and about 30,000 militants denounced their militancy activities. The amnesty policy therefore = 2000 to 2009 = 0% and from 2010, the effect became 100% since which time there has remained relative peace in the region resulting in uninterrupted crude oil production. As stated earlier, above, the upward slope in the graph representing rate of government revenue is the result of the rise of crude oil production which, by implication, resulted in the rise in government proceeds from the sector. Figure 9.2a shows the result of amnesty policy interventions. The graphs shows that militancy (9.2a) before 2009 increased exponentially increasing the rate of vandalism (9.2f) and also increasing crude oil theft (9.2c) slowing down in 2009 and after 2009 decreasing crude oil theft (9.2c) as well as crude oil spill (9.2d) leading to exponential increases in crude oil production (9.2e).

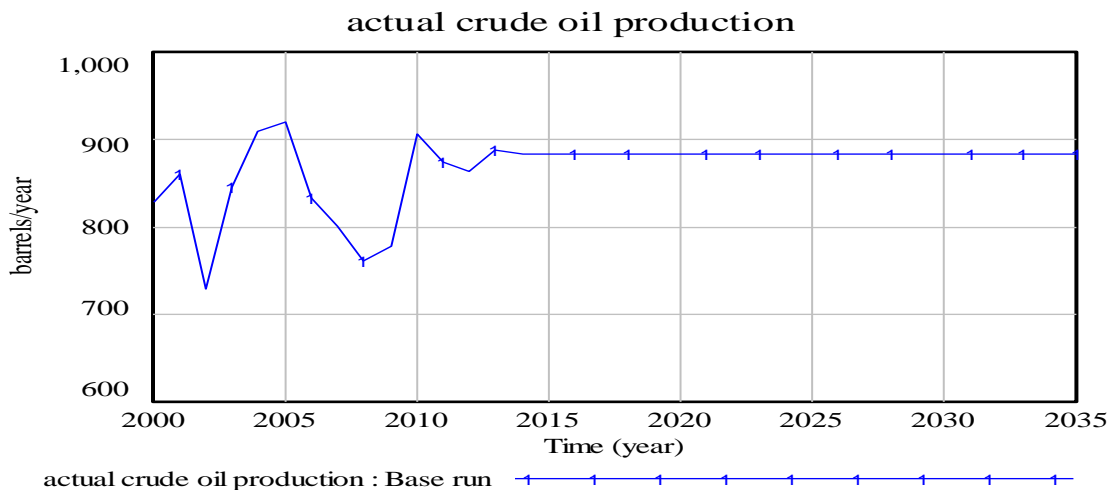
**Figure 9.2b Base run – militants**



**Source: Author's work.**

Militancy is determined by the rate of militants, potential militants and effects of the proliferation of arms on militants. The first two are influenced directly and indirectly by the rate of unemployed youths (with some delay). When unemployed youths increased, potential militants increased together with the rate of militants. The effect of the proliferation of arms is decided by the proliferation of arms as directly determined by rate of illegal money. Since the effects of proliferation of arms are strong, militants continued to grow and showed an exponential growth. The following figures 9.2c (represents base run for actual crude oil production) 9.2d (represents cumulative crude oil produced) 9.2e (represents vandalism) and 9.2f (represents rate of vandalism).

**Figure 9.2c Base run – actual crude oil production**

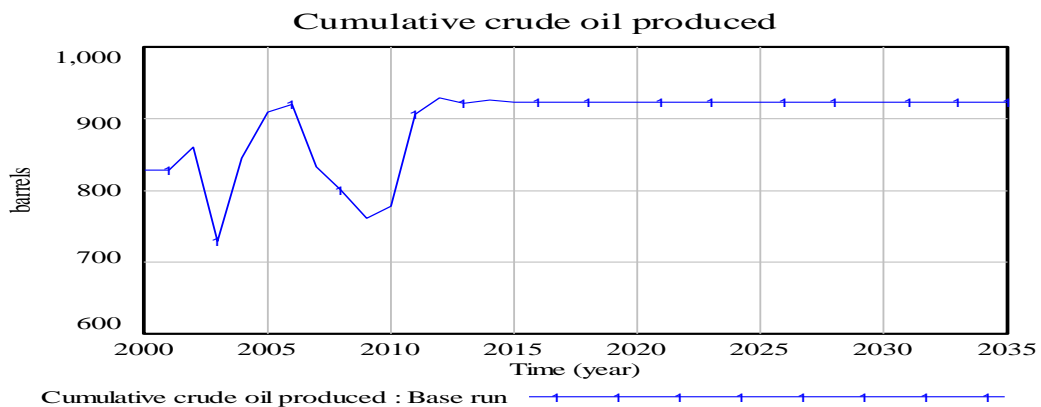


**Source: Author's work.**

In the base run of the model, the values of actual crude oil production before 2014 were from historical data and after that actual crude oil production witnessed an exponential rise and then stayed constant after 2015 to the end of the simulation. In the model, the period before 2009 represents a period where there was no policy intervention and hence it could also be observe that crude oil production skyrocketed from 2010 before it gradually dropped down and rose again and from 2013 to the end of the simulation crude oil production remained constant. The actual crude oil production accumulated to produce cumulative crude oil produced as shown below in figure 9.2d.

It was observed that the simulation outputs for actual crude oil production have short settling times to equilibrium. Upon further scrutiny it was discovered that actual crude oil production should ideally have static value and should not be changing based on the fact that it is a function of either OPEC quota or potential production. On the other hand the effect of production shutdown on potential production results to fluctuation in actual crude oil production. So after the implementation of the amnesty policy intervention, both vandalism and rate of crude oil theft which combined to affect rate of oil spill that increase pollution which in turn affects means of livelihood of the populist leading to poverty which in turn provokes communal unrest is stopped. Therefore actual crude oil production will take a static value once community unrest ceases because of the effect of community unrest on production shut in.

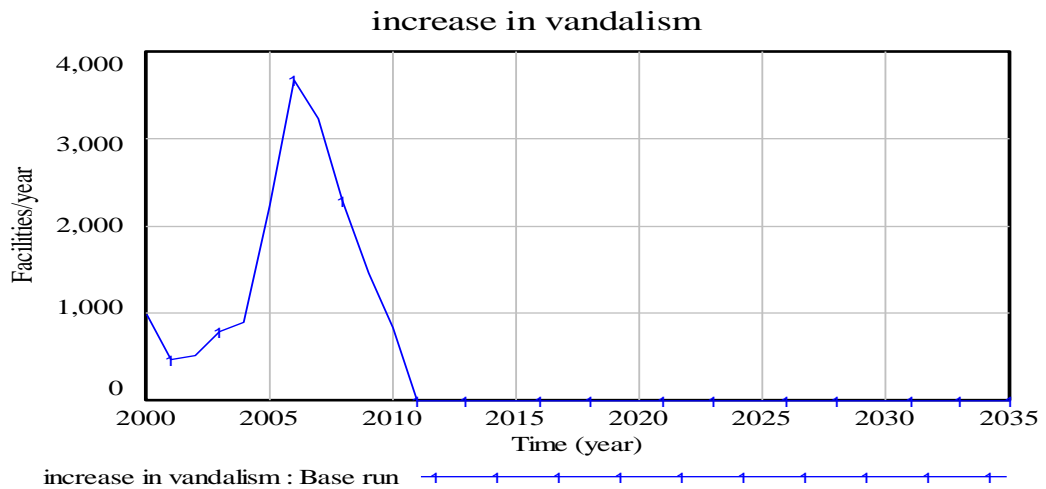
**Figure 9.2d Base run – cumulative crude oil produced**



**Source: Author's work.**



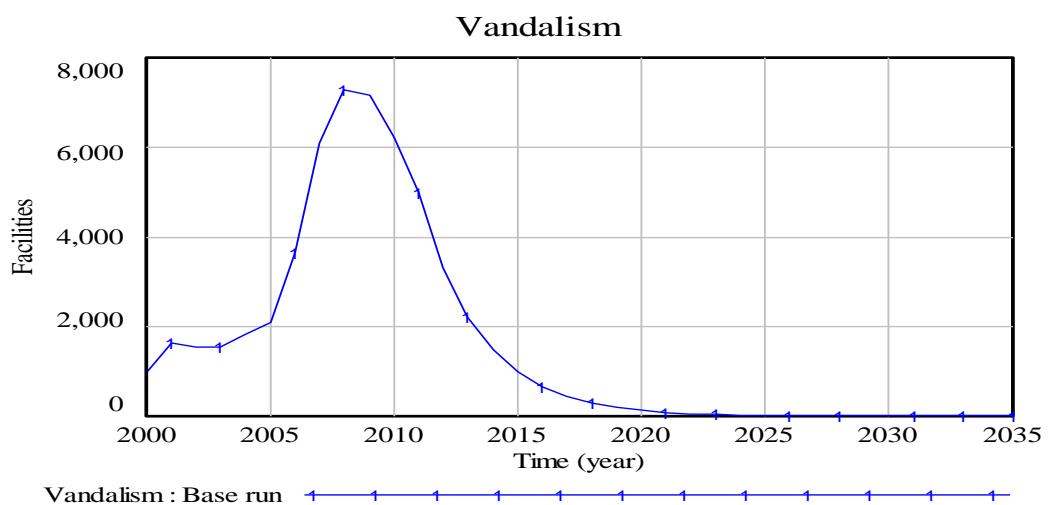
**Figure 9.2e Base run – increase in vandalism**



**Source: Author's work.**

It was observed in figure 9.2e that the simulation outputs for cumulative crude oil produced have short settling times to equilibrium. Upon further scrutiny it was observed since cumulative crude oil produced is a function of actual crude oil production less crude oil sales and rate of oil theft, therefore as soon as amnesty measures have been put in place, production shut in and rate of crude oil theft ceases thus cumulative crude oil produced will be stable as it will only remained a function of production and sales of crude oil hence the fast steady settling.

**Figure 9.2f Base run – vandalism**



**Source: Author's work.**

### **9.3 Summary and Conclusion**

In this chapter, the simulation behaviour of the model under the baseline scenario depicting the dynamic behaviour of the model from the base year (2000) to the end of the simulation period (2035) has been presented. Specifically the baseline model run was conducted with emphasis on system behaviour in both the pre- and post-policy era. The pre and post policy era imply the periods before the implementation of amnesty and transparency measures and after the implementation of amnesty and transparency policy measures respectively. In each case, the analysis focuses on the variables whose behaviours the policy measures aimed to alter. The observed behaviour in this chapter serves as the foundation for the subsequent chapter. In particular, the chapter that follows presents model validation and tests for this research work. This is because in order to be able to accept the model and have confidence in its soundness, certain tests must be conducted and the model must therefore pass each of the tests performed

## **CHAPTER TEN: MODEL TEST AND VALIDATION**

### **10. Introduction**

This chapter presents all the validation and test for the model. The aim is to develop confidence regarding the usefulness of a model thus assists to understand underlying structure; ascertain the sensitivity and robustness of the results based on the assumptions made regarding interactions among variables and model boundary.

#### **10.1 Model Validation**

The validation of the model developed is conducted using both empirical tests as well as system dynamics tests (Forrester and Senge, 1980; Barlas, 1989; Barlas, 1996). Based on Forrester and Senge (1980) and Forrester (1973), the model is validated by attempting to develop confidence in terms of the usefulness and soundness of the model. The discussions below therefore explore these tests extensively beginning with the two classes of SD tests; the structural and behavioural tests.

#### **10.2 Structural Validation**

The structure tests evaluate the validity of the model's structure of the model by comparing it with what is known about the real system. It specifically involves taking individual relationships (including mathematical equations) and making comparisons with available knowledge regarding the real system. The incorporation of the system actors in the modelling process constitutes a methodological step for enhancing the validity of the developed model. In fact, inductively validating propositions regarding causal relationships and assumptions concerning values of parameters was possible in collaboration with system actors. Structural tests conducted in this thesis include parameter and structure confirmation, boundary adequacy, extreme conditions and dimensional consistency.

### 10.2.1 Structure Confirmation

The test for the confirmation of structure is of fundamental relevance in the entire validation exercise as it tests whether the structure of the model is consistent with available knowledge of the system under consideration. Model development in this research work involves document reviews and consultation with system actors; however, understanding of challenges facing revenue generation emerged from both literature and discussions leading to a preliminary model as well as its refinement as already highlighted in chapter 8. In these consultations, both the CLD and SFD were presented (see figures 8.3-8.6 and 8.7-8.10 in sections 8.4.1 and 8.4.2). These processes were important towards establishing the ownership of the model as well as its credibility on the basis of clarity, logical structure, practical relevance, comprehensiveness, intelligibility and applicability (see questionnaire as instrument for model validation).

### 10.2.2 Parameter Confirmation

Limitations on the availability of numerical information imply that it is not possible to estimate all model parameters. In practice, judgemental and statistical techniques are collectively employed. Confirmation of parameter determines whether the model's parameters are consistent with relevant numerical and descriptive knowledge of the system. The parameter values used in this research were derived from numerical data on the Nigerian oil industry and other published sources (NEITI 2005, 2010; OPEC, 2010; IMF 2010) as well as qualitative interviews and expert judgments. For the sake of clarity, Table 10.1 presents all the parameters in the model and their respective values.

**Table 10.1 Parameters and assigned values for sub views**

The parameter categories for model sub views			Sources
Model sub views	Selected parameters	Assigned values	
Exploration	Discovery coefficient	0.12/year	Focus group
	Initial value for unproved crude oil reserves	60000000 (000)	EIA 2006
	Initial value for proved crude oil reserves	21700	EIA 2006
	Average depletion rate	0.15/year	Focus group

Development	Average project completion period	5 years	Focus group
	Initial value for accrued interest	8431.36	NNPC 2010
	Initial value for development investment	353102	NNPC 2010
	Initial value for cumulative cash call short fall	105392	NNPC 2010
	Oil wells available for development	62	DPR 206
	Government approved budget	120000000 Naira	NNPC 2010
	Cash call obligation		NNPC 2010
	Maximum cash call shortfall possible	150000000 Naira	NEITI 2004, 2010, 2013.
	Average annual inflation rate	0.007	CBN 200-2013
	Annual incremental cost of a project	2,000,000 Naira/year	Focus group
		Average time taken to pay interest	5 years
	Average oil well life	10 years	Focus group
	Average cost of a single well	\$20,000,000 (conversion is made for Naira equivalent for respective years)	EIA 2010
	Interest rate	8%	Focus group
	Average cost of a project	3,000,000 Naira	EIA 2011
Production	Average cost of a single arm	1,000 Naira	Paki and Ebienfa 2011
	Average number of arms	1,000,000 arms	Ojakotu and Aiyedogbon 2012
	Average time taken for repairs of vandalised facility	3 years	Focus group
	Maximum pollution possible	2 000,000 tons	UNDP 2006
	Average standard of living	0.5	UNDP 2006
	Maximum poverty possible	5	UNDP 2006

	Average oil price	1.8	OPEC 1999, 2005 and 2013
	Compensation		NNPC 2010
	Rate of community unrest	3	Inokoba and Imbua 2010
	Production capacity	950000	EIA 2013
	Maximum community unrest possible	10	Inokoba and Imbua 2010
	Initial population	25200	NPC 2006
	Population growth rate	0.026	NPC 2006
	Rate of gas flared	0.3	Afinotan and Ojatorotu 2009
	average gas per barrel of crude oil	2000	NNPC 2010
	Initial value of pollution	3938	DPR 2006
	Initial value of vandalism	984	DPR 2000
	Initial value of illegal money	143434	Paki and Ebienfa 2011
	Fraction of arms reduced	2%	Asuni 2009
	Initial value of arms	10000	Asuni 2009
	Average cost of a single arm	N500, 000	Asuni 2009
	Fraction of unemployed youths	40%	UNDP 2010
	Fraction of youth population	62%	NPC 2006
	Initial value of unemployed youths	4181057	UNDP 2010
	Initial value of potential militants	1254317	NPC 2006
	Initial value of militants	125	NPC 2006
	Initial value of actual crude oil production	857.5	NNPC statistical bulletin 2009 to 2013
	Fraction of money spent on arms	50%	Asuni 2009
	Initial value of ex militants	0	-

	Maximum number of facilities	7000	DPR 2010
Revenue	Maximum corruption possible	5	TI 2000 to 2013
	Initial value of actual crude oil revenue	1.591683	NEITI 2005
	Initial value of corruption	1.2	TI 2000
	Initial value of potential crude oil revenue	2.732682	CBN 2000
	Annual growth in corruption	0.3	TI 2000 to 2013

### 10.2.3 Boundary Adequacy

The main purpose for boundary adequacy tests is to assess the suitability of the boundary of the model for the purpose at hand. Boundary adequacy ensures that basic structures and concepts for tackling policy matters are endogenous in the model. Despite the fact that both government and private oil companies played active roles in the Nigerian oil industry, this research is limited to the aspects affecting government. Hence, for the purpose of this model, all the modelling effort focuses on the government aspects of the industry. Several factors affect optimal revenue generation from the industry. These factors are endogenously modelled to help in understanding the complexity of this dynamic system.

For simplicity, it is reasonable to exclude GDP, economy and all aspects relating to the private multinational oil companies operating in Nigeria in the model and make the assumption that all is well with them. In the present model, the entire major aggregates in the model's sub views are endogenously generated. Only 16 variables are exogenous variables. Historical data on the majority of them are available from 2000 to 2013; and future values were determined with the aid of linear extrapolation. In summary, this model possesses adequate boundaries for the purpose at hand.

#### **10.2.4 Extreme Condition**

Generally, models should be robust under extreme conditions. Model robustness under extreme condition implies that the behaviour of the model should be realistic regardless of the degree of the policies or inputs imposed on it. The test for extreme condition enhances the validity of the model by analysing the behaviour of the model far beyond its initial boundary. The tests determine whether model behaviour is suitable when extreme values such as zero or infinity are assigned to the model. This test is normally conducted using Vensim software in dual ways: by simulation or by direct inspection of the equation of the model.

The model equation is checked along with the assessment of the test for structure assessment which seems reasonable for the purpose of the research. On the basis of this, once the model possesses any structural flaws, these structural flaws will be figured out by a simulation with clearly false behaviour. In this regard, the test specifically focuses on the following indicators: potential militants, ex-militants, militants, fraction of youth population, and growth rate of population, vandalism and interest on alternative funding. These types of tests labelled reality checks by two classical System Dynamicists (Peterson and Eberlein, 1994) unearth hidden flaws thus serving a unique advantage in a big model. In this case, the value of the extreme testing is compared with the baseline run values. The following constitute the tests conducted.

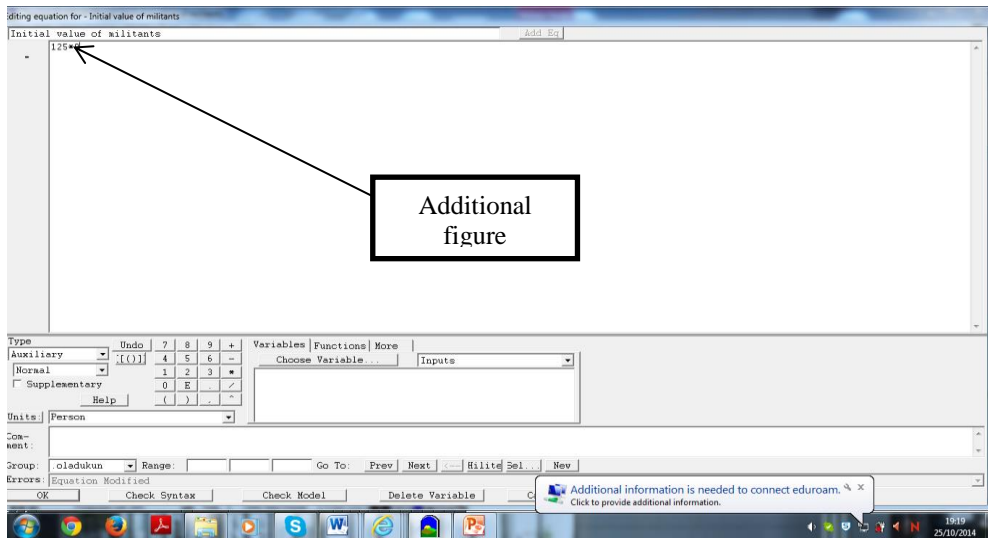
##### **(a) Zero potential militant's population from 2000**

If there are no people who are potential militants at the beginning of simulation, but there exists an inflow to the population of potential militants, it is expected at the onset (beginning), the graph of the militants commences growing at a point below the original model (production sub view) i.e., the starting point. Both graphs will exhibit the same behaviour (S-shaped form) and that, at a particular point, both graphs will be similar. At this point, the initial value does not in any way affect the behaviour any longer. This test will be conducted by multiplying the initial value of potential militants by zero while all other things remain the same.

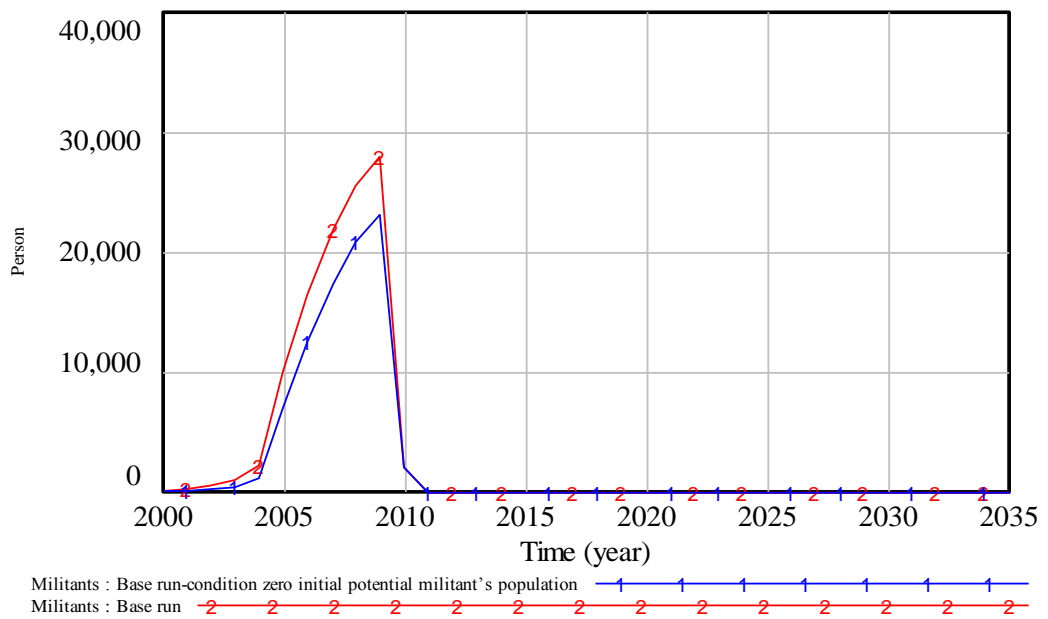
Militants = initial potential militants \* 0 from year 2000



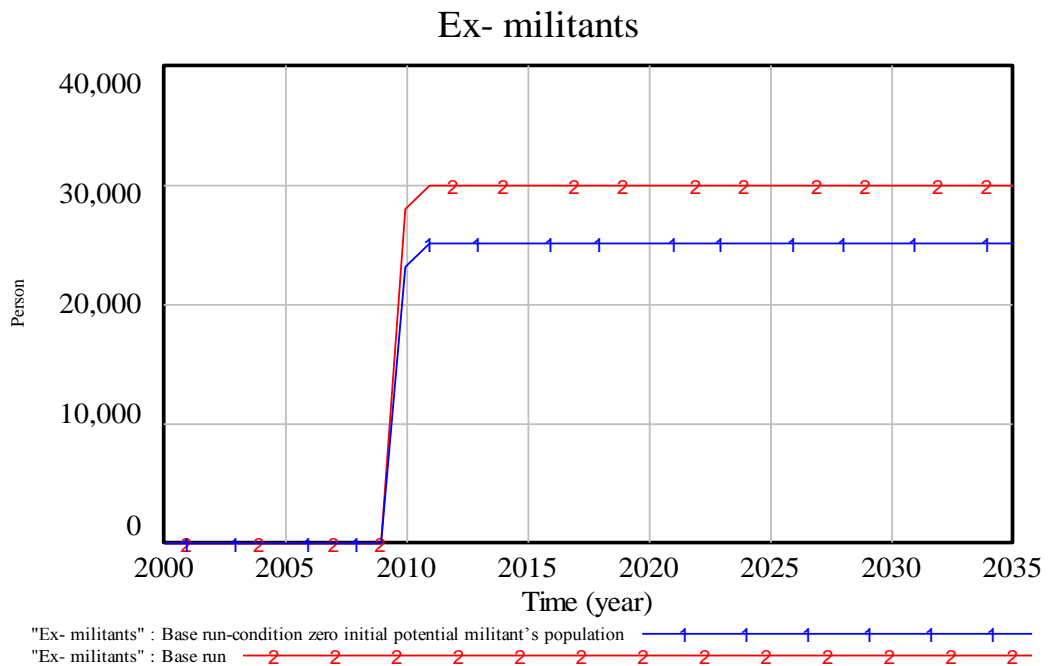
**Figure 10.1: Additional figure in the potential militants' initial value**



### Militants



**Figure 10.2: Extreme condition zero initial potential militants' population**



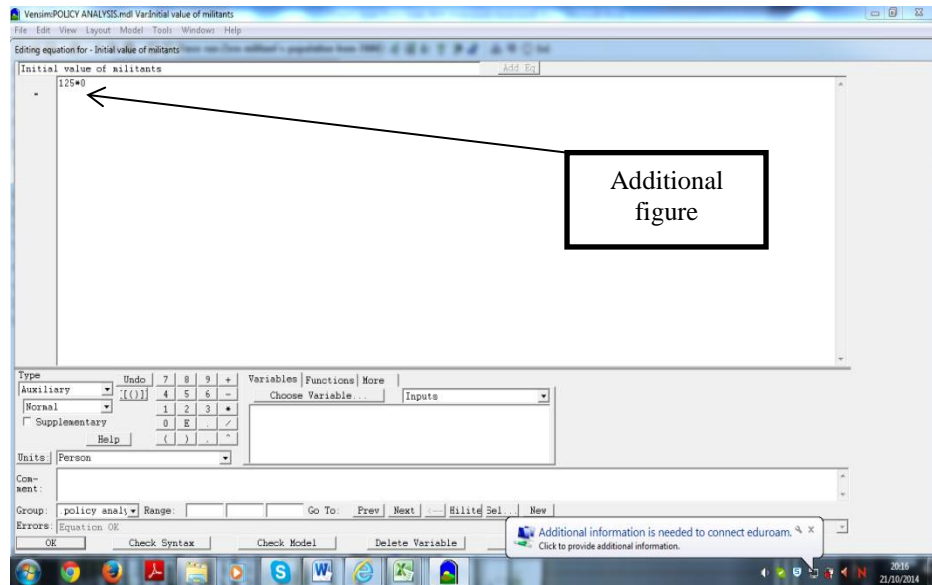
The model behaves well as expected: the stock of militants in 10.2 grows below the graph in the original (production sub view) model albeit the two graphs grow at the same level around year 2010. The stock of ex-militants in figure 10.2 grows equally as the baseline run from the base year up to after year 2009 when the stock of ex-militants grow below the graph in the original (production sub view) model up to the end of the simulation. The reason has been that the policy came on board in 2009.

**(b) Zero militant's population from 2000**

If there are no rates of militants, we expect the stock of militants to remain at zero throughout. We expect that the stock of ex militants to be zero as well because there will be no ex militant at all and there will be no more rate of militants. We will conduct test by setting the value of militants at zero from the beginning of the simulation year 2000.

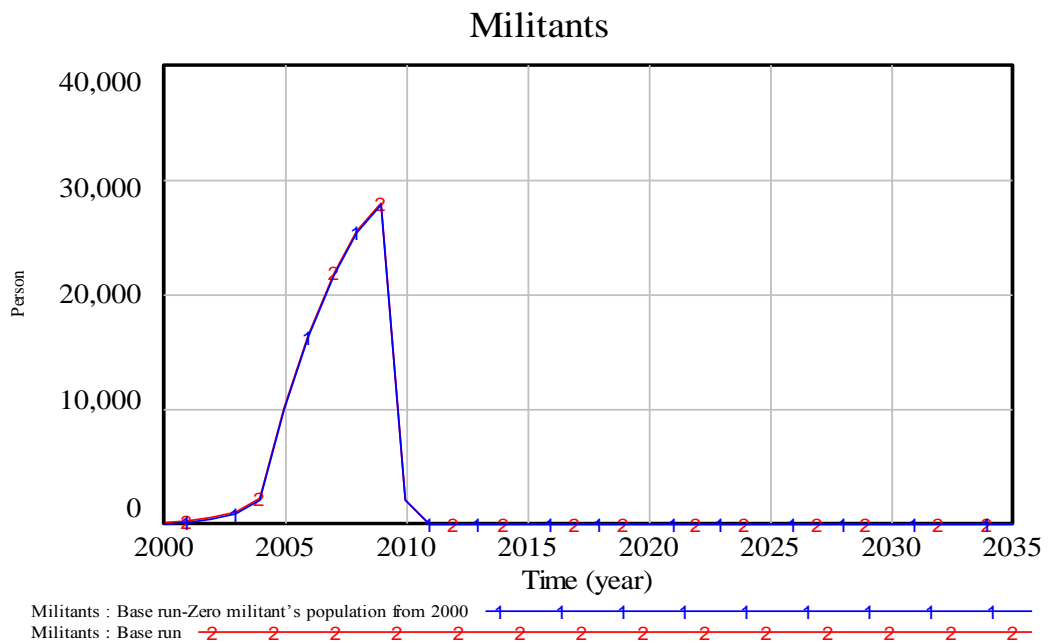
Militants = 0 from year 2000

**Figure 10.3** Zero initial militant's population value out of the original (production sub view) model.

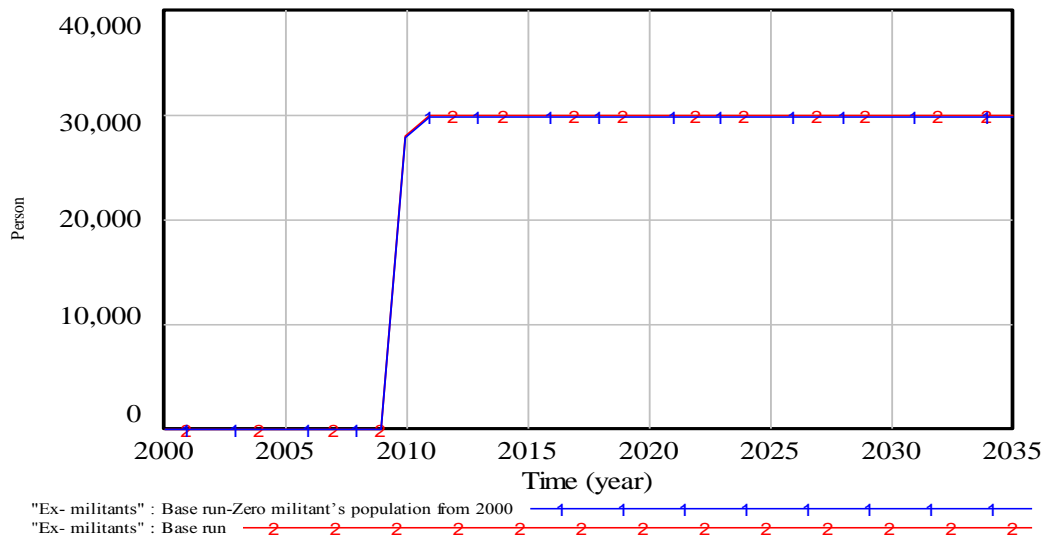


The graph below presents the behaviour of the test and the original (production sub view) model is utilized.

**Figure 10.4** Extreme condition test militant population = zero



### Ex- militants

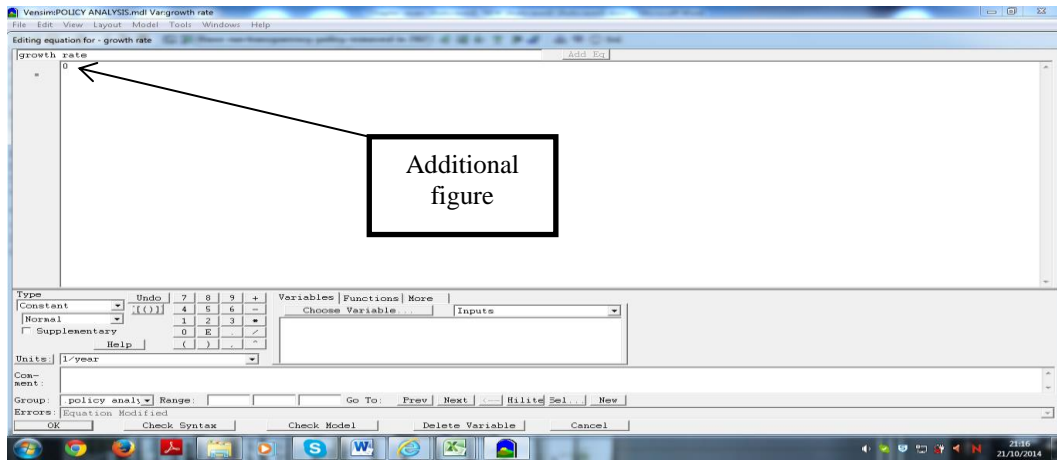


The model behaviour is as expected in the real system: the stock of militant's remains at zero at the beginning below the base run although the two graphs grow the same around year 2010. On the other hand, the stock of ex-militants went to zero up to year 2010 and still remained a little below the baseline run up to the end of the simulation.

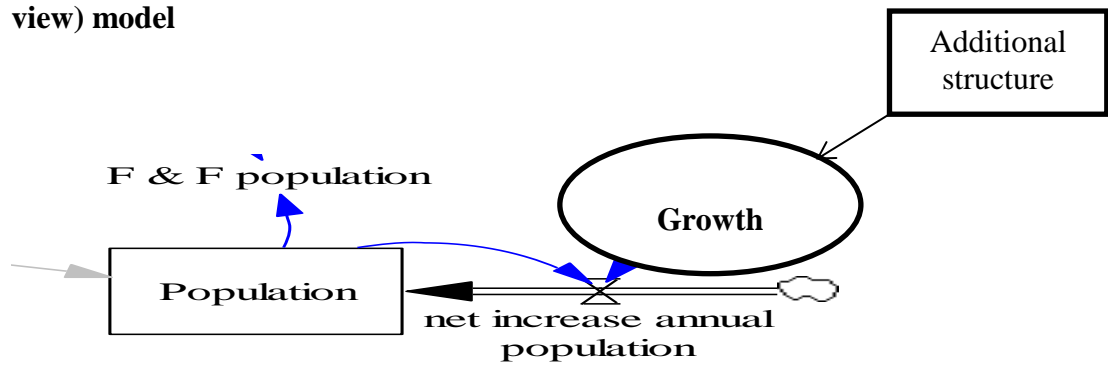
**(c) Zero initial population and zero growth rate of population**

If the fraction of youth population is equal to zero from year 2000, that means the behaviour of unemployed youth will start diminishing to zero from its initial value. At the beginning of observing the population the stock of potential militants will start to grow because there were few potential militants but will soon start decreasing again because there is no more rates of unemployed youths.

**Figure 10.5 Zero growth rate of population using the original (production sub view) model.**



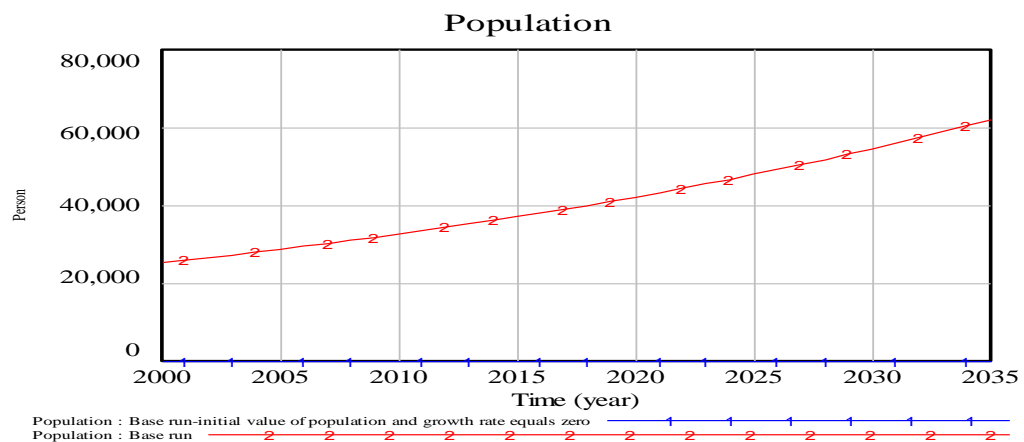
**Figure 10.6 Youth population control added to the original (production sub view) model**



Population growth rate = 0.026 \* growth rate control

Growth rate control = 0 from year 2000

**Figure 10.7: Initial population and population growth rate equals zero**



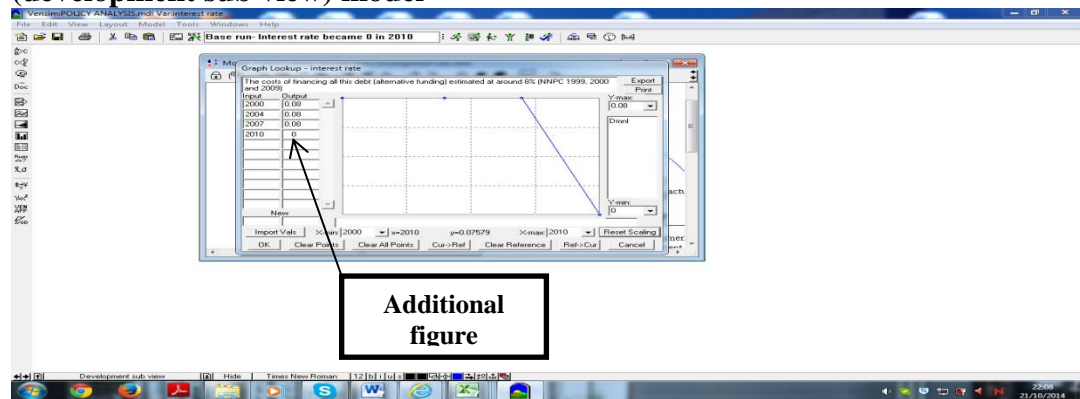
The behaviour of the model is in line with expectation and is in line with the real world: the population remains at zero up to the end of the simulation because there is no initial population and there is no rate of growth of the population.

**(d) Interest rate equals zero from year 2010**

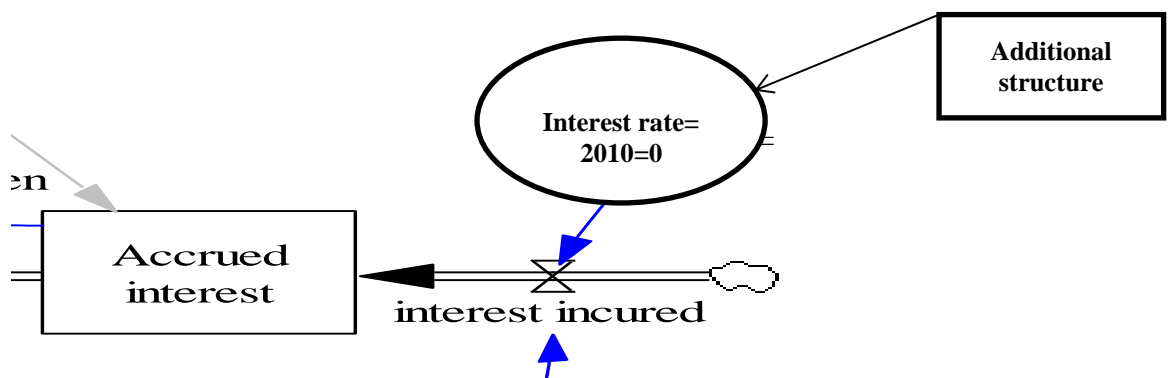
If interest rate dropped to zero from 2010, it means there will be no more interest incurred. Stock of accrued interest must go to zero after year 2010. This test is conducted using the original (development sub view) model with an additional model structure.

$$\text{Interest rate} = 0.8 * \text{interest rate control}, \text{Interest rate control} = 0 \text{ from year 2010}$$

**Figure 10.8 Interest rate varied to zero after year 2010 using the original (development sub view) model**



**Figure 10.9 Interest rate control added to original (development sub view) model**



The result of this test is depicted by figure 10.10 below.

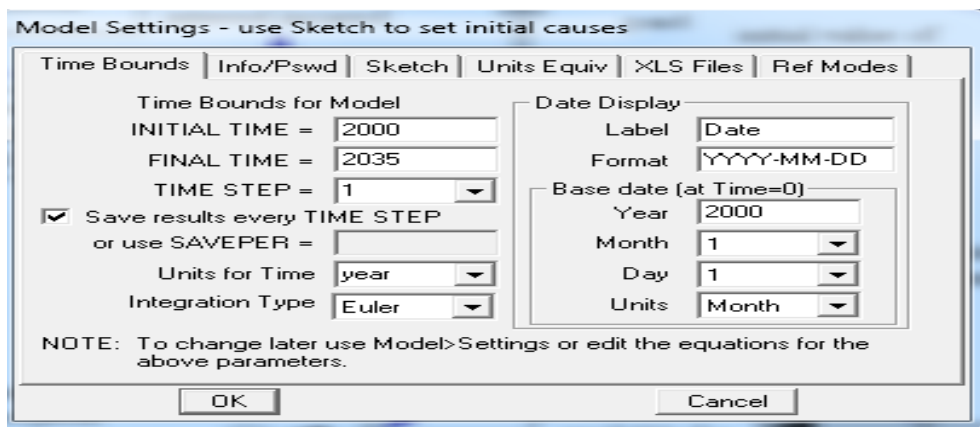


obtained at the end of each test. The model is considered to be robust when general behaviour is generated despite the extreme uncertainty in the values of parameters (Ford, 1999; Sterman, 2000).

**a) Integration error**

The model output should not be sensitive to the selection of integration method or time step. In this research, the “DT error” test proposed by Sterman (2000) was applied and no sensitivity was found in terms of integration method, not to the time step. Specifically, 1 was used as the time step in this research throughout the modelling effort as shown in Figure 10.11

**Figure 10.11 Time step**



**Time Step 0.25**

However, in order to test whether or not the model passed the integration error test, the *Time Step* for the model was reduced to 0.25 from 1. This is to know if there are changes in the behaviour of output of variables of interest. The test is performed by formulating a hypothesis that there is no statistically significant difference between the means of variables of interest for *Time Step* of 1 and 0.25. Using mathematical notation, the null ( $H_0$ ) and alternate ( $H_1$ ) hypotheses are represented in equations 10.1 and 10.2 respectively.

$$H_0: \mu_{i \text{ Time Step}=1} - \mu_{i \text{ Time Step}=0.25} = 0 \quad (10.1)$$

$$H_1: \mu_{i \text{ Time Step}=1} - \mu_{i \text{ Time Step}=0.25} \neq 0 \quad (10.2)$$



Where  $\mu_i$  indicates the mean of variable of interest in the model

In order to test the hypothesis indicated in equations 10.1 and 10.2, it is necessary to conduct a paired sample t-test for five (5) variables of interest. These variables include: community unrest, actual crude oil production, Vandalism, Militants, rate of ex militants. Decision rule was formulated in order to take a decision of the results of the hypotheses. For example, the significance value calculated will have to be compared with the significance level, which in this case is taken as 0.05. If the significance value of the variable of interest is less than the significance level (0.05), the null hypothesis is rejected, otherwise the null hypothesis is accepted. In order to demonstrate this, the  $t$  statistics were computed for five variables of interest as indicated in Table 10.2 and they were used to compute the significance values. It is apparent from the results in Table 10.2 that all the five pairs of variables of interest have the significance values greater than 0.05. This means that the null hypotheses are accepted for all the five pairs of variables of interest, while the alternate hypotheses are rejected. The interpretation of these results is that there is no statistically significant difference in the means of output of variables of interest. This means that there are no changes in behaviour of the selected variables for the Time Step of 1 and 0.25.

Table 10.2

	Paired Differences					
	Mean	SD	SEM	t	df	Sig. (2-tailed)

Pair 1	community unrest - Time Step of 0.25 - community unrest - Time Step of 1	.00306	.01191	.00198	1.539	35	.133
Pair 2	actual crude oil production - Time Step of 0.25 - actual crude oil production - Time Step of 1	-.03611	.26525	.04421	-.817	35	.420
Pair 3	Vandalism - Time Step of 0.25 - Vandalism - Time Step of 1	2694.01417	2211.45626	368.57604	1.309	35	.199
Pair 4	Militants - Time Step of 0.25 - Militants - Time Step of 1	1240.64472	2340.80969	390.13495	0.180	35	.858
Pair 5	rate of ex militants - Time Step of 0.25 - rate of ex militants - Time Step of 1	559.64417	1880.04527	313.34088	1.786	35	.083

*SD = standard deviation, SEM = standard error mean,*

In addition to the above test this research also focuses on two perspectives in terms of sensitivity analysis tests: sensitivity test on selected parameters and sensitivity test on policy parameters.

**(b) Policy sensitivity test**

A policy sensitivity test and a policy parameter test were conducted to determine if the suggested policies were sensitive to extreme value (refers to policy test in chapter eleven).

(c) **Policy parameters - influence on the structure of feedback loops**

Parameters that influence the degree of strength of feedback loops were identified. Parameter values were then changed and the impact on the feedback structure during simulation was assessed.

**Figure 10.12 Potential policy parameters**

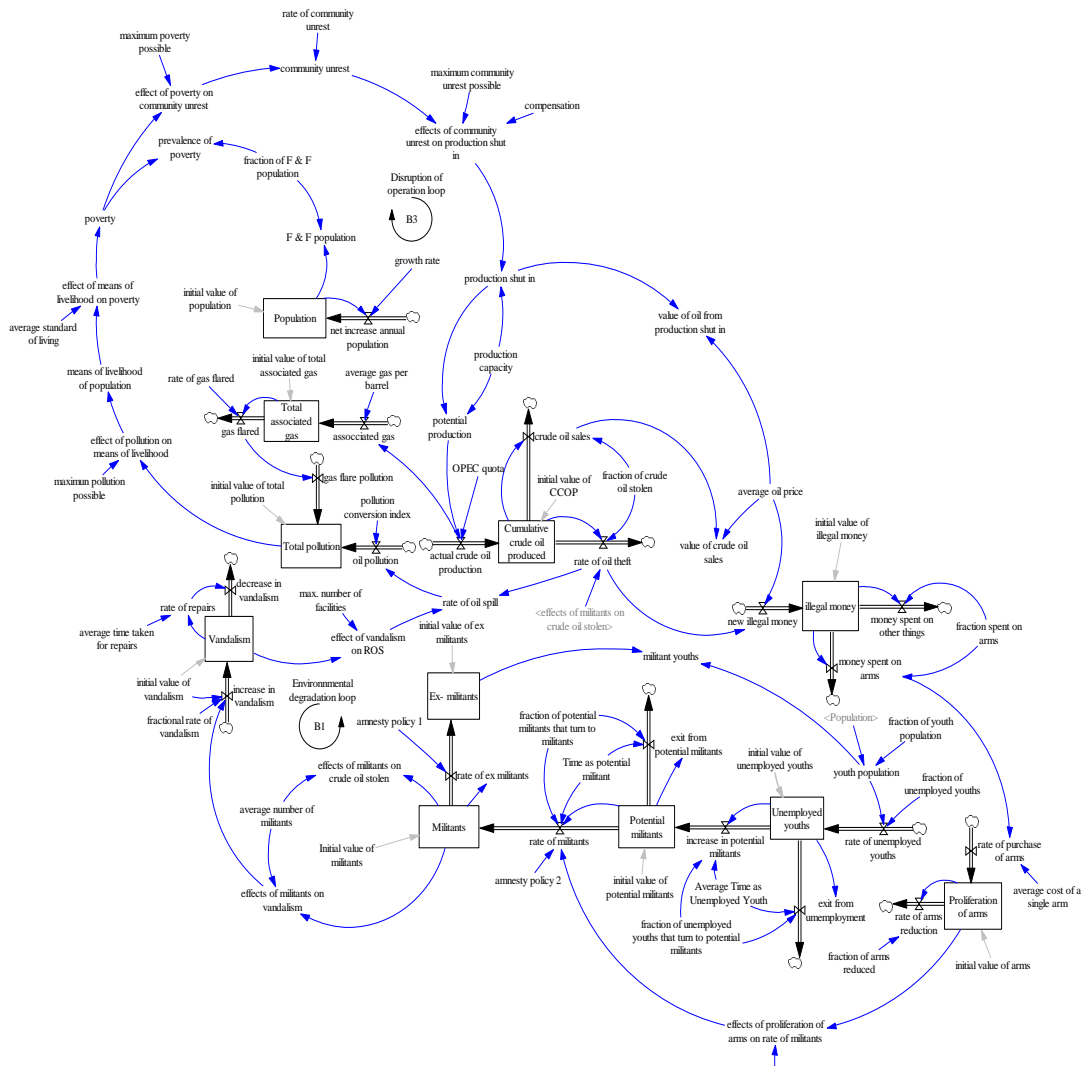


Figure 10.12 represents the policy parameter. These are, in principle, manageable, and it is expected that by varying them, the model behaviour will be different; i.e. it can potentially improve the behaviour of the model.

(i) Loop B1

In this model, 2 parameters influencing loop B1 are average time taken for repairs and rate of gas flare. Average time taken for repairs affects loop B1 (indirectly) and rate of gas flare affects loop B1 (directly). It is feasible to vary the stocks that influence the feedback structure. In the case of human population, such as militants, however, this does not naturally translate into an alternative in the real world.

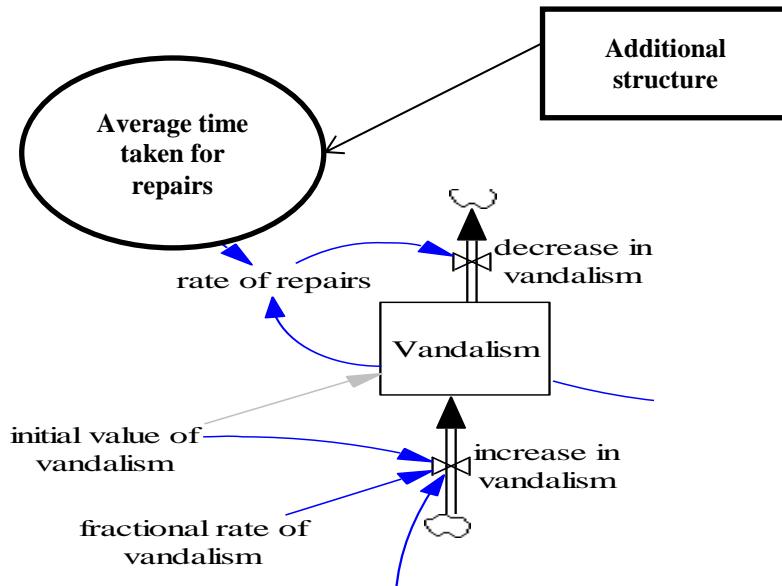
(ii) Loop B3

In this model, loop B3 is affected by the same parameters. Average time taken for repairs affects loop B2 (indirectly) and rate of gas flare affects loop B2 (directly). Both loops are affected by both parameters. It is, however, unrealistic in the real world to change the parameter effects on a single loop without equally changing the parameter effect on the second loop. On the basis of this, it is, therefore, unnecessary in this case to investigate the separate sensitivity of individual loops to variations in parameter value(s). In some instances, it may be significant to investigate loops individually in the policy search for means to enhance good loops and relax bad ones.

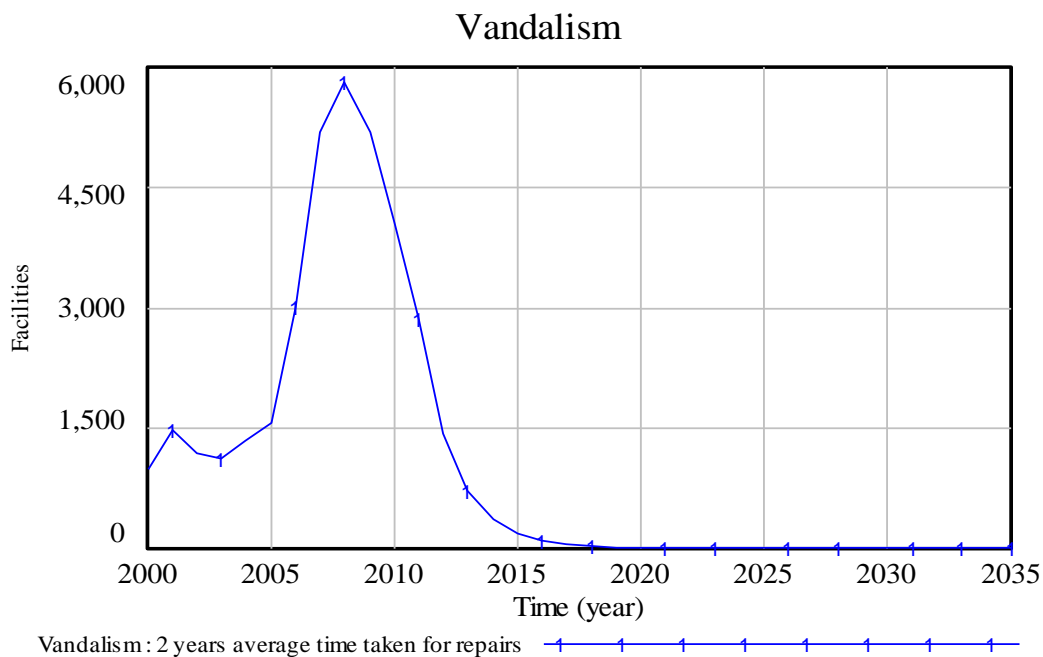
**(d) Sensitivity analysis test - average time taken for repairs**

We have assumed the average rate of repairs for vandalised facilities to be 3 years (NNPC 2010) and (Interview). To test the model sensitivity to variation in the model parameters, the research simply simulates the model using different values. Based on suggestion by Sterman (2000), sensitivity test can be conducted using a wide range of values. We will now conduct the sensitivity of level of vandalism to variation in the average time taken for repairs. This is carried out using 3 different tests with 2, 4, and 6 years as average time taken for repairs.

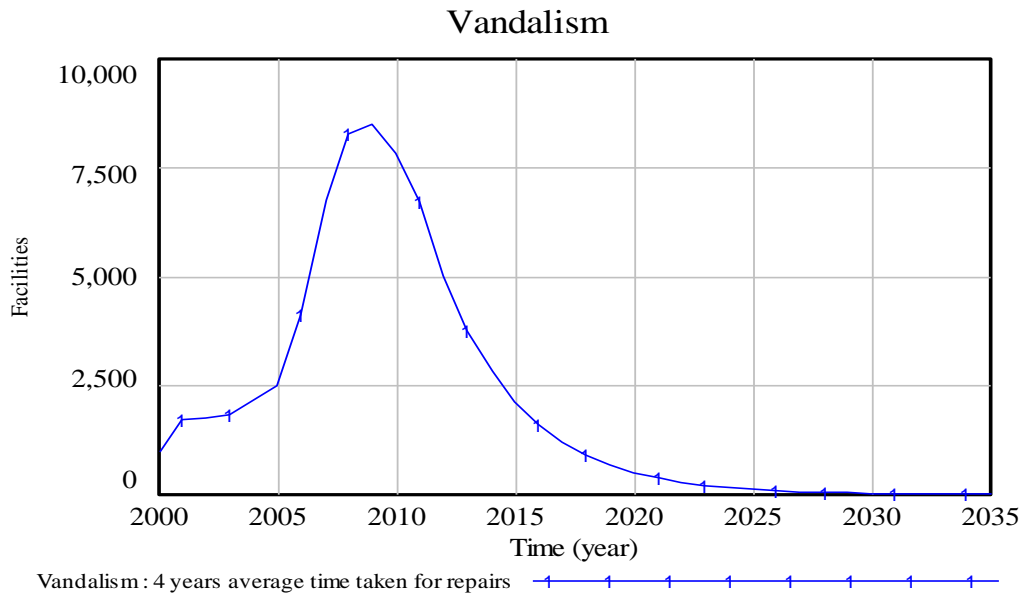
**Figure 10.13 Additional structure to original (production sub view) model (average time taken for repairs)**



**Figure 10.13 (a): Sensitivity to the level of vandalism to variations in the average time taken for repairs (2 years)**



**Figure 10.13(b) Sensitivity to the level of vandalism to variations in the average time taken for repairs (4 years)**



**Figure 10.13(c): Sensitivity to the level of vandalism to variations in the average time taken for repairs (6 years)**

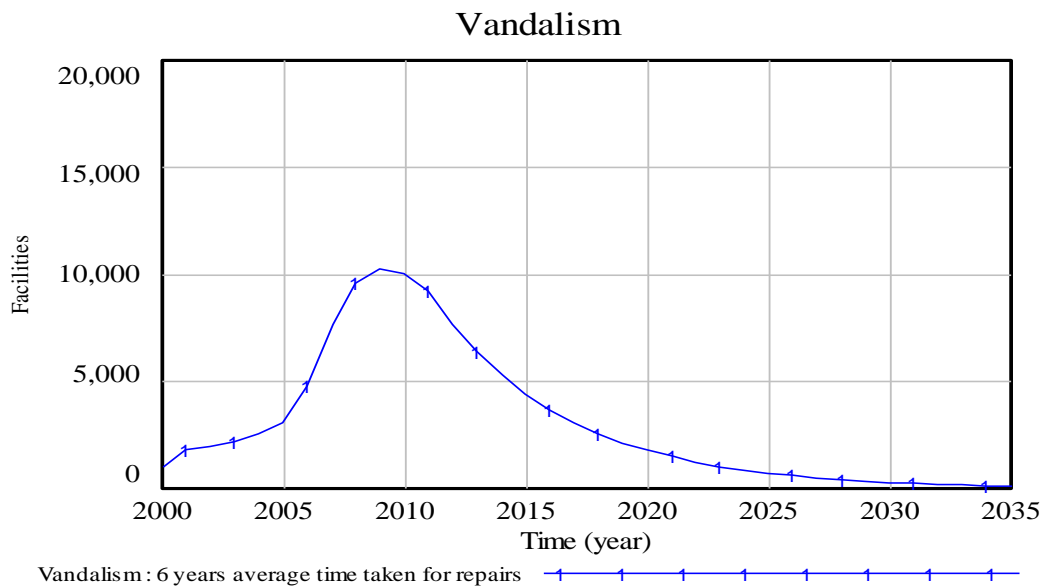


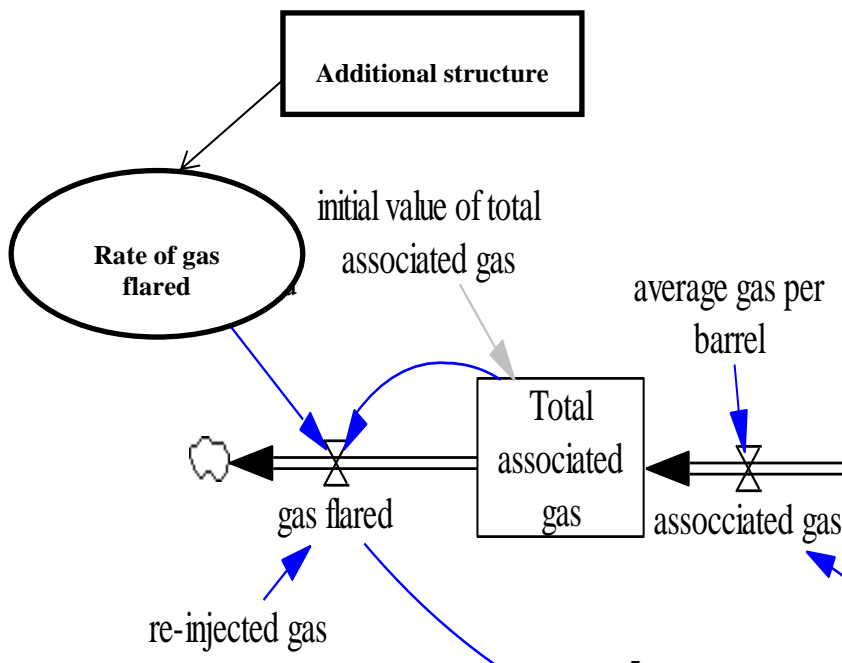
Figure 10.13(a) indicates that with 2 years being the average time taken for repairs, the level of vandalism rises to a peak of about 6000 by the year 2009. When, however, the average time taken was increased to 4 years, the level of vandalism rose to attain a peak of around 8500 around year 2009. Finally, when the average time taken for repairs was increased to 6 years, the level of vandalism rose to attain a peak of about 10,000 in the year 2009.

This test indicates that, controlling the average rate of repairs possesses the potential for dramatically reducing the rate of oil spill which has an impact on environmental deterioration that ultimately leads to civil unrest which eventually negatively impacts on the potential production via production shut in.

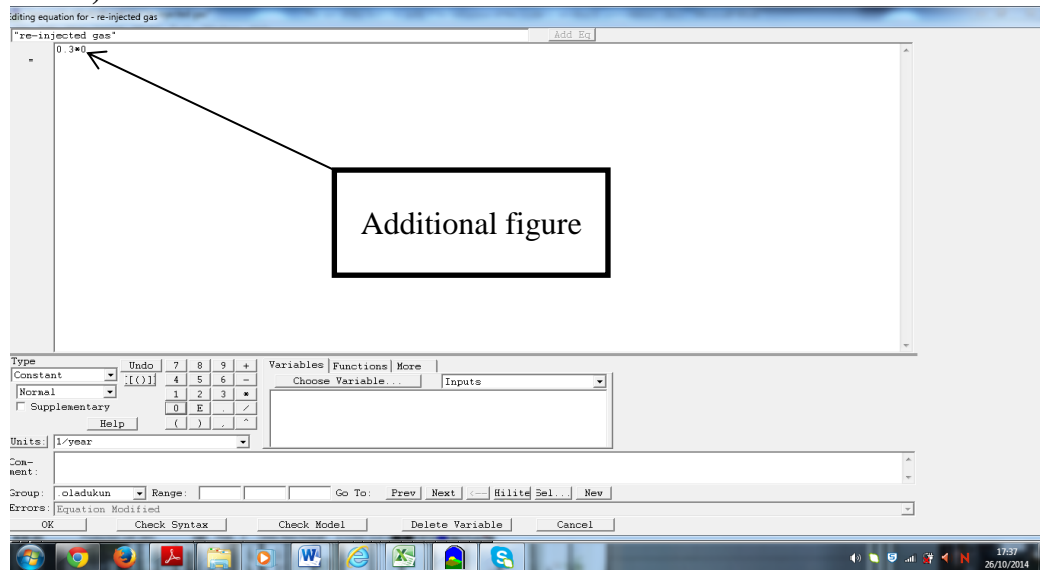
**(e) Sensitivity analysis test - rate of gas flare**

The rate of gas flare was assumed to be 0.65 (World Bank, 2006; NNPC, 2010) and (interviews 2013). It was assumed that the majority of the associated gas was flared with little re-injected (0.3). To test the model’s sensitivity to variation in this parameter, the model was simply simulated with 3 different values as well. In the process of this test it was assumed that gas re-injected equals zero and the original (production sub view) model is also used with additional structure. The three tests highlighted above were performed using 0.60, 0.80, and 0.90 rate of gas flared.

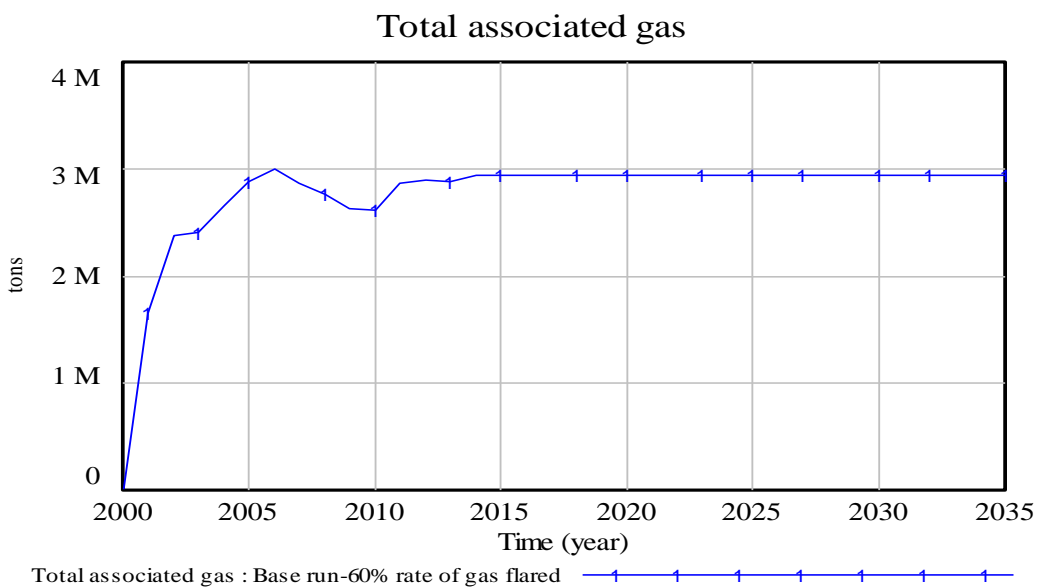
**Figure 10.14 Additional structure to original (production sub view) model (rate of gas flared)**



**Figure 10.15** Additional structure to original (production sub view) model (rate of gas flared)

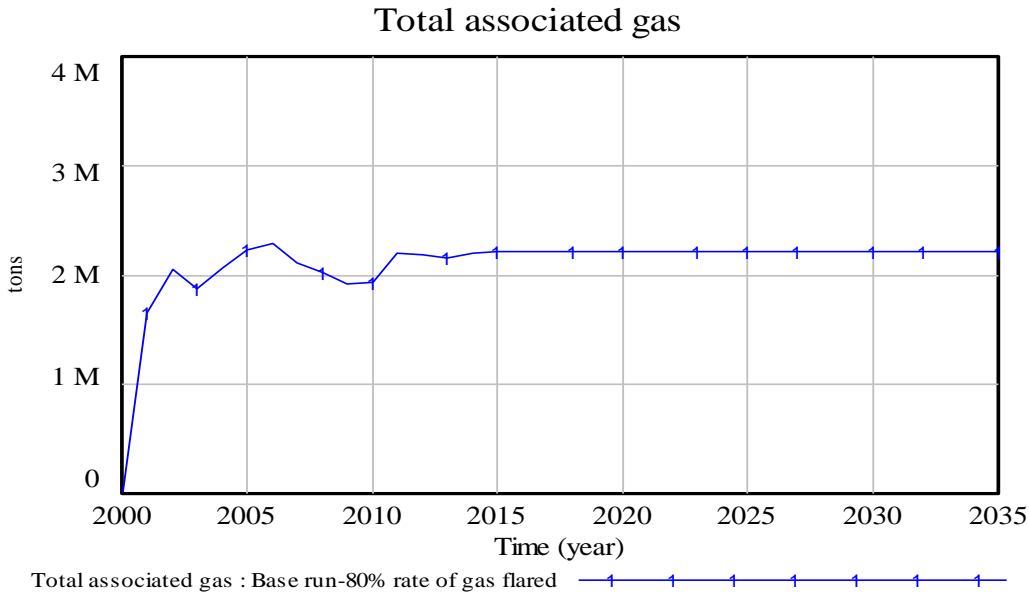


**Figure 10.16(a)** Sensitivity to level of total associated gas to variation in the rate of gas flared (60%)



**Figure 10.16(b)** Sensitivity to level of total associated gas to variation in the rate of gas flared (80%)





**Figure 10.16(c) Sensitivity to level of total associated gas to variation in the rate of gas flared (90%)**

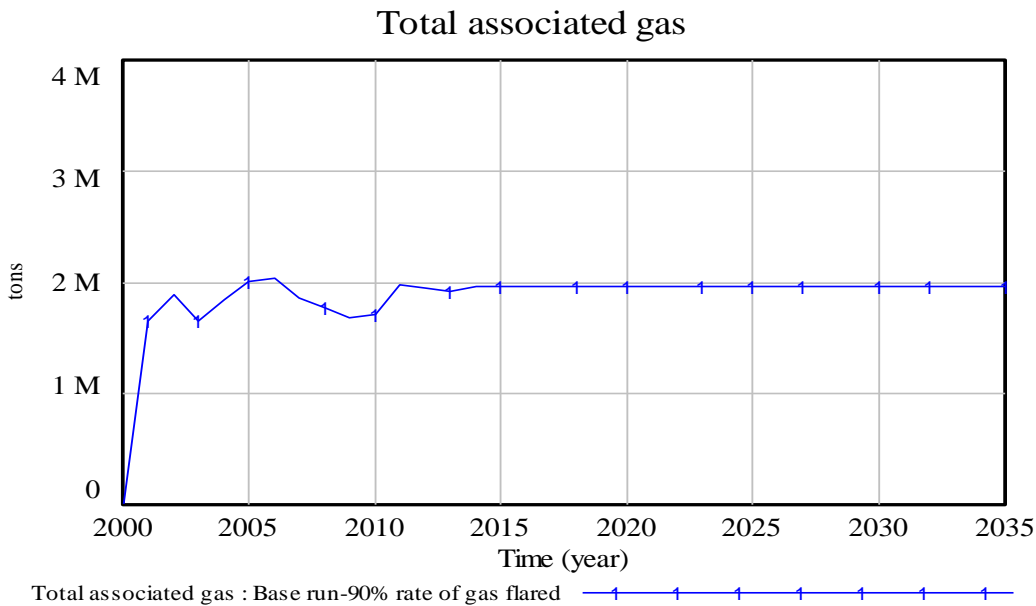
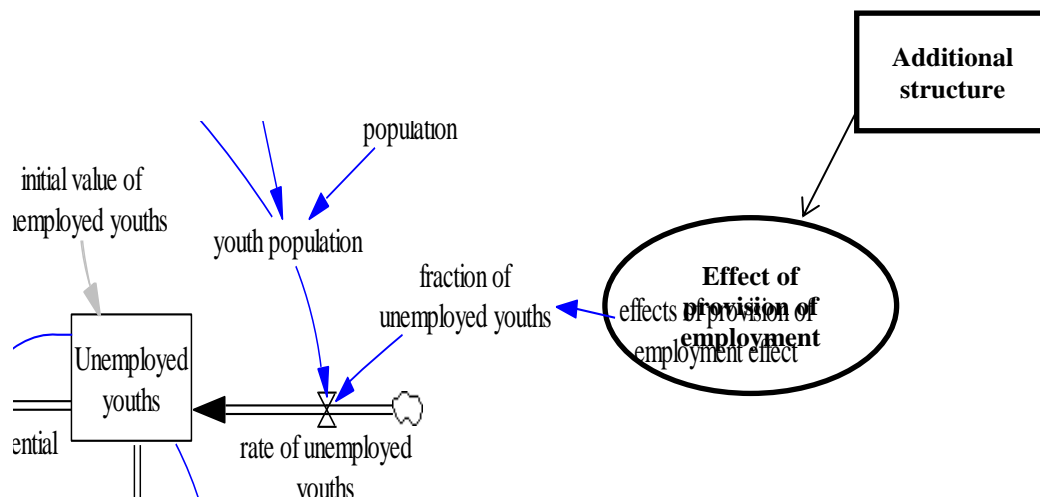


Figure 10.16(a) indicates that with a rate of gas flared of 60%, the total associated gas reduces to a peak of around 3,000,000 tons by the year 2006. If the rate of gas flared is increased to 80%, the total associated gas reduces to a peak of around 2,300,000 by the year 2006. Finally, if the rate of gas flared is increased to 90%, the total associated gas reduces to a peak of around 2,000,000 tons by the year 2006. This test indicates that, controlling the re-injected gas has the potential for dramatically increasing the associated gas.

**(f) Sensitivity analysis test: fraction of unemployed youths**

In this model, fraction of unemployed youths is determined by a demographic factor- specifically youth population and we set it to be 50% of youth population although as it is indicated in the model building process, the fraction of unemployed youths is a constant but yet it is being shaped by youth population which is determined by the whole youth population as a function of the whole population. More so the fraction of unemployed youth may vary but yet in our model we assumed no provision of employment because of lack of availability of data to support the provision of employment. The sensitivity of militants/potential militants to variation in fraction of unemployed youths will now be examined. We will assume a maximum reduction of fraction of unemployed youths by 40%, 70% and 100% from year 2006 to 2010 due to provision of employments. This test will be conducted using the original model (production sub view) model.

**Figure 10.17 Additional structure to original (production sub view) model (provision of employment)**





### 10.3 Behavioural Validation

The main validation (test) for behaviour comprises the replication of behaviour, behaviour sensitivity, anomalous behaviour and behavioural boundary. At this point only behaviour replication will be discussed since it links the output of the simulation generated by the equation interactions and the initial condition with the structure of the model itself.

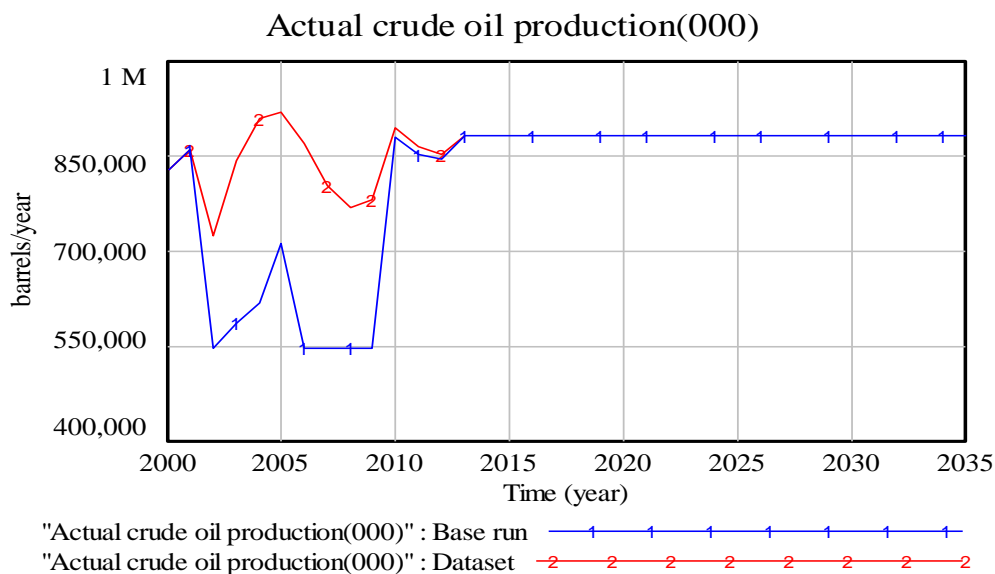
#### 10.3.1 Behavioural replication

In order to compare the reference modes in figure 8.4 with simulated behaviour, three simulated pattern of behaviour, including actual crude oil production, production shut in and cash call shortfall trend are presented below.

##### (a) Actual crude oil production

The dynamics of actual crude oil production has been elaborated in the production sub view. In the context of the test for the replication of behaviour, the simulated behaviour for actual crude oil production in Figure 9.1 is comparable with the reference mode in figure 8.8. As depicted in figure 10.21, actual crude oil production dropped at the peak of instability occasioned by militant activities in the year 2009 and peaked up immediately after the implementation of the amnesty policy intervention.

**Figure 10.20 Actual crude oil productions**



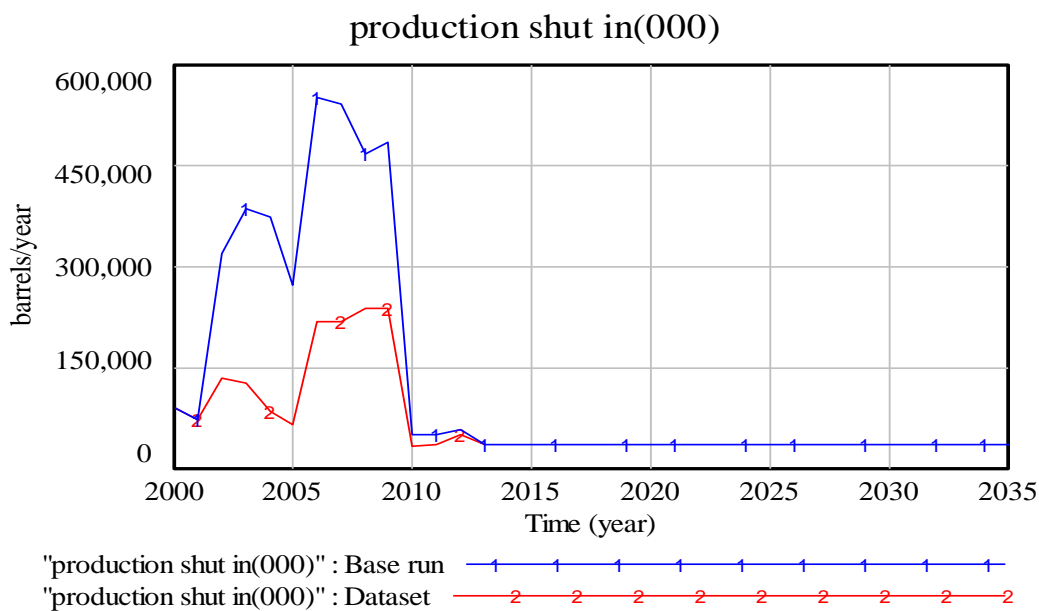
The variation in the simulated behaviour as opposed to the

reference mode is unarguably insignificant since the rise and fall of both the simulated behaviour and the reference mode at the beginning and at the end are the same. Additionally both exhibit the same pattern of behaviour.

**b) Production shut in**

The norm of production shut in in the Nigerian oil industry is applicable to all players. Figure 10.21 depicts an unstable behaviour of production shut in reflecting that series of disruption of operation was witnessed especially between years 2006 to 2009. This is relatively perfect of the reference mode behaviour of the same figure 8.1b

**Figure 10.21 Production shut in**

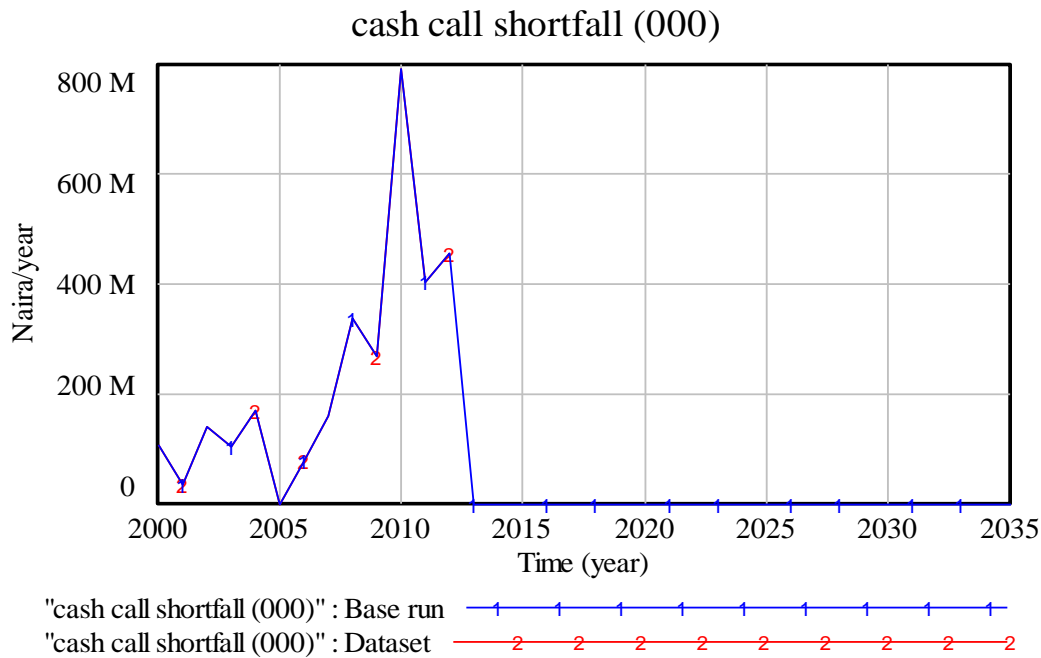


**(c) Cash call shortfall**

The persistent cash call constraints in the Nigerian oil industry is a well-known issue. The simulated behaviour of the model in figure 10.22 depicts an unstable behaviour for cash call short fall, reflecting that the cash call obligation outweighs actual funds allocated by the government (government budget). Moreover, cumulative cash call shortfall is determined by consistent cash call shortfall as well as alternative funds provided. In the context of the replication of behaviour tests, the simulated behaviour for cash call shortfall in figure 10.22 is comparable with reference mode in figure 8.5. As depicted in figure 10.22, the cash call shortfall trend maintained an upward growth thus depicting government’s continuous failure

to meet its call obligation correctly. This perfectly reflected in the reference mode in figure 8.5

**Figure 10.22 Cash call shortfall**



Summary Statistics for validation of System Dynamics model of Nigerian oil industry.

According to (Sterman, 1984), the analysis of the historical fit of a model to output is concerned with the test for behaviour reproduction. The aim of the test is not to seek for the exact comparison of the correspondence of actual and simulated output (Sterman, 1984). As opposed to that it focuses on the pattern of the simulated output. The aim of validating model and then mimicking past behaviour was to build the confidence in the model as a plausible way of the exploration of decisions in addition to understanding the rational for behaviour in a particular way (Moizer and Moffatt 2000). Modelling clients can be reluctant to have confidence in the model that is not subjected to some kind of summary statistics to measure its historical fit (Sterman, 1984). Moizer and Moffatt (2000) noted that an acceptable way of identifying whether the origin of the error between actual data and their composition and observed data is through the application of Theil inequality statistic. In his view Sterman (1984), noted that the sum of the squared error over the range of available data between actual and simulated output is lower in regression models than system dynamics models. This arises based on the fact that majority of single equations are disaggregated by the non-linear, multi-loop nature of system dynamics complex feedback systems. Notwithstanding this

Sterman suggests that models within the framework of system dynamics may capture system behaviour devoid of matching the historical output on an exact basis.

Specifically, the entire error may be significant and huge, even if the output of the model precisely replicates the relevant mode of behaviour. As a consequence of this, employing the coefficient of determination in the measurement of goodness-of-fit may not be suitable for models within the framework of system dynamics. Therefore, Sterman suggests an alternative for the measurement of the root mean squared percentage error (RMSPE) and mean squared error (MSE) to determine the goodness of fit between observed and simulated outputs.

RMSPE is defined as:

$$\frac{\sum (S_t - A_t)^2}{A_t}$$

MSE is defined as:

$$\sum (S_t - A_t)^2$$

Where;

n = number of observations (t = 1, n)

**S<sub>t</sub>** = Simulated value at time t

**A<sub>t</sub>** = Actual value at time t

It not only important to discover the magnitude of an error but it is also more important to discover the origin of an error. An error can be resolved into random and systematic portions by a method known as Theil's inequality statistic. The genesis of Theil's inequality statistic is traced from MSE decomposition. This statistic figures out the size of MSE that is responsible to bias ( $U^m$ ), unequal covariance ( $U^c$ ) and unequal variance ( $U^s$ ). A comparison can be made for a fit between the simulated and historically observed output to assess the composition of error and its proportion using Theil's inequality statistic and RMSPE. The RMSPE exhibits a normalised measure of the size of the error implying the proportional variation between the observed and simulated, as a size of the observed, averaged over the frame of time. The inequality statistics and MSE presents a measure of the entire error, and where the error decomposes proportionately into unequal variation, unequal covariation and bias. Division of each of the error's components over the total error of mean square, the proportions of the inequality are derived:

$$U^m = \frac{\sum (s - A)^2}{n \sum (S_t - A_t)^2}$$

$$U^s = \frac{\sum (SS - SA)^2}{n \sum (S_t - A_t)^2}$$

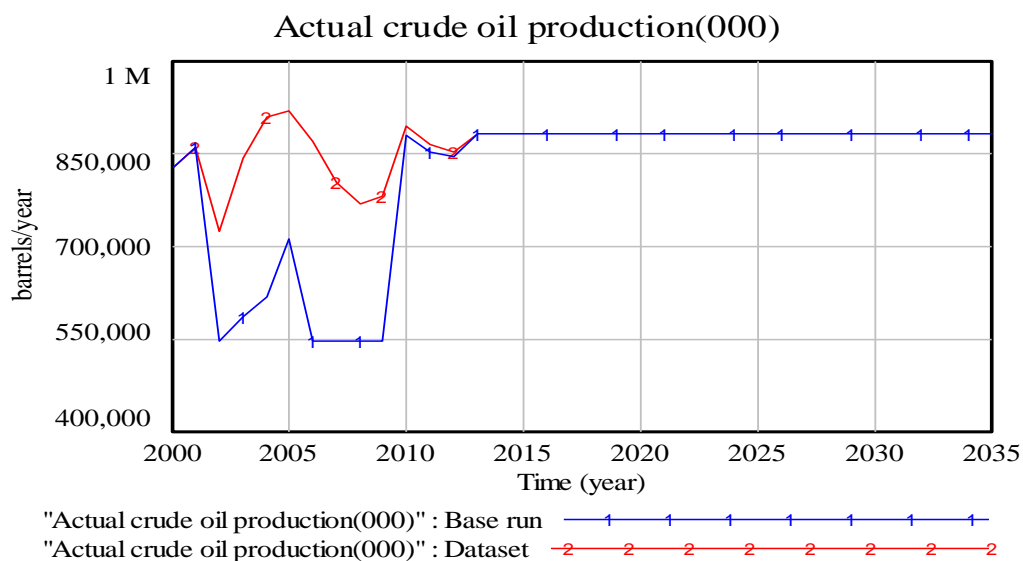
$$U^c = \frac{\sum (1 - r)SSA}{n \sum (S_t - A_t)^2}$$

The following  $U^m + U^s + U^c = 1$ , therefore,  $U^c, U^m, U^s$  is a reflection of the fraction of the MSE as a result of unequal variance, unequal covariance and bias.

#### Interpretation of error between observed and simulated actual crude oil production

Figure 10.20 depicts the simulated runs of actual crude oil production and that of the historical behaviour of actual crude oil production. The actual (historical) crude oil production is characterised by significant variation from the in the simulated behaviour of actual crude oil production. This is of no great surprise, as actual crude oil is expected to have frequent fluctuations as a result of production shut in arising from community unrest.

**Figure 10.23: Actual crude oil production**



From this data set, the error composition,



RMSPE and RMS can be determined. Table 10.3 presents the outcomes of these computations. Assessing the historical fit of the actual crude oil production reveals that the RMSPE is  $3.931 \times 10^{-4}$  per cent. This represents the value of the average squared difference between simulated and observed and exceeds 100%. This depicts a very high number. This error may be attributable partly to the limited assumptions built in the model concerning the causes of the actual crude oil production pattern. This model was not developed and calibrated in order to replicate short-term variability in the system. Therefore, for the sake of the model despite the very high number of the RMSPE of the model it however does not render the results of the model invalid. Aligning to a more pessimistic path, it could be suggested that the structure controlling actual crude oil production is not correct or this model is internally not consistent. Table 10.1 show the summary of statistics measuring level of correspondence between the simulated and actual values of crude oil production.

Table 10.3

$\Sigma(S_t - A_t)^2$	$1.737 \times 10^9$	$\bar{S}$	867602.6	<b>r</b>	0.985
$\frac{\Sigma(S_t - A_t)^2}{A_t}$	$2.326 \times 10^{-3}$	$\bar{A}$	867056	<b>U<sup>m</sup></b>	0.0063
<b>MSE</b>	$4.963 \times 10^7$	<b>S<sub>S</sub></b>	40926.81	<b>U<sup>s</sup></b>	0.0501
<b>RMSPE</b>	$3.931 \times 10^{-4}$	<b>S<sub>A</sub></b>	39349.14	<b>U<sup>c</sup></b>	0.9436

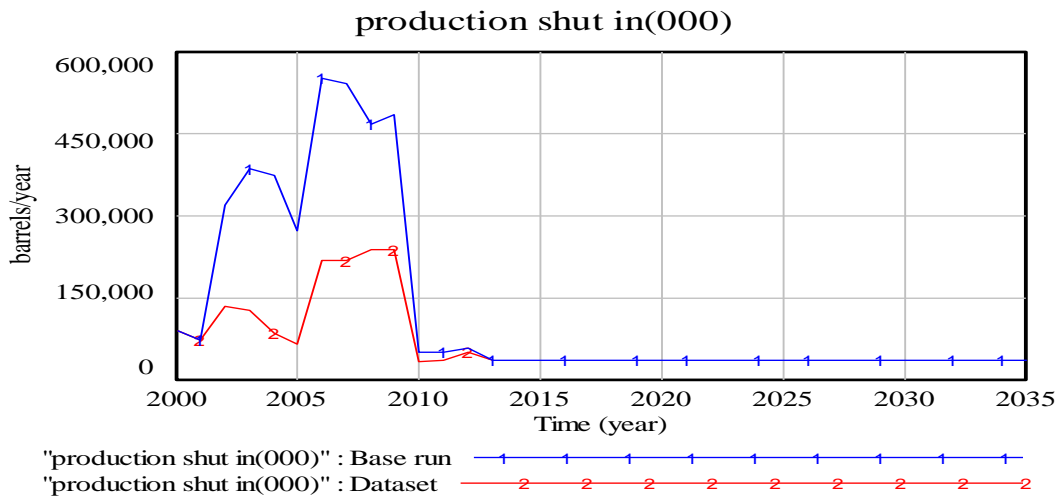
Further explanation on the problem would be shed by decomposing the error. Despite the fact that the RMSPE is  $3.931 \times 10^{-4}$  per cent, less than 1 per cent of the mean squared error is attributable to bias. Only 5 per cent of the error results from unequal variation, leaving a little over 94 per cent of the error attributable to unequal covariation. The implication is that the results exhibit little systematic error.

The underlying trend is almost perfectly tracks by the simulated actual crude oil production, simply deviating on an exact pattern. Despite the high value of the RMSPE is of little consequence and does not compromise the model's purpose.

#### Interpretation of error between observed and simulated production shut in.

Figure 10.21 shows the simulated runs of production shut in and the historical behaviour of the same output. The actual production shut in is characterised by unstable behaviour of production shut in reflecting that series of disruption of operation was witnessed especially between years 2006 to 2009.

**Figure 10.24 Production shut in**



For the sake of this data set the error composition, RMSPE and RMS can be determined. Table 10.2 presents the results of these computations. Assessing the historical fit of the production shut in reveals that the RMSPE is 2556.343 per cent. This represents the value of the average squared difference between simulated and observed and exceeds 100%. This depicts a very high number. This error may be attributable partly to the limited assumptions built into the model concerning the causes of the production shut in pattern. This model was not developed and calibrated in order to replicate short-term variability in the system. Therefore, for the sake of the model despite the very high number of the RMSPE of the model it however does not render the results of the model invalid. Aligning to a more pessimistic path, it could be suggested that the structure controlling production shut in is not correct or this model is internally not consistent. Table 10.3 show the summary of statistics measuring level of correspondence between the simulated and actual values of crude oil production shutdown.

Table 10.4:

$\Sigma(S_t - A_t)^2$	$1.737 \times 10^9$	$\bar{S}$	67485.8	$r$	0.9965
$\frac{\Sigma(S_t - A_t)^2}{A_t}$	15123.528	$\bar{A}$	68031.94	$U^m$	0.0062
<b>MSE</b>	$4.963 \times 10^7$	$S_S$	67070.61	$U^s$	0.4042
<b>RMSPE</b>	2556.343	$S_A$	62591.47	$U^c$	0.5896

Further explanation on the problem would be shed by decomposing the error. Despite the fact that the RMSPE is 2556.343 per cent, less than 1 per cent of the mean squared error is attributable to bias. Only 40 per cent of the error results from unequal variation, leaving

nearly 60 per cent of the error attributable to unequal covariation. The implication is that the results exhibit little systematic error.

The underlying trend is almost perfectly tracks by the simulated production shut in, simply deviating on an exact pattern. Despite the high value of the RMSPE is of consequence and does not compromise the model's purpose.

#### **10.4 Summary and Conclusion**

This chapter addresses relevant validated tests and described the process adopted in conducting each test. Several validation tests were conducted in order to build confidence in the model developed. This includes both behavioural and structural tests. The tests were conducted under well-established processes. Based on the results of the various tests, it can be concluded that this model is useful for the purpose of representing challenges facing revenue generation in the Nigerian oil industry. Therefore the chapter presents the results of the validation of the model thus consolidation the empirical rigour in the in the existing relationship between the structure of the model and data. In the chapter that follows policy analysis will be conducted based on the outcomes of the validation and tests conducted in this chapter.

## CHAPTER ELEVEN: POLICY ANALYSIS AND EVALUATION

### 11. Introduction

In this chapter both the two policies will be run, analysed and discussed. Specifically the analyses will focus on two different dimensions: model run without any policy intervention and model run with policy intervention. The output of the model under these scenarios will be compared with the baseline run in order to examine the effect of these policy interventions. This research will aim to achieve this under the following headings.

#### 11.1 Policy Analysis

This section presents the behaviour and analysis of the model under different scenarios. In view of the fact that exploring the effects of policy interventions and conducting policy experiments with alternative formulations of policy is not feasible in the real system, it therefore became imperative to use computer simulation in this regard. Consequently, this activity will be discussed under the following headings.

##### 11.1.1 Transparency Measures

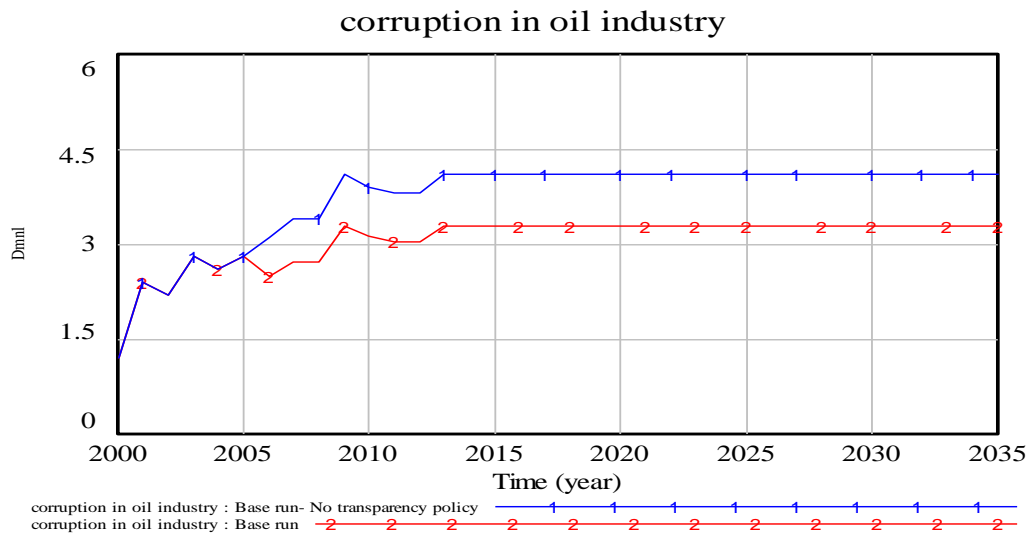
The transparency policy measure is studied at two levels: reduction in corruption in the oil industry and the promotion of actual government revenue from the industry. The following figures represent the effect of this policy initiative in the Nigerian oil industry. Specifically a comparison is made between the situation without transparency intervention and the situation under transparency intervention.

##### (a) *Corruption in the oil industry -*

*The effect of a transparency policy is measured by removing the policy intervention.*

After simulating the baseline (with transparency policy intervention) in the system, the model was simulated without policy intervention. This allows the comparison of the baseline behaviour to the behaviour of the situation where there is no transparency policy measure in order to see the effect of transparency measures on corruption and the rate of government revenue from the industry. Figure 11.1 below presents the first analysis that lead to further analyses of associated variable(s).

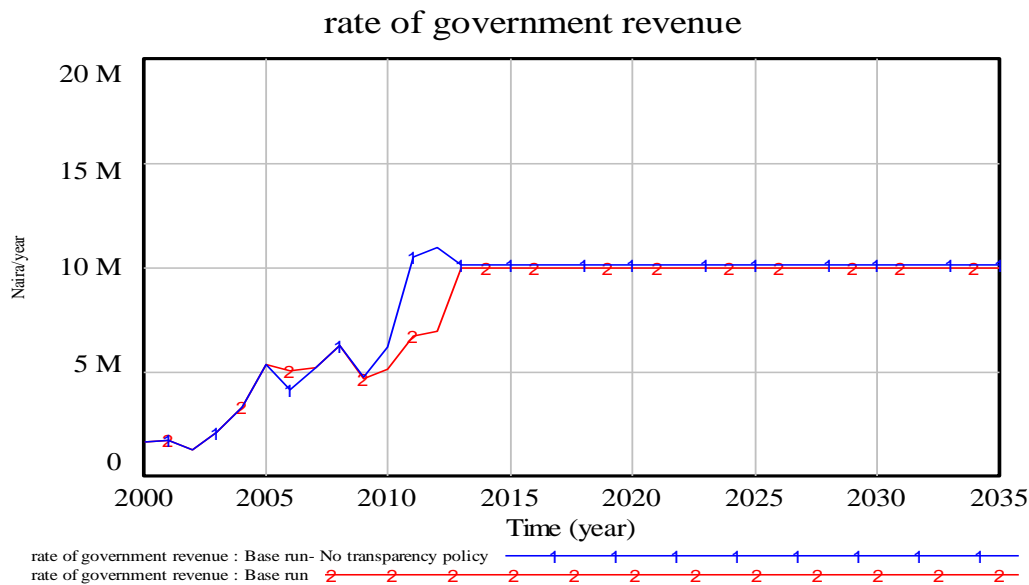
**Figure 11.1 Corruption in oil industry (Step 0, 2006)**



From the description of the model in chapter 8, it was discovered that the variable transparency policy measure is used as a policy lever in order to block revenue leakages occasioned by corrupt practices in the industry. On the basis of this, the behaviour of the base run is compared with the behaviour of the model after the removal of the policy intervention as presented above in figure 11.1. The aim of removing the policy intervention was to analyse the behaviour of the model with emphasis on the behaviour of corruption in the oil industry and rate of government revenue from the industry as earlier stated. It follows that corruption in the oil industry increased above baseline behaviour when the policy was removed up until 2013 and increased again after 2013 and then stayed constant to the end of the simulation.

Based on this behaviour, it is an unarguable fact that corruption in the industry has reduced to some extent from 2006 after the implementation of the transparency policy measure. The reduction in corruption in the industry is, however, manifested in other parts of the model, notably amongst the actual government revenue from the industry. It can also be observed that the transparency policy is only able to arrest and not reverse the actual corruption in the oil industry as evident from the behaviour of variable (corruption in the oil industry). This might not be unconnected with fact that at the moment the initiative covers only limited areas in the industry as it gradually progressing to cover all aspects of the operations of the industry. This perhaps might also be the reason on which the stakeholders in the industry claimed that the effect of transparency measures in the industry is around 20%.

**Figure 11.2 Rate of government revenue (Step 0, 2006)**

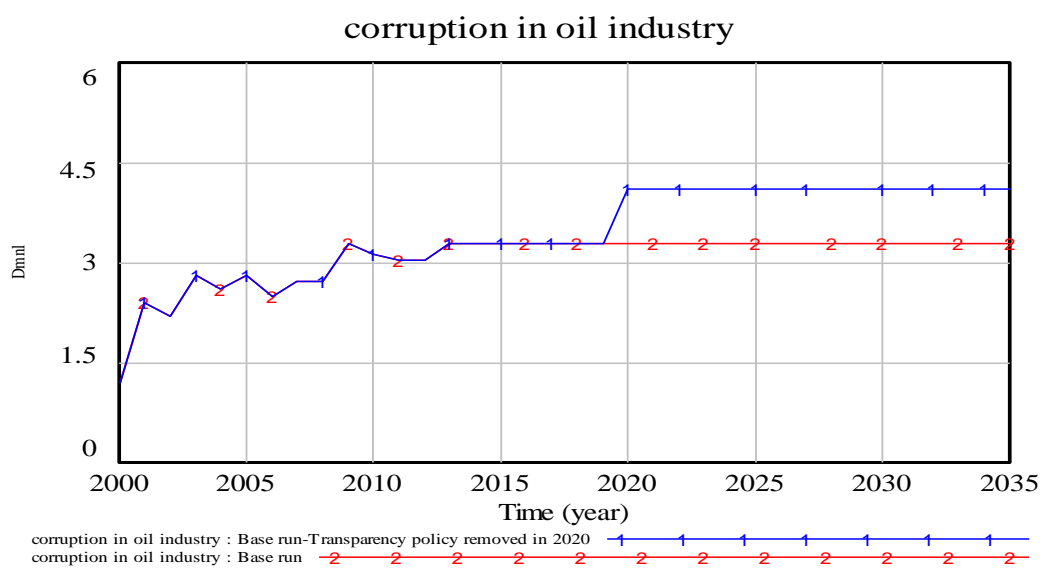


The reduction of corruption in 2006, after the implementation of transparency measures, succeeded in reducing the effect of corruption on government revenue from crude oil as it may be observed from the simulated behaviour presented above in figure 11.2. Actual government revenue from the industry witnessed a dramatic decrease from 2006 up to 2008 before it finally peaked from year 2009 to year 2012 and then slowed down in 2013 and finally stayed constant to the end of the simulation. An initial surprise was that actual government revenue decreased and then improved above baseline up to 2013 and then decreased a fraction before it stayed constant from 2014 to the end of the simulation. Upon further scrutiny it was found that the reason might not be unconnected with the situation when CBN reported having collected crude oil revenue above what NNPC claimed to have remitted to government.

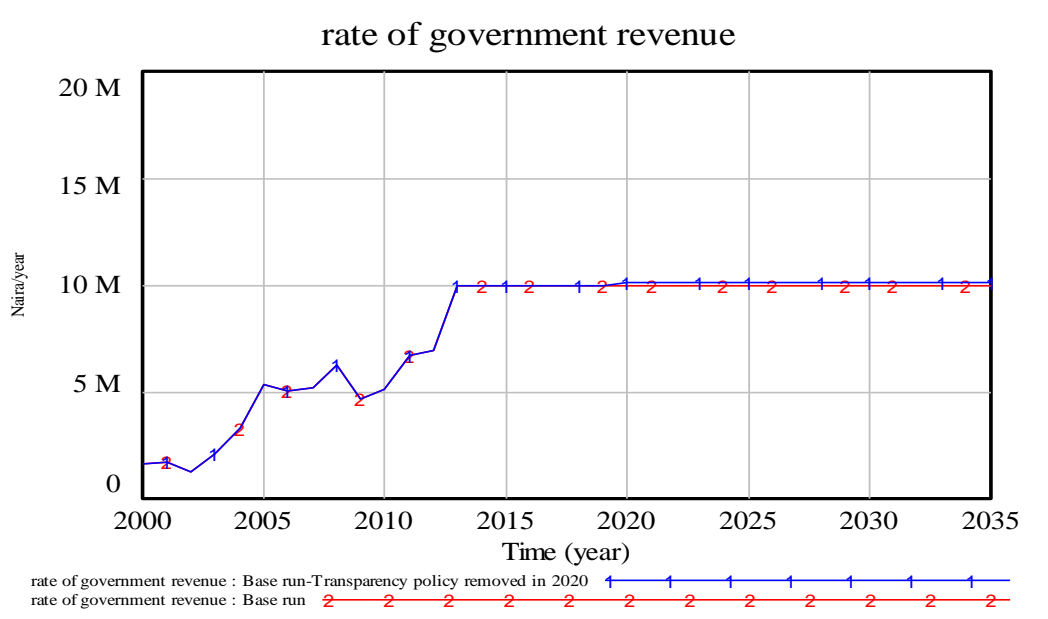
### 11.1.2 Transparency Policy Measure 2006: Removed in 2020

As seen in the base run scenario, corruption in the Nigerian oil industry increased up to year 2013 and then stayed constant from 2013 to the end of the simulation. It is interesting to observe the effect of transparency policy in this situation. After observing corruption in the oil industry stayed constant for a number of years; the policy (transparency policy) was, therefore, removed in 2020. The result of this action is presented below and the analysis focuses on the following observed model behaviour.

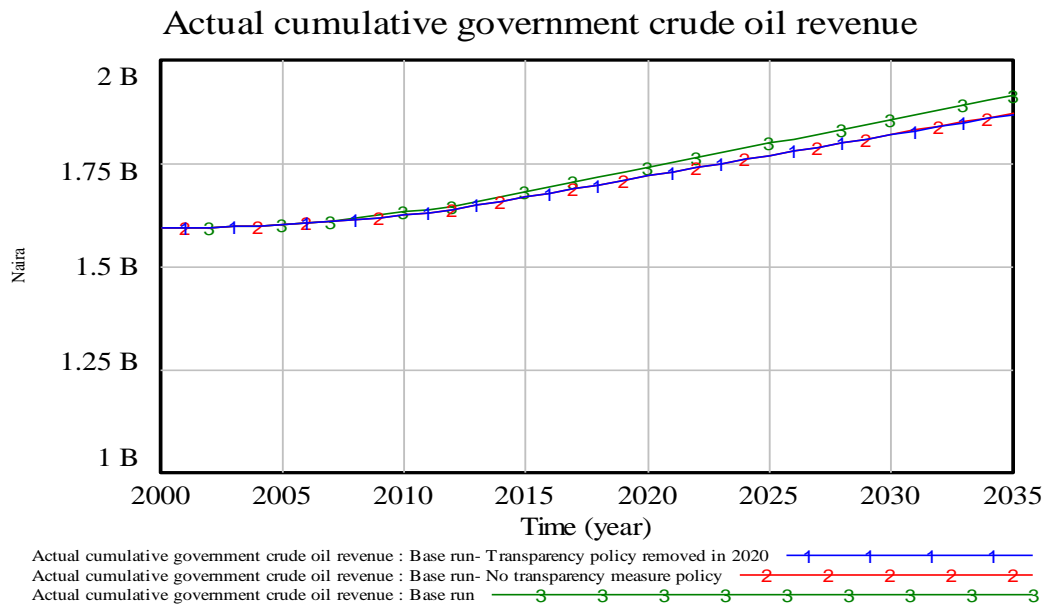
**Figure 11.3 Transparency policy removed in 2020 (corruption)**



**Figure 11.4 Transparency policy removed in 2020 (rate of government revenue)**



**Figure 11.5 Transparency policy removed in 2020 (actual government cumulative crude oil revenue)**



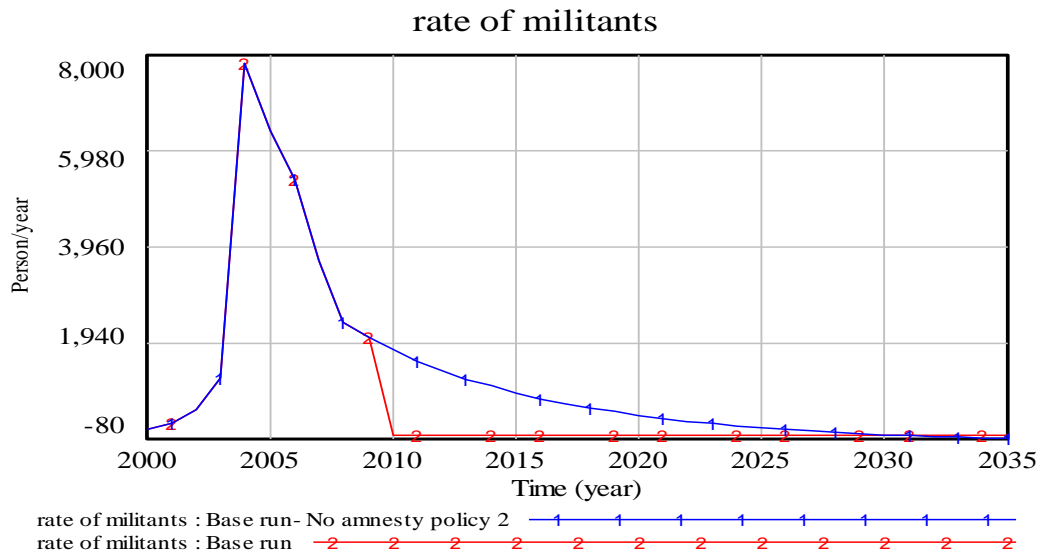
It can be observed that, compared to the base run projection, corruption increases at far above the base run from 2020 after the removal of the policy intervention. This continues up to the end of the simulation. Also, while the rate of government revenue remained constant from 2013 up to the end of the simulation under the base run, the rate of government revenue under the scenario after the removal of the policy in year 2020 followed the same pattern of behaviour as when there existed no transparency policy measure up to the end of 2020 when the transparency policy was removed. Following this, the rate of government revenue deviation, was a little above the base run behaviour and then stayed constant to the end of the simulation. Upon further scrutiny, it was discovered that this unexplained behaviour might not be unconnected to the reason earlier advanced above.

## 11.2 Amnesty Measures

An attempt was made to simulate the baseline (without amnesty policy intervention) in the system and compare it to the behaviour of the base run (with policy) using the relevant indexes earlier used for the sake of analysis. The aim of this was to determine the impact of the amnesty measure policy on the system. Firstly, the rate of militants was obtained as presented in figure 10.6 below.



**Figure 11.6 Rate of militants PULSE (1, 2009)**

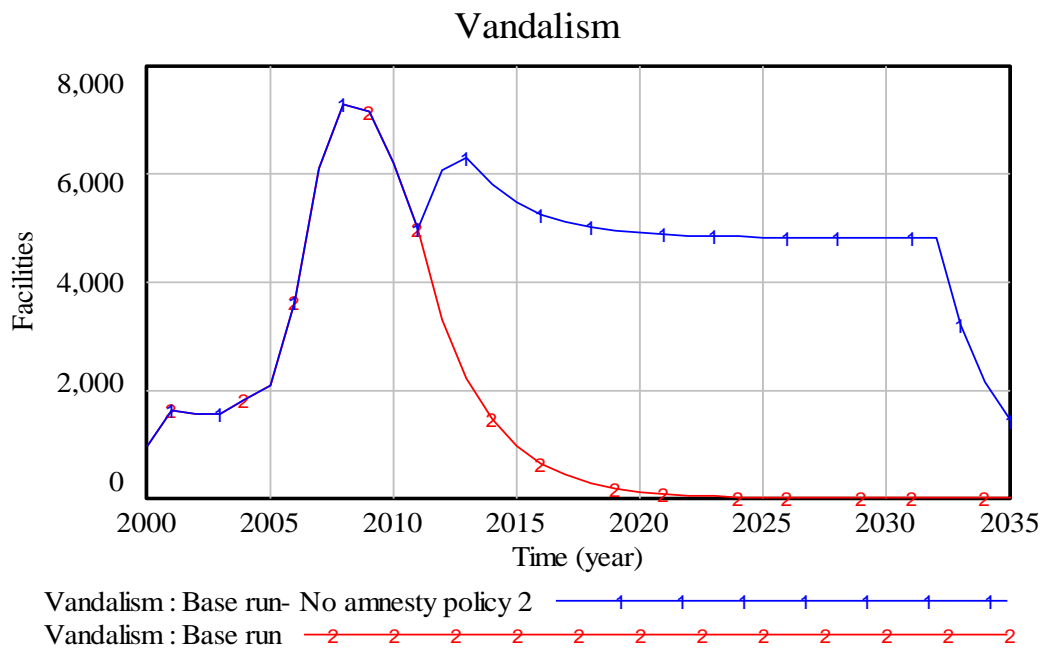


Recalling the description of the model in chapter 8, figure 8.12, the amnesty policy measure is modelled as a policy lever. Specifically, the policy measure has two aims: to stop the rate of militants and engage the militants in a variety of vocational training. On this basis, the policy lever is modelled as amnesty policy 1 and amnesty policy 2 for the sake of the modelling exercise. After the implementation of the amnesty policy measure in 2009, therefore, the inflow of rate of militants is stopped using PULSE (1, 2009) and the outflow of the rate of ex-militants is modelled to represent the exit of militants to the stock of ex-militants using the function STEP (1, 2009).

In line with figure 11.6 above, a comparison of the base run simulated model behaviour with that of no amnesty policy measure was conducted for the sake of evaluating the effect of the amnesty policy measure in the industry. In this case the policy measure was removed. It was observed that the rate of militants continued to increase slowly up to the end of the simulation. Based on this, the analysis further focused on the behaviour of the following related variables: militants, vandalism, crude oil theft, and crude oil spillage.

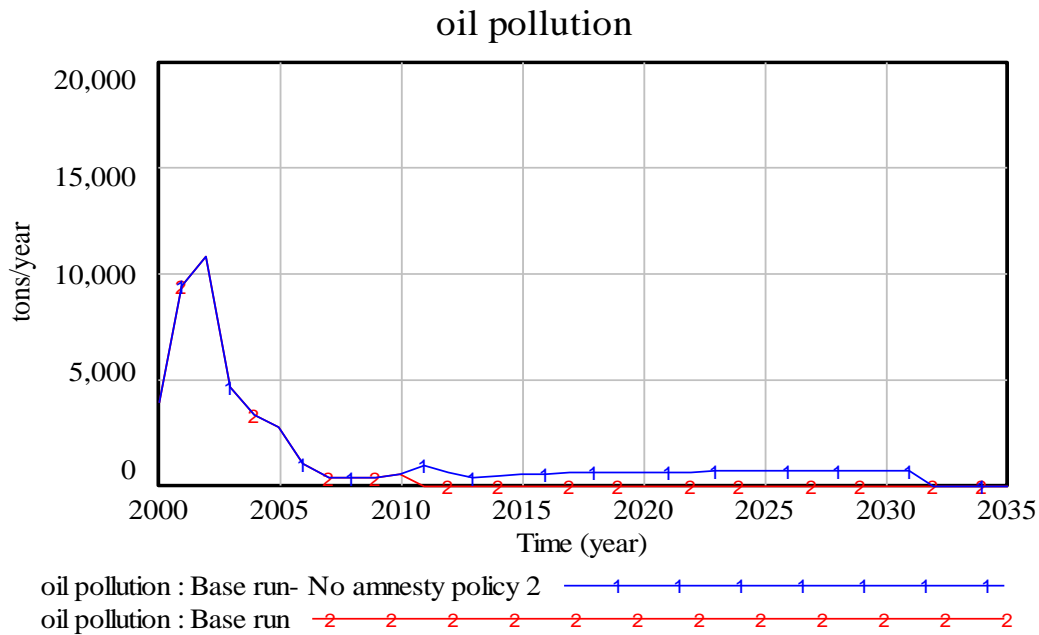


**Figure 11.9 Vandalism**

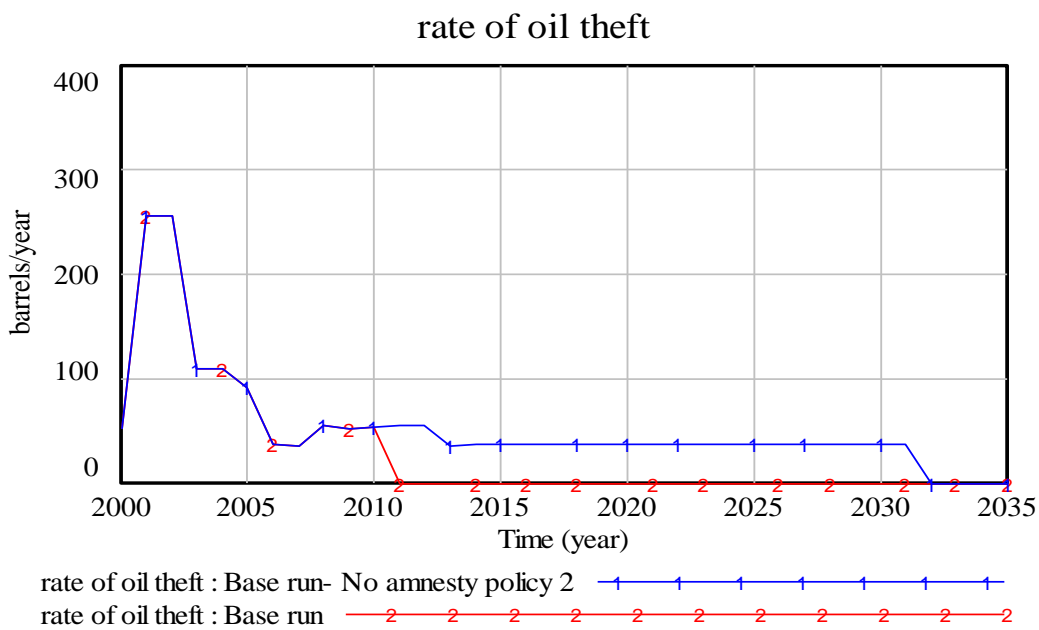


Vandalism which is modelled as stock is determined by two flows i.e. inflow and outflow which are increase in vandalism and decrease in vandalism respectively. The stock of vandalism is primarily influenced by the stock of militant through increase in vandalism and decrease in vandalism which is influenced by rate of repairs of vandalised facilities which is also determined by the time taken to repair vandalised facilities. However, the implementation of amnesty policy intervention in 2009 which addresses the militant activities as a successful policy measure is also responsible for the exponential decay of the stock of vandalism immediately after the policy intervention thus falling to zero around year 2022. Upon further scrutiny, it was discovered that the reason behind the continued exhibition of exponential decay by the stock of vandalism until around year 2022 despite the total collapse of the stock of militants which is responsible for increase in vandalism is attributed decrease in vandalism which is determined rate of repairs which is also determined by the time taken to repair vandalised facilities as stated above. Despite the fact that vandalism stops with the cessation of rate of militants yet it required substantial time to repair the vandalised facilities that continue to accumulate before the eventual implementation of the policy intervention.

**Figure 11.10 Oil pollution**



**Figure 11.11 Rate of oil theft**



Compared to the baseline projection, militants, increase in vandalism, vandalism, oil pollution, and rate of oil theft all rose as a result of the removal of the policy. Specifically, militants continued to increase at a slower rate from 2010 in the absence of the amnesty policy measure contrary to the baseline projection. The slow increasing growth of the militants continues up to 2025 when it finally becomes almost equal to the baseline projection

of the model. This shows that the policy measure was able to bring the rate of militants under control. Upon further scrutiny, it was concluded that the dramatic drop in the population of militants in 2025 is not unconnected with the number of potential militants because over time some of the potential militants also exit the stock of potential militants through the outflow of exits from the potential militants.

This naturally decreases the number of potential militants that become militants in the long run. Besides this, the increase in vandalism exhibits an exponential increasing rate. Increase in vandalism rose from 2010 slowing down in 2013 before it reached its equilibrium from 2013 up to the end of 2032. On the other hand, vandalism exhibited similar behaviour even though the rate of vandalism stops at 2032, vandalism did not stop until the end of the simulation. Rate of oil theft increased up to year 2012 and suddenly dropped a fraction up to 2013 and then remained constant up to 2032. Upon further scrutiny, it was discovered that this behaviour might not be unconnected with the rate of militants that stopped before the end of the simulation. Finally, oil pollution equally exhibited the same behaviour albeit slightly cyclical from 2012 to 2015 before it finally maintains equilibrium up to year 2032 where it finally stops.

### **11.2.1 Amnesty Policy Measure 2009: Removed in 2020**

As we have seen in the base run behaviour, rate of militants have persistently increased from the base year up to 2009 when the policy intervention was implemented. Specifically, the policy was in two ways as highlighted above. On the basis of this, we will examine the impact of this policy in the two ways mentioned above. The examination will be conducted focusing on comparison of the baseline model run and that of a scenario where the policy is removed in the year 2020. This allows the analysis of the relevant variable in two different ways: base run behaviour and comparison with no policy situation as well as two different faces: no amnesty policy 2 and no amnesty policy 1.









drop of militants to zero in 2010, (following the implementation of the amnesty measure) to the end of the simulation. This shows that the amnesty policy measure exerted a significant impact on the rate of militants in the Niger delta. Also, the population of militants increased exponentially after the removal of the amnesty policy measures 1 and 2 up to the end of the simulation relative to the base run where the rate of militants dropped dramatically from 2010 after the implementation of the policy measure.

On the contrary, when only amnesty policy measure 2 was removed, the population of the militants followed similar behaviour to the base run projection albeit slightly above the baseline run up to 2020 when it exactly equals the baseline run up to the end of the simulation. Upon further scrutiny, it was discovered that the removal of amnesty policy 2 and 1 upset the halting of the rate of militants and also stopped the exit of militants to the stock of ex-militants thus resulting in the exponential growth of the militants to the end of the simulation.

Under the scenario of no policy 1 and 2, ex-militants became zero throughout the simulation period. On the other hand, when amnesty policy 2 was removed, the population of ex-militants increased exponentially above the baseline run from 2000 to the end of the simulation. This shows that, when only amnesty policy 2 is removed, the rate of militants continued to increase and hence increased the stock of militants which allowed exits of militants to continue thus leading to an exponential growth of ex-militants contrary to the base run that maintained equilibrium from 2010 to the end of the simulation. Moreover, from 2000 to 2009, there were no ex-militants in both cases. An increase in vandalism, in both case no amnesty policy 2 and 1 and no amnesty policy 1 follows the same pattern of behaviour with the base run up to 2010, after which the two scenarios rose exponentially to 2012, decreased in 2014 then stayed constant to the end of the simulation in the case of no amnesty policy 2 and 1 whereas in the case of no amnesty policy 2, it witnessed a dramatic drop in 2032 equal to the baseline run to the end of the simulation.

Upon further scrutiny, it was discovered that despite the removal of amnesty policy measure 2 which allowed the rate of militants to continue, the presence of amnesty policy measure 1, on the other hand, neutralised the effect of militants on vandalism as it succeeded in reducing the population of militants. This explains the sudden drop in the increase in vandalism in 2032. On the other hand, the removal of amnesty policy 2 and 1 allowed an uninterrupted effect of the militants on the rate of vandalism thus leading to an increase in vandalism

staying constant under this regime up to the end of the simulation. In the case of vandalism, in both cases: no amnesty policy 2 and 1 and no amnesty policy 2, vandalism increased exponentially in 2011 contrary to the base run that decreased dramatically in the same year up to 2025 when it became zero to the end of the simulation.

Specifically, the exponential increase of vandalism under the two aspects: no amnesty policy measure 2 and 1 and no amnesty policy measure 2; witnessed a slight drop in both cases at an equal rate up to 2020 when vandalism in both cases stayed constant to around year 2033 at which point vandalism under the no amnesty policy 2 scenario collapsed completely, whereas vandalism under the scenario no amnesty policy 2 and 1 remained constant to the end of the simulation. Upon careful scrutiny, it was found that both scenarios distorted the stoppage of the rate of militants occasioned by the policy thus increasing the stock of militants leading to a negative impact on the rate of vandalism thereby increasing the stock of vandalism.

On the other hand, the sudden collapse of vandalism under no amnesty policy measure 2 was based on the fact that despite the continuous flow of militants, (as a result of the removal of the policy), the existence of the amnesty policy 1 allowed the exit of militants to the stock of ex-militants thus reducing the stock of accumulated effects of militants on vandalism and thereby leading to the collapse of vandalism in 2032. The situation regarding the rate of oil theft followed the same pattern as the base run in both cases up to 2010. In year 2010, contrary to the base run where rate of oil theft went down dramatically, the two policy aspects continued to stay constant up to 2013 where both scenarios led to a slight drop of crude oil theft and then oil theft maintained equilibrium to the end of the simulation in the case of no amnesty policy 2 and a sudden collapse in 2032 in the case of no amnesty policy 2.

### **11.3 Policy Test 1: Transparency Policy increase to 30%**

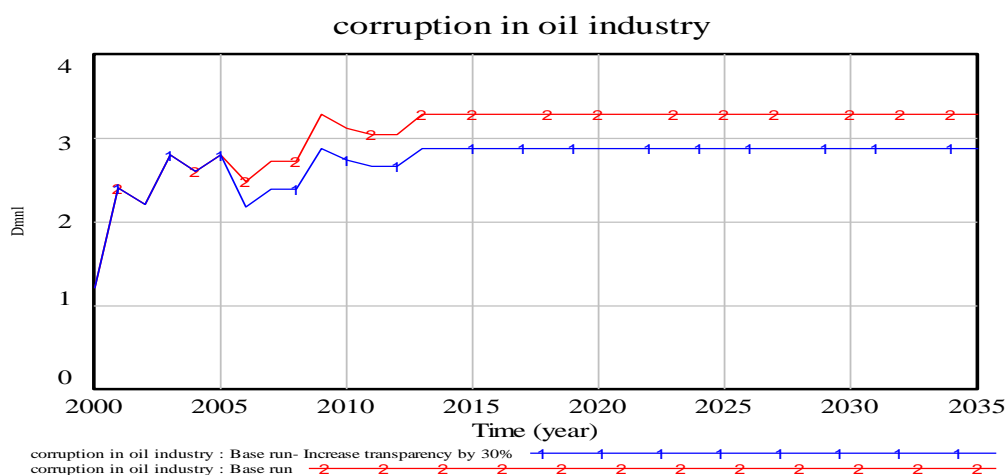
In this scenario, after observing the behaviour resulting from corruption in the oil industry and rate of government revenue from the same industry, the rate of transparency policy measure in the industry was increased by 30% in order to see the impact of the policy on the performance of the following variables.

Despite the difficult in measuring how increase in transparency, but it can be observed that the transparency intervention (NEITI) at this stage focuses only on publishing some information concerning revenues received from the industry which hitherto remained secret, as discussed in section 3.5.2. On the other hand, McPherson and MacSearraigh (2007) noted

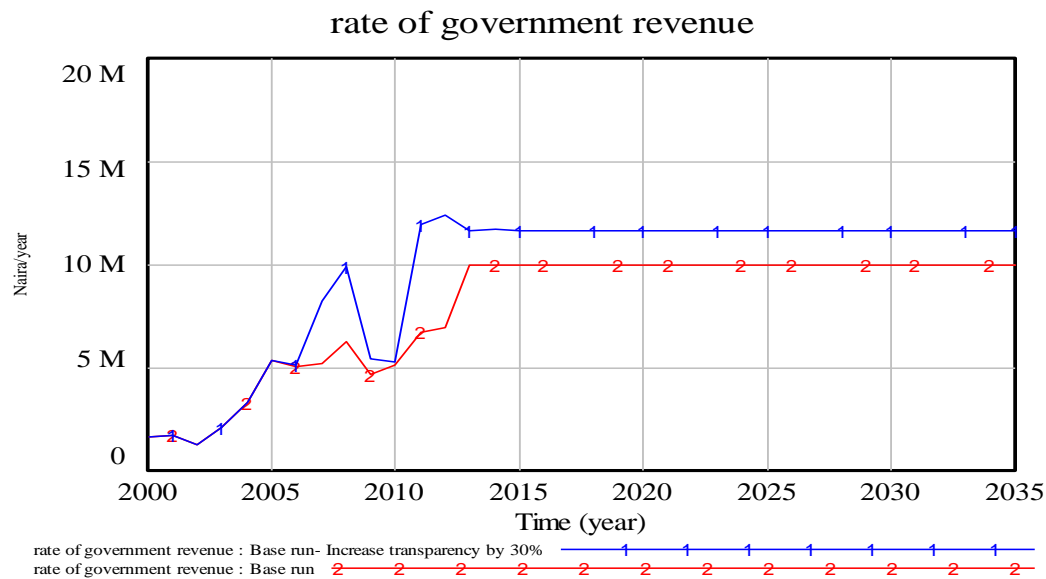
that corruption exists at each phase of the value chain in the oil industry ranging from exploration to the retail activities. Therefore expanding the scope of transparency to cover these areas would automatically translate to expanding the percentage of coverage. This perhaps explains the viewpoints of those who assert that increase in transparency has a corresponding decrease in corruption and go further to assert that currently the industry had attained 20% level of transparency as a result of NEITI interventions resulting in 20% corresponding reduction in corruption. Therefore transparency can further be increased until all other aspects of the industry are covered.

For the sake of this research the expert’s judgement is relied upon in measuring the influence of transparency on corruption in the Nigerian oil industry hence describes as: If higher transparency, then lower corruption; if lower transparency, then higher corruption. From a system dynamics point of view both corruption and transparency measures in this research are treated as *exogenous* variables, since their effects are not part of the dynamics themselves (Figure 8.19). Additionally, both corruption and transparency policy are “qualitative” variables that have been modelled as a stock and as a constant respectively in the model. The measurement of corruption in this model is based on a subjective measurement by Transparency International (TI) which is presently considered as the best arbitrary measurement. The score ranges from 1 to 5 with 5 considered the highest level of corruption by TI. This allows corruption to be modelled in the industry since corruption in the Nigerian oil industry is a reflection of corruption in the Nigerian society (Usman 2011).

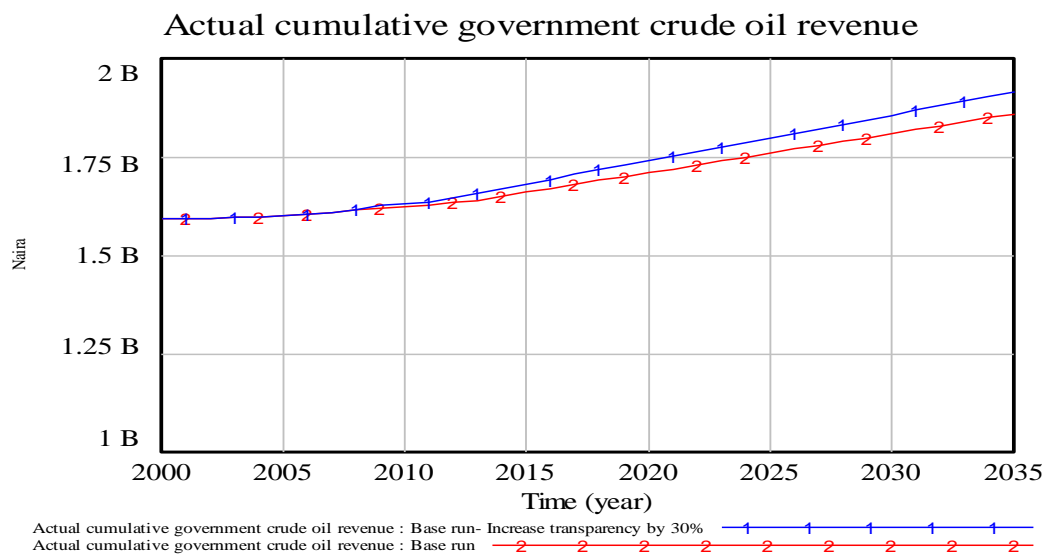
**Figure 11.18 Corruption in oil industry (step 30, 2006)**



**Figure 11.19 Rate of government revenue (Step 30, 2006)**



**Figure 11.20 Increase in transparency by 30%**



It can be observed that corruption in the oil industry decreased far below the base run up to 2013 and then stayed constant from 2013 to the end of the projection. In the case of government revenue from the industry, it increased sharply above the baseline run from 2006 to 2008 before it suddenly dropped in year 2009 (albeit still above the baseline run) and then increased again far above the baseline to end of 2013, then staying constant to the end of the simulation. Upon further scrutiny, it was discovered that the sudden fall and rise of government revenue from crude oil between the period 2008 and 2009 is not unconnected

with the introduction of the amnesty policy measure by the federal government in 2009. More details regarding this policy intervention will be presented in the subsequent section. Moreover, actual cumulative government crude oil revenue increased constantly above the baseline run from 2006 to the end of the simulation.

#### **11.4 Policy Test 2: Reduce production shut in and increase potential production**

##### **Reduction of rate of gas flare**

The first type of policy intervention is specifically designed to decrease the rate of gas flare in the process of crude oil production. In this case, a gas re-injection process was considered. Through re-injection of gas for the purpose of converting it for other purposes such as domestic purposes, this laudable proposal could be achieved. The policy of re-injection has been considered and is being practised by several other oil producing countries including Norway. It was assumed that this decreased the rate of gas flare which is one of the major causes of pollution (amounting to about 70%).

The effort of Nigeria to reduce gas flare (which stood at about 30%) needed to be improved. This test is performed by assuming that a decreased rate of gas flare has increased. In addition to that, it is assumed that government embarks on a massive gas re-injection programme. It is assumed that reduction in gas flare will reduce pollution which has remained a source of concern in the industry. The test will be conducted using the original (production sub view) model with additional structure. Figure 11.4 shows the immediate impact of the reduction of rate of gas flare in the industry. For this new simulation only the rate of gas flare parameter has been adjusted while all other parameters remained in their original form.

**Figure 11.21 Reduced gas flare to 10%**

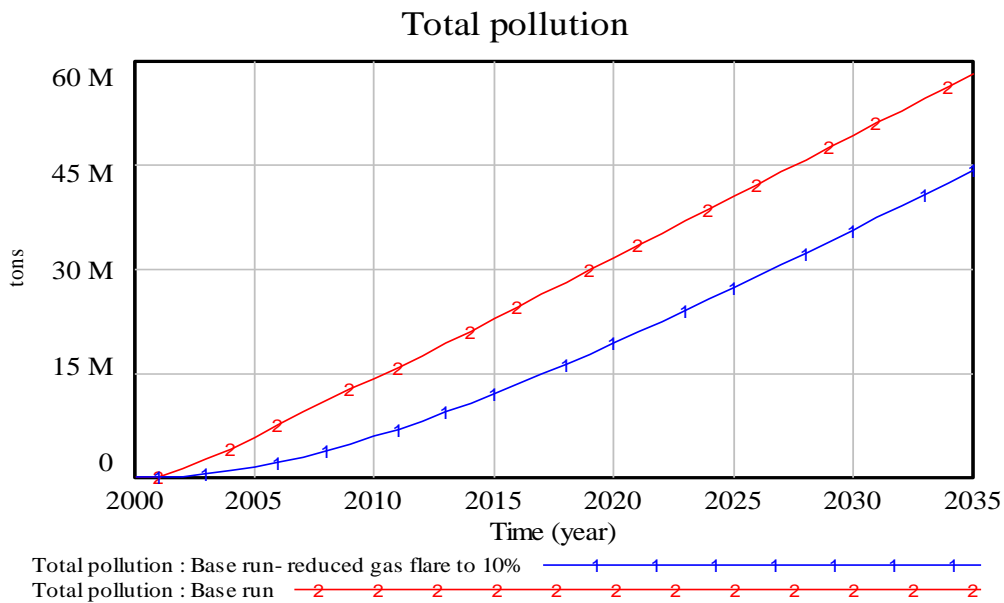
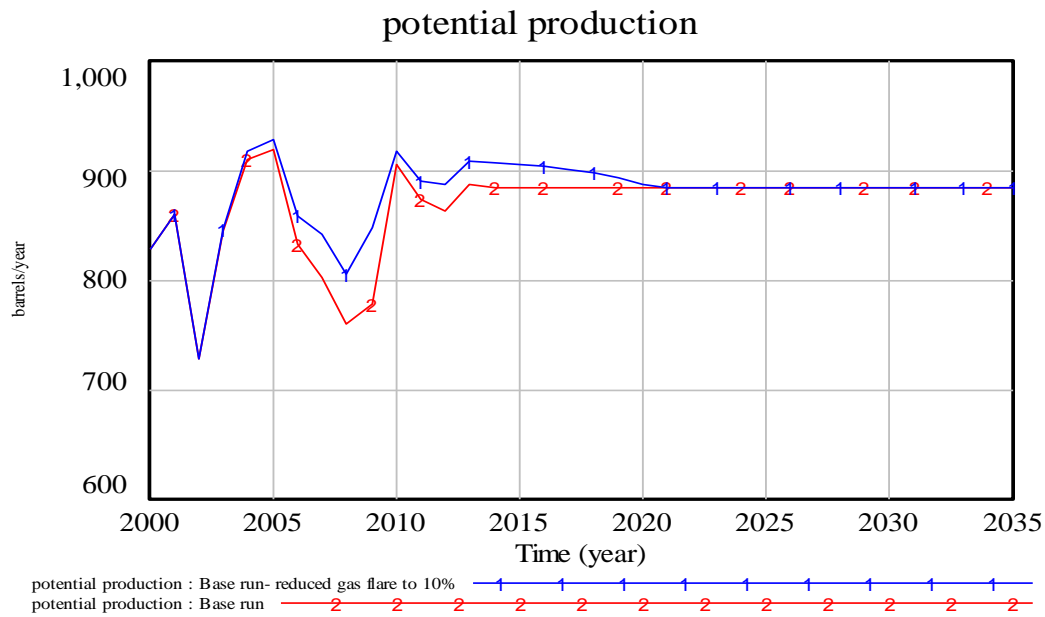


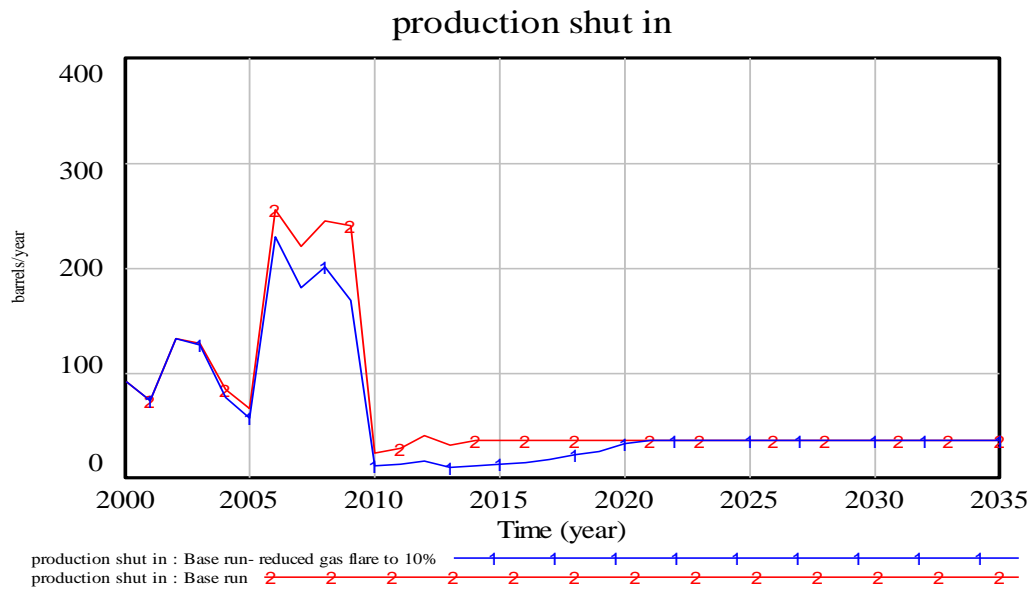
Figure 11.21 shows that reducing the rate of flare to a minimum of 10% dramatically impacted on reducing total pollution in the industry. A decrease in the rate of flare had a multiplier effect on the whole system. For example, a decrease in gas flare eventually reduced production shut in which, by extension, increased potential production which eventually increases actual crude oil production and eventually crude oil produced. As it clearly shows, this kind of intervention dramatically reduced the level of pollution in the industry which affects the means of livelihood of the host communities thereby creating poverty which triggers communal unrest and hence leads to production shut in.

The general conclusion is that the reduction of rate of gas flare will have a significant impact on other variables in the system. The following graphs depict the behaviour of the variables that are associated with the rate of gas flare in the industry.

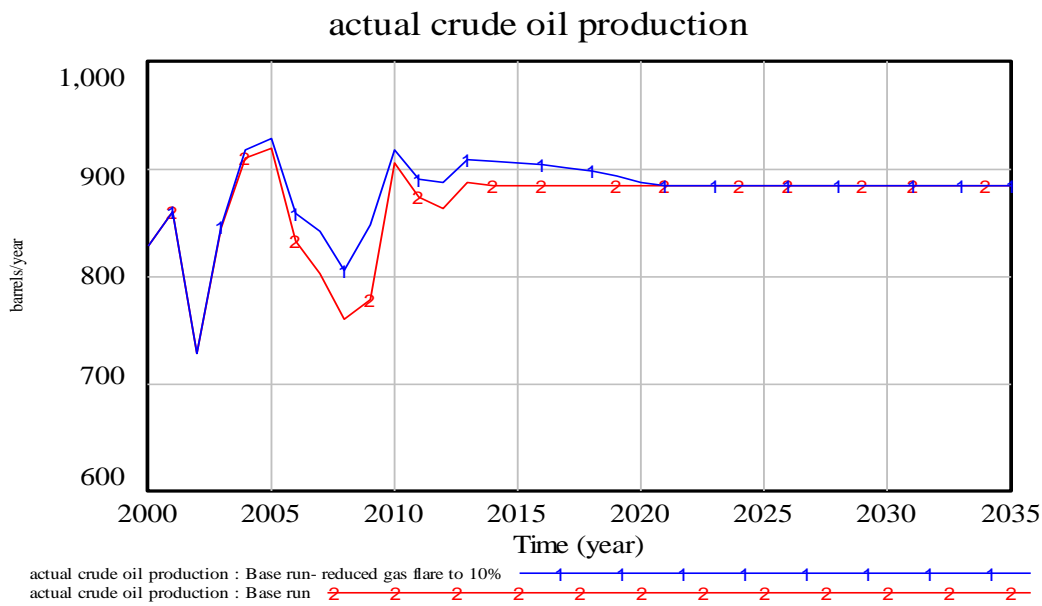
**Figure 11.22 Reduced gas flare to 10% (potential production)**



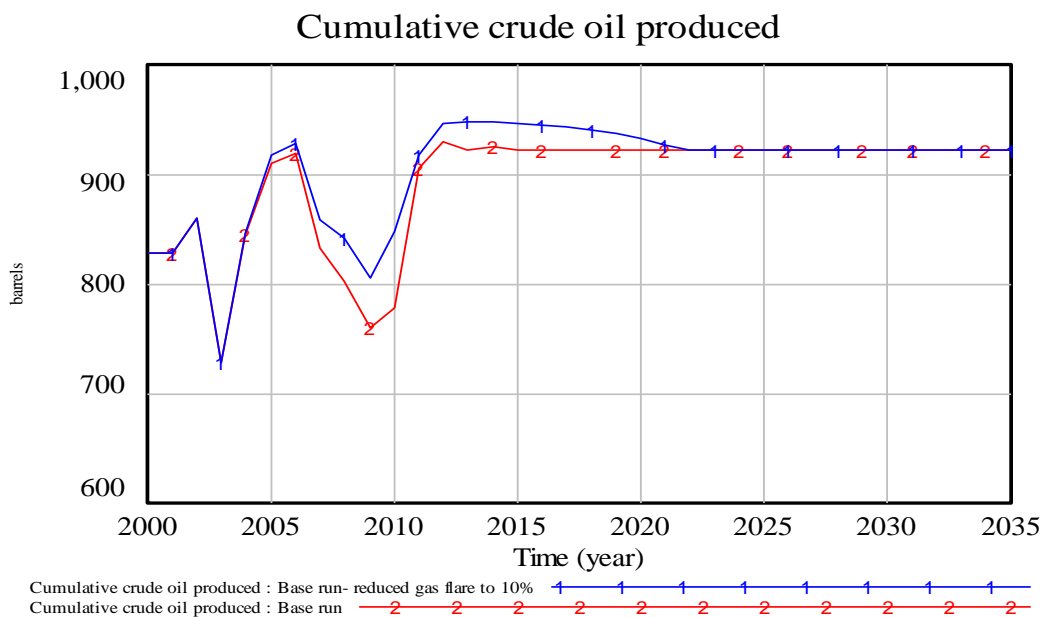
**Figure 11.23 Reduced gas flare to 10% (production shut in)**



**Figure 11.24 Reduced gas flare to 10% (actual crude oil production)**



**Figure 11.25 Reduced gas flare to 10% (cumulative crude oil production)**



**11.5 Policy Test 3: Reduce vandalised facilities and reduce rate of oil spill**

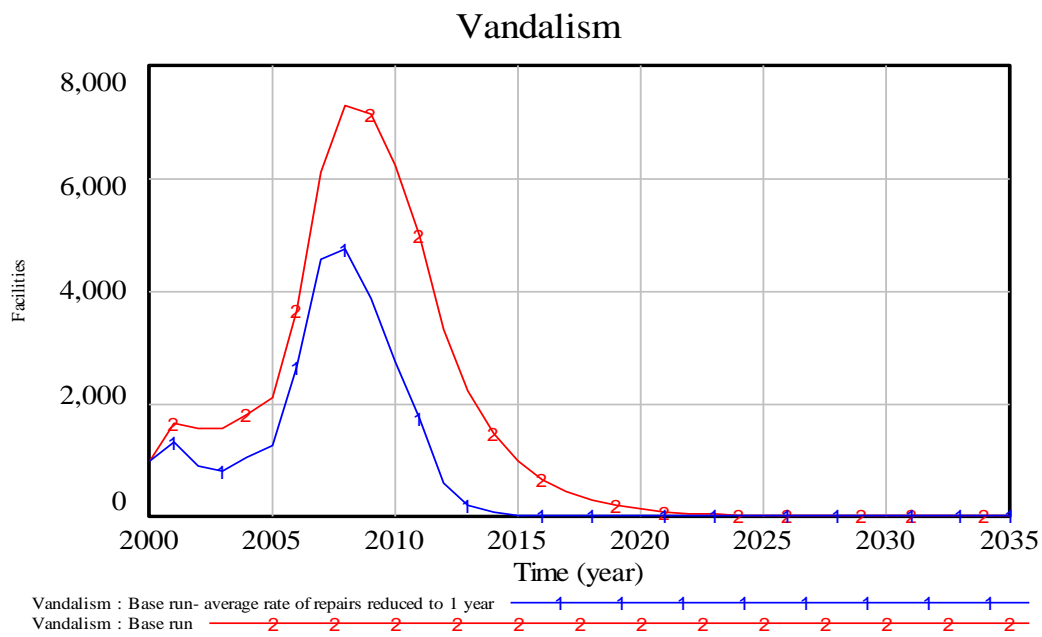
**Reduction of time taken for repairs**

The second policy to be tested relates to the reduction in the time taken to repair vandalised facilities in the industry. The level of vandalised facilities can be high or low depending on several factors among which includes the effects of militants on the rate of vandalism as well



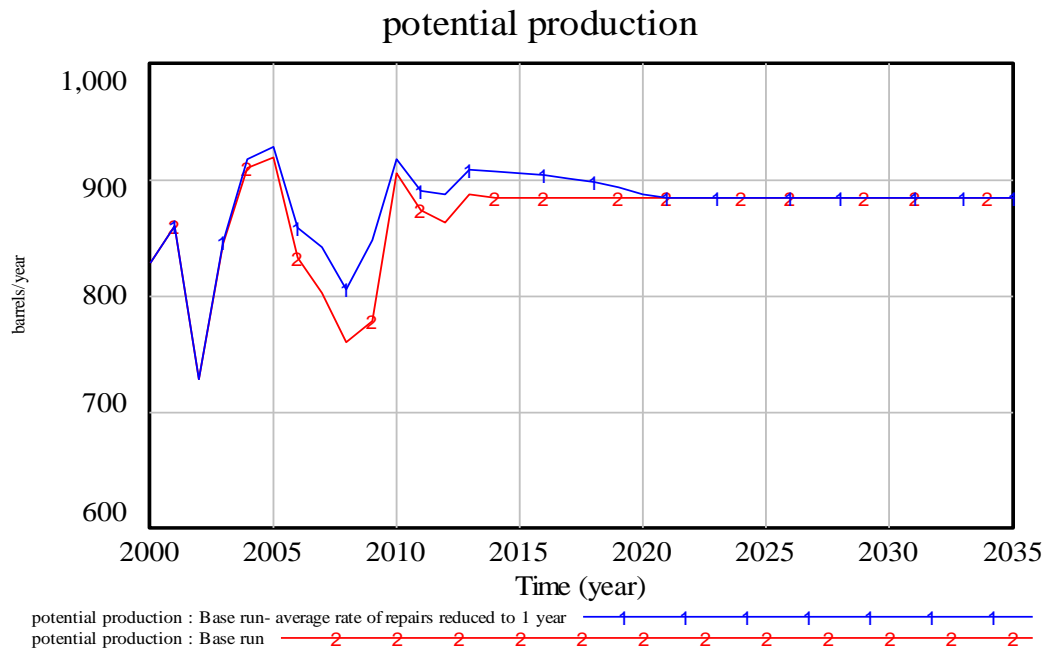
as the time taken in repairing vandalised facilities in the industry. To test the effect of time in reducing the level of vandalised facilities in the industry, it was assumed a reduction of 2 years from the average time taken of 3 years in repairing vandalised facilities in the industry. In reality, if well carried out, this measure can reduce the level of vandalised facilities in the industry, reduce rate of oil spill and also exert a significant impact in reducing level of pollution in the environment with a final impact on the actual crude oil production in the industry.

**Figure 11.26 Average rate of repairs reduced to 1 year (vandalism)**

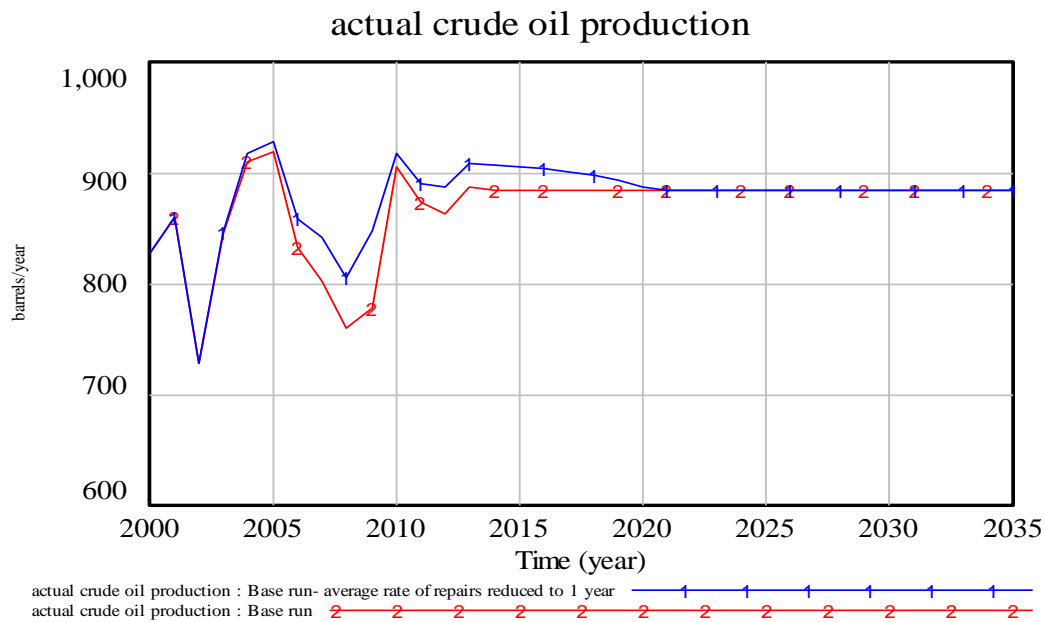




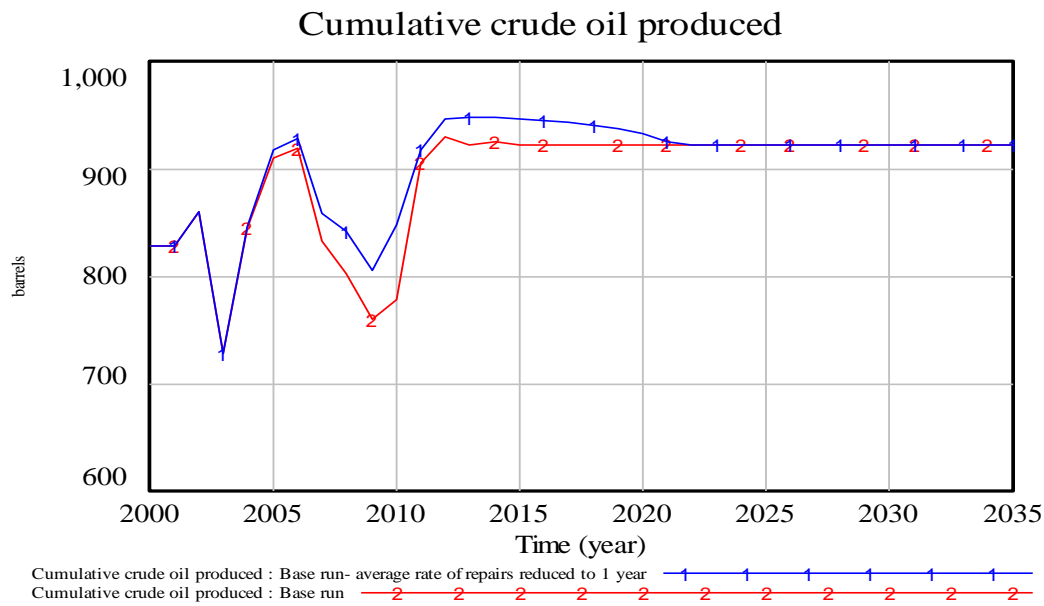
**Figure 11.29 Average rate of repairs reduced to 1 year (potential production)**



**Figure 11.30 Average rate of repairs reduced to 1 year (actual crude oil production)**



**Figure 11.31 Average rate of repairs reduced to 1 year (cumulative crude oil produced)**



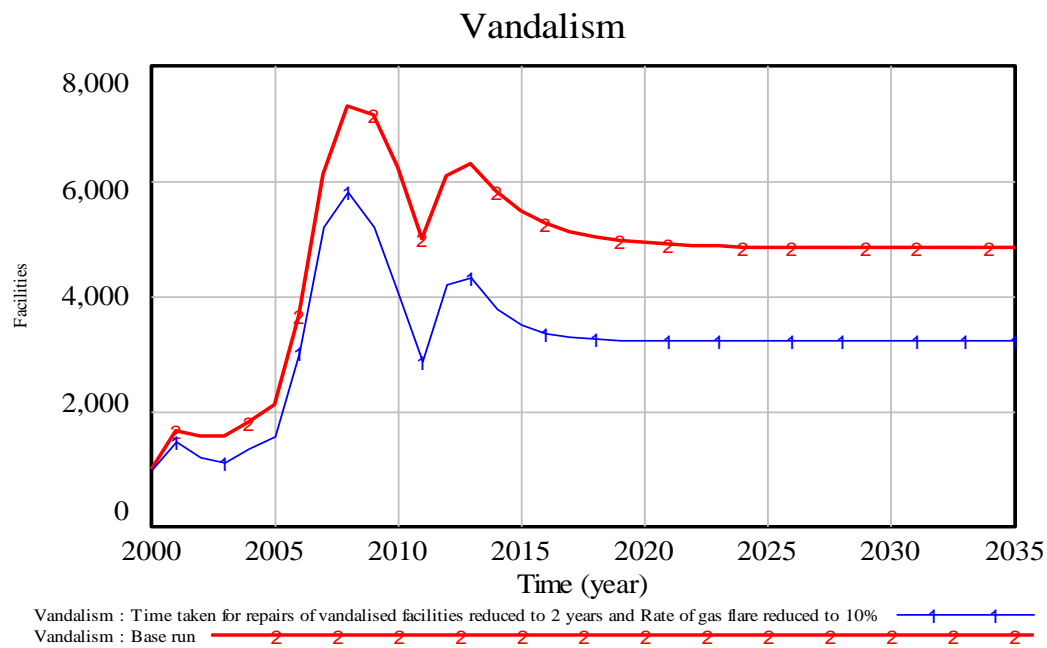
### 11.6 Multiple policy intervention scenarios

In this section, multiple policy interventions within the scenarios are considered. This allows the behaviour of variables of interest to be studied under different policy combination. Consequently, this policy combination in form of multiple policy scenarios will be discussed under the following headings.

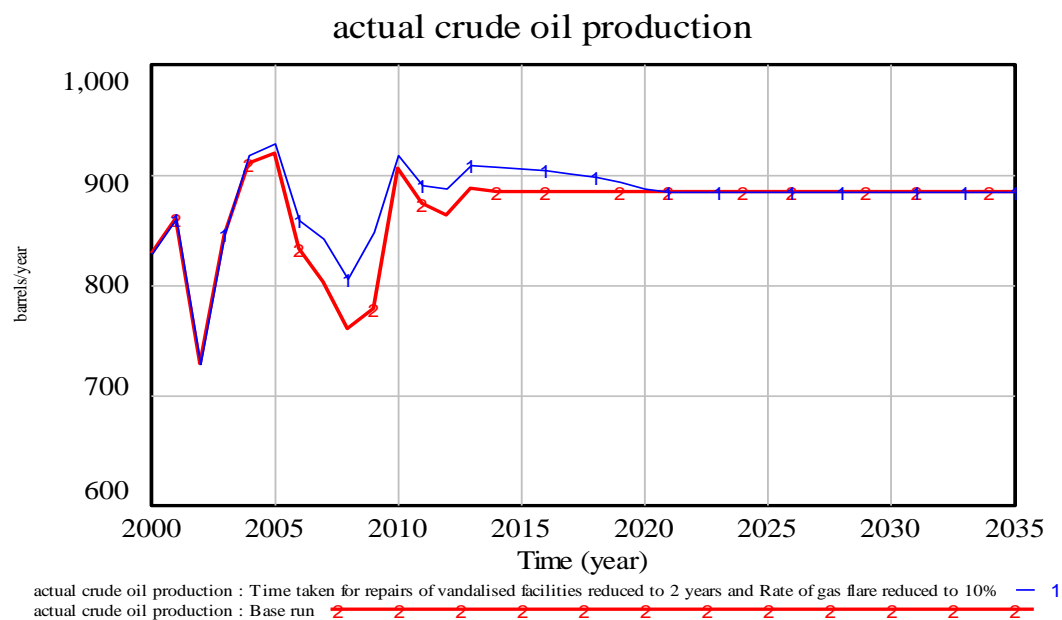
***Reduce time taken to repair vandalised facilities to 2 years and reduce rate of gas flare to 10 per cent***

The following figures represent the effect of this multiple policy initiative in the system. Specifically a comparison is made between the base run and a situation where these policy interventions were put in place. The following variables of interest (vandalism, actual crude oil production and potential production) are studied.

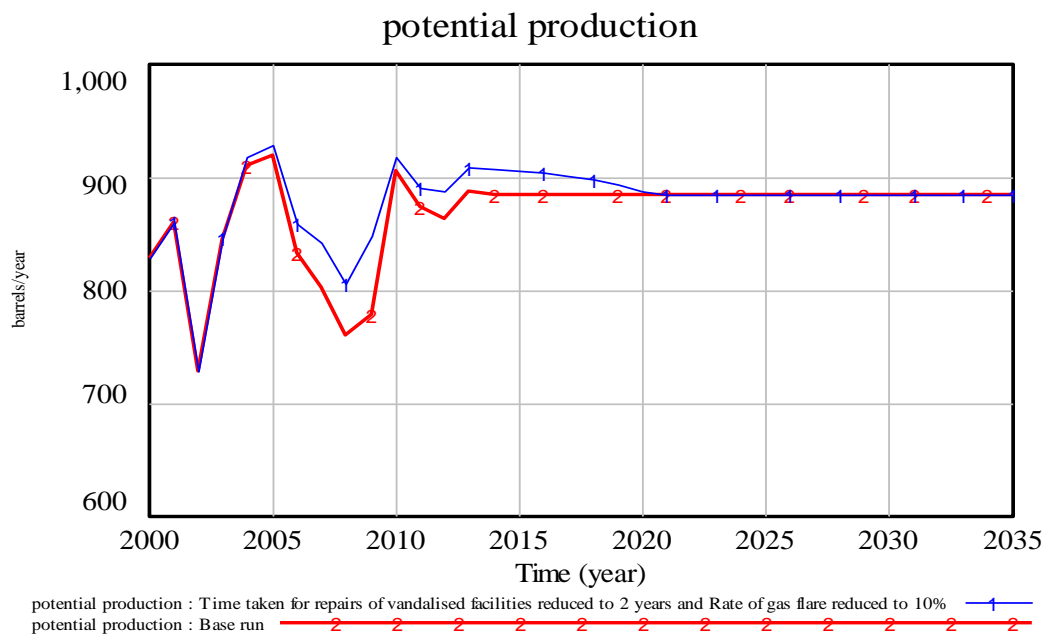
**Figure 11.32 Reduce time taken to repair vandalised facilities to 2 years and reduce rate of gas flare to 10 per cent**



**Figure 11.33 Reduce time taken to repair vandalised facilities to 2 years and reduce rate of gas flare to 10 per cent**



**Figure 11.34 Reduce time taken to repair vandalised facilities to 2 years and reduce rate of gas flare to 10 per cent**



The model was simulated using multiple policy intervention in through the combination of time taken to repair vandalised facilities which is reduced to 2 years and rate of gas flare also reduced to 10 per cent. This allows the comparison of the baseline behaviour to the emerging behaviour. Figure 11.32 (vandalism) above presents the first analysis that lead to further analyses of associated variable (actual crude oil production and potential production).

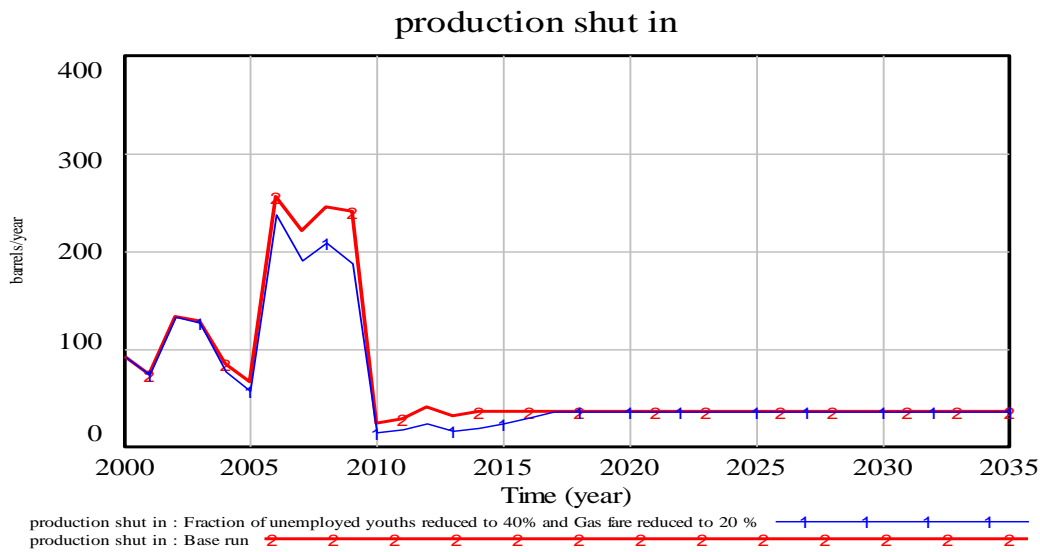
It can be observed that vandalism decreased far below the base run up to the end of the simulation run. Upon further scrutiny, it was discovered that the decrease in vandalism has also triggered variations in the behaviour of other variables such as actual crude oil production and potential crude oil production. Both actual crude oil production and potential crude oil production also increased above the base run as a result of this policy combinations.

***Fraction of unemployed youths reduced to 40 per cent and gas flare reduce to 20 per cent***

The following figures represent the effect of this multiple policy initiative. Specifically a comparison is made between the base run and a situation where these policy interventions were put in place. The following are the variables of interest.



**Figure 11.37 Fraction of unemployed youths reduced to 40 per cent and gas flare reduce to 20 per cent**



The model was simulated using multiple policy intervention in through the combination of time taken to repair vandalised facilities (which is reduced to 2 years) and rate of gas flare also reduced to 10 per cent. This allows the comparison of the baseline behaviour to the emerging behaviour. Figure 11.35 (production shut in) above presents the first analysis that lead to further analyses of associated variable (actual crude oil production and potential production).

It can be observed that production shut in decreased far below the base run up to 2018 and then stay constant equal to the base run up to the end of the simulation. Upon further scrutiny, it was discovered that the decrease in production shut in has also impacted on the behaviour of other variables such as actual crude oil production and potential crude oil production. Both actual crude oil production and potential crude oil production also increased above the base run as a result of this policy combinations.

### 11.7 Summary and Conclusion

This chapter has been devoted to the analysis of the two policies: transparency policy measures and amnesty policy interventions. Specifically, the chapter evaluated the effectiveness of the two policies in terms of addressing challenges facing revenue generation in the Nigerian oil industry. This evaluation is grounded on the stakeholders' judgement and procedurally testing the behaviour of the model using a variety of scenarios. The behaviour of



the model at each point was compared with the baseline behaviour and hence the resultant outputs documented as a basis for analysis. Additionally the chapter presented the results in a logical manner. In summary, the analysis performed in this chapter resulted in the overall conclusion on the degree of effectiveness of the two policies mentioned above and the likely outcome of potential policy interventions.

## **CHAPTER TWELVE: CONCLUSION, LIMITATION AND RECOMMENDATION**

### **12. Conclusion**

The integration of System Dynamics and social and management science techniques in this research have contributed to the development and design of a robust and more rigorous modelling architecture. By implication, this integration addresses the limitation of System Dynamics in the integration of data collection and analysis into its methodology and its inability to incorporate qualitative data collection and analysis leading to the development process of a System Dynamics model for the Nigerian oil industry. A System Dynamics model for the Nigerian oil industry was subsequently constructed thus serving as the measure of relevance for this unique integration. Consequently, two remarkable outcomes were realised: 1) the integrated qualitative (grounded theory) data analysis technique for the development of the System Dynamics model; and, 2) a decision support tool for the Nigerian oil industry underpinned by mathematical equations and feedback.

#### **12.1 Contributions and Major Findings**

This research work has illuminated the complex nature of the Nigerian oil industry and economic challenges facing the industry. It has investigated the challenges as well as policy interventions to combat these challenges. Specifically, this research work utilised a System Dynamics adaptation of energy models, instability models, and corruption models with contributions from resource curse theory and other socio-economic challenges related to natural resource endowed economies. In broad terms, the research has generated a systematic System Dynamics model that promoted understanding of the dynamics of the challenges facing revenue generation in the Nigerian oil industry. Additionally, the research has assisted stakeholders in the Nigerian oil industry to better understand the system they are dealing with. In this research work, the model has replicated the reference mode. On the basis of the purpose of the model several model tests were implemented.

Overall, the model is useful for the real purpose of the dynamics and enhancing the understanding of the dynamics of challenges facing revenue generation. The research has provided insights into the manner in which policy makers will have more understanding of the challenges facing the industry and also for the model to serve as a policy tool to study

challenges and combat those challenges, as well as where the structure highlights more clearly the process that generates the challenges. The methodology utilised in this study provides an important tool that can be employed to predict the rise in challenges and effectiveness of policy interventions.

To the best of the researcher's knowledge, this model is the first System Dynamics model in Nigeria which has been applied to study challenges facing the Nigerian oil industry in general and challenges facing revenue generation in particular. Additionally, this research is the first research that studies all the challenges facing revenue generation in the Nigerian oil industry collectively as a system. The model has also replicated historical data obtained for the sake of this research to evaluate existing policies and to test a variety of policy scenarios. This model also facilitates the testing of numerous policy combinations. The strategy for the combination of various policies consisting of a mixture of combinations seems to be an appropriate and excellent way to address challenges facing the industry.

## **12.2 Summary of Contributions**

As stated in chapter one, this research work emanated from the observation that a System Dynamics model in energy issues focuses more on developed countries and also concentrates on policy, planning and economic issues. Additionally, studies of the challenges facing the Nigerian oil industry focus more on specific aspects of the challenges, as opposed to the overall facets of the challenges in their entirety. The fundamental cause of this bias was discovered to be the nature of the challenges themselves (dynamic, complex, and non-linear), and the limitations of the majority of existing methods to offer equal ways of solving quantitative and qualitative facets of challenges, including the human aspects involved. Based on this, it is an unarguable fact that this study addressed problems of a dual character: theoretical (absence of methodological procedures for addressing challenges facing the Nigerian oil industry without compromising the scope of the problem) and practical (dealing with dynamic, non-linear and dynamic issues).

With the adoption of the System Dynamics and Grounded Theory approaches, this study has aimed to solve both practical and theoretical perspectives of the problem. On the basis of this, this research has provided contributions to the application of System Dynamics modelling as well as energy sector research.

## **12.3 Contribution to Theory**

### **12.3.1 Feedback systems thinking for presentation of challenges facing revenue generation in the Nigerian oil industry**

Chapter two and chapter four, on the oil industry's revenue related challenges, are rooted in the underlying dynamics, non-linearity and complexity of the system structure in the energy sector. Attempts at solving these challenges prior to understanding their underlying causes have often translated into no lasting solution. Principles of feedback system thinking, however, have not received attention in studies on the Nigerian oil industry, in particular, and the country in general, as depicted by the absence of publications utilising this approach in the body of the literature relating to Nigeria in general and the energy sector in particular. This research has extended beyond the current state of the art and thus positioned feedback system thinking among the techniques for energy sector revenue problem representation and conceptualisation. This positioning has offered insight into the relevance and rationale of feedbacks in research relating to challenges facing the energy sector.

### **12.3.2 Conceptualisation of the effectiveness of Grounded Theory in System Dynamics modelling**

Research concerning design improvement of the System Dynamics modelling process has enjoyed little attention, possibly because System Dynamics modellers view current designs as inadequate. Grounded Theory, however, which involves theory produced from data, requires methodological steps that depict how data translate to theory and then to link the results to a simulation model. By offering a generic technique for integration of Grounded Theory to System Dynamics modelling, this research work extends the contribution of qualitative research in the collection and analysis and utilisation of qualitative data for the development of System Dynamics modelling. This contribution is presented in detail in chapter six.

### **12.3.3 Theoretical validation of System Dynamics model for the Nigerian oil industry**

A validation instrument has been utilised to assess the relevance and rigour of the System Dynamics model developed for the Nigerian oil industry, the analysis of which is presented in section 6.1.8. Specifically, this entails the outcome from rigorously applied focus group discussion with stakeholders within the Nigerian oil industry. This is linked to the view that stakeholders' views constitute an important aspect of model validation.

## **12.4 Contributions to Practice**

### **Decision support tool for challenges facing energy sector**

The energy sector is one of the core System Dynamics research areas since it has been widely applied in that area since the inception of System Dynamics in the early 1950s. Most of the energy models have, however, narrowed the scope addressing specific issues such as economy, planning and policy. In this research, the model developed attempted to model the challenges that affect government revenue from the energy sector – specifically the oil industry. In the realisation of this, the general contribution of this research has been a general theory provision concerning an energy sector system that integrates instability, corruption and energy issues using feedback with subsequent validation in a System Dynamics simulation model underpinned by mathematical equations.

### **General qualitative modelling design**

The development of a System Dynamics model for this research work has made a contribution towards the absence of methodological guidelines in the collection, analysis and integration of qualitative data into the modelling effort. By utilising this design, a comprehensive model was developed as reflected in the modelling process that cannot be developed by relying on literature alone.

## **12.5 Contribution Based on the Analysis of Research Objectives**

The specific contributions of this research are greatly correlated with the specific objectives accomplished. This accomplishment is highlighted by the analysis of the outcomes of individual objectives in the light of the underlying involvement approach as depicted in table 12.1.

**Table 12.1 Analysis of the objectives of the research, descriptive technique approach and outcomes**

<b>Research Objectives</b>	<b>Description Approach</b>	<b>Outcomes</b>
Investigate challenges facing revenue generation in the Nigerian oil industry	Literature review Interview	Problem identification and model boundary
Construct an SD model based on the causal relationships documented in the CLD and calibrate the model initially (contribute) to assessing the validity of the initial SD model by comparing it to the reference mode.	System Dynamics tools	-Feedback structures of Nigerian oil industry -Simulation results and outputs
3. Assess the impact of the two current policies aimed at improving revenue generation in the Nigerian oil industry.	Interviews Focus group discussions System Dynamics tools	Policy analysis
Utilise the SD model developed for policy evaluation.	System Dynamics tools Interviews	Policy(ies) recommendations

As presented in table 12.1, the outcome of this thesis can logically be summarised into three sections: firstly, an integrated methodological framework for qualitative research was designed for the research; secondly, this research has demonstrated the utility of system thinking tools as applied within this methodological framework in depicting complex challenges involving the energy sector; and thirdly, in reality, this tool assists system actors and policy makers in better understanding and identifying the fundamental cause and effect structures relevant to their areas.

## **12.6 Limitations and Future Research**

This System Dynamics model has been developed in a simplified way using simple structures and several simplified assumptions. For the sake of future research work, some assumptions (like combined vandalism for both production and non-production facilities) can be relaxed in order to make the model more convincing. Alternative funding should be aggregated between carry agreements, loans, and other forms of alternative financing so as to keep track of the various sources of funding for development purposes. In this model, details concerning different classes of funding alternatives that could warrant the development of such a model, and expand the model in future, are considered. Additionally, the proliferation of arms should

also be disaggregated into different classes of arms so as to keep track of different kinds of weapons in order to make the model more explicit. The main recommendation concerning the model structure emanating from this research is that future work should disaggregate the stock of potential crude oil revenue and actual crude oil revenue into seven stages for each (NEITI 2006, 2010) to allow the adequate representation and quantification of all cases of revenue streams from the industry. This idea could not be implemented in this research due to data constraints.

Additionally, the model can be adapted for use in other natural resources (especially oil and gas) endowed economies facing similar challenges such as the Niger Republic in West Africa and the Republic of Iran in the Middle East. Specifically; there will be a need for the inclusion of other local conditions, as well as structural modifications, if the model is to be applied and tested for a situation that differs from the characteristics of the location of this study.

Several studies suggest a close relationship between crude oil revenue, economic growth and economic development (Ayodele 1998; Mcphail 2000; (Akinlo 2012). This research, therefore, recommends that future modelling should consider the impact of crude oil revenue on economic growth and development.

Finally, the work of other interested researchers aimed at enhancing, improving and extending the model is gladly welcomed by the sponsoring body and the Nigerian government.

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25. Federal Government of Nigeria (2003) National Energy Policy Applicable to Oil and Gas
26. Federal Government of Nigeria (2000) The Corrupt Practices and Other Related Offences Act 2000.



## **APPENDIX A: Interview information sheet**

Business Management Research Institute

University of Bedfordshire Business School

Luton Campus, Vicarage Street

Luton, LU1 3JU

### INTERVIEW INFORMATION SHEET

This interview is part of a research project aimed at developing a policy decision tool (using system dynamics: a modelling approach that has proved suitable in addressing policy related issues) in the Nigerian petroleum industry at the University of Bedfordshire, United Kingdom. The research programme is financed by the Petroleum Technology Development Fund, Nigeria.

The objectives of the research are to develop:

- A better understanding of the current state of affairs in terms of policies aimed at addressing challenges facing revenue generation in the Nigeria petroleum industry.
- A system dynamics simulation model that can be used to study the impact of variety of policy options and alternatives that may optimise revenue generation from the industry.

The findings of this research will be reported in a doctoral thesis. Some of the findings may also be presented in conferences and/or published as journal articles.

The sole aim of the interview is to capture your understanding, perception and viewpoint regarding the two policies currently being applied; Transparency and Amnesty programmes vis-à-vis addressing the challenges facing revenue generation in the Nigeria petroleum industry including perceptions regarding past and current situations as well as reaction to potential future policies and changes in the system structure with a view to evaluating them and also design new policies and organisational structures that will lead to greater success in

terms of revenue generation. The interview is expected to last for approximately forty five (45) minutes.

Your input will be treated with utmost confidentiality and your personal details will not be disclosed in the study without your prior approval. The interview will only be recorded with the approval of your consent. Participants may however choose not to answer questions, request materials not to be used or pull out of the interview at any time. A transcript of responses will be sent to the participants via email so that you can confirm that it is a correct recording of your responses. Any complaints or questions can however be addressed to the ethics committee of the University.

I am grateful for you spending the time to discuss these issues with me. For further queries, please do not hesitate to contact the researcher or the Director of study. Do you have any question before we both start the interview?

Kind regards

Idris A. Musawa

Contacts:

Mr. Idris Musawa (idris.musawa@beds.ac.uk)+447550382406(Researcher)

Prof. Michael Kennedy (michael.kennedy@beds.ac.uk) (Director of Studies)

## **APPENDIX B: Interview schedule**

### Open questions:

1. Can you tell me your experience and views about the challenge(s) facing Nigerian petroleum industry as a whole in terms of optimising revenue generation?
2. Could you explain whether the present situation represents an improvement, deterioration or steady state as compared to the previous situation?
3. What about the next few years? Do you expect the challenges in optimising revenue generation to increase, stay about the same, or decrease?
4. Can you explain the reason(s) for this expectation as to future trends?

(Transition)

### Policy related questions:

#### Transparency initiative(s) in the Nigerian Petroleum Industry.

5. Tell me little about “transparency” in the context of Nigerian Petroleum industry?
6. What do you understand to be the objectives of the “transparency initiative(s)?
7. What is your opinion as to whether this measure has, or has not, achieved its objective(s)?
8. What measure(s) do you think, if further applied, would yield the desired result?
9. Can you describe what you think would happen as a result of the application of the measure(s) you suggested?
10. How would this happen?

#### The Nigerian Amnesty programme.

11. Tell me little about “Amnesty programme” in the context of the Nigerian petroleum industry?
12. What do you understand to be the objectives of the Amnesty programme?
13. What is your opinion as to whether this programme has achieved, or has not achieved, this objective(s)?
14. What measure(s) do you think, if further applied, would yield the desired result?
15. Can you describe what you think would happen as a result of the application of the measure (s) you suggested?
16. How would this happen?

(Transition)

Organisation specific questions:

17. Can you tell me about measure(s) taken if any, by your organisation to assist the nation in generating optimal revenues from the petroleum industry?
18. Would you say that the measure (s) adopted by your organisation are, or are not, assisting the nation in generating optimal revenue benefits?
19. How has the measure(s) taken by other organisations contribute to your organisation`s efforts of optimising revenue generation?
20. Can you suggest any measure(s) that, if applied by your organisation, can assist further in optimising revenue generation within the industry?
21. Can you please tell me what you think would happen as a result of the application of the measure (s) you suggested?
22. How do you think that this is what will happen?

23. Is there anything else you consider important to let me know regarding revenue generation in the Nigerian Petroleum industry?

\*Can I contact you in case I need additional information or have additional questions?

Thank you for your time. Please provide your contact detail if you would like to have a copy of the results obtained from this interview.

## APPENDIX D: Instrument for validation (Questionnaire)

### Challenges facing government revenue from the Nigerian petroleum industry: A System dynamics approach.

#### SECTION ONE:

These questions refer to the CLD (Causal loop diagrams) that I presented to you.

1. Based on the CLD presentation, please assess the model on the basis of the following criteria (e.g. clarity). Further clarification may be given in text form in answer to questions 2 & 3 (below).

Criteria	Rating						
	7	6	5	4	3	2	1
	Excellent	Very good	Good	Neither good nor poor	Poor	Very poor	Extremely poor
Clarity							
Logical structure							
Practical relevance							
Comprehensiveness							
Intelligibility							
Applicability							

2. Model's point of weakness

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3. Model's point of strength

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**SECTION TWO:**

Please answer the following questions using (7- Strongly agree, 6- Agree, 5-Slightly agree, 4- Neither agree nor disagree, 3- Disagree, 2-Strongly disagree, 1- Very strongly disagree)

4. Does this diagram depict an accurate economic representation/description of the Nigerian petroleum industry?

Strongly agree	Agree	Slightly agree	Neither agree nor	Disagree	Strongly disagree	Very strongly
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			disagree			disagree
7	6	5	4	3	2	1

Please add any further comments:

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5. Do you feel that the model adequately captures the major challenges facing revenue generation in the Nigerian petroleum industry?

Strongly agree	Agree	Slightly agree	Neither agree nor disagree	Disagree	Strongly disagree	Very strongly disagree
7	6	5	4	3	2	1

Please add further comments:

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6. Do you feel that the model has suitably indicated all the cause and effect relationships between the variables?

Strongly agree	Agree	Slightly agree	Neither agree nor disagree	Disagree	Strongly disagree	Very strongly disagree
7	6	5	4	3	2	1

Please add further comments:

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The following questions refer to the stocks/flow model that was presented.

7. Do you feel that the stocks in the model represent all the variables that accumulate or deplete over time and the flow represent all the variables that either increase or decrease the stocks (level)?

Strongly agree	Agree	Slightly agree	Neither agree nor disagree	Disagree	Strongly disagree	Very strongly disagree
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7	6	5	4	3	2	1
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Please add further comments

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**SECTION THREE**

8. In your opinion is there any other method you feel can be better used to describe the industry and what are its advantages and disadvantages?

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9. Are you experienced in evaluating or managing revenue related issues in the industry?

- i. Yes
- ii No

10. How many years of experience in revenue related issues in the industry do you have?

i. 1-5

ii. 6-10

iii. 11-15

iv. 16-20

v. 21-25

vi. Others.....

## APPENDIX E: List of variables

Relationship	Sign	Source	Remark
<b>Exploration</b>			
U/crude reserves → rate of oil discovery	+	Fagan, 1997; Watkins 2006	
Proved c/oil reserves → rate of depletion	-	Sorrell et al., 2012	
Rate of depletion → proved c/oil reserves	-	Sorrell et al., 2012	
P/crude reserves → unproved reserves	-	Fagan, 1997; Watkins 2006	
Rate of oil discovery → proved crude reserves	+	(Fagan, 1997; Watkins 2006)	
<b>Development</b>			
Cash call shortfall → C/cash shortfall	+	ABD 2009; NNPC 2010	
Production → Oil well life	-	Hook et al., 2014	
Oil well life → Abandonment	-	Hook et al., 2014	
A/funding → C/cash call shortfall	-	NNPC 2010	
C/cash shortfall → A/funding	+	NNPC 2010	
Abandonment → Oil wells	-	Jahn,Cook and Graham, 2008	
Oil wells → production	+	Hook et al., 2014; Craft & Hawkins 1959	
Funding gap → cash call short fall	+	Nlerun 2010.	
Cash call obligation → Funding gap	+	Mbendi, 2000	
Actual cash call paid → funding gap	-	Nlerun 2010	
C/cash call shortfall → Project delay	+	Baloi and Price 2003	
Investment provided → A/cash call paid	+	NNPC 2010	
Rate wells develop → wells for production	+	Nlerum 2010	
A/funding → Development Investment	+	NNPC 2010	
D/investment → Rate of investment	+	Odularu2008	
Project delay → project costs	+	Baloi and Price 2003	
Project costs → Investment provided	+	Baloi and Price 2003	
A/ cash call paid Development → Investment	+	Odularu2008	
<b>Production</b>			
Potential militants → Militants	+	Inokoba and Imbua 2010	

Militants	→	Oil spill	+	Inokoba and Imbua 2010	
Production/Operations	→	Gas flare	+	Inokoba and Imbua 2010	
Gas flare	→	Pollution	+	Afinotan and Ojakorotu 2009	
Environmental damage	→	Means of livelihood	-	Jike 2004	
Means of livelihood	→	Poverty	-	Jike 2004	
Poverty	→	Community unrest	+	Okafor 2011	
Militant	→	Vandalism	+	Oshwofasa, Anuta, and Aiyedogbon 2012	
Vandalism	→	Oil spill	+	Oshwofasa, Anuta, and Aiyedogbon 2012	
Oil spill	→	Pollution	+	EIA 2012	
Shutdown operation	→	Production	-	Aiyedogbon 2012	
Vandalism	→	Accidental death	+	Opukri and Ibaba 2008	
P/production	→	Production shutdown	-	EIA 2012	
P/production	→	Actual production	+	UNDP 1996	
Production	→	Crude oil	+	Ebeku 2008	
Communal unrest	→	Production shut in	+	Asgill, 2012.	
Poverty	→	Communal unrest	+	Inokoba and Imbua 2010	
Level of corruption	→	Effects of corruption	+	Stulhofer et al., 2008	
Vandalism	→	Crude oil produced	-	Oshwofasa, Anuta, and Aiyedogbon 2012	
Bunkering(oil-theft)	→	Crude oil produced	-	Paki and Ebienna 2011	
Bunkering (oil theft)	→	illegal money	+	Asuni 2009	
Purchaseofweapons	→	Proliferation of arms	+	Asuni 2009	

Profilferation of arms → Militants	+	Ojakotu and Uzodike 2007	
Pollutio → Health	+	Afinotan and Ojatorotu 2009	
Drop in production → Countrys economy	-	NEITI 2005	
Unemployment → Propensity to militancy	+	Oshwofasa, Anuta, and Aiyedogbon 2012	
Oil spill & pollution → Farming & Fishing	+	Owolabi 2012, UNDP, 2006	
Unemployed youths → Militants	+	UNDP 2006	
<b>Revenue</b>			
Corruption → Cumulative crude oil revenue	-	Mohammed 2013; Hanson 2007	
C/crude oil revenue → rate of G/ investment	+	Akinlo 2012	
G/investment → C/crude oil revenue	+	Akinlo 2012	
T/measure → Corruption	-	NEITI 2011	
A/crude oil revenue → C/crude oil revenue	+	NEITI 2011	

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## APPENDIX F: Model equations

Equation	Unit
Accrued interest= INTEG (interest incurred-interest paid, initial value of accrued interest)	Naira
actual cash call paid=investment provided	Naira/year

actual crude oil production=MAX(OPEC quota, potential production)	barrels/year
actual crude oil revenue= value of crude oil sales*effect of corruption on government revenue from crude oil	Naira/year
Actual cumulative government crude oil revenue= INTEG (rate of government revenue-rate of government investment, initial value of actual government crude oil revenue)	Naira
alternative fundings=cash call shortfall	Naira/year
amnesty policy 1=STEP(1, 2009)	1/year
amnesty policy 2=PULSE(1, 2009)	Dmnl
annual growth in corruption:=GET XLS DATA ('Book1.xls', 'sheet1', 'A', 'AN2')	1/year
annual incremental cost of project=2000	Naira/year
associated gas=actual crude oil production*average gas per barrel	tons/year
average annual inflation rate:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'I2' )	1/year
average cost of a project=3e+006	Naira/year
average cost of a single arm=1	Naira/arms
average cost of a single well:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'W2' )	Naira/well
average depletion rate=0.15	1/year
average gas per barrel=2000	tons/barrels
average number of arms=1e+006	arms
average number of militants=10000	Person
average oil price:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'S2' )	Naira/barrels
average oil well life=10	year
average project completion period=5	year
average standard of living=0.5	Dmnl
Average Time as Unemployed Youth=5	year
average time taken=5	year
average time taken for repairs=3	year
cash call obligation:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'G2' )	Naira/year
cash call shortfall=funding gap	Naira/year
community unrest=effect of poverty on community unrest +(rate of community unrest)	Dmnl

compensation:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'AS2' )	Dmnl
Corruption= INTEG (increase in corruption, initial value of corruption)	Dmnl
corruption in oil industry=Corruption*(1-transparency measure policy)	Dmnl
crude oil sales=(1-fraction of crude oil stolen)*Cumulative crude oil produced	barrels/year
cumulative revenue gap=Cumulative government potential crude oil revenue-Actual cumulative government crude oil revenue	Naira
Cumulative cash call shortfall= INTEG (cash call shortfall-alternative fundings, initial value of cumulative cash call shortfall)	Naira
Cumulative crude oil produced= INTEG (actual crude oil production-crude oil sales-rate of oil theft, initial value of CCOP)	barrels
Cumulative government potential crude oil revenue= INTEG (potential crude oil revenue, initial value of potential crude oil revenue)	Naira
decline rate=average depletion rate*Proved crude oil reserves	barrels/year
decrease in vandalism=rate of repairs	Facilities/year
Development investment= INTEG (actual cash call paid+alternative fundings-rate of other investments-rate of wells investment, initial value of development investment)	Naira
discovery coefficient=0.12	1/year
effect of corruption on government revenue from crude oil= WITH LOOKUP (corruption in oil industry/maximum corruption possible, ((0,0)-(5,2) ,(0,0),(0.24,0.729481),(0.44,0.669205),(0.448,0.792675),(0.48,1.14795),(0.496,0.666355),(0.52,0.893422),(0.544,0.697639),(0.544,0.551179),(0.56,0.8968),(0.608,0.610394),(0.608,0.5721),(0.608,0.445858),(0.624,0.576568),(0.656,0.694698),(5,1) ))	Dmnl
effect of means of livelihood on poverty=average standard of living/means of livelihood of population	Dmnl
effect of pollution on means of livelihood= WITH LOOKUP (Total pollution/maximum pollution possible, ((0,0)-(1,1) ,(0.1,0.7),(0.2,0.4),(0.385321,0.197368),(0.568807,0.0964912),(0.8043,0.0438596),(0.9939,0.02193) ))	Dmnl
effect of poverty on community unrest=poverty/maximum poverty possible	Dmnl
effect of vandalism on ROS= WITH LOOKUP ("max. number of facilities"/Vandalism, ((0,0)-(6,10) ,(0,0),(1,1),(2,4),(4,4),(6,10) ))	Dmnl



effects of community unrest on production shut in=community unrest/maximum community unrest possible*compensation	Dmnl
effects of cumulative cash call shortfall on projects delay= WITH LOOKUP (Cumulative cash call shortfall/maximum cumulative cash call shortfall possible, ((0,0)-(1,20)],(0,0),(0.7026,0.333),(1,15) ))	Dmnl
effects of militants on crude oil stolen= WITH LOOKUP (ZIDZ(average number of militants, Militants), ((0,0)-(2,1)],(0,0),(0.5,0.2),(1,0.3),(1.5,0.5),(2,1) ))	Dmnl
effects of militants on vandalism= WITH LOOKUP (ZIDZ(average number of militants,Militants), ((0,0)-(3,1)],(0,0),(0.5,0.2),(1,0.4),(1.5,0.8),(2,0.8),(2.5,0.9),(3,1) ))	Dmnl
effects of proliferation of arms on rate of militants= WITH LOOKUP (average number of arms/Proliferation of arms, ((0,0)-(4,4)],(0,0),(1,1),(2,1),(3,2),(4,3) ))	Dmnl
"Ex- militants"= INTEG (rate of ex militants, initial value of ex militants)	Person
exit from potential militants=(1-fraction of potential militants that turn to militants)*Potential militants/Time as potential militant	Person/year
exit from unemployment=(1-fraction of unemployed youths that turn to potential militants)*Unemployed youths/Average Time as Unemployed Youth	Person/year
"F & F population"=Population*"fraction of F & F population"	Person
FINAL TIME = 2035	year
fraction of arms reduced=0.02	1/year
fraction of crude oil stolen:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'D2' )	1/year
fraction of development investment:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'AB2' )	1/year
"fraction of F & F population"=0.7	Dmnl
fraction of potential militants that turn to militants:INTERPOLATE::=GET XLS DATA ( '?ModelData' , 'sheet1' , 'A' , 'K2' )	Dmnl
fraction of unemployed youths=0.5	1/year
fraction of unemployed youths that turn to potential militants=0.2	Dmnl
fraction of youth population=0.62	Dmnl
fraction spent on arms=0.2	1/year
fractional rate of vandalism:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'AK2' )	1/year
funding gap=cash call obligation-actual cash call paid	Naira/year

gas flare pollution=gas flared	tons/year
gas flared=rate of gas flared*Total associated gas	tons/year
government approved budget:=GET XLS DATA('Book1.xls','sheet1','A','H2')	Naira/year
growth rate=0.026	1/year
illegal money= INTEG (new illegal money-money spent on arms- money spent on other things, initial value of illegal money)	Naira
increase in corruption=annual growth in corruption	1/year
increase in potential militants=Unemployed youths*fraction of unemployed youths that turn to potential militants/Average Time as Unemployed Youth	Person/year
increase in vandalism=IF THEN ELSE ( effects of militants on vandalism>0 , initial value of vandalism*fractional rate of vandalism , 0)	Facilities/year
INITIAL TIME = 2000	year
initial value of accrued interest=GET XLS CONSTANTS ('?InitialData', 'Sheet1', 'V2')	Naira
initial value of actual government crude oil revenue=1.59168e+009	Naira
initial value of arms=500000	arms
initial value of CCOP=828.2	barrels
initial value of corruption=1.2	Dmnl
initial value of crude oil reserve=2.17e+007	barrels
initial value of cumulative cash call shortfall=1.05392e+008	Naira
initial value of development investment=3.53102e+008	Naira
initial value of ex militants=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'U2')	Person
initial value of illegal money=143434	Naira
Initial value of militants=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'H2')	Person
initial value of oil wells available for production=62	well
initial value of population=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'R2')	Person
initial value of potential crude oil revenue=2.73268e+009	Naira
initial value of potential militants=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'G2')	Person
initial value of total associated gas=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'S2')	tons

initial value of total pollution=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'T2')	tons
initial value of unemployed youths=GET XLS CONSTANTS('?InitialData', 'Sheet1', 'F2')	Person
initial value of vandalism=984	Facilities
interest incurred=alternative fundings*interest rate	Naira/year
interest paid=Accrued interest/average time taken	Naira/year
interest rate=0.08	Dmnl
investment provided=MIN (total cost of a project, government approved budget)	Naira/year
"max. number of facilities"=7000	Facilities
maximum community unrest possible=10	Dmnl
maximum poverty possible=5	Dmnl
maximum corruption possible=5	Dmnl
maximum cumulative cash call shortfall possible=1.5e+008	Naira
maximum pollution possible=2e+007	tons
means of livelihood of population=effect of pollution on means of livelihood	Dmnl
militant youths=youth population-"Ex- militants"	Person
Militants= INTEG (rate of militants-rate of ex militants, Initial value of militants)	Person
money spent on arms=illegal money*fraction spent on arms	Naira/year
money spent on other things=(1-fraction spent on arms)*illegal money	Naira/year
net increase annual population=Population*growth rate	Person/year
new illegal money=average oil price*rate of oil theft	Naira/year
oil pollution=rate of oil spill*pollution conversion index	tons/year
Oil wells available for development= INTEG (rate of oil wells development-rate of decommissioned wells, initial value of oil wells available for production)	well
one year=1	year
OPEC quota=548	barrels/year
pollution conversion index=7.667	tons/barrels
Population= INTEG (net increase annual population, initial value of population)	Person

potential crude oil revenue=interest paid+new illegal money+value of oil from production shut in+value of crude oil sales+variation	Naira/year
Potential militants= INTEG (increase in potential militants-exit from potential militants-rate of militants, initial value of potential militants)	Person
potential production=production capacity-production shut in	barrels/year
effects mainly vandalism of oil facilities (poverty=effect of means of livelihood on poverty)	Dmnl
prevalence of poverty=poverty/"fraction of F & F population"	Dmnl
production capacity:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'P2' )	barrels/year
production shut in=production capacity*effects of community unrest on production shut in	barrels/year
project delay=average project completion period*effects of cumulative cash call shortfall on projects delay	year
Proliferation of arms= INTEG (rate of purchase of arms-rate of arms reduction, initial value of arms)	arms
Proved crude oil reserves= INTEG (rate of crude oil discovery-decline rate, initial value of crude oil reserve)	barrels
rate of arms reduction=Proliferation of arms*fraction of arms reduced	arms/year
rate of community unrest:=GET XLS DATA ( 'Book1.xls' , 'sheet1' , 'A' , 'O2' )	Dmnl
rate of crude oil discovery=discovery coefficient*Unproved crude oil reserves	barrels/year
rate of decommissioned wells=Oil wells available for development/average oil well life	well/year
rate of ex militants=Militants*amnesty policy 1	Person/year
rate of gas flared=0.7	1/year
rate of government investment= government approved budget	Naira/year
rate of government revenue=actual crude oil revenue	Naira/year
rate of militants=IF THEN ELSE( effects of proliferation of arms on rate of militants>0 , Potential militants*fraction of potential militants that turn to militants/Time as potential militant , 0 )*amnesty policy 2	Person/year
rate of oil spill=rate of oil theft*effect of vandalism on ROS	barrels/year
rate of oil theft=IF THEN ELSE( effects of militants on crude oil stolen>0 , Cumulative crude oil produced*fraction of crude oil stolen , 0 )	barrels/year

rate of oil wells development=rate of wells investment/average cost of a single well	well/year
rate of other investments=(1-fraction of development investment)*Development investment	Naira/year
rate of purchase of arms=money spent on arms/average cost of a single arm	arms/year
rate of repairs=Vandalism/average time taken for repairs	Facilities/year
rate of unemployed youths=youth population*fraction of unemployed youths	Person/year
rate of wells investment=Development investment*fraction of development investment	Naira/year
reserve production ratio=Proved crude oil reserves/actual crude oil production	year
SAVEPER = TIME STEP	year
Time as potential militant=2	year
TIME STEP = 1	year
Total associated gas= INTEG (associated gas-gas flared, initial value of total associated gas)	tons
total cost of a project=average cost of a project+variation	Naira/year
Total pollution= INTEG (gas flare pollution+oil pollution, initial value of total pollution)	tons
transparency measure policy=STEP( -0.2, 2020 )	Dmnl
Unemployed youths= INTEG (increase in potential militants-exit from unemployment-rate of unemployed youths, initial value of unemployed youths)	Person
Unproved crude oil reserves= INTEG (-rate of crude oil discovery,6e+007)	barrels
value of crude oil sales=average oil price*crude oil sales	Naira/year
value of oil from production shut in=production shut in*average oil price	Naira/year
Vandalism= INTEG (increase in vandalism-decrease in vandalism, initial value of vandalism)	Facilities
variation=annual incremental cost of project*average annual inflation rate*project delay	Naira/year
youth population=Population*fraction of youth population	Person

**APPENDIX G: Data from various corruptions index scores from TI (2000-2013).**

<b>Year</b>	<b>Score</b>	<b>Rank</b>	<b>NOC</b>	<b>Year</b>	<b>Score</b>	<b>Rank</b>	<b>NOC</b>
2000	1.2	90	90	2007	2.2	147	179
2001	1.0	90	91	2008	2.7	121	180
2002	1.6	101	102	2009	2.5	130	180
2003	1.4	132	133	2010	2.4	134	178
2004	1.6	144	145	2011	2.4	143	182
2005	1.9	152	158	2012	2.7	139	174
2006	2.2	142	163	2013		144	177

**APPENDIX H: Overview of sources of data and rational behind them**

<b>Data source</b>	<b>How</b>	<b>Why</b>
<b>Interviews</b>	The questions in the semi-structured interviews were open-ended and specifically focused to refine and obtain a deeper understanding of the various challenges facing the industry in terms of revenue generation from various stakeholders.	To gain an understanding of individual perceptions, refine understanding from literature review and in order to generate a deeper understanding.
<b>Focus groups</b>	Combined interactive session of relevant stakeholders were held to obtain a broader view of their experiences of challenges facing the industry as it relates to revenue generation and also the validation and modification of the model.	View the perceptions and ideas of a significant sample size and at the same time saving in terms of both resources and time. In order to obtain a deeper understanding of variety of interpretation of reality regarding the model.
<b>Literature</b>	Literature search was extensively conducted using the library facilities of the university, e.g. books and articles through both manual and electronic channels. Keywords used for searching relevant materials were crafted as they relates to the themes identified	To acquire and extensive appreciation of holistic issues regarding the myriad of challenges facing revenue generation in the Nigerian petroleum industry. Also to situate current research in relation to previous research work.

**Sources of data used in this research work.**

## APPENDIX I: Definition of variables in the policy sensitivity analysis

Definition	Link	Data support	Literature support
<u>Average time taken for repairs</u> : means the taken to repair a single facility vandalised by militants.	Average time taken for repairs affects rate of repairs		Focus group interviews
<u>Militants</u> : is an aggressive and active tendency embarked upon towards the support and/or defence of a given cause (usually political) mostly to an extreme extent.	Militant affects increase in vandalism		Inokoba and Inbua (2010)
<u>Vandalism</u> : refers to serial attacks meted out to oil facilities by militants in the Niger Delta.	Vandalism affects rate of oil spill		Ajaero (2009)
<u>Rate of oil spill</u> : is the loss of oil as a result of destruction of oil facilities and installations leading to pollution.	Rate of oil spill affects oil pollution		Ajaero (2009)
<u>Pollution</u> : is the destruction of the environment as a result of crude oil spill and gas flare.	Pollution affects means of livelihood		Owolabi (2012), UNDP (2006)
<u>Means of livelihood</u> : this refers to the main occupation of the inhabitants (people) in the oil producing region. The main occupation is farming and fishing	Means of livelihood affects poverty		Jike (2004)
<u>Poverty</u> : this refers to the state of lack of basic needs occasioned by the destruction of means of livelihood of the inhabitants of the oil producing region.	Poverty affects communal unrest		Okafor (2011)
<u>Community unrest</u> : are the periodic hostilities between oil companies and host communities	Communal unrest affects production shut in		Inokoba and Imbua (2010)
<u>Production shut in</u> : suspension of operation as a result of vandalism and community unrest.	Production shut in affects potential production		Aiyedogbon (2012)



<u>Potential production</u> : this is the quantity of crude oil that can produced devoid of challenges affecting production	Potential production affects actual production		UNDP (1996)
<u>Actual crude oil production</u> : this is the quantity of crude oil production as a result of challenges affecting what can potentially be produced	Actual production a affects cumulative crude oil produced		UNDP (1996)
<u>Cumulative crude oil produced</u> : this is the accumulation of actual crude oil production less crude oil theft and crude oil sales	Cumulative crude oil produced affects rate of oil theft, cumulative crude oil produced affects crude oil sales.		Paki and Ebienfa (2011)
<u>Rate oil theft</u> : illegal process of taken away crude oil by militants.	Rate of oil theft affects illegal money		Paki and Ebienfa (2011)
<u>Illegal money</u> : this is the money generated from sale stolen crude oil	Illegal money affects rate of purchase of arms		Paki and Ebienfa (2011), Asuni (2009)
<u>Rate of purchase of arms</u> : is the acquisition of weapons by the militants for their militant activities	Rate of purchase of arms affects proliferation of arms		Paki and Ebienfa (2011)
<u>Proliferation of arms</u> : it is the degree of spread of weapons among youths in the region.	Proliferation of arms affects rate of militants		Asuni (2009)
<u>Rate of gas flare</u> : is the quantity of associated gas discharged into the environment in the process of crude oil production.	Rate of gas flare affects gas flare pollution		Afinotan and Ojakorotu (2009)