

**Applying System Dynamics Modelling To Building Resilient Logistics: A
Case of the Humber Ports Complex**

A thesis submitted

By

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MBA (Log.), B.Ed. (Math/Sc), Dip. Math

To

**The Hull University Business School's Logistics Institute in partial
fulfilment of the requirements for the degree of Doctor of Philosophy in**

Management

University of Hull

UK

2015

Dedication

To my son Robin Yaw Buor Koranteng for the enormous sacrifice he has made.

Dedications also to the less privileged of any society in the world, especially to the mustard seeds whom, for the lack of support, the perceived “haves” cite them as accursed.

The Abstract

This research employs system dynamics modelling to analyse the structural behaviour of the interactions between Disaster Preparedness, Environment Instability, and Resilience in maritime logistics chain as a response to policy change, or strategic risk management interventions, at ports on the Humber Estuary.

Port authorities, logistics operators, agencies, transporters, and researchers have revealed that disasters lead to interruptions in free flow of supply chains, and has the potential to disrupt the overall performance of a logistics chain. There is strong evidence about the rise in frequency, magnitude, and disruption potentials of catastrophic events in recent times (e.g. 9/11 attack, the Japanese earthquake/Tsunami and the aftermath nuclear disaster, Hurricanes Katrina and Haiyan, Super Storm Sandy, and many more). However, it appears that risk managers are not able to anticipate the outcomes of risk management decisions, and how those strategic interventions can affect the future of the logistics chain. Management appears to misjudge (or miscalculate) risks, perhaps due to the assumed complexity, the unpredictability of associated disruptions, and sometimes due to individual managerial approach to risk management. The uncertainties and states assumed notwithstanding, investors and regulators have become increasingly intolerant for risk mismanagement. Shipowners and port authorities tend to managing cost instead of managing risk. Hence they appear to invest little time and fewer resources in managing disruptions in their logistics chains even though they seem to frequently conduct risk assessments. We suggest that disaster preparedness that leads to resilience in maritime logistics chain is the best alternative to preventing or reducing the impacts of disruptions from catastrophes.

We aim at improving current level of understanding the sources of disruptions in port/maritime logistics system through analysing the interdependencies between key variables. The dynamic models from this research have revealed that there is strong influence relationships (interdependencies) between Disaster Preparedness, Environment Instability, and Resilience. We found that potential sources of disruptions along the spokes of maritime logistics system can be port physics related, however the subtle triggering factors appear to be port size related. We also found that policy interventions geared towards risk management have the potential to produce unintended consequences basically due to unacknowledged conditions. Thus the relevance of the research and the SD models was to provide strategic policy makers with real-time decision evaluation tool that can provide justification for acceptance or rejection of a risk management intervention prior to decision implementation

Declaration

I hereby declare that I have carried out this research and that this thesis is entirely my work.

John Kwesi Buor

Acknowledgement

The journey has been long, the road has been narrow and sinuous, the terrain has been dangerously undulating, and very difficult for the “lone-ranger”. However, like a conqueror, I cannot pocket the cake of success alone without acknowledging people, institution, and other stage-setters, but for whose immense contributions and support my journey to the academic world and for that matter, this thesis would have remained a mirage. Firstly I express a measureless gratitude to the HUBS whose scholarship offered me the chance to study in the UK.

Next, I would like to thank the committee members for my thesis defence (viva), especially Dr Khalid Bichou and Dr Alessandro Creazza. Your brilliant comments, fair critiques, and pieces of advice during my thesis defence and thereafter, helped me to chisel the rough edges in order to add finesse to this piece of artefact. Above all, your expertise is a wakeup call on me in my early career as a researcher. Professor David B. Grant, I appreciate your role in steering the affairs of the committee and thereafter, the materials you mail to me for review. I share the credit with my supervisor Professor David A. Menachof who keeps his smiles and welcomes my ideas in an experienced, friendly, but critical manner even in the very stressful moments. David, your efforts, coupled with that by the CILT members (especially Geoff Catterick) has been very substantial in making access to people at the top echelon in the industry where I did my interviews possible.

In addition to the above, the following academics whose attitude and ingenuity have influenced me positively deserve commendation. I am indebted to Dr Raphael Akamavi for your regular encouragement, general advice, and constant reminder of my responsibilities as PhD student. Your personal experience and influence kept me working even when there seem

to be no hope in sight. When everyone else seem to have forgotten of my existence as a student, Raphael kept in touch to ask about my weekly and monthly progress as well as to spur me on with word such as “the thesis is your own; work on”. It is also a great pleasure for me to reckon the role of Professor Terry Williams (Dean of HUBS) for breaking his tight schedules to help me reshape my model. Thank you Terry for your arrangement which enabled me to have a face-to-face discussion with one of the originators of the SD modelling tool (Professor Emeritus George Richardson) whom I referenced copiously in my analytic chapter. Collectively, I say thank you to Terry and George. Many thanks to Professor Gerald Midgley and Dr Jennifer Wilby, both of you took personal interest in my research topic and offered me the opportunity to present in my first ever international conference at the ISSS. Gerald, the articles you mailed to me on systems sciences and cybernetics have opened a big window for me in my research. I cannot overlook the dexterity with which Professor Chee Wong performed the first surgery on my upgrade report. Prof, your critical lens won me a lot of admirations from those present at my upgrade presentation. I appreciate the stage you set for me to really understand my work and to become independent in my research work. I also remember how an interview turned into an interesting 3.5hour lecture on ‘port vs environment relationship’, without both of us knowing that we had spent that much time. Professor Mike Elliott of the Institute of Estuarine and Coastal Studies (Marine biologist), I sincerely appreciate your work which contributed immensely to my research. Mike I have completed this chapter, but I have not ended the challenge to take up research in the field of logistics and environmental science.

Furthermore, I must also acknowledge the contributions made by my research colleagues who kept me company even in the cold nights and sometimes, in the hostile conditions at our studies centre. Your academic arguments, the challenging problems you brought forth, and the mutual assistance we shared have broaden my mind, and have even challenged me on

several occasions to cross novel fields in my quest to understand our world. Special names pop easily in this category: Godfrey Nyamrunda, Daniel Ufua, Abraham Adu-Boateng, Roland Getor, Bola Babajide, Yvonne Ndefo, Xiaolan Chen, Piyya Muhamm, Shehzad Ahmed, and many others. You spurred me on to become a good leader among us.

There are some very special personalities who made gold out of the dust in me and deserve my most heartfelt gratitude. A special appreciation goes to my former middle school head teacher, the late Mr GKZ Abrompah, who personally paid for my 'common entrance examination fee'. Your effort has paid off today and has opened the education gateway for me. I cannot measure the wonderful role that the late Mr SK Appreku also played in my secondary school life. I live to attain heights by your making. May your individual souls rejoice with me whiles your bodies rest in perfect peace.

I owe my life and everything I can do or acquire to the one I knew as my Grandmother - the late Madam Rosa Adjontey. Thank you grandma for making me a humble and an appreciative man. To the rest of my family (both nuclear and extended), words cannot express how grateful I am to you. Your prayers and support have propelled me on to this level. You have done an incomparable work and I know more of your prayers is needed even as I expand my horizon. Most especially, and the greatest of all, my deepest gratitude goes to Mr and Mrs Diop Frimpong for being there for me whenever I called. You have been my source of inspiration. Even though I have none of my own, you fit well into the shoes of my parents and you took me as your own. For those who shut their doors at the sight of me, thank you very much for not letting me in and for making life choices look so easy for me. But for your action, I would have gone into sleep thinking that that is the end of my journey. You did not know that your cruel treatment was rather going to open many more and bigger doors than what you shut behind you. Thank you all.

Abbreviations

HE	Humber River Estuary
HPC	Humber Ports Complex
SD	System Dynamics
CLM (D)	CAUSAL Loop Mapping (Diagram)
ABP	Associated British Ports
AAK UK Ltd	AarhusKalshamn UK Ltd
SC	Supply Chain
SCM	Supply Chain Management
SCV	Supply Chain Vulnerability
SCS	Supply Chain Security
UNCTAD	United Nations Conference on Trade and Development
GDP	Group Definition Practice [This is different from the economic definition which stands for Gross Domestic Product]
MARPOL	Marine Pollution [This is the international convention for the prevention of pollution from ships – convention adopted in 1973 as modified by 1978 protocol]
IMO	International Maritime Organisation
LPG	Liquefied Petroleum Gas
MSD	Musculoskeletal Discomfort
LGV	Large Goods Vessels
HSE	Health and Safety Executive
CRO	Chief Risk Officer
VTS	Vessel Traffic Service
HES	Humber Estuary Service

UNDRO	United Nations Disaster Relief Organisation
DRI	Disaster Risk Index
UNDP	United Nations Development Programme
COR	Conservation of Resources
JIT	Just-in-Time
IEEE	Institute of Electric and Electronic Engineers
DE	Discrete Event simulation modelling
AB	Agent Based simulation modelling
DS	Dynamic Systems modelling
CEO	Chief Executive Officer
CFO	Chief Finance Officer
COO	Chief Operations Officer
F2F	Face-to-face
UKDA	UK Data Access policy
HUBS	Hull University Business School
GT	Grounded Theory
CILT	Chartered Institute of Logistics and Transport
DP	Disaster Preparedness
IPRA	Increasing Preparedness due to Resource Accumulation
DPRU	Decreasing Preparedness due to Resource Usage
PEI	Port Environment Instability
RCI	Rate of Change in Instability
RPL	Resilient Port Logistics
IRPL	Increasing Resilient Port Logistics
DRPL	Decreasing Resilient Port Logistics

CPRA	Change in Preparedness due to Resource Accumulation
CPRU	Change in Preparedness due to Resource Usage
DRPL	Decrease in Resilient Port Logistics
I[C] T	Information [Communication] Technology
EIA	Environmental Impact Assessment
AP	Appropriate Assessment
GPS	Global Positioning System
EDI	Electronic Data Interchange
RFID	Radio Frequency Identification
SPA	Statutory Port Authority
BP	British Petroleum
ISO	International Organisation of Standards
ISM	International Safety Management code [This is the code for safe operation of ships and for pollution prevention as adopted by the assembly as may be amended by the organisation]
ISSS	International Society of Systems Sciences

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Chapter One: Research Overview

1.1 Introduction

This research is set to examine the potential causes of disruptions in the maritime logistics and supply chain system. Stopford (1997) defines the 'Port' as: “[...] *geographic area where ships are brought alongside land to load and discharge cargo; usually a sheltered deep water area such as the bay of a river mouth*”. Maritime transport and logistics [or maritime logistics] is part of the larger logistics chain that enhances distribution of goods and services across the globe. The scope of this research covers only water/ocean surface transport plus the shore-side infrastructure and personnel together which facilitates cargo handling (and passenger movement) that is essential to maintain efficient (cost-effective, reliable, and seamless) operation. Specifically we shall focus on the industrial cluster of ports on the Humber River Estuary (HE) also known as the Humber Ports Complex (HPC). In the vital link of global logistics, ports are the nodes (hubs), while shipping networks are the links (spokes) that connect the supply chain parties for the enhancement and promotion of competition, efficiency, development, and growth of global trade and economy. Generally, over 80% of global trade (by volume) is seaborne. Unfortunately, shipping also seem to be the most exposed (vulnerable) mode of transport to natural and anthropogenic hazards (risks) that can lead to frequent accidents and disruptions in the logistics system anywhere along the supply chain network especially on the spokes. The complexity in planning and control systems is increasing (Chung and Snyder, 2000), and the ability to forecast internal/external activities (Koh et al., 2000) of the

maritime logistics chains is becoming increasingly difficult. Additionally, logistics chains have become elongated, and more competitive (Bose, 2006). These appear to make accurate predictions of risks and response to operational disruptions in port/maritime logistics rather difficult. Arguably one of the biggest management dilemmas of recent times is how to develop the understanding for the causes of disruptions in logistics/supply chains, and the factors that influence (Melnyk et al., 2009) their occurrences. Port authorities and logistics companies have revealed that disasters may lead to interruptions in free flow of supply chains (Tang, 2006) that can also disrupt the overall supply chain performance (Hendricks and Singhal, 2003, 2005a; 2005b). Many practitioners and researchers have also acknowledged the effects that supply chain disruptions have on the overall supply chain performance (Eskew, 2004; Frohlich and Westbrook, 2001; Narasimhan and Jayaram, 1998; Shin et al., 2000). Additionally there is strong evidence that both natural and anthropogenic catastrophic events are becoming more frequent (Coleman, 2006); increasing both in their potential for disruptions and in magnitude (Blackhurst et al., 2005). However most investors [including the port authorities and ship owners], invest little time and fewer resources into risks management, even though they appear to regularly conduct risk assessments (Rice and Caniato, 2003; Zsidisin et al., 2004; Zsidisin et al., 2000). It seems that disaster preparedness leading to resilience is an alternative strategy to overcoming supply chain disruptions (Bowman, 2011; Melnyk et al., 2009) and to gaining competitive advantage.

The broad aim of this research is to improve the current levels of understanding potential causes of disruptions in port/maritime logistics chains using system dynamics

(SD) simulation models. We selected the Humber Estuary (HE) as case study from which we built models that can help key stakeholders to learn how certain risk management decisions can affect the interactions between environment, disaster preparedness, and resilience of a maritime logistics chain. Though organisational resilience (in the dimensions of vulnerabilities and capabilities) comes with a price that can erode profits (Pettit, 2008), yet the lack of resilience may even go beyond profit erosion, to exposing any company to total failure and possible extinction. Several authors have defined resilience variously in different contexts, and also in different perspectives, according to their fields of orientation. For example, in supply chain management, Christopher and Peck (2004) define resilience as “the ability of a system to return to its original state or move to a new desirable state after being disturbed” by a stressor [e.g. accidents and their resultant disruptions in a supply chain]. A couple of definitions for resilience, including psychology, ecology, and socio-scientific perspectives shall emerge later in the literature review.

Currently the following trends in port/maritime logistics appear to manifest: a growing interest in port decongestion and regulations that indirectly lead to the creation of large inventory on the high seas; increasing vessel size (gigantism) as enhanced by technological advancement, innovation, and quest for high efficiency in performance; growing cultural fusion leading to uniform consumer taste and preference thus enhancing global production; expanding global trade by volume of goods and services to new regions. The vastness of the sea and the apparent borderless trade it promotes has increased the vulnerability of the maritime industry to changes in geological dynamics (earthquakes and tsunamis) meteorological conditions (sharp contrast in

water and weather conditions), political (terrorism, and conflicts), and legal (environmental regulations, e.g. the MARPOL conventions) situations without any/adequate prior warning. These changing trends have the potential to leave stakeholders in the maritime industry unprepared for systemic risks. What seems to contribute to the lack of preparedness may result from risk perception in the logistics/supply chain (Mitchell, 1995; Zsidisin, 2003); management understanding and definition of constructs such as disaster, disruption, emergency; and the perceived security (Lee and Whang, 2005; Prokop, 2004) in terms of the external environment and its influence on the logistics infrastructural capacity to cope with significant changes (policy change or strategic interventions). The solution appears to lie in management capacity to anticipate the outcomes of risk interventions prior to decision implementation.

1.2 Background of the Research

Logistics/supply chain activities play very important role in UK's economy. This role ranges from energy supply chains, through food distribution, down to waste management. The logistics industry is worth £74.5billion to the UK's economy and employs some 2.3million people across 190,000 companies nation-wide (DfT, 2008). In the Yorkshire/Humber region, the logistics industry employs some 91,000 people (i.e. 9% of UK's total logistics job), contributes £4.2billion to the region's economy, and hosts some 6925 companies (Regional Economy Model Experian Jan, 2010; www.isn-uk.org) spread across the region.

Currently, seaborne trade is the UK's most important international freight handling method (Dobson and Reed, 2009). Out of 120 active ports, 15 of them handle some 80% volume of freight (DfT, 2008); a third of which is handled by the ports of Southampton and Felixstowe. The Humber Ports Complex (HPC) as a unit is the most significant and busiest ports complex in the UK making over 40,000 shipping movement per year (www.TIDE-project.eu). The HPC also accounts for about 33.3% seaborne traffic by tonnage in 2004 (Dobson and Reed, 2008) with the major freight being solid bulk (coal, wood, agro-products, steel, project freights), and liquid bulk (petrochemicals) rather than container freight. Records indicate that the combine bulk freight handled by the ports of Grimsby and Immingham is 17% of UK's total 86 million tonnes. It is also on record that Immingham alone ranks the 16th (i.e. 1.5% market share) largest port in Europe in terms of liquid bulk handling, and 7th (i.e. 2.3% market share) in dry bulk handling (Notteboom and Rodrigue, 2009). Hull is the leading port for handling soft wood products in the UK and is the only passenger transport port in the HPC. Port of Hull handles some 10million customers a year to and from the two main destinations of Zeebrugge and Rotterdam (P & O Ferries, 2008).

Sometimes firms choose to relocate to sites where infrastructure and positioning can have significant influence on profitability, maximum vehicle turn-around, and minimum traffic congestion (Reed, 2008)¹. Located on the trade corridor running from Ireland to the Baltic States, and opened to the North of continental Europe, the HPC

¹ It is difficult to develop a measure of regional road congestion because it may not be the entire route that will be congested. Reed (2008) notes that many routes close to A and B roads may be underutilised: therefore traffic congestion usually refers to segments of the road network rather than the entire road system (Stroper, 2004)

has many other economic potentials. For instance the HPC is linked to major conurbations in the North England by M62 corridor; there is abundant skilled labour at relatively low cost; and a large customer size of over 170 million that is suitable for port-centric (Mangan et al, 2008) or near-porting (Sherman et al, 2010; Menachof, 2010) activities. Further discourse of the HE/HPC's unique feature has been done in section 2.2.6 of this research.

Judging from the wide variety of shipping activities, coupled with the apparent central interconnectivity role of the HPC in terms of UK's trade (both internal and external), one may conclude that any major disruption in the logistics chain can affect many social and economic activities of the region and the UK as a whole.

1.3 Research aim and objective

In line with the last paragraph above, we aim at applying SD modelling to analyse the interdependencies between the environment, disaster preparedness, and resilience as policy changes (strategic risk management interventions) are implemented. Ultimately, the research should improve current level of understanding the causes of disruptions in port/maritime logistics chain. To achieve this lofty aim, we considered the following objectives:

Objective 1

To identify potential risks/hazards in the logistics chain of ports on the HE.

Objective 2

To analyse the structural behaviour of the interactions between environment instability, disaster preparedness, and resilience, as different policy changes (strategic interventions) are tested on the logistics network of HPC

Objective 3

To employ models to help risk managers in:

- a. testing for robustness and efficacy of strategic interventions (policy change) prior to their implementation
- b. communicating (debate) potential outcomes of policy interventions prior to decision implementation

1.4 Research problem/questions

Apparently, one can draw a correlation between risk perception, stimulus for response to warning, engagement in protective/preventive measure (Kirschenbaum, 2006; Peacock et al., 2005; Slovic, 2000), and industry resilience. Lindell et al. (2012) as well as Lindell and Perry (1992) acknowledge that how one perceives risk is related to a previous encounter as well as the anticipation for future occurrence of that risk event. This notwithstanding, Peacock et al. (2005) argue that one's previous experience rather reduces the level of risk perceptions and consequently the preparedness for disasters especially when the expected event did not happen. It also seems that when preparation is more than the risk encountered entity tends to feel invulnerable (Fahey et al., 1977; Millstein and Halpern-Felsher, 2001; Norris et al., 1999) and perhaps become less alert when the actual event occurs. Obviously, the lack

of preparedness could have direct relationship with the system's resilience to disruption. Therefore, to understand how strategic interventions (policy change) can influence port instability, disaster preparedness, and resilience, we will focus on answering the following questions:

1. What risks/hazards types prevail in the logistics chain of ports in the HE?
2. What impact can frequent policy change bring on to the port/maritime logistics industry in the HE?
3. What is the relationship between port stability, disaster preparedness, and resilient logistics?

1.5 Significance of the research

Based on literature search and interview data, it became apparent that we approached the research with a focus on the "actuals", by examining the two sides of port-environment relationships relative the location. We viewed the location effects in two dimensions:

- a. size of port operations (port capacity, number of vessels, call frequency etc.); and the
- b. Port's Physics (physical characteristics) – river/port depth, water turbidity and content, hydrologic cycle and activities of the river basin (river dynamics),

coastline activities including erosion, simultaneous sinking and isostatic rebound²).

It emerged from the field interviews that there exist a bi-directional influence relationship between the port and its environment (i.e. port is risk to environment and environment is risk to port). For example, many scholars are of the view that the construction/extension of terminals at Immingham docks increased siltation, accretion, as well as bio-pollution in that part of the Humber River. Similar episodes have been reported in relation to the construction or the extension of major infrastructure and ports elsewhere the world over. Such activities have produced both spatial and temporal dimensional effects as mentioned in Kink and Kink (1995) concerning the proposed extension of the port of Rotterdam. Knowing this relationship between the port and the environment can enhance one's level of preparedness for disruptions and the sustenance of port logistics operations even under difficult condition.

Thus models such as the ones in this research can allow systemic vigilance as well as enhance scientific debate among management (policy makers) and key stakeholders. Our models can help researchers and problem owners to test for decision outcomes and be able to communicate potential consequences in real-time (situational outcomes) based on behaviour of the graphs that will be generated under different scenarios. The understanding of such feedback dynamics and their long-term effects on systemic

² Isostatic rebound refers to the rise of land masses that were depressed (or suppressed) by huge weight of ice sheets during the last glacial period, through a process known as isostasy. The term is also associated with the rapid removal of overlying rock, via erosion, which further causes the weakened area of crustal rock to uplift from the apex of the river. These are tectonic uplifts.

behaviour may result in the redesigning and re-alignment of the logistics structures, improve change management, as well as system's performance. We expect the research findings to initiate policy changes towards increasing disaster preparedness and resilience in the maritime logistics industry. The SD approach can close the methodological gap of the quantitative - qualitative paradigmatic polarisation of research as pertains in maritime logistics security and risk management. By involving stakeholders in the model building and testing processes, model acceptability may become high; the need for strategic policy change can be laid bare to enhance seamlessly smooth transition from one intervention to another devoid of strives and antagonisms that can result in operational disruptions in the logistics chain. Authors such as Coyle (2000), Haraldsson and Ólafsdóttir (2006) and Fredericks, Deegan et al. (2008), have employed such models to model the Sahel/Sahara water crisis, Iceland's human population carrying capacity, and for the evaluation of organisational programme implementations respectively

1.6 Research limitations and constraints

By their nature, a research project cannot complete without any limitations, and so this research has inevitably faced a few constraints which we acknowledged would have affected the final outcome slightly (positively or negatively) but not to the extent that can nullify the entire research outcome. The first of those challenges was the inability to do exhaustive iterative data work as required in the Grounded Theory (GT) philosophy and also by SD modelling approach. Generally, the SD modelling process requires the researcher to work in collaboration with problem owners, to build the model in stages so that there can be full participation by problem owners. However

time constraint did not allow that to happen fully. Also, one will argue that the premature termination of data collection without going through all the stages may have produced truncation error which can affect the randomly generated numbers that translated into the nature of graphs under the simulation exercises. However we do not believe that these can affect the SD simulation models (graphs) so significantly.

Furthermore, mental modelling is the presumption that cause and effect are local and immediate. This does not allow one to think into distance and space. Having acknowledge this short fall in time horizon we suggest that future research may think of extending the time far beyond the 100 day into the future so that we can observe very long-term effect of the scenarios.

The timing for data collection was another limitation. Data was collected at the time when the ports seem to be operating below their peak volumes; at the time when many port executives were on holiday. We have to choose this period because the port authority had warned that (for safety reasons) it does not allow access when business is in full swing. The effect was that, we could not increase the number of participants we interviewed and possibly involved other volunteers at the top management positions who have experienced disaster situation in the ports within the scope of the case study.

Originally, we thought of gathering all respondents in the premises of the Logistics Institute at the Hull University Business School (HUBS) in a kind of conferences or seminars, or forum, so that we can have the actual feel of the modelling in groups to enhance the sharing of ideas till we got the desired model structure. However this was not possible because of differences in time schedules and availability by the respondents. This left the researcher with no other option than to complete the mental

models from the textual data we extracted from the interviews. It seems this could create some representation biases leading to some results being influenced by the subjective opinion of the researcher.

The small-N we involved in data collection, coupled with the state whereby a large majority of the respondents came from the docks at Port of Hull may raise the suspicion that opinions may not be wide and diverse enough as we expected at the beginning of the research. Narrations seem to be localised apart from the research being built on a single case which can be a potential set-back for research quality and generalizability. Socially desirable answers were also possible because of the use of the same constituency. For example, it was logically incorrect for a respondent to say that they have a duplicate part for every component of a large complex manufacturing plant. Though there is sign of expansion works ongoing on the site and a new plant is almost ready for commissioning at the time of the interview, the whole of the second site cannot be a backup for the existing plant.

Though there was no visible display of discrimination of any kind, however, we perceived that some of the CROs could have been more willing and less economical with words when discussing security issues if the researcher were an indigenous British, than they did to a foreign researcher.

Another limitation was that the researcher could not afford the professional version of the Vensim ® software used, we have to rely on the trial version which is good only for training purposes. This constraint affected the structure of some of the causal relationship diagrams that subsequently became the dynamic structures for the simulation processes. For example the ‘flow’ connecting PEI was intended to have

double headed arrow indicating that the same pipe represents the inflow and outflow respectively. However, the trail software was not able to represent it clearly as in the actual mental database of the modeller.

We sent interview agenda (questions) in advance to enable respondents to prepare ahead of the interview. Whereas this was a good practice, some respondents appeared to have capitalised on that to hijack the interview proceedings. However it was good we did so; judging from their non-verbal communications, some respondents found some of the questions a bit difficult even though they had access to the questions at least for one clear week ahead. For example a CRO who was interviewed on board a vessel could not answer some of the questions perhaps because in his case he did not get access to the interview questions earlier.

It is worth noting that the withdrawal from participation by two vital candidates from the Immingham Port could have affected the results. One of these key respondents was an executive from ABLE Ports whose management is different from ABP and who might have provided a different worldview all together. Even the other potential respondent may have first-hand information that may not be available to the senior member of the same ABP group in Hull even though they are all located and operate within the same industry cluster of the HE. It is also apparent that being the same person performing the same function in the same company at different location, that senior member may be privileged to have only the executive summary of events that may not give detail accounts of what exactly took place on the spot. Therefore the withdrawal by those respondents can slightly affect the research findings in terms variations in opinions.

Despite all these apparent constraints, we do not think the research outcome can be significantly compromised. One setback might have been compensated for in another step elsewhere to produce the expected results. For example, the shortfall in the interview process appears to have been compensated for in the simulation processes.

1.7 Organisation of the thesis

This section describes the route through the thesis by briefing the reader about what to expect on a chapter by chapter basis. The introductory chapter (Chapter 1) discusses the general background of the research which includes: a brief on the HE/HCP, the research aim and objectives, questions, constraints, and significance.

Chapter 2 highlights some key concept relevant to the topic in an attempt to craft understanding as well as to establish the theoretical foundation upon which the research was built so that we can answer the research questions (or problems). Therefore we reviewed several literary materials (journal articles, books, company reports, charts etc.), with the view to bringing to bare the relevant definitions/meaning of key constructs in supply chain including its management, disruption, vulnerability, risk (classification, management), and security. Further down in the literature review (section 2.2), was the discussions bordering maritime logistics including the role, ownership, management, functions, as well as trends and impact of ports on economic growth. The reader will also notice that this chapter discussed in brief the geography and profile of the HE which forms the scope of the research as well as made an effort to unearth the relation between the port and its *environment*. In sections 2.3 and 2.4, we reviewed as well as analysed the theoretical context of other two main research

constructs “*resilience*” and “*disaster*”. The review zoomed on the definitions, characteristics, causes, metrics, theories, and some management (best practices) strategies drawing from various fields. Section 2.5 distinguished among model types, and laid bare the preferred model for the thesis.

The methodology chapter (chapter 3) begun with a brief presentation of the theoretical framework of the thesis. We then proceeded to discuss the methodological design backed by literature and appropriate justifications. The research approach, philosophy, and paradigmatic orientations were duly touched on. This was followed by a detail discussion of the CLM/SD models, how they have been used elsewhere, as well as how these can be adopted in the current research. In sections 3.10-3.14, data collection and analysis protocols were detailed such that it will enable both the reader and anyone else to understand chapter 4.

The fourth chapter describes how we employed the methodological tools in chapter 3 to arrive at the research results. In some cases, details of the technique [providing further literature on the analytic tool] and its use elsewhere was given to justify its application in this circumstance. Sections 4.5-4.10 for instance details how some steps of the grounded theory philosophy aided the research to transform qualitative (textual) data into testable quantitative SD model. At the end, the behaviour of interactions between the environment, disaster preparedness, and port resilience became bare for quantitative analysis. Section 4.12 concludes the chapter by summarising the outcomes from the “extreme condition tests”.

The research finding and discussion forms the core of chapter 5. This chapter has been divided into two sections for the sake of convenience. The first part “A” seeks to

address the four main themes of the research as embedded in the research objectives and problems: identify potentially prevailing hazards in the HE; discuss the risks management strategies being followed at the moment; investigate sustainability of anticipated changes in the maritime logistics industry, and how such policy issues can affect disaster preparedness. This part addresses the first research objective as well answers the first research problem (question). The second part “B” considers the quantitative relationships between the key research variable (environment, disaster preparedness, and port resilience) and how policy change/interventions (as auxiliary variables) can influence the structural behaviour of each of the state variables (first separately, then collectively) as portrayed in the respective graphical representations of the subsystems. The chapter ended with a brief discussion on the need for disaster preparedness in the logistics chain. This part addresses the second and third research objectives and answers research questions two and three.

Finally, we summarised the whole thesis in chapter 6 by restating the research aim, objectives, and problems. This final chapter also summarises the research methodology and wrapped up with a brief on the research finding. The chapter ends with a conclusion based on the research results and the way forward in future research.

Chapter Two: Literature Review

This second chapter of the thesis reviews what has already been done in the fields and attempts to lay the foundation for the research. We reviewed key and relevant supply chain concepts, and went ahead to discuss contemporary issues in port/maritime logistics domain from which the relationship between port and its environment became revealed. We reviewed books, journal articles, charts, etc. (documentary evidence). Engaging search engines such as Google Search, Google Scholar, ESCO, and ProQuest, we looked for key words that are relevant to our research area such as ‘risk’, ‘disaster’, ‘resilience’, and phrases like ‘disaster preparedness and resilience’, ‘maritime logistics risk and security’, ‘maritime policy and disaster management’ etc. These are contemporary issues that practitioners and academia discuss at meetings, seminars, workshops, conferences and others. We read abstracts and conclusions of relevant materials from which we built the research constructs, theories, and the research questions.

2.1 A review of relevant concepts in supply chain

2.1.1 Defining supply chain (SC) and supply chain management (SCM)

Stevens (1989) defines supply chain as ‘a system consisting of material suppliers, production facilities, distribution services, and the customers who are all linked together via the downstream feed-forward flow of materials and services [*deliveries*], and the upstream feedback flow of information [*orders*]’.

It is believed that the essence of a supply chain is to integrate its components in order to enhance systemic operational efficiency, profitability, and competitive positioning of a firm and its partners (Cooper et al., 1997). Apparently, the notion of supply chain integration is further stressed in Christopher and Peck (2005) who posit that [...] *“today’s supply chains are not simple linear chains or processes, rather they are complex networks upon which products and information flow within and between nodes in a variety of networks linking organizations, industries, and economies”*. Therefore supply chains no longer exist as separate entities (Drucker, 1998; Lambert and Cooper, 2000), they work together as dynamic network of interdependent (Håkansson and Snehota, 1989) system (Min and Zhou, 2002) entities which aims at creating a thorough tunnel for the three flows of logistics and supply chains³ (Christopher, 2005). The network may be composed of transporters, retailers, distributors, suppliers and storage facilities as well as the logistics infrastructure which can be horned together to promote the manufacture, delivery, and sales of an item.

Deductions from definitions for supply chain suggest that the efficient management of these activities can offer organisations the opportunities to reduce cost, cut down product lead-time, and improve quality of performance. It therefore upholds that supply Chain Management (SCM) is *“the systematic or the strategic coordination of traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of*

³ The three flows of logistics and supply chain include: information, product/material, and financial flows according to Christopher (2005)

improving the long-term performance of the individual companies and the supply chain as a whole” (Mentzer et al., 2001). The managerial ability to integrate and coordinate this complex network of business interactions and interrelationships among members in the chain leads to the ultimate success (Drucker, 1998; Lambert and Cooper, 2000). Thus it seems that the successful supply chain integration is heavily dependent on accurately forecasting, rapidly shared information plus resources among the entire membership of the supply chain in an uninterrupted manner.

2.1. 2 Supply chain disruptions

Disruption occurs when an event interrupts the flows in the logistics chain, resulting in an abrupt cessation of the movement of goods/services (Wilson, 2005). Many authors further explain that supply chain disruptions are usually unplanned and unanticipated events that interfere with the normal flow of goods and services within a network (Hendricks and Singhal, 2003; Kleindorfer and Saad, 2005; Svensson, 2000).

From a strategic management perspective, matching (or aligning) organizational resources with the organization’s context, and especially aligning to environmental opportunities and threats, is a major task for decision-makers (Miles et al., 1978; Venkatraman and Camillus, 1984). It has become clear with increasing concern about the rise in risks of disruptions in today’s logistics chain, particularly the negative impact that disruptions can have on the entire logistics chain’s performance in recent times (see Frohlich and Westbrook, 2002; Narasimhan and Jayaram, 1998; Rosenzweig et al., 2003; Shin et al., 2000). The trend of development can be

attributable to the strong evidence that catastrophic events are becoming more frequent (Coleman, 2006) in their occurrence. For instance Elkins et al. (2005) observe that there has been an increase both in the potential for disruptions and in the magnitude of catastrophic events in supply chains. Likewise, Munich Re (2007) also stated in its annual report on natural hazards that *'since 1950, there has been a long-term upward trend in the number of events and the amount of economic and insured losses'*. As a consequence, disruptions underscore the importance of supply chain risk management concepts and measures. Hendricks and Singhal (2003, 2005a, 2005b) and many other scholars have shown that severe disruptions have substantial negative consequences on the health of the affected logistics chain.

Studies in recent times have further revealed that when disruption occurs anywhere in a supply chain, it could have direct effect on the entire organisation's ability to continue operations, and its efforts to provide goods and services to the end-user (Jüttner et al., 2003). Some authors (Braithwaite and Hall, 1999) even posit that the effects of disruptions can be so pronounced in a supply chain such that it may extend to several members of the logistics/supply chain tiers. In maritime logistics, the effect may spill over to engulf different companies, different geographical boundaries, and even different cultures. Consistent with this proposition, Stauffer (2003) states that disruptions have the consequence of exposing firms within the supply chain or even the whole economy to operational and financial risks. For example in 2002 the Longshoreman Workers' Union strike at a USA West Coast Port, interrupted transshipments and deliveries to many US-based firms, apart from it forcing port operations and schedules to go into comma for at least up till six months after the

strike had ended (Cavinato, 2004). Similar effects have been experienced during 9/11 terror attacks and the Japanese earthquake/tsunami of March 2011. Countless events of this nature have been recounted elsewhere the world over. Perhaps it is based on such findings that Hendricks and Singhal (2003) speculate that it could take an average of more than two years for impacted companies to recover from major supply chain failures.

Disruptive events within a logistics chain can also impact negatively on the financial capabilities for affected individual organizations in the supply chain. For instance Knight and Pretty (1996) as well as Hendricks and Singhal (2003, 2005a) report that some publicly traded firms, have had their stock market values declined as large as up to 10% of total capitalization as shareholders react to announcements of some disruptive events. As a further example, Latour (2001) reports that Ericsson lost \$400 million due to disruptions in deliveries of computer chip from the Philips plant in New Mexico due to fire outbreak at the plant. The exact cost of supply chain disruptions cannot be quantified, however an attempt by Rice and Caniato (2003), through a survey on a single firm, pegged the estimated daily cost impact of a single disruption on one firm's supply network in the neighbourhood of \$50-\$100 million per day. Though extant literature on supply chain disruptions have not been able to calculate the exact cost figures, it has provided a picturesque view of related issues in the field such as supply chain disruption and risks management (Chopra and Sodhi, 2004a), supply chain disruption and vulnerability (Svensson, 2000), supply chain disruption and resilience (Sheffi and Rice, 2005), as well as supply chain disruption and business continuity planning [*or disaster preparedness*] (Zsidisin et al., 2005).

Williams et al (2008) and several authors in the field conclude that supply chains will continue to face or suffer disruptions and attacks (Sheffi, 2002) therefore disruption/disaster preparedness through proper planning is necessary (Hale and Moberg, 2005). Preventive security measures (Zsidisin et al., 2005), rapid response (Hale and Moberg, 2005; Sheffi, 2002; Zsidisin et al., 2000), and mitigation plans that will lead to rapid recovery from disruptions is necessary in a logistics network. Arguably, researcher assert that well prepared and resilient logistics chains will be able to anticipate disruptions (in their supply chains as well as minimise their impact through proactive risk-mitigation steps) than their less prepared and less resilient counterparts.

Following from the above arguments, we note that both public and private (as well as humanitarian) logistics entities will benefit from understanding how organisations can improve performance in a sustainable manner if they can eliminate (or reduce) disruptions in their logistics chains. Our research findings reveals the relationship between the environments⁴, preparedness for risks of disruption (disaster), and port logistics resilience, such that management can adjust intervention strategies in order to be able to mitigate looming crisis before they occur. It seems the level of disruption and the entity's capacity to proactively mitigate them is a function of the network's vulnerability to risks.

⁴ Many authors have noted that the environment is a major determinant to the type of risk/disruption event of a region and hence the kind/level of preparedness an entity must put in place.

2.1.3 Supply chain vulnerability (SCV)

Vulnerability issues have attracted considerable attention from academics and consultants across the world (Brindley, 2004; Hallikas, 2003; Kisperska-Moron and Klosa, 2003) as well as from practitioners of logistics and supply chain. The development of interest in SCV has come about as a result of increases in discussions on supply chain risk, and risk management (Peck, 2006). Vulnerability has been explicitly referenced in many growing fields such as in; corporate governance (Marshall and Gurr, 2003), business continuity management (Power et al., 1999), emergency planning and national security (Gaddum, 2004).

Svensson (2002) defines SCV as: “*exposure to serious disturbances, arising from risks within the supply chain as well as risks external to the supply chain*”; also as “*a condition that is caused by time and relationship dependencies in a company’s activities in a supply chain*”. It therefore stands right for one to say that SCV is linked to risk, in the sense that something that “is at risk, or is vulnerable, can most likely be lost [to a catastrophic event] or damaged” (Haywood and Peck, 2003; Peck, 2005). Peck (2005) states further that “what is at risk” could be the performance, the survival of a process, vital assets, infrastructure, an entire organisation, an inter-organisational network, an economy, or a society. One will agree that SCV is perhaps indeterminate, it is event-dependent, and analogous to entity’s susceptibility to risks that are disruptive to the logistics chain.

Despite its importance, there is still no clear empirical meaning and managerial approach to the concept of vulnerability in supply chain (Jüttner et al., 2003). However, literature shows an increasing interest in more systematic and structured approach to conceptualise vulnerabilities and supply chain risks in recent years (e.g.

Johnson, 2001; Lindroth and Norrman, 2001; Sheffi, 2001; Svensson, 2000, 2002; Zsidisin et al., 2000). As a result, Wagner and Neshat (2010) identify four causes of increasing interest in SCV. They include: increase in disaster intensity in recent years; supply chains becoming more complex; efficiency-driven supply chains that overly rely on lean and agile concepts; and the fierce competitive pressure that could be experienced under calculated risk condition. We note that some of these same points have been mentioned in Coleman (2006), Chung and Snyder (2000), Koh et al. (2000) and many others. We note that vulnerability is highest when both the likelihood and the impact of risk of disruption are high⁵ (Sheffi, 2001). Arguably, 9/11 has revealed that logistics/supply chain disruption can manifest in different forms (such as delays, information and network failure, capacity failure, and many others) which occur both from within and/or external to many organisations (Chopra and Sodhi, 2004). Flows in logistics chains can suffer disruption if the system's vulnerability continues to grow high. We acknowledge that disruptions in supply chain are costly (Hendricks and Singhal, 2005). Consequently there is the need to assess and understand (review) the impact of disruption on logistics chains' operations so that entities can devise strategies to reduce the effects of those impacts. Wilson (2005) allude that disruptions can occur in a supply if it is vulnerable to natural events (earthquake, climatic events, volcanism etc.), or human factor (terrorism, and political instability), or both. Therefore it requires preparedness (or advance planning) for uncertainties if organisations wish to reduce risk of disruptions, or wish to improve

⁵ Further explanation emerges under the subheading risk and risk management below.

resilience in their logistics chains. However, Pettit's (2008) claim that organisational resilience comes with a price that can erode profits seems not only to be right, but we add that the lack of resilience also has the potential to expose a company to total failure. In conclusion, Pettit suggest that resilience should be assessed in the dimensions of company's vulnerabilities and capabilities: where vulnerability assesses the fundamental factors that make an enterprise susceptible to disruptions, while the capability examines the attributes that enable an enterprise to anticipate and overcome disruptions (i.e. disaster preparedness).

2.1.4 Supply chain risks and risk classification

Series of researches have been conducted into risk management in various fields in an attempt to devise strategies that can lead to mitigation against occurrence of incidents (see Cachon, 2004; Chen et al., 2000; Lee, 2002; Lee and Billington, 1993; Lee et al., 1997; Levy, 1995; Sterman, 1989; Zsidisin and Ellram, 2003). According to the classical decision theory (cited by Christopher and Peck, 2004), risk is "*the variation in distribution of possible outcomes [impact], their likelihood, and [their] subjective values*". In terms of how much is lost or damage (or the impact) to a business, Christopher and Peck define 'risk' as the product of the probability of a given hazardous/catastrophic event occurring and the severity of loss on the system. Many other definitions of 'risk' exist from various fields including: business risk, economic risk, logistics/supply chain risk, social risk, political risk, environmental risk, safety

risk, investment risk, and many others. In all these fields, it appears that risk is conceptualised as the sum of some “uncertainty” and a “loss (or damage)”⁶ to be suffered by the entity due the occurrence of an event. In relation with the popular definitions by the authorities above, one will infer that the variations and the likelihoods emanate from the lack of anticipation of the outcome of an event (uncertainty).

However in the context of SCM, ‘risk’ is “*the potential occurrence of an incident in a supply chain which can lead to the chain’s inability to meet customer demands*”, (Zsidisin et al., 2000). The cause of such variations (occurrences) could be attributable to natural disaster, or human induced causes (Atkinson, 2006), or both. Such variations (or incidents) may include: hurricanes, earthquakes/tsunamis, bush fires, climate change and floods, legal liabilities (Giunipero and Eltantawy, 2004), poor demand/supply forecast resulting from lack of proper coordination (Christopher and Lee, 2004), unstable price of raw materials and factory inputs such as energy cost (Barry, 2004), inaccuracies in shipment due to poor qualities and quantities from a supplier (Zsidisin, 2003), legal actions on a firm and its allies due to poor observance of environmental practices (Carter and Jennings, 2004; Klassen and McLaughlin, 1996) and many more.

We have already acknowledged the growing perception about the increasing frequencies in logistics chain disruptions in the recent years in the introductory

⁶ Further reading in relation to this definition can be seen in Kaplan and Garrick (1981) in their article titled “On the quantitative definition of risk”. The authors symbolically defined the term as Risk = Uncertainty + Damage.

chapter. Some have explained this trend of the phenomenon as the consequence of increasing globalization, increasing drive to outsource noncore businesses, and the adoption of perceived best practices such as lean and agile supply chains (Aitken et al., 2005; Aitken et al., 2002; Christopher and Lee, 2004) in addition to practitioners becoming more aware of the dangers of disruptions. Many authors including Norman and Lindroth, (2004), Juttner et al., (2003), Juttner, (2005), Manuj and Mentzer, (2008) propose collaborative management tools as the panacea to these uncertain occurrences. However, in addition to the many propositions, we wish to emphasise on the need for becoming more ‘disaster-aware’ (anticipation), by better understanding the causes and potential effects of disasters on a logistics chain. Arguably, being prepared before event occurs, can be the ultimate solution, since preparedness may have the capacity to avert or alleviate the effects of disruptions on the functions and operations of a logistics network.

To ease understanding and adoption of strategic solutions/interventions to risks that may lead to supply chain disruptions, several researchers and practitioners sought to classify risks (Harland et al., 2003) in various ways including the few examples listed in table (1) below:

Risk Categorisation	Source Review
By sources; consequences of the risk sources; risk drivers (that could turn risk into consequences); and the Strategies that could be used to address the risk	Juttner, Peck and Christopher (2003)
Risks internal to focal firm, risks external to focal firm, risks internal to the supply chain, and risks external to supply chain (distinction of risk by source)	Juttner, Peck and Christopher (2003)
Risks linked with process, control, supply, demand, and the environment	Peck (2003)
Network or supply chain risks, operational risk, demand risk, security risk, environmental risks, policy risks, competition risks, resource risks (according to associated components)	Manuj and Mentzer (2008)
Financial risk, chaos risk, decision risk, and market risk	Christopher and Lee (2004)

Table 1: Categorisation of supply chain risks

This research gives much attention to those risks that might emanate from environmental events leading to chaos and disruption in a logistics network. Uncertain and complex logistics chain is capable of creating chaotic systems. Chaos may lead to nervousness, over-reactions, panicky interventions, guess works, mistrust, and information distortions (Childerhouse et al., 2003). We argue that, such stimulus-response behaviour could be due to the lack of preparedness for disruptive events in the logistics chain. Thus it is imperative that management understand risk categories, their potential sources/causes, as well as the risk drivers, so that the appropriate

interventions can be selected towards reducing risk impacts on the organisations (De Loach, 2004). Apparently, when risk issues are properly addressed through proper assessment, it can lead to proper disaster preparedness (or planning) that may translate into reduction in disruptions such that resilience can improve in the logistics chain. Nonetheless, we note that proper/adequate planning may depend on the choice of appropriate risk management strategies (interventions) adopted by the entity.

2.1.5 Supply chain risk management strategies

One can deduce from the above section that 'risk' can lead to a state of uncertainty where some of the possibilities can involve a loss, a catastrophe, and other outcomes. Perhaps it suffices to say that organisational awareness about need for risk management as well as the need to prepare for uncertainty is in the right direction. Literature shows a rise in this direction over the past decades as evidenced by wide spread publications in various subjects fields such as in economics (Kahneman and Lovallo, 1993; Kahneman and Tversky, 1979), finance (Smith et al., 1990), strategic management (Bettis and Thomas, 1990; Simons et al., 1999) and international management (Miller, 1992; Ting, 1988). Paulson (2004), and many other authors describe supply chain risk management as the intersection between supply chain management and risk management. It involves planning and controlling processes of supply chains in order to improve their capabilities to handle risks in a collaborative manner.

Knowing the class of risk that an organisation is grappling with could determine the strategies to adopt in order to build a stable and self-adaptive logistics chain/network

that can withstand disruptions and yet still function in a normal way (uninterrupted). Among risk management techniques, De Loach (2004) suggests risk: avoidance; transfer; reduction; and retention as some of the strategies for risk management. In another instance, Manuj and Mentzer (2008) suggest a five step global supply chain risk management strategies which include: identification, assessment and evaluation, selection of appropriate risk management strategies, strategic implementation, and risk mitigation using simulations.

Several writers have supported risk avoidance as a good risk management strategy. Proponents of this strategy explain that a firm could avoid risk by exiting a market, or by speculating (or anticipate) risk occurrence and then adequately prepare for it. As it will emerge later in this research (in chapter 4), we will attempt to model scenarios of potential policy changes and how those decisions may affect the structural behaviour of the stocks (or key variables). Such models should help problem owners to gain insight into outcomes of different decision as they seek to improve sustainability of maritime. Consistent with Manuj and Mentzer (2008), we attempt to identifying possible sources of risks in the HE, assess and evaluate them using SD modelling so that best mitigation measures can be developed and adopted prior to implementation of the required policy changes.

2.1.6 Supply chain security (SCS)

According to Closs and McGarrell (2004) and also in Hale and Moberg (2005), logistics and SCM literature has still not yet been able to comprehensively provide

enough understanding of SCS, let alone, its best practices. Closs and McGarrell (2004) as cited in Williams et al. (2008) define SCS as:

“The application of policies, procedures, and technology to protect assets [product, facilities, equipment, information, and personnel] from theft, damage, terrorism, and to prevent the introduction of unauthorized contraband, people or weapons of mass destruction into the supply chain” (p. 8).

We note that the seemingly narrow definition above was coined in the context of container security. However Fisher et al. (2008) provide an apt and more general definition that fits well in our research. According to the co-authors:

“Security implies a stable, relatively predictable environment in which an individual or group may pursue its ends without disruption or harm and without fear of disturbance or inquiry” (Fischer, Halibozek and Green, 2008, p. 31).

Security issues are possibly going to continue to influence logistics chains, relationships in the chain, and the efficient movement of goods and logistics services. Security threats and attacks will be inevitable and supply chains at large will suffer (Sheffi, 2002) from such threats and attacks. Nonetheless it appears that adequate preparedness through planning for potential disruptions in the logistics chain is a necessity (Hale and Moberg, 2005). As part of the preparedness plan, supply chain organisations need to integrate preventive security measures (Zsidisin et al., 2005), and rather be adequately prepared to rapidly respond to disruptions when they occur (Sheffi, 2002; Hale and Moberg, 2005; Zsidisin et al., 2005) and possibly provide room for recovery from any resultant disruptions.

2.2 Port/Maritime logistics chain: the role, ownership, management, and functions

Under the section, we reviewed the role of ports, their ownership, port management schemes and functions. We also reviewed the impact (positive and negative) of port activities on the regional, national, and the global economy. We critically looked into contemporary maritime logistics risk issues, and rounded the section up with a brief geography of the HE as well as the potential security threats in the port industry. By the end of this section, the relationship between port and the environment became apparent.

2.2.1 Definition and composition of port

Transport services [logistics/supply chain links] and transport infrastructure [logistics/supply chain nodes] are key elements of efficiency in logistics systems (Mangan et al., 2008). Under the logistics system, the port (see definition in Stopford, 1997) is just one of the numerous nodes in a particular supply chain. According to Robinson (2002), seaports are not simply places with particular functions; rather, they are nodes in the supply chain. Characteristically, the seaport acts as a firm in the supply chain such that it can deliver value to shippers through the transport nodes they offer in the maritime logistics industry. Ports have been acknowledged by writers to be the gateway for the development of value-added logistics and other proximate activities. In a highly competitive environment, the port is not simply the node for operational efficiency, or the location which brings the difference, but it plays the role of resource allocations in its logistics chain. Accordingly Hlomoudis (2001), posits that ports have acquired characteristic dynamic nodes where the combine effects of

infrastructure and services lend them exceptional importance both at national and international levels for transport procedures.

A close study of the port will show that they are usually a composition of terminals consisting of one or more berths that may be dedicated to a particular (or general) cargo handling activity. Depending on the type of freight cargo that the port or its terminals handle, there may be found different types of handling equipment and port infrastructure. Together, de Langen (1999) calls the port and its composite units a “port cluster⁷”. Seemingly, the concept of port clusterisation generated another definition which states that: “[...] *a port is a cluster of organisations in which different logistics and transport operators⁸ are involved in bringing value to the final consumer*” (Carbone and Martino, 2003).

It follows therefore that the port is perhaps best viewed by its major clients as one of the sub-systems in the logistics system. Therefore it is not surprising to find that the port and its immediate environment can become a concentration of services interface that support quality and reliability of the entire transport chain.

The above notwithstanding, van Klink (1995) argues that it is difficult to highlight the geographical boundaries of a port cluster. The argument is that port related activities are not just located within the port premises, they can be spread across a wide

⁷ A port cluster is “a population of geographically concentrated and mutually related business units, associations and public (-private) organisations centred around a distinctive economic specialisation” Porter, M. E. (1990), “The Competitive Advantage of Nations.” *Harvard business review*, No..

⁸ Port operators include stevedore firms, cargo handling companies, and terminal operators. They play major roles in port communities just like the central government and port authorities by pursuing conventional microeconomic objectives such as profit maximisation, growth, and targeting increase in market share if they are given the authority to do so.

geographical area, so that it can be actually described as port network instead of a cluster. The characteristics and compositions as mentioned in the preceding discourse suggests that ports must be adequately resourced and prepared to respond in order to reduce impact of unforeseen circumstances that they can most likely encounter. Therefore, “*Ports clusters should not only focus on cost leadership alone (economies of scale), they should strive to create economies of scope by building inimitable and durable core competences*” (De Langen, 1999; Notteboom and Winkelmanns, 2001) by making their logistics chain more resilient.

2.2.2 Port operations and the impact on port community

Port cities often provide employment, industrial activities, as well as many social amenities that set the pace to regional/national development. Consequently port cities grow to become urban centres (as in Hull, Grimsby, and Immingham). Many ports attempt to encourage the development of value-added services that include chandlery, ship repairs, container maintenance, marine appraisal, actuarial/insurance services, banking, and telecommunication services; most of which are required on the basis of strategic development policy. In regions where maritime transport has dominated the transportation sector, ports have significantly influenced the regional growth, and they constitute a determining factor for economic performance (Polyzos et al., 2008).

According to Baird (1997) ports perform three core functions, namely; landownership, utility (port operations), and regulatory functions. However, a careful study of the port systems will reveal that ports produce two main kinds of goods (public goods and private goods). The public goods may include such products as public safety, security,

and healthy port environment including coastal protection works that are necessary for the protection of the neighbourhood of the port's area of operation. Such goods may not be directly consumable, just as they may not be easily broken into smaller units. The provision of public goods usually involves great economic externalities such that their provision does not necessarily bring direct financial profit to the private enterprise. Therefore they often do not arouse the interest of the private sector. Rather, the provision of those public goods create positive externalities [between the port and the society] because the social benefits they can generate usually yield greater satisfaction than the financial rewards that they may generate if they were in the hands of private enterprise. As a result of the importance, there is the need for public intervention in the production and maintenance of public goods in adequate quantities at all times. Private goods are the direct opposite of the public goods, consequently they generate direct economic benefit to the private enterprise. The production of public/private mix of goods and the multiplier effects that they can have on the economy has been cited by many ports as the reasons why there is need for direct public interest and subsequent investment in the port industry. These same reasons seem to be the cause of complexity in port logistics and supply chain system; particularly in relation to port safety, port security, and the protection of port environment.

Generally, large ports become locations for seed industries and distribution nerve centre for many related companies. For example, the Ports of Hull is home to BP chemicals, and AAK edible oil. While Immingham port hosts Yara-UK Ltd (fertilizer manufacturing); SeaFront (seafood manufacturing) and many others. It appears that

these developments may be due to transport reliability, short-transit container service that enhances JIT purchase orders, and it can also be the result of public policy or they can be business-driven. For instance, one manager at AAK once acknowledged that Hull was selected as site for two of their largest refineries in the UK because it is one of the busiest ports which is capable of handling the huge quantities of materials that the companies need for uninterrupted operations.

To sum up this subsection, one will agree with authors such as Polyzos et al. (2008), that ports constitute a maritime commercial gate for the distribution of products for local enterprise. Port also constitute important infrastructure for tourism growth as well as a hub around which various shipping services develop and may form the core of economic growth of the region, perhaps due to the economy of scale that such enterprises are bound to benefit for locating within the port enclave. Ports sometimes, also provide some significantly beneficial services to ship-owners, seamen, passengers and carriers. The services provided by ports are many and some have been mentioned earlier in paragraph one of this sub-section, including pilotage, towage, ship repairs, and general logistics services. For further reading on the services that ports provide, port economic activities, job creation as well as port city growth and development refer to Mylonopoulos (2004); Pardali (1997) and Haynes et al. (1997). For example, an EU data shows that in the year 2005, the port industry's employment capacity stood at 350,000 workers (Coppens, 2007; Gripaios and Gripaios, 1995; Psaraftis, 2005). One therefore can conclude that ports play very significant role, both at the regional and national levels, as it shall emerge in the next subsection reviewed below.

2.2.3 The role of ports in economic growth

The United Nations Conference on Trade and Development's (UNCTAD, 1985) *handbook for port planners in developing countries* lists the role of national port authorities⁹ as including: investment; financial policy; tariff policy; labour policy; licensing; information and research; and legal roles. A careful study of ports also show that majority of them actually play, or attempt to play, very important roles wherever they establish.

Many authors including Jung (2011) have said that ports function as the gateway of international trade. Accordingly, ports tend to be regarded as major accelerators of local economic development particularly in this era of globalisation. The gateway role cum that of international trade route has been enhanced by technological advancement in transportation and communication, low costs, and large volume of cargo freight transport per shipment. These can induce rapid mobility and hence have given rise to the integration of regional economies into the world economy. Thus the functions of ports in modern era span from the role of transshipment hubs through to the role of important logistics nodes.

Arguably, operational activities of the port in a particular region may be described as derived demand. Many people argue that the role that ports play in a particular location depends on the supply chain strategies adopted by those who use that particular port

⁹ A port authority is 'a state, municipal, public, or private body, which is largely responsible for the tasks of construction, administration and operation of port facilities and, in certain circumstances, for security' (www.ppiaf.org).

facilities. However, on a global logistics chain's perspective, Panayides (2006) notes that:

“[...] the demand for maritime transport nowadays cannot be solely considered to be derived demand emanating from the need for products, but rather as an integrated demand emanating from the need to minimise costs, improve reliability, add value, and a series of other dimensions and characteristics pertaining to the transportation of goods from the point of production to the point of consumption”.

Following from the above, Heaver et al. (2000) note that, the role of the port and port authorities has to be redefined to guarantee that it remains a fully-fledged player in modern day's fast evolving market. The redefinition of roles may lead to change in policy which can result in costly consequences; some of which may be unintended (see Giddens, 1979 theory of structuration).

In another instant, it appears that port efficiency is a determinant to the overall national and regional economies. We may be right to state that maritime logistics chains play a dominant role in international freight movements especially in the wake of growing trend in international trade. According to Cullinane and Song (2002) ports constitute a critical link in the supply chain and thus the level of port performance and efficiency can influence a country's competitiveness. Sanchez et al (2003) made similar comment in the context of a number of ports in Latin American countries. In the UK context, Byan et al (2006) for example, give a comprehensive account about ABP (in south Wales) and the role that their activities play in the economic development of that region.

Many ports have also become the location for industrial clusters ¹⁰ sometimes due to targeted development policies [by the national/regional government], at other times it can be due to unplanned growth of interrelated industries in a particular geographical area. Perhaps, a large majority of the public might be aware that governments use growth policy to justify their involvement in basic port infrastructure either directly or indirectly. The objective for such public policy is to create a competitive market structure and management through licensing, leasing, and concessioning so that port resources can be efficiently allocated to deserving entities at any particular time. Many pundits also argue that the investment in port assets is likely to have multiplier effects on the entire national economy. Such pundits conclude that commitment of public resources is a necessary encouragement for co-investment by the commercial and industrial sectors in areas that the private sector would not otherwise think of getting involved in. However, it seems that these activities and policies may come along with some risks as it shall emerge under the SD modelling in section (4.11).

2.2.4 Trends in maritime transport and shipping

The growth in world trade in the past decades and the increasing emphasis it places on maritime efficiency requires that all key industry players (port owners, port operators, shippers, and shipowners) will remain alert and be ready to tackle potential causes of disruptions in their logistics chain. For instance, as part of the changing trend, many

¹⁰ Industrial clusters are geographic concentration of companies. They are usually a value-chain, or a web of interrelated activities that are mutually supportive and continuously growing. Their activities may improve the competitive advantage of members of the cluster by increasing productivity, reducing transaction cost, improving technological innovation, and drawing in, or enticing new companies into the cluster.

countries that have ports appear to be witnessing increases in export as a percentage share of GDP that is contributed by cargo exports by sea. Other revolutions have occurred in areas such as globalised production, increased reliance on sea transport for import and export, technological changes and increase in vessel size ('Gigantism'¹¹) leading to port specialisation and some congestions at some ports due to large quantity of goods and documentation required. According to Livey (2005), factors that tend to favour the evolution and gigantism are good geographical location that promotes best vessel transit/steaming time and port rotation, port's nearness to large consumer market, port having the necessary facilities that are sufficiently flexible to allow service even if vessel is out of schedule. However, these revolutions can apparently lead to increasing cost of operation, increasing influence of harsh weather, and increasing human errors. The issue of human error comes about perhaps due to inexperienced crew from emerging economies with low training standards, reduced crew number leading to fatigue for the sake of cost saving by vessel owners. Human errors also come about from increased bureaucracy on board the ship (Allianz.co.uk)

Though it is normal for large-sized-long-distance vessel to get delayed at ports occasionally, there should be enough berthing facilities so that delays can be handled effectively should they occur. Ironically, ports have rather witnessed increase in regulations towards decongestion in the maritime logistics sector in recent years perhaps due to their environmental impact, and maritime/port security (Psaraftis, 2005). Particularly the regulation increase came in the post 9/11 era, and also in the era where

¹¹ Gigantism is a hub and spoke relationship between main ports that handle larger sized vessels and other ports in the neighbourhood.

environmental sustainability and the reduction of carbon footprint are still dominating discussions at world forums.

In addition to the changing trends listed in the preceding paragraph, one can also see another trend developing along the traditional functions of the port. Port functions are gradually changing from being just transshipment hubs for the transfer of freight between ship and landside transport to include the provision of other ancillary services. There appears to be some changing trends in inter-port competition as well. It is therefore not surprising for Notteboom and Winkelmanns (2001) to note that the competition has intensified even among distant ports, and particularly among European ports. Current literature indicates that actual competition in the future is going to be between a handful of 'total logistics' instead of competition between ports, or individual transport carrier (Fleming and Baird, 1999). Finally, Brooks and Cullinane (2006) note the increasing shift in port ownerships and management. Brooks and Cullinane note with great concern that many governments are withdrawing from port operations and are rather concentrating on monitoring and oversight responsibilities. Baird (1995) speaks more about the private/public models of port administration and is worth mentioning here, though the detail is beyond the scope of this research.

In summary, the extensive borderless global coverage of the maritime transport region increases the industry's vulnerability to several risks. One will acknowledge that any major disruption in the supply chain could have drastic effects on the global economy (Acciaro and Serra, 2013). There is therefore a greater need than ever to improve maritime logistics chain's efficiency and to sustain improvement in performance. This

need thus call for good anticipation and possible elimination of potential disruption tendencies (risks). It also calls for improvement of systemic resilience through adequate disaster preparedness.

2.2.5 Negative impact of port activities on the port environment

Maritime transport accounts for well over 90% of world trade and is widely acknowledged to be an environmentally friendly mode of transport as compared to other modes of transport such as road, rail and air. We have also acknowledged the positive impact of the functions and operations of ports in section 2.2.3 under economic growth. We recall that from port establishments emanate industrial clusters, economic growth, social development, and urbanisation, to mention only a few. Yet maritime logistics systems are the most exposed to environmental vagaries. Port/maritime activities have been known to impact negatively on the environment, particularly in the promotion of environmental pollution (both coastal and urban pollution). Often times the adverse environmental impacts may be growing in one region while the pollution prevention efforts will be focused in another (Bailey and Solomon, 2004).

Being industrial hubs and high population centre, port cities have arguably become significant contributors to global anthropogenic emission (Tzannatos, 2010). Apparently, the reason for this development is the fact that ports attract shipping traffic which appears to constitute the point of concentration of ship exhaust emission. Tzannatos (2010) suggests that the urban character of ports, highlight the spatial impacts from exhaust emissions. Current literature also supports the perception that

increase in emissions of air pollutants can affect local as well as regional air quality (Galloway, 1989; Prather et al., 2003; Rodhe, 1989; Streets et al., 2000). The sources of such pollutants have been traced to ships which run on bunker fuel without emission controls, daily running of diesel trucks at ports, diesel run locomotives, and grease/oils spills from handling equipment (Bailey and Solomon, 2004), or sometimes from catastrophic accidents such as ship grounding or collision. These normal daily activities in the maritime industry can cause a wide array of environmental impacts on the local communities, aquatic, and terrestrial lives, and possibly the entire ecosystem by causing water, ground soil, or air pollution.

Several researchers have cited increased cases of cancer in the adjoining communities to ports, production of smog and dust, and contamination of water bodies as some of the risk impacts of port activities on human life. Research findings over the past decades also show that the introduction of alien species to port environment is on the rise. Alien species have the potential to destroy an entire ecosystem, not excluding the aesthetic effects of the communities and public lands of the local environment. Some may argue that port emissions do not significantly contribute to the total emissions generated by the maritime transport industry, but it is worth noting from Tzannatos (2010) that the impacts of ship exhaust pollutants has a direct effect on the human population and built environment of many ports that are located in urban centres. The environmental problem posed by port activities becomes worst felt if the port is located in an estuary or on fresh-water river (such as in the case of ports on the Humber River estuary). This phenomenon is common particularly at busy ports and/or also along busy shipping routes.

Ports in general are associated with activities such as construction/extension, port maintenance, dredging and reclamation. However, these activities seem to be more frequent for ports that have been sited on rivers and estuaries perhaps due to river dynamics. The impact of many of these activities is that they can cause increases in water turbidity, change in river course and depth, degradation of marine resources including beaches, wetlands, and land forms. Furthermore, harbour operation can produce sewage, bilge waste, and oil discharge into surface water which thereby create unfavourable condition (e.g. eutrophication) for the ecosystem of the estuary, the river, and the port city's inhabitants (see Goulielmos and Pardali, 1998; Gupta et al., 2005).

Another source of pollutants to the port environment which reduce air quality as identified in Gupta et al (2005) comes from secondary sources such as from urbanisation and vehicular emission. Emissions from ships for instance, can be danger to sensitive ecosystem and human habitation given that most ports are situated close to densely populated urban cities, or ecological sites (Giercke, 2003; Isakson et al., 2001; Trozzi et al., 1995) particularly for ports sited on rivers and estuaries. Most of the emissions come from high sulphur and nitrogen content in the heavy fuels used in running vessels at the port. To regulate sulphur content in ships' fuel and emission of nitrogen oxides and the concomitant environmental pollutions both at ports and at the sea, the MARPOL Convention Annex VI (Wright, 1999), and the European Commission (EC, 2000a, b) were instituted.

Further literature shows that although issues concerning maritime policy did not meet the attention of European Environmental Policy makers (Kula, 1992), marine environment pollution became a matter of interest to international organisations such

as International Maritime Organisation [IMO] (ESCAP, 1992), United Nations Conference on Trade And Development (UNCTAD, 1993), United Nations (UN, 1994; 1996), and many others including the World Bank (Davis, 1990). For example, agenda 21 of the UN (1994) considers port activities as one of the sectors that affect coastal areas. Therefore ports need (and it became a requirement for ports) to provide reception facilities where oily and chemical residues and garbage can be collected. As part of the new requirements, ports must organise regular workshops on the environmental effects of their operations, as well as on any developmental project they wish to carry out.

Ports use to play the passive role as hubs for the exchange of what comes onto the mainland and what needs to be transported via the sea (Pronk, 1993) by the virtue of their strategic locations. Thus ports receive lots of pollutants from three different sources: the port's hinterlands; vehicular activities; and the water front. As mentioned earlier in two paragraphs away, Goulielmos and Pardali (1998) note that a port may be polluted through ship accidents, accidents in port, land activities, ship bunkering, noises, garbage, dust, dredging, port maintenance, ship air pollution, traffic congestion, sewage, and many others. In the view of Goulielmos (2000), these issues were reasons for the creation of many international conventions: for instance the MARPOL 73/78 addresses matters concerning dredging and provision of facilities for reception of oil waste at the ports, whiles the 1990 convention requires port to address oil related pollutions in emergency situations under the *Convention of Oil Pollution Preparedness, Response, and Cooperation*.

Authors (Finney and Young, 1995; Guhnemann and Rothengatter, 1999; Vandermeulen, 1996) have questioned the relationship between port development and the environment as traffic expands. The role of ports have changed or are in the process of changing from simply linking the hinterlands to the terminals, to becoming complex node in the logistics chain and possibly leading to change in port infrastructural layout (UNCTAD, 1993). We fail to deny the fact that, port development is inversely proportional to environment¹² purity. Thus as ports development increases (all things being equal), the port environment deteriorates proportionately.

At the local scene (in the Humber River), and drawing from the above discourse, one can infer that ports by their nature can be hotspots for risks due to the highly probable nature of their logistics networks. Despite the uncertainties, ports have a key role to keeping everyone and the environment as safe as possible for an uninterrupted operation. For example, most navigable rivers, channels, ports, harbours and berths can be subject to dangers such as tidal variations, swift currents, river swells, sand bars, revetments, and other possible features (natural or artificial) as may be associated with the middle-lower course of a river. Such dangers may be controlled by the use of lights, buoys, signals, warning signs, and other aids which can enhance proper navigation. Furthermore the dangers can be overcome through careful and proper manoeuvre of vessels and the good handling of vessel content in accordance with rules of good

¹² Pearce and Atkinson (1995) speaks about the 'environment' as a natural capital; which is synonymous to natural resources or natural assets (renewable and quasi renewable) for the production of ecological services. In another perspective, environment can also be considered as input (Fisher, 1995), or as a constraint to growth, based on the principle of interconnectedness between growth and environment.

seamanship in order to building the port's reputation. Any damage done to a port's efficiency and safety record may impact on its reputation, and by extension, to its trade both within and also with the outside world. In table (2) below we attempted to summarise a few port activities and the potential hazards/risks which can be associated with them to refresh the port stakeholders' memory.

Cargo	Description	Associated Hazards
General	Forest products, steel, scraps etc.	falls from cargo, hatches, unfenced non-working docks/wharf edges, unsafe lifting operations, collapse of load, transport, access-egress
Bulk-solid	Coal, grain, aggregate, fertilizer including ammonium nitrate	Dust, transport, falls from ships' hold access, unguarded machinery, confined spaces, access, explosion of badly stored ammonium nitrate
Bulk-liquid	Liquefied Petroleum Gas (LPG), oil	Fire, explosions, confined spaces, access
Containerised Load on/Load off (Lo-Lo)	Containers lifted by crane on/off ship	Transport especially in container terminal, falls from containers, unsafe cargo securing (i.e. lashing) points on ship, Musculoskeletal Discomfort (MSD) in crane operators, exposure to fumigants in containers, struck by doors or goods of overstuffed containers
Containerised Roll on/Roll off (Ro-Ro)	Containers taken by tug and trailer or Large Goods Vessels (LGV) on/off ship-cars also transported on Ro-Ro vessels	As above, also transport on ramp and during lashing, noise, struck by over-tension lashings, exposure to fumes in older ships
Passenger ferries and cruise liners		Baggage manual handling at cruise terminals, transport especially segregation of passenger/traffic, Ro-Ro vessel also often carry passengers

Table 2: Hazards associated with cargo types and operations (HSE, 2009)

It would be an understatement that these hazards can be highly dependent on factors including: the geographical configurations of the port, the prevailing weather condition,

port water depths, height and strength of the local tides. Arguably the Harbour Master (on the basis of advice from the CRO and the risk management team) uses “local knowledge” about these factors to inform their decision making regarding the manner and circumstances in which vessels of any kind are permitted to enter and leave their port’s jurisdiction. Sometimes in formulating safety policies, there may be miscommunication apart from the high probabilities associated with human judgement. Hence there is need for models such as the one employed in this research that can aid one to gain insight into the possible outcomes of risk/disaster interventions prior to policy implementation.

Reiterating what has already been said elsewhere in the literature, we add that the increase in international trade, the rise of container traffic, and the integration of supply chains have altered the role of ports in the global economy especially in terms of the functions and competitiveness (see Mackloet, 2006). Whiles these developments are welcoming news, they pose great challenge and uncertainty to the maritime logistics chain, both in terms of business competition and also in their level of exposure to risks of disruption. Arguably, it takes more to attract cargo and customers than just providing the requisite ports facilities. It seems that ports and their components forming the cluster do not only need to adapt to changing circumstances, they also need to change their management strategies accordingly.

2.2.6 Geography of the Humber Estuary

Humber Ports and the terminals have been considered as the region’s engine of economic growth. The ports’ locations and the vastness of land area (15,420km² or

approximately 5,953sq miles) provides the opportunity for structural expansions as well as for exploitation by businesses to expand, enter into new markets, add more companies to the industrial cluster, and perhaps provide opportunity for huge amounts of inward capital investment into the industrial cluster. An ABP (2011) report states that the geographical location of the HPC gives it unique access which is not equal to that of any port complex in the whole of UK. Continuing from section (1.2, p. 6 of this thesis), the ports in the HE/HPC and the region in general enjoy numerous competitive advantages. Some examples include: excellent roads networks (i.e. M62 which is a thoroughfare linking the East to West; the North – South routes linked by M1, A1 and A19 as well as the Grimsby - Immingham connectivity of M180 (Philips, 2008). The region can also boasts of good rails system, and an airport. It appears that these transportation networks have opened the region to some 40 million consumers. Additionally, the HPC currently controls over 60% of UK's manufacturing capacity and is just about within a maximum of 4hour drive to significant business centres and crossing time to continental Europe of as low as 10hours (ABP, 2011).

Records shows that six (6) major rivers feed the HE (i.e. Ouse, Wharfe, Aire, Don, Trent, and Hull). We have also learnt that the greatest distance of tidal influence is 147km - from the outer estuary at the Spurn Point to Cromwell Weir on the Trent with a mean river tidal range of 5.7m and maximum of 7.4m near Hull (at Saltend). The 2006 population census ranked the Yorkshire (the Humber) region as the 6th in the UK with a total population of 5,142,400 and population density of 328/km². The HE is surrounded by hills that have climatic effects on the bordering land with a high water-table (Glentworth and Dion, 1950). Towards the coast, the land is low-lying

floodplains stretching towards the east, and opening into the North Sea. Arguably that feature could explain the liability of large portions of the region to floods. For detail descriptions of the regional geographical features and the Humber Estuary, see Quinn et al. (2009) and ABP (2011).

Vehicular traffic control on the Humber River into the ports is the responsibility of ABP [who is the statutory port authority] through its VTS station which is based in the Spurn Point. According to ABP's (2011) records, 21000 of the 40,000 ships that enter or leave the HE require VTS pilotage services. There is a division called the Humber Estuary Services (HES) which is responsible for the conservancy of the estuary. Its functions include maintenance of safety and navigation activities for all vessels that use the channels. These functions are conducted by a hydrographical team that conduct regular surveys from which they provide detail information about the depth and location of channels as well as provide publications of nautical charts and notices to mariners. HES broadcast changes that have occurred or are likely to occur in terms of depth and channel alignments at any time. The ABP's (2011) report states that HES is also responsible for marking channels and marking navigational hazards with buoys, marks, and lights especially in the upper reaches where the marker buoys are moved as often as every fortnight so that it can ensure that channel marks remain accurate.

2.2.7 Port security and threats

Securing logistics/supply chain security particularly at any nation's entry points (including seaports) is of particular interest to many governments. However maritime

supply chain security requires a broader strategy (Wilson, 2005) that assumes national and international dimensions especially in the post 9/11 terrorist attack era. The assertion is that sea transport in particular could be and is becoming potentially vulnerable to many hazards (natural, or human, or both sources combined) and particularly a significant target route for terrorist attack. The risk potentials increase proportionately on container carriers, at container ship terminals, at busy seaports, and possibly at terminals for boarding cruise ships. For instance, by the nature of container terminals, in terms of easy access by unauthorised persons, the large size of their yards (Longo, 2010), and the nature of container shipment¹³, it makes them become the spawn for terrorism at seaports. The post 9/11 security became focused on preventive security that requires adequate preparedness through vigilance in the supply chain network. It is therefore in the right direction when writers such as Zsidisin et al. (2005) call for an integrated collaboration in preventive security measures for the elimination or the mitigation of disruptions that could originate from security lapses. According to Fischer et al. (2008), security:

“Implies a stable, relatively predictable environment in which an individual or group may pursue its ends without disruption or harm and without fear of disturbance or inquiry.”

In the context of this research, Closs and McGarrell (2004) defines security as:

“The application of policies, procedures, and technology to protect supply chain assets [product, facilities, equipment, information, and personnel] from theft, damage, or terrorism and to prevent the introduction or unauthorized

¹³ Containers shall not to be tampered with (sometimes even during inspections) until they reach the end user Steenken, D., Voß, S. & Stahlbock, R. (2004), "Container terminal operation and operations research-a classification and literature review." *OR spectrum*, Vol. 26, No.1: pp. 3-49..

contraband, people or weapons of mass destruction into the supply chain” (p. 8).

The definitions therefore, call into the mind that a logistics chain’s security relates to moves which can enhance the protection of the three flows, or the prevention of disruptions in the flow of logistics activities. Good logistics chain security may be a form of preparedness that involves systemic disaster planning (Arnold, 2008) leading to an agile response to adversity. Being prepared for logistics disruptions sometimes go beyond mere plans to protect physical infrastructure. Preparedness may include planning which can improve the capacity to address and/or reduce the likelihood of socio – political actions such as terrorism (Williams et al., 2008), strikes, sabotage and other human induced disasters. The fact is that disruptions cannot be eliminated completely in any logistics chain, as per the assertion by most pundits¹⁴. However, disaster preparedness through proper planning is necessary (Hale and Moberg, 2005) so that preventive security measures (Zsidisin et al., 2005) can be taken such that it will enhance rapid response to disruptions (Hale and Moberg, 2005; Sheffi, 2002; Zsidisin et al., 2005) as well as provide a platform for rapid recovery from disruption in a sustained manner.

Williams et al. (2008) attempt to fill the knowledge gap in understanding supply chain security and its best practices by building on (Closs and McGarrell, 2004) and (Hale and Moberg, 2005). But one will note that Williams et al (2008) and several other

¹⁴ Pundits believe that “supply chains will continue to suffer disruptions and attacks” Sheffi, Y. (2002a), "Supply chains and terrorism." *The Towers Lost and Beyond, A Collection of Essays on the WTC, Massachusetts Institute of Technology*, available at: <http://web.mit.edu/civenv/wtc>, No, Williams, Z., Lueg, J. E. & LeMay, S. A. (2008), "Supply chain security: an overview and research agenda." *International Journal of Logistics Management, The*, Vol. 19, No.2: pp. 254-281.

researchers including Peleg-Gillai et al. (2006) and Gonzalez (2004) relate supply chain security to organisational performance using different approaches. They did not draw clear relationships between the environment, preparedness, and resilience.

Perhaps the complex nature of port supply chains and the built – in feedback characteristics of their structure (Wilson, 2005) calls for models which can help both researchers and problem owners to gain insight into how structural behaviour resulting from interacting variables can influence each other. Thus as it shall emerge in chapter 4 of this thesis, SD models was selected as analytic tool (because of their feedback characteristics) to help study how different processes (including policy intervention) can cause different responses in HPC's logistics chain such that a clear relationship can be drawn between the three state variables of this research (i.e. environment, disaster preparedness and resilience). This will provide room for policy assessment which may lead to redesigning or realignment of logistics chain policies in the HE/HPC so that disaster preparedness can be given more attention than it is being done currently.

We used SD simulation models based on the influence relationships we gathered from raw interview data to study the relationship between disaster preparedness and resilience in port logistics chain at the HPC. Interestingly Drenzo (2007) advocates scenario – based models that consider dynamic parameters such as traffic congestion peak time, impact of domino effect, lean concept or cost volatility effects (Drewry Shipping Consultants, 2009; Merrick et al., 2001; Rytönen, 2007), and how to reduce the risks of possible terrorist threats on ports. Security issues are sometimes classified, therefore requisite secondary data to back-up this research claims (Williams et al.,

2008) were not available. One of the alternatives available is the SD modelling approach which allows theory generation from raw data.

2.3 The concept resilience

Subsection 2.3 deals with the construct “resilience” in its various context based on extant literature. A few attributes of resilience have been reviewed and some relevant theories were also touched on. The section unfolded by reviewing some metrics of resilience as we sought to operationalise the concept.

2.3.1 Defining resilience

The term ‘resilience’ has been defined variously by several writers from across different subject fields to explain specific concepts in different contexts. That notwithstanding, the meaning and applications of the construct has been entrenched in the natural sciences, particularly in ecology and physics, and also in psychology. A couple of definitions for resilience that seem relevant to this research topic have been considered below:

“[...] the tendency of material to return to its original shape after the removal of stress that has produced elastic strain”(Pettit et al., 2010);

“[...] the ability for an ecosystem to rebound from a disturbance while maintaining diversity, integrity, and ecological processes” (Holling, 1973; Walker et al., 2004).

We have developed keen interest in two definitions in the field of logistics and supply chain, which referred to resilience as:

“Situation awareness, management of keystone vulnerabilities and adaptive capacity; in a complex, dynamic and interconnected supply chain environment” (McManus et al., 2007).

“The adaptive capability of a supply chain to prepare for unexpected events, respond to disruptions, recover from disruptions, and maintain continuity of operations at the desired level of connectedness and control over structure and function” (Ponomarov and Holcomb, 2009).

The two definitions above appear to fit in this research’s ideology and therefore they form the bases for our discussion. Both definitions seem to link resilience with risk management strategies (interventions) and supply chain security issues which we have reviewed under section (2.1.5 - 6) above. The key issue at stake here is that whether the term is used in the context of business, or in physical sciences, or in biological sciences, Ponomarov and Holcomb (2009) note that all resilient entities show the following common characteristics:

- ✓ they have capacity to adjust and maintain desirable functions under extremely challenging conditions (Bunderson and Sutcliffe, 2002; Edmondson, 1999; Weick et al., 2005);
- ✓ they have dynamic capacities to grow and develop over time (Wildavsky, 1988);
- ✓ they have the ability to bounce back from disruptive events or hardships (Vogus and Sutcliffe, 2007).

We seek to expatiate the construct “resilience” with a focus on some aspect such as resilient practices, and the metrics for resilience. Therefore in addition to what has already been said, the term resilience may also be considered as *“the positive ability of*

a system (company, society, institution etc.) *to adapt itself to the consequences of a catastrophic failure* (see www.Wiktionary) triggered off by a stressor. Arguing from developmental perspective, Sutcliffe and Vogus (2003) state that resilience should rather be viewed as an ability that develops over time from continually handling risks, using internal and external resources to successfully resolve new issues so that the entity under crisis can bounce back from adversity, and become more strengthened and more resourceful. To that effect therefore, resilience can be associated with growing attempts to moving quickly to improve entity's response to unforeseen events, or to quickly recover from disruptions caused by disastrous events.

The resilience of an organisation is dependent on its critical infrastructure. Consistent with Flynn (2004), we consider the critical infrastructure as the core structures (activities) which when attacked by catastrophic event, can disrupt the operations and functioning of a maritime logistics chain. Such critical infrastructure in a port setting may include: roads, rails, lockgates, cranes, trucks/vessels, power supply grids and plants, communication systems/gadgets (particularly the VTS equipment), physical buildings, the waterway, human resource etc. Damage to any of these structures, facilities, and resources could disrupt important social, economic and life activities of the port or the maritime logistics industry.

In 2005 Sheffi analysed the adverse effects that disruption can have on operations of corporations and also how investments in resilience can give a business, the competitive advantage over others who have not prepared to put contingency plans in place. Sheffi concludes that organisation's ability to recover from any disruption can

be attained by building ‘redundancy¹⁵’ and ‘flexibility’ in its supply chain. It seems that logistics chains which prepare for disasters (or risks) are able to recover from disruptions more quickly than those who do not prepare. For instance, the aftermath of Hurricane Katrina (in the USA in 2005) reveals a preparedness deficiency and lack of resilience as compared to the Japanese tsunami in 2011. Also the casualty and level of economic loss that was suffered in 9/11 may have been lower if it should happen again due to the higher security alertness of today’s social network. The perception by many people is that preparedness and resilience are two vital components for survival. See examples in Ericsson’s proactive supply chain management approach after a serious sub-supplier accident (Norman and Jansson, 2004; Latour, 2001); and Burby’s (2006) Katrina paradox.

According to an economy report (Reform Institute, 2008) there are four phases of resilience: preparedness, protection, response, and recovery. Thus it is appropriate that as part of the investigation we look critically at the relationship between disaster preparedness, environmental instability, and resilience of logistics chains. Such an investigation is necessary due to the growing concern by entities all over the globe to adopting slogans such as ‘resilience’ and ‘sustainability’ (Demos, 2009; Australian Gov, 2009) and particularly in the field of logistics.

¹⁵ Redundancy refers to the maintenance of the capacity in the logistics chain to respond, largely through investment in capital and capacity prior to the point of need. An important distinction with flexibility is that the additional capacity may or may not be used – it is the additional capacity that would be used to replace the capacity loss of a disruption (Sheffi and Rice, 2003; 2005)

2.3.2 Dynamic attributes and theories of resilience

Bruneau et al. (2003) theorise that resilient systems have four key properties (or dynamic attributes), including: robustness, redundancy, rapidity, and resourcefulness.

Robustness refers to the ability to withstand stress without resorting to disruption. It is the characteristic strength of a resource and the probability of its deterioration under stress. Longstaff (2005) adds that a resistant strategy [or policy] is robust if it can keep out or counteract a wide variety of dangers. But such a strategy is non-robust and could be said to be fragile if it can work only under a small number of possible scenarios.

Redundancy is the ability or the extent of resource substitutability [in terms of resource availability and flexibility] in the wake of disruption. Redundancy comes in as strategic reserved resource which may not be needed immediately but will serve as backup such that it becomes useful in times of emergency. Redundancy can be a built-in device as in the field of engineering resilience (see Gunderson, 2000), or can also represent human and intellectual capital, including preparedness strategies for mitigating the effects of disruptions in the event of a disaster.

Rapidity refers to the capacity to achieve goals in a timely manner so as to forestall or to void disruption in a logistics chain. Rapidity comes about when strategic plans are far laid out, and such disaster management plan have been tested so that they entity can always have several alternative plans to fall on during crisis [disaster preparedness].

Finally, resourcefulness refers to the capacity of entity to identify problems [ie forecast accuracy], then mobilise resources when conditions threaten the system.

Apparently, resilience fails when resilient resources (e.g. sensitive equipment for monitoring and handling operations) are themselves damage or disrupted by a stressor such as those resulting from meteorological elements (floods, erosion, neap tide,

extreme temperature etc.), geological catastrophes (earthquake/tsunami, volcanism), or anthropogenic including technological causes (terrorism, strikes, vandalisms, sabotage, technology accidents). For instance assume that floods cause damage to sensitive handling and moving equipment at the port, or assume a vessel collision, thus making the ports inaccessible for a period. Then resourcefulness in any of these scenarios is the capacity to identify the existence of such problems and the potential extent of damage so that resources (from redundancy) can be committed to handling and mitigating the disruptions that could ensue, leading to rapid restoration of operations at the ports (rapidity). If this is successful without resorting to significant disruption, the system will be described as being robust. In conclusion, all four attributes need to be fulfilled in order for a system to be described as being resilient.

Hobfoll (1998; 1988) and Hobfoll et al., (2007) developed the theory of “Conservation of Resources (COR)”¹⁶ in which they note that “individuals strive to obtain, retain, protect and foster those things that they value”. The COR theory observes that stress occurs when resources are threatened; when resources are lost; or when an entity fails to gain necessary resources following a significant investment in other resources [perhaps as policy issue]. Furthermore, disaster can also cause resource deterioration faster than it would have being. The COR theory seems to support the need to invest in “necessary redundancy” and making resources more efficient (through upgrade of existing resources or acquisition of new resources). Many people seem to believe that those who have and use appropriate resources are less vulnerable to risk of disruption

¹⁶ The COR theory requires advanced preparedness. It links with the concept redundancy. Many strategies exist to ensure resilience such in Hobfoll et al (2006), Lonstaff (2005) Godschalk (2003) and many others. This research suggest the use of models to generate debate that can set up goals for the adoption of the best mix of from an array of interventions.

than those with fewer resources. Thus Norris et al (2008) concludes that resource [availability and flexibility] can be correlated with symptom of severity of risk. In that document, Norris et al developed five roadmaps (they called them ‘stops’) that speak about the need for planning which also involves planning for uncertainty as well as planning for not having plan¹⁷. Management need to acknowledge the inevitability of disasters/disruptions and the complexity/uncertainty in their management strategies. There seem to be the need to engage adaptive strategies that rely on trusted information for rapid decision making instead of rigid plans, or ‘command-and-control strategies’ (Longstaff, 2005) which often time are not subject to review. To add to this Godschalk (2003) predicts that:

“The public and private organisations of a city [that research was in the context of community disaster management] would plan ahead and act spontaneously. They would avoid simple command-and-control leadership [typical of the military emergency management] and rather use network of leaderships and initiatives [such as the debates generated in the SD model]. They would set goals and objectives, but they should be prepared to adapt these in the light of new information and [new] learning” (Godschalk, 2003, p.139).

Norris et al. (2008) present a theory on resilience that roped in contemporary understanding of stress, adaptation, wellness, and resource dynamics using literatures drawn from different disciplines. The authors conclude that resilience is [...] *“a process that links network of adaptive capacities to adaptations after a disturbance or adversity”*. Norris et al further suggest that adaptation is manifest in population’s

¹⁷ Planning for not having plans may involve being flexible and focused on building effective and trusted information system and communication resources that function in the face of unknowns.

wellness in terms of healthy behaviour, functioning, and quality of life. Norris and co-authors observed that the adaptive capacity for community resilience emerges in economic development, social capital, information and communication as well as in competences - all of which work together to provide disaster preparedness strategies. Just like earlier authorities and researchers (e.g. Quarantelli, Kreps, Mileti, Dynes, Drabek etc.), Norris et al (2008) add that resilience involves risk reduction, reduction in inequalities, engaging local people in mitigation, creating organisational linkages, boosting and protecting social supports, planning for not having a plan (which means being flexible), decision making skills, and having trusted sources of information that could function even in the face of unknowns. Although these steps are community disaster management focus, we uphold that they are principles or ideas that can be adopted (if not already in use) in the port/maritime logistics environment.

Resilience is a metaphor (Norris et al., 2008) that sprouts out of the physical sciences. Resilience does not consider the magnitude of displacement, but rather the speed at which equilibrium is achieved is what matters. Since Holling's (1973) study, resilience concept has been applied in many fields to describe the adaptive capacities of the individual (as in Bonanno, 2004; Butler et al., 2007; Rutter, 1993; Werner and Smith, 1982), the human communities (see Brown and Kulig, 1996; Sonn and Fisher, 1998) and the wider society as a whole (Adger, 2000; Godschalk, 2003). The reader may refer to Norris et al (2008) for the table of various theories of resilience.

Even though most of the extant theories on resilience centred on community disaster management, there are two main theoretical convergences: one speaks about resilience as a concept that signifies ability or process rather than an outcome (Brown and Kulig,

1996; Pfefferbaum et al., 2007); the other focuses on resilience as a concept of adaptability rather than a concept of stability (Handmer and Dovers, 1996; Waller, 2001), even though circumstances show that systemic stability (i.e. failure to change or being static) could sometimes be a sign of lack of resilience.

From the perspective of Adger (2000) and Klein et al (2003) a system depends on the ability of at least one of its components to change or to adapt in response to changes in other components. The conclusion is that a system would fail functioning if that component which is subject to change remains static or freezes or *'changes too slowly than is expected'*. According to Gunderson (2000) 'engineering resiliencies' are pre-designed states or functions that help to reverse systems to normalcy or better, after disturbance. This is contrary to ecological resilience which allows for many possible desirable states that match the environment. It is the fusion of systemic adaptability and engineering resilience (through appropriate policy and behavioural change on disaster preparedness) that entities can continue to operate and function efficiently even if they are impacted by environmental adversities. With respect to this research, we expect to see certain policy changes (systemic or engineering changes) as the maritime environment changes in terms of infrastructure, human resource, and many more components, so that ports in the HE will be able to respond to current changes that take place within the maritime logistics industry. The effects of those policy changes will become clear in chapter 4 under quantitative analysis as we performed extreme condition test on the selected state variables.

2.3.3 Metrics for resilience

A Canterbury University Resilient Organisation programme prepared by Kachali et al. (2012) developed an outline (or tools) to benchmark resilient organisations. Some of the tools used include: leadership, staff engagement, situation awareness, decision making, innovation and creativity, effective partnerships, leveraging knowledge, breaking silos, internal resources, unity of purpose, proactive posture planning strategies, and stress testing plans. The conclusion is that because resilience is a global concept, the resilience of one organisation is dependent on that of another organisation. In the opinion of this research, it appears that such measurement tools can be rather subjective and ruled by perception.

Mileti (1999) emphasised that organisation resilience is key to halting the rapid increases in losses to disaster. Based on this assertion, Miletti defines a disaster-resilient entity as one that *“is capable to withstand extreme natural events with tolerable level of losses”* and is also capable of taking mitigation actions consistent with achieving a desirable level of protection. The tolerable level of losses and mitigation actions are usually preceded by strategic planning that is continually updated in consonance with the dictates of the time that measures and tests organisation’s strategic capabilities.

In a related development, Bruneau et al (2003) proposes a framework that both defines and helps in measuring disaster resilience [though in the context of earthquakes]. Accordingly Bruneau et al define resilience as the [...] *“ability of social unit [organisation, community etc.] to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimise social*

disruption and mitigate the effects of future earthquakes [disaster event]". Bruneau et al (2003) thus suggest three characteristics along which resilience could be quantitatively measured so that a better understanding of the concept, the various contributory factors, and how entities can become more resilient can be found. These characteristics include: the probabilities of reducing failure in a system; the capabilities of reducing consequences of failure from a system; and ability to reduce recovery time in case disaster occurs [i.e. $\text{resilience} = \text{Prob}(\text{failure}) * \text{Consequence} * \text{Time}$]. In Bruneau et al. submission, they posit that resilience may be conceived along four main dimensions: technical; organisational; social; and economic (TOSE).

For instance, technical resilience refers to how well a physical system performs when subjected to disruptive elements. The organisational resilience was explained as the ability to respond to emergencies and to carry out critical functions during/after a disruption. Furthermore, social resilience is the capacity to reduce the negative societal consequences of loss of critical services during an event. Finally economic resilience was related to the capacity to reduce both direct and indirect economic losses resulting from an event. Bruneau et al (2003) further explained that the technical and organisational dimensions are paramount for a system to perform and remain resolute during crisis. Components of these dimensions collectively may form the basic critical infrastructure requirement for an entity such as the HPC [such as the VST station, power supply, wharfs and jetties, lockgates, vessels, key installation, handling facilities etc.]. The social and economic dimensions also combine to form policies and safety measures that can be put in place in order to minimise disruptions that can emanate from disasters. One area that this research critically examines is how these policies and

disaster preventive measure (as they manifest in disaster preparedness plans) can influence quick response and recovery from disruption using scenarios.

2.4 Disaster Management - Concept and Theory

Here, we focused the review on the construct “disaster”; looking at the definitions, the characterisations, causes and some metrics of the concept. Some relevant theories on disaster preparedness was reviewed as well. In short, we attempted to operationalise “disaster preparedness” in this section.

2.4.1 Defining disaster

The world appears to float in a flux of disasters, looking at the apparent increase in the number of disaster cases (Drabek, 1995; Murphy and Bayley, 1989) that have been declared, the value of economic losses, and the number of disaster victims (Blaikie et al., 2004) recorded in the world’s communities in recent times. According to Quarantelli (1991), certain trends show that disasters will increase in frequency and in magnitude with time. One can observe that there seem to be an increasing dependence on technology, increasing urbanisation, and increasing social (or organisational) complexity, all of which have the potential to worsen the effects of disasters in the future. Smelser (1991) adds that what will quicken the pace in the changing trend as per the prediction by Quarantelli may include the drive towards economic productivity, the pressure to improve technology, and internationalisation (or globalisation) of world economies.

Many more authors (Berle, 1998; Blaikie et al, 1994; Brammer, 1990; Hartmann and Standing, 1989; Donohue, 1982; Kates and White, 1978) suggest that human development, human settlement, and other human activities that have been extended to certain areas of the earth, have increased the vulnerability to risks and can be instrumental in the induction of hazards. Subsequently, Richardson (1994) notes that the apparent increases in environmental turbulence and crisis is not the cause of overcrowded world alone, it is also because the world today has more powerful technology that has the capacity to detect disaster as well as to generate disaster (e.g. computer failure, nuclear disaster, air plane crashes, collapse of oil rig platform on high seas, wreckage and piracy on the high seas plus terrorism attempts, environmental pollution [through emissions], trends of draughts and famine, as well as bad weather). The over dependence on technology driven world and the complexity of technology-based systems can create a butterfly effect (Lorenz, 1993)¹⁸, and seem to be the centrepiece of the chaos theory (Gleick, 1997). Burton (1993) gives a succinct description about how technology can expose humans to natural disasters which was also cited in White et al (2001) and Faulkner (2001). The features and characteristics discussed herein appear to have created difficulty in assigning meaning, definition, as well as prediction of “disaster”, in addition to the difficulty in its management.

Over the decades attempts have been made (especially in the 1960s) to define ‘disaster’, particularly in the fields of sociology and geography (Baker and Chapman,

¹⁸Small change or accumulation of latent weaknesses, or little failures in a system can precipitate major disruptions due to mutually reinforcing positive feedback processes. This will emerge clearer under the discourse on qualitative data analysis under CLM/SD.

1962; Barton, 1969; Fritz et al., 1961). In Quarantelli (1985, 1995), the author expressed concern about the lack of consensus in the definition for disaster. However, he was quick to add that the definition for the term charts along some key terms, or some objectives. These objectives may include: the agent involved; the physical impact of the physical agent; the assessment of physical impacts; the resultant social disruption from physical impact; social construction of the reality in perceived crisis situations; political definition of the crisis situation; and the imbalances in demand/capability ratio during crisis situation and in crisis management. The chapter six (6) of Cutter (1996) also appeared to have identified most of these key terms as what drive the meaning of 'disaster' as they were discussed under the sub-topics: *Hazard, Vulnerability, and Risk Analysis*. Concluding an argument, Quarantelli (1996) suggests that definitions based on such key terms could further compound the definitional problem for the construct 'disaster'.

From the geographical perspective, disasters are considered as 'the extremities arising from geological events (faulting, earthquakes, volcanicity, mass slide), or meteorological events (floods, hurricane, storm surge, draughts, extreme temperatures)'. However, today's view and knowledge about disaster, spreads wider than the geographical and political views. Current views encompass functions of ongoing social disorders (strikes, war, and terrorism), human–environmental relationships (pollution, encroachment of designated sites, landfills and reclamations) and historical structural processes (land reclamation, coastal squeezing erosion isostatic rebound).

Another perspective of the definitional problem is the objectivity-subjectivity views of disaster (Oliver-Smith, 1999) which relates to how entity will respond to a disastrous incident. For example, the objectivity view sees disaster as something that has physical impacts on the entity (individual, business, community, and environment). In the view of Cutter (1996), disaster impact comprises the physical and social dimensions. The physical impact includes casualties (deaths and injuries) and property damage which are usually measurable. The social impact on the other hand, may compose of the psychological impact (Bolin, 1985; Gerry Flynn, 1997; Houts, Cleary and Hu, 1988; Perry and Lindell, 1978), demographic impact (see Smith, Tayman and Swanson, 2001), economic impact (Committee on Assessing the Cost of Natural Disasters, 1999; Charvériat, 2000; Mileti, 1999), and political impacts (Bates and Peacock, 1989; Bolin, 1985; Bolin, 1994) of a disaster, some of which might show up immediately and others show up in the future. For instance there appear to be a scientific evidence that the pollution caused by 1986 Chernobyl nuclear disaster in Russia is still affecting social life of the people in that region, and may continue to do so for many decades to come.

Turning to the subjectivity (internal complexity) view, Oliver-Smith (1999) upholds that disaster is a socially constructed perception. There are many other divergent views which suggest that disaster should not be perceived as a fixed event within a time frame (Quarantelli, 1995; Kreps, 1995; Kroll-Smith 1998). Such view have broaden the definition and applicability of “disaster”, apart from it enabling researchers to rope in social constructs and technological events which might cause or have the potential to cause social disruptions. Additionally, there can be socio-psychological and psycho-cultural (Oliver-Smith, 1999) dimensions to the term ‘disaster’. Having considered all

these views, we wish to focus on the material and infrastructural damage (failures), or the physical impacts that have the potential to trigger off the socio-psychological and psycho-cultural dimensions as mentioned in Oliver-Smith's (1999) article "*The angry Earth*".

The above discourse notwithstanding, we will consider a few definitions for "disaster" from different angles. For example:

"Disaster is a result of vast ecological breakdown in the relationship between man and his environment, a serious and sudden/slow onset disruption, on such a scale that the stricken entity (individual, community, organisation, society) needs extraordinary efforts to cope with it, often resulting in dependence on outside help or international aid" (World Health Organisation [WHO]);

Or

"[...] a potentially traumatic event that is collectively experienced, it has an acute onset, and is time delimited; disaster may be attributable to natural, technological, or human causes" (McFarlane and Norris, 2006, p. 16).

The definitions above suggest that 'disaster' may cover acts of nature (e.g. flood, storms, earthquake, mass slides and avalanche); large scale marine and industrial accidents (transportation and nuclear); and episodes of mass violence (e.g. terrorism, industrial unrest leading to vandalism); the aggregates of which we considered highly in this research. According to Hollick-Jones (1995), disasters can disrupt the general routines of the entity, destabilise social structures and long earned adaptations, as well as endanger worldviews of system meanings. Thus it becomes apparent that disruption is a consequence of disaster and the vice versa. Many people often use these two terms (disaster and disruption) interchangeably.

From a different perspective, Dynes (1993) also reveals that an entity's perception, response, and involvement, can determine the meaning to (or definition for) disaster.

Taking this view rightly suggests that disaster is more of a behavioural phenomenon in a specified context of disruptions/damage as expressed by the entity that experienced it. Disaster is not a snapshot event, it is characterised by series of time stages and spatial dimensions (Wallace, 1956) that involve varied activity requirements at the different stages, role associations, and constraint impositions by the event to normal life activities of the entity. For instance the roles and activities required for pre-disaster planning may be different from those required during the disaster and post-disaster phases.

Due to the way entities and their socio-economic systems are calved (or founded), all can be susceptible to some degree of risk. Lindell and Prater (2000), Birkland (1997), Weinstein (1980), and Meltzer (1979) wrote about how proximity to resources dictate human activities and the consequences. We note that two most important things which human beings must address relative to their environment are: the natural resources that enable them to meet their needs, and the challenges they need to adjust to in order to survive (Peoples and Bailey, 1997). Entities must exploit their resources efficiently, yet at the same time deal effectively with their environment to ensure sustainability. The key word therefore for the blend of survival in sustained environment is “adaptation¹⁹”.

Perrow (1984) argues that disasters are a gauge of success or failure of the adaptation efforts of an entity. The question of adaptation requires us to find out the fitness of the

¹⁹ Adaptation in the view of the anthropologist is the socio-cultural tendencies adopted by entity to enable it to cope with conditions within social, economic, modified, and built in environment to enable it to survive or to prosper (Bennett, 1996; Peoples and Bailey, 1997).

entity especially those we perceive to have the capacity to control their environment. Finding out the fitness of entity means to assess the plausible possible risks of disaster/disruption in relation the entity's proximity or the location effects. Risk assessment will usually identify latent causal factors and estimate probable losses to destructions/disruptions as well as contingent vulnerabilities of exposed elements. Risk assessment therefore helps to inform one's efforts to reducing risk and losses through proper planning (preparedness). Assessment may make some risks foreseeable and thus provides motivation for preparedness which leads to risk reduction. When risk factors are identified it increases the potential to shift from emergency response and disaster reconstruction to disaster preparedness, loss prevention, and reduction in disaster recovery time (Dilley et al, 2005). However the research will uphold that risk assessment and disaster planning may not be enough to anticipate outcomes of policy changes. Very often the level of preparedness lags behind the disaster event. Hence we suggest the use of SD models to test the potential effects of policy interventions prior to implementation.

2.4.2 Characteristics of disaster

It seems the characteristic external variability and internal complexity (Oliver-Smith, 1999) have made it difficult to reach a consensus in the definition of disaster. External variability refers to the wide range of 'objective' phenomena, both natural and technological, that can trigger off disasters of different kinds which also produces varied impacts on entity [see also Bryant (1991); Perry and Lindell (1990), Saarin and Sell (1985), Warrick et al. (1981)]. By characterisation on the basis of external

variability, disaster can be described as slow-onset (e.g. drought, climate change, floods, leakage in pipeline, and spread of some toxin in the environment), or as rapid-onset such as earthquake/tsunami, fire outbreak in chemical plant, mechanical/technological breakdown or failure, and terrorism (see Gruntfest et al., 1978; Lindell, 1995). These characteristic external variability seems to blur the concept 'disaster', and also contributes to the lack in exact definition.

In terms of their characteristic internal complexity, disaster focuses on the interwoven processes and events that take place and need to be managed over varying lengths of time: in relation to social, cultural, political, economic, physical, and environmental events (Oliver-Smith, 1999). Complex systems are extremely difficult to analyse, to understand how they function, to predict their behaviour, and also to determine their performance. The totality of these embodiment defines the social structure which is constantly oscillating (exhibiting stability and instability, coherence and contradiction, harmony and disorderliness), showing the characteristics of chaos (see chaos theory and the butterfly effects of Lorenz, 1972 and Gleick, 1987). Internal complexity also describes how the physical, biological, and social systems interact with their entities (i.e. individuals, groups, organisations, institutions, communities, societies, or nation states) and their socio-cultural constructions (or make up). The characteristic internal complexity appear to force researchers to confront the many and shifting faces of socially constructed reality, giving the multiple perspectives that exist and the surfeit of enactment and constructions that a disaster may take (Oliver-Smith, 1999). This includes the multiple interpretations from different disciplinary approaches, the varied methodological tools and theoretical/practical goals as there exist currently in relation to disaster management.

2.4.3 Causes of disaster

Disaster losses are an intersection between hazardous events and the characteristics of exposed elements (including valuable vulnerable elements such as people, critical infrastructure, and environment) that make them susceptible to damage (Cutter, 1996 cites Watts and Bohle, 1993). Burton et al (1993) state that a hazard's potential to destroy is a function of the magnitude, duration, location, and time of the event. An entity that is exposed to a given type of hazard must have intrinsic characteristics or must be vulnerable to the hazard in order for it to get damaged (UNDRO, 1979). Thus the cause of disaster may depend on the characteristic composition of the entity's vulnerability.

Portiriev (1995) posits that the concept of vulnerability, which centres on understanding disaster in the total social and environmental context, is more appropriate for explaining the origin and causes of disaster rather than the definition. In fact knowing the cause of disruption (source and the precursor) leads to investigating why events happen, and the way they happened. Thus Oliver-Smith (1999) notes that [...] *“if cause is, in fact, an appropriate issue in the definition of disaster, then we need to develop an alternative to understanding why disasters happen, and why they happen in the form they do”*.

In thinking about what-why, or the cause-effect approach of disaster, we are trying to situate origin of hazards to environmental forces - a concept which Hewitt (1985; 1995) criticises for being too simplistic. However this research takes the cause-effect approach, with a focus on the subtle interactions (or interdependencies) between the

society [port] and the environment (Ingold, 1992) in the quest for adaptation. It appears that with better understanding of the phenomena that potentially cause disaster and consequently the disruptions in the maritime logistics industry, policy makers may be better informed and would devise alternatives to confront future problems as well as to provide business continuity plan that will help to recover from the disruptions associated with disasters. We accept Dombrowsky's (1995) stand that human system's failure to understand and to address the interactions [interdependencies] between the set of interrelated systems produce a collapsed cultural protection, which results in a set of effects called "disaster".

It is said that humans continue to expand their activities, which bring a strain on to the limits to human adaptation capacity and compromise the resilience of nature. Human exploitation of the environment today brings risk factors that may haunt us tomorrow (see Giddens, 1979 theory of structuration). Holling (1994) notes that globalisation processes have produced problems that are basically nonlinear in causation and are discontinuous in both time and space such that they become highly unpredictable. This character of nonlinearity makes it almost impossible to devise a definite strategy hence the application of models (System Dynamics models) can help analyse strategic decisions before they are implemented.

2.4.4 Importance of studying disasters

Quarantelli's (1991a) studies about disasters yielded three major uses: instrumental/action²⁰ use; the conceptual/understanding²¹ use; and political use²². We provide a conceptual understanding of the causes and effects of disruptions in maritime logistics chain, based on which policies for preparedness towards real-time response and real-time recovery (resilience) from disaster may be designed and implemented by ports in the Humber Estuary (HE) and perhaps other ports or organisations elsewhere. For instance by simulating different scenarios, the stakeholders may be able to gain insight into the outcomes of policy interventions prior to their legitimisation.

The conceptual realm also looks at the temporal and structural dimensions of disaster (Drabek, 1986). In the temporal dimension Drabek posit that disaster, as a social response process, should be tied to response planning and readiness (preparedness), recovery, and mitigation. Thus, disasters can be viewed as test to ascertain how prepared an entity is in terms of the real-time response to uncertain events. The structural dimension concerns with studying different systems levels such as individual, group, organisation, community, society, international, or global levels and the way in which they can be affected by the same event (Drabek, 1986). This classification does not differentiate whether the disaster is geographically based, or whether it is caused by social agent, or a natural cause, or technological cause. Thus

²⁰ The instrumental (or action) use relates to specific studies which can be used as a basis for future decision making on specific issues.

²¹ The conceptual use provides background information and perspectives which influence future action in the broader sense.

²² The political use provides a litigating function for certain policies [according to Quarantelli (1991a)]

the response to disaster by the various social levels provides the understanding of the consequences (Dynes and Drabek, 1994) of a disaster incident which may be modelled by policy makers.

2.4.5 Defining disaster preparedness

Disaster preparedness is a process of ensuring that: an entity has complied with risk preventive measures; the entity is in a forecast state of readiness to contain the effects of a disastrous event in order to minimise loss of life, injury and damage to property; the entity can provide rescue, relief, rehabilitation and other services in the aftermath of the disaster; and has the capability and resources to continue to sustain its essential functions without being overwhelmed by demand placed on them (BusinessDictionary.com). Dynes and Drabek (1994) suggest that disaster preparedness and disaster planning could be the future direction of many entities because of the increasing worsening disaster situations in today's system. The authors predict that future research on disaster will be cast in interdisciplinary terms.

Besides describing disasters as a collective misfortune that does not deserve public policy, some authors (Dynes and Drabek, 1994) have also described disaster as a 'metaphor' that explains universal human action. Disaster can be an act of God and therefore their occurrence may be uncontrollable. It seems, being alert for anything that has the capacity to disrupt the smooth running of a logistics chain [or being disaster prepared] can be a way to maintaining sustainable systemic logistics functions.

2.4.6 Theories of disaster preparedness

Disaster (risk) preparedness and social mitigation issues seem to have become dominant subjects in many researches and conferences of late. However, there has not yet been any general contemporary theory (or theories) to tie the subject field to. Major strides have been made by gurus such as Quarantelli (1974); Dynes (1970); Fritz et al (1961); Barton (1970a) and Kreps (1982) in the field of disaster management with the aim to developing theory (or theories). But it is sad to note that despite those strides made, there had been no explicit incision into theorising disaster preparedness, or hazard mitigation at the moment.

Most studies on disaster (or hazard) mitigation²³ embed in them the theory of social functionalism. The functionalism theory perceives the society as a complex system whose component parts work together to promote stability (Parson, 1902 – 1979). Therefore institutions are established with the view to promoting social stability and integration (or social equilibrium). However some writers (Bogard, 1988) criticise the social functionalist theory for rather being reactive, and aimed at mitigations that are directed at reversing hazard situations to normalcy after an incident had occurred. Bogard's concept of disaster/hazard mitigation is not entirely different from the definition for disaster preparedness that which is found in businessdictionary.com. Therefore one will fail to disagree with this research for adopting the theories in hazard mitigation for disaster preparedness.

²³ Where Mitigation is defined as those collective actions taken by individual, or groups (public or private), to reduce the potential harm posed by an environment Bogard, W. C. (1988), "Bringing social theory to hazards research: conditions and consequences of the mitigation of environmental hazards." *Sociological Perspectives*, No.147-168.

Extant literature shows that sociologists have had interest in tracing the cause and effect of every rational action. Rational actions have been taken on the basis of historical data which may cover diverse humanistic disciplines. Rational action is goal oriented and thus it considers how public policy, economic choice, and political strategies affect the mitigation of environmental hazards (Dacy and Kunreuther, 1969; Rossi et al., 1982; Slovic et al., 1974). Theorists suggest that social effects of rational actions can actually be irrational (Bogard, 1988). To these effects, Marx (1963) and Weber (1958) observe that some effects of rational organisation as well as the economy on the entity may include alienation, bureaucratic red tape, dehumanisation, contradiction, and conflict. The effects of rational action has continued in varied forms in subsequent theoretical work such as the social functionalism theory, game theory, chaos theory and others. For instance the social functionalism theory maintains that rational action can be explained by referencing its unintended effects on social organisation (Merton, 1957; Coser, 1971) [i.e. *actions can result in unintended outcomes*]. From the game theorist's perspective, one can discern that uncertainty (risk) permeates the entire choice of decision making process (Elster, 1978) by any entity. Elster posits that the use of rational choice criteria in making strategic decisions may lead to suboptimal or 'counterfinale' solutions because the rational choice model assumes perfect information, homogeneity, and equal access – conditions which are rather over ambitious and utopian. Thus Simon (1954) and Lindblom (1964) identify these as theoretical and practical limitations to the rational action model.

Giddens (1979) summed up the numerous theories (in the above paragraph) together at

the action level into what he called the ‘structuration theory’. Giddens acknowledges that social life is more than random acts, and is not merely determined by social forces. It does not matter the number of micro-level activities but rather it is the macro-level (aggregate) explanation (the general effects or the consequences of an event) that matters. Giddens implied that human agency and social structure relate to each other such that the repetitive acts by individual agents can produce a structure in the form of traditions, institutions, moral codes, and established ways of doing things. Changes can occur when agents start to ignore, replace, or reproduce the social structures in a different way. Thus there is a dynamic relationship between behaviour and structure. Giddens’s argument centres on the fact that sociological theories must account for the fact that all rational actions operate within a dynamic framework of unacknowledged conditions and unanticipated consequences. Giddens’s ‘stratification model of action²⁴’ (see Giddens, 1979, pp. 55-59) is deemed to adequately specify the general structural considerations about distribution of power and resources in society. In that model, reflexive monitoring, rationalisation and motivation of action, collectively point to the fact that human activities and actions are purposive, intentional, and feedback oriented [desirable or otherwise]. It is from this theory that emerged the behaviour of the stock and flow structures of this research and the subsequent analysis of SD models as we find later in chapter (4) section (11). There is need therefore to account for every action or behaviour using the same social knowledge that is implicated in the production of the structural behaviour. In this wise, the medium and

²⁴ This model is a system by which a society ranks categories of people in hierarchy (by status, power, wealth etc.)

outcome of rational social action matters to the structure of social knowledge. In other words the knowledge we have about something (disastrous phenomenon or an event) determines our actions and how we respond to situations including disruptions in life as well as in business environment. Hence the SD models will inform policy makers to choose among alternatives the best combination that can make operations in maritime logistics chain more sustainable.

Despite the apparent validity of the above argument, it seems that knowledge about our environment is neither complete nor readily available in explicitly codified form (Bogard, 1988). What we know is often uncritically taken for granted. For example, certain regularly occurring events (e.g. leakages from pipeline; or coastal erosion; or cracks in flood barriers; waste management; power outages; breakdown in communication equipment; or inefficient, over age, and regular breakdown in critical infrastructure) might be taken as something normally associated with port (maritime) industry and may not be deemed as serious development that requires prompt attention. On the other hand what is not known may form the background of uncertainty. For example, the full effects of a disaster such as earthquake, extreme weather, terrorism, or chemical spillage, on maritime infrastructure and its immediate environment cannot be determined prior to occurrence of the incident.

Whether social knowledge is taken for granted, or it is uncertain, the inference from the above discourse is that rational action is bounded by its unacknowledged conditions. Therefore, rational actions may result in unforeseen and unintended outcomes which can escape the radar or can overwhelm the scope, and the purpose of the actor (Bogard, 1988; Giddens, 1979). This is linked to, and could be further explained by Lorenz's (1993) butterfly effect and the chaos theory (Gleick, 1987). The

above theoretical discourse forms the basis for which we selected the SD model through which insight can be gained into the phenomena of study. Feedback loops can help the research to analyse cause-effect and the intended (unintended) outcomes of rational actions from management and policy makers' (CROs) perspective at the case organisation (HPC).

Next to the rational action theory, we examined the functionalism theory within its concept of latent functions. Interestingly, we noted that Bogard (1988) had criticised the theory of sociological functionalism for the reasons that: it is problematic as it assigns teleological (ultimate causality) explanations; it is prone to anthropomorphism (i.e. attribution of human cause (or behaviour to nonhuman characteristics) for collective entities; it is inclined towards theoretical conservatism, for its rationalism approach, and for its equilibrium explanation of social actions. For example the social functionalism theory believes that disruptions are human errors that can be caused by being resistant to change to new ideas/technology, and therefore mitigation efforts should aim at re-establishing normalcy. Elster (1983) suggests that the social functionalists tend to overstress the benefits of unintended consequences of actions rather than the consequences that may be disvalued or disruptive.

Literature shows that Giddens's (1979) 'structuration theory' contradicts the functionalism theory, or, it can be said to anti-functionalism. According to Bogard (1988) the anti-functionalist does not follow the teleological form of explanation; it does not hypostatise the societal need that action must function beneficially in order to maintain equilibrium. Bogard argues that unacknowledged condition of hazard mitigation may consist of two parts: the mythological part and the uncertainty part. The mythological part talks about how entities tend to behave during crisis time (e.g.

panic reactions, frustrations, and egoistical behaviour among others) as observed by Wenger (1985) as well as Wenger and Friedman (1986). The uncertainty part relates to the constraints posed to mitigation due to lack of information. This may be due to the fact that disasters are highly unpredictable, or they can be variably unpredictable and are generally endemic in the daily life of entities. It is further thought by Bogard (1988) that uncertainties can be grouped as those that belong to or are related to physical parameters of future occurrences propelled by the environment; such as the nature of event (slow onset or rapid onset) and length of time that entities will suffer an ordeal (duration), as well as the impact of the uncertain event. This area of uncertainty can examine the response (or real-time) to event by entity.

The unanticipated consequences of hazard mitigation is the theory that evoke the notion that the occurrence of event is a probability that is contingent on event happening (similar to Bruneau, 2003), the object, and the location's potential to cause harm due to entity's vulnerability to environmental hazards (Bogard, 1988). When we think along this direction, then we are concerned about the beneficial intent of mitigation – i.e. to reduce losses during crisis (Anderson, 1969; Perry, Lindell, and Greene, 1981). But often-times, it seems mitigation efforts rather increase vulnerability to other risks apart from cost increases. The unanticipated disvalued consequences of actions may be deemed as mitigation action that can give rise to new structural parameters of knowledge for further action (Bogard, 1988).

We therefore agree with extant theorists that unacknowledged conditions and unanticipated consequences feed back into decisions and thus change the bounded knowledge which the decision maker has about the environment. Sometimes the policy maker manages to reduce the level of uncertainty by learning from mistakes and may

never remove uncertainty completely (Bogard, 1988). Our investigation wish to focus on low probability but high impact risks incidents (i.e. impact on the economic, social, and environmental life). Thus it makes sense to conduct a research into how disaster preparedness and mitigation strategies can be influenced by policy interventions that may produce unacknowledged conditions plus unanticipated consequences in the port system using the SD models (see section 4.11 of this thesis).

2.4.7 Metrics of disaster preparedness

As part of the Fritz's project for assessing Disaster Preparedness in the Bay Area of the USA, Covington and Simpson (2006) reviewed literature on disaster preparedness with the main focus of creating deeper understanding of the concept and specifically to find how best to measure the levels of preparedness. The authors found that there are several issues to consider when we are devising disaster preparedness metrics, yet there is no particular format or any prime measure. The authors recommend that careful consensus needs to be developed about measurements apart from being careful in their application if we intend to improve preparedness at the long run.

Preparedness is a fluid and dynamic concept that keeps changing any time and is event dependent. Each event and each entity affected by disaster may also be unique, thus requiring a unique approach to solution. The event dependence and the uniqueness of each event makes it almost impossible to match preparedness with best practice, since the latter often lags behind the former. Up till to date, there seem to be no single theory or theories that have been identified as core concept on which one can base disaster preparedness plan and practice (Covington and Simpson, 2006) albeit many have

identified the need for a solid emergency or disaster preparedness theory. The co-authors attribute this development to the lack of a holistic approach to, as well as the juvenile nature of the concept of disaster preparedness. It appears that this makes practitioners to choose from varied options, the paradigm(s) that most fit to their particular situation and view, then tailor that paradigm to their specific needs.

Few “disaster preparedness specific” (Covington and Simpson, 2006) or some set of indicator indices and measurements do exist though. For example Munich Re (2002) proposes an index that is intended to measure the potential loss to a catastrophic event in an urban area. This index is a natural hazard index for megacities in 2002. The purpose of the index is to measure disaster loss due to companies in the megacities since the insurance companies have vested interest in knowing with high degree of accuracy the determination of risk portfolios. The power to destroy and vulnerability usually results in covariate losses during an event wherever population and economic investment is dense. Megacities are usually highly concentrated cities, with high density capital investment. Thus Munich Re’s Natural Hazards Index model covers the total risk of loss and equates this to hazards, vulnerability, and exposed value [i.e. Total Risk = Hazard x Vulnerability x Exposed Value, or TR = HVE]. According to Covington and Simpson (2006), the index is both composite and multiplicative in nature. Hazard is measured as the average annual loss to any major event including earthquake, flood, fire, etc. (Munich Re, 2002). The Munich Re index also measures vulnerability as quality of construction, building density, standard of preparedness (e.g. number of disaster preparedness drills and exercises within a period), and building regulations (codes). In support of this view, Cutter (1996) suggests that through building construction practice (such as following building codes and content protection

practices), structures can be made less vulnerable to natural hazards. The exposed values measured the average household's gross domestic product (GDP), and the overall global significance. By this the entity will be able to compare cost of preparedness with probable loss if preparedness had not been made and then decide whether to create "necessary redundancy" or to discard "redundancy", and continue with lean/agile practices to the core (i.e. inventory free system).

Besides the above index, the UN has also created a Disaster Risk Index (DRI) to examine global risk factors which allows for the calculation of fatality risk for countries that experience earthquakes, hurricanes, and floods. That metric also identified socio-economic and environmental variables that may contribute to and can be correlated with disaster associated deaths (UNDP, 2004). DRI's index calculates physical exposure and vulnerability to risk. Under this, the physical exposure calculates the number of people in a country that are exposed to an event on a yearly basis, while vulnerability is calculated using two methods: first method calculate Manifest Risk as equal to total number of people killed in a disaster divided by total number of people that are exposed in a country. The second method of the UNDP calculates vulnerability using 26 vulnerability indicators and statistical analysis using multiple logistics regressions (UNDP, 2004).

Other metrics such as the World Bank's commissioned report titled: "*Natural Disaster Hotspot: A Global Risk Analysis*" assesses disaster-related outcomes of death and financial loss, in a more localised or hazard – specific case studies. The method used for calculation of risk level combines hazard exposure of entity with historical records on vulnerability for two indicators of risk elements (gridded population, and the GDP

per unit area). This looked at six natural disasters including: earthquake, volcanism, landslide, flood, drought, and cyclone; with the help of GIS to doing the sub-national level analysis for small grids. In this measurement the multi-hazard index was calculated as the sum of all the single-hazard mortalities in the grid cell for all the hazard types. This measure cannot be used by this research because it is focusing on a smaller area (the HE) whereas the method requires data from large area. Furthermore this research will not be concerned with GDP and or a large population that will need gridding. These metric calculations may enable a research to identify the highly susceptible and vulnerable areas for various kinds of disruptions at the HE, but it cannot help policy makers to understand or gain insight into consequences of their decisions. Therefore we fail to adopt such metrics in this research.

2.4.8 Disaster preparedness - a theoretical dilemma?

According to Fox (2006) the construct “disaster preparedness” is at its juvenile years and that just as it is common with any concept which is in its budding stage, researchers and practitioners are still struggling to get the construct to stand as they attempt to develop theories and best practices. These teething problems led Covington and Simpson (2006) to conjecture the possible reasons why such problems still persist. The co-authors identify multiplicity of stakeholder involvement in disaster related issues where each group tried to project its own image as well as to justify its presence and legitimize its operation. Twigg (2002) for instance identified eighteen disciplinary institutional groups involvement in one single case of disaster reduction, during a presentation at an International Conference on Climate Change and Disaster

Preparedness. Each member of the eighteen groupings also represents a broad stakeholder classification, thus creating problem in coordination and collaboration. Kirschenbaum (2002) further states that the problem of lack of cross-compatibility that results from the crowding of the disaster arena by multitude of groups affects language consistency, creates definitional misalignment, and subsequently hinders theory creation for the term disaster preparedness.

Covington and Simpson (2006) posit that the definition of disaster preparedness entails the perspective of the authors. However the co-authors assert that disaster preparedness could mean being satisfactorily prepared for a catastrophic event. The question is: how can one determine how an entity is satisfactorily prepared? Some researchers such as Christopolis, Mitchell and Liljelund (2001) emphasise that efficiency, effectiveness, and impact of disaster response, are the central goal to preparedness. Many other writers (McEntire, 2003; Twigg, 2002; UNDP, 2004) believe that hazard mitigation is central and core (critical) resource to disaster preparedness and in fact that both terms (i.e. hazard mitigation and disaster preparedness) can be used interchangeably or are deemed to be synonymous. In any case an attempt to describe hazard mitigation involves describing aspects of disaster planning and preparation. McEntire (2003) went further to state that disaster preparedness is a function of the local government; it includes hazard and vulnerability assessments. The preceding conversation is an indication that the construct disaster preparedness is loose (not specific), yet it is all embracing and holistic requiring the individual, organisational, community, national and global (entity's) commitment in accurate assessment of hazard vulnerability and mitigation.

Apart from definitional problematics, there appears to be no specific emergency

management model that can be applicable to all disasters perhaps due to the uniqueness of each event. Models currently in use are attributable to military type of 'command-and-control system that is meant for attacking enemy'. According to Dynes (1994) such an approach may not work well under civilian emergency management situations. In McEntire et al (2002) emergency planning paradigms such as disaster resistant, disaster resilient, sustainable development, and sustainable hazard mitigation, have been said to provide an insight for a comprehensive emergency management planning. Though these concepts are gaining currency, they seem not to provide concrete and sufficient grounds for theory creation as well as for designing best practice and policy on disaster preparedness. Others seem to follow the view that population dynamics and technological advancement give rise to modern disastrous consequences of disasters (Cutter, 1996; Munich Re, 2004). Thus urban [organisational] concentrations in a geographical area can increase the potential for ordinary natural disaster incidents to become exceedingly costly as concentrated areas bring with them complex infrastructural layout (road, rails, warehouses, etc.).

Accompanying the issues of concentration and congestion is the problem of identification and protection of the vulnerable²⁵ as well as critical infrastructure as required for modern port operation. The vulnerability is identified by virtue of location, characteristics of infrastructure, and socio-economic factors [wherein we classify as location effect and port activity in this research]. Thus vulnerability identification influences preparedness for a disaster. For instance most parts of the UK

²⁵ Cortis and Enarson (2006) define vulnerability as a "condition wherein human settlements or buildings are threatened by virtue of their proximity to a hazard, the quality of their construction or both, with the degree of loss (0 -100%) resulting from a potentially damaging phenomenon".

and the Humber region (in particular) is floodable but they are not known for hurricane or volcanism. By the location the HPC for instance is strategically placed (near central point) and easily accessible to both internal and external trade. Thus though the region is strategically located in economic terms, a terrorist organisation can choose this zone as one of the potential spots where the UK government is likely to feel the pinch most. Knowing the vulnerability level of the system may help policy makers to prepare for the uncertainties by putting the appropriate policy measures in place in order to mitigate the effects and different form of potential disasters that may result from disruptions in logistics chain's functions.

2.4.9 Strategies (Best practices) in disaster management

Bogard (1988) observes that mitigation cannot be a simple response, reaction, or adjustment to an actual or potential threat from the environment. Rather mitigation should be conceptualised as a set of strategic actions that actively reshape and redistribute the social parameters of hazards. Accordingly Miletti (1980) had developed strategies for disaster mitigation which considered settlement constraints and loss reduction or redistribution at a general classification level (see Miletti, 1980, p. 329). Furthermore, Rossi et al (1982) also identified that mitigation strategies could include: free market approach; relief and rehabilitation assistance approach; technological fixes approach; and land use management approach (Rossi et al., 1982, pp. 4-9; of the book, *Natural Hazards and Public Choice: The State and Local Politics of Hazard Mitigation*). In addition, Milliman (1982, p.5) mentions eight different strategies of disaster mitigation such as: siting decisions, land use regulations,

construction codes, insurance, warning and prediction [forecast], evacuation and relocation [rescue mission], emergency planning, relief and reconstruction aid. Cutter (1996) also writes about three types of pre-impact interventions that can affect disaster impact. These categorisation of strategies were good in acquainting a reader with different mitigation poses, but according to Bogard (1988) an approach for strategy categorisation only increases one's questioning of theories concerning how and why mitigation redistribution patterns of harm caused by a disaster has never been fairly or equitably distributed. Bogard's article further posits that mitigation continued to be unreflectively defined in terms of how entity responds to the actual or perceived disruptive effects of an environmental event on social life. A careful study of recent happenings therefore changes the hitherto status quo whereby a disaster process usually begins with an environmental extreme event at one end and social response at the other end of the continuum. Modern studies tend to place the extreme events at the middle of the causal chain. This allows one to think about the pre-disaster impact (inflows), as well as the post-disaster impact (outflows) of an event, in order that strategies (models) for preparedness and mitigation can be tailored towards the specific stages.

Researches in the 1970s onwards saw the need and made attempts to expand mitigation strategies by extending them beyond simply responding to extreme events, to also include responding to the potential threats of losses to those events (Sorenson and White, 1980; Burton, Kates, and White, 1978; Haas and Mileti, 1976; White and Haas, 1975; White, 1974). This led to the paradigmatic migration from hazard response strategy to disaster response strategy - a shift towards explanation of modes of response to extreme events [policy interventions] rather than explanation of needs

for adjusting to the risk of future disaster (Mileti, 1980). Hence the reader will find that the state variables (stocks) were placed at the middle of the experiment to enable the research test for extremities.

Critiques of the language of adjustment to disaster do so based on three assumptions - one of which is the problem of ultimate causality (teleology) explanation where all disasters are explained as having been triggered by extreme environmental event probably based on past experiences. Therefore mitigation efforts should be tailored at adjusting systems towards future occurrences including events which in actual fact could be highly uncertain or have very low probability of occurrence. In relation to the teleological assumption, a second assumption is that policy makers respond to future impacts of environmental events. This makes mitigation appear as a reactive response activity which could have an effect instead of it to produce effects that bring change in future occurrences of events. Finally, there is the assumption that calamity can be directed through mitigation and by controlling the environment. This links to the notion of creating an equilibrium (ideal) state [recall the Talcott Parson's (1902 – 1979) functionalist theory]. Or it also can lead to the goal that society should be in balance or be in tune with the environment by removing stresses that can potentially result in disruption. These have been some of the strategies and assumptions that practitioners have adopted under various disaster situations to try and manage the menace.

2.4.10 Results from strategies (Best Practices)

It appears that many logistics networks face the risk of disruptions (Snyder et al,

2006). We refer to highlights of recent events such as Hurricane Katrina in 2005, Japan earthquake/tsunami in 2011, 9/11 terror attacks in the USA, fire at Philips semiconductor plant in 2001 and the consequential effects on Ericsson (Latour, 2001), the Great Australian floods in 2010/2011 and many more. Though the causes of disasters and their consequential disruptions will not likely remain the same even for the same logistics network, there is need to plan for the risk of disruptions in port logistics. Disruptions in general are inevitable, however, some disruptions can be controllable to an extent while others can overwhelm human capacity. Once triggered, there is little immediate recourse regarding the logistics infrastructure, since it takes time for strategic decisions to transform into changes. Therefore it behoves planners and policy makers to consider all possibilities, the chances of their occurrence, the extent of damage or destruction that is likely to occur, as well as to understand the consequences of strategic decisions, so that necessary mitigation approaches can be designed and realigned before any implementation.

Snyder et al (2006) argue that planners/policy makers have a wide range of options available to them in designing resilient logistics networks. But their choice of approach is dependent on the financial resources available, decision makers risk perception and preference, and the type of network under consideration among others. Thus the SD models from this research appears to allow policy makers to assess and test their decision or intervention choices under varied scenarios. It is then that they can optimise strategies and resources for ascertaining resilience to risk of disruptions that can emanate from disasters through designing procedures that could mitigate effects of disaster and disruptions in case they do happen [see Cutter (1996) for detail description of emergency preparedness interventions]. For example Fox (2005) writes that ‘Home

Depot' had a policy for different types of disruptions based on different geographical locations in the USA. Thus during the Katrina disaster, 23 of their 33 stores in the affected region which belong to 'Home Depot' were able to open for business operation just within the space of one day. Other organisations in the region stayed longer to recover while many others perished with the storm. Many other examples abound in the logistics and supply chain literature and elsewhere. The difference in results from these life examples is superior contingency planning or preparedness for unforeseen disruptions. It seems preparedness can mitigate the impact of disruption in port logistics network as well.

Today's logistics networks appear to be more vulnerable to risk of disruptions, thus requiring systemic systematic analysis of levels of vulnerability, security and resilience (Elkins et al, 2005; Lynn, 2005; Sheffi, 2005; Juttner et al, 2003; Rice and Caniato, 2003). One way of attaining disaster preparedness can be by creating necessary redundancy (Sheffi, 2005). However some scholars have argued that 'slacks' or 'redundancy' is expensive, but as compared to lean/agile and its accompanying Just-In-Time (JIT) concept, preparedness (which some writers regard as "necessary redundancy") provides buffer against various forms of uncertainty and pays off real dividend before, during, and after crisis. We re-echo Snyder et al (2006) contention that policy makers should consider various kinds of risks or uncertainty when planning their strategies for operation. Planning should be flexible enough so as to allow for modification since very little changes can be done when disaster strikes without advanced preparation. This is one of the essence of the models which we have designed in collaboration with the CROs interviewed so that management can use such models to analyse, to gain understanding of the phenomena of study, and also to test

the systemic behavioural outcomes under different scenarios prior to change implementation.

Booth (1993) observes that management of organisations recognise crisis situations too often too late, usually because of organisational policy requiring for the need to follow standard procedures that have been entrenched as normal besides the bureaucracies which one must follow in order to get ideas through. These “normal” standard procedures can blur the vision of managers, thus make them sometimes unable to recognise early warnings of impending disaster, or make them develop the tendency to ignore them. This can leave management and their organisations unprepared when disaster strikes. Disruption [disaster] generates chaotic states (Faulkner and Russell, 1997; Peat, 1991; Gleick, 1987; Prigogine and Stengers, 1985). Good management tries to remove much of the risks and uncertainties associated with disruptions (Fink, 1986) through risk (disaster) preparedness.

Dynes and Drabek (1994) note that there is increasing attention that is directed towards disaster preparedness and planning by various organisations and nation states in the 1990s. For instance the UN, the World Bank, insurance companies, and many other agencies (e.g. Red Cross) are concern about building disaster preparedness into development planning process. However, Huque (1998) challenges the claim to disaster preparedness by most emergency service managers and other organisations. It seems that hierarchical structure (in Giddens, 1979 stratification model) and bureaucratic policies are hindrance to prompt response to emergency. A case was reveal by Heath (1995) in his study on Kobe earthquake in Japan in which he observed how real response time of emergency services was badly affected by bureaucratic

procedures. Heath also cites five other impedances to response time in relation to the Kobe quakes (p. 17). The suggestion is that policies and logical decisions do not work well during crises situations. Structure and form of command cease to exist under real emergency conditions. This could be one of the causes of chaos [but preparedness thrives]. Nevertheless, there is need to have internal coordination but not the bureaucratic structure and power relations that restrict organisational ability to promptly respond to disruptions. The result from that analysis by Heath (1995) emphasis the need to incorporate cascaded strategic priority in disaster planning phase. The cascade strategic planning requires that tasks are rank in an order of priority from highest to lowest according to their importance. Cascaded strategic priority profile must be understood at the various levels of management and must be properly articulated to all members in order to enhance lean logistics (waste elimination) and avoidance of duplication and antagonism in actions. This is the role that the feedback SD models of this research seem to have played; to bring understanding to the causes and effects of the phenomena of concern in this research, and to ease communication of ideas (debates) between stakeholders in the HPC and elsewhere.

2.5 Modelling and simulation

Under the above subheading, we will attempt to define ‘modelling’ and identify the typologies. We will also try to state the preferred model for this research to enable us link the heading with chapters 3 and 4. The final section will attempt to justify the use of modelling in this thesis.

2.5.1 Modelling and simulation techniques

A model is a simplified representation of real-world process (Maddala and Lahiri, 2009); a construct expressing a specific theory, or hypotheses (Barton, 1970). In the view of Borshchev and Filippov (2004), modelling becomes useful when a process could not be prototyped or when experimenting with real-world situation could be costly or impossible (e.g. earthquake, flood, strike/riots, extreme weather, oil spillage, war or terrorist attack), yet one wants to gain insight into the outcome of some strategic decisions prior to their implementation. A modelling process involves mapping real life problems on to their models (through abstraction), analysing, optimising, and then the solution is mapped back to the real world system as shown in figure (1) below.

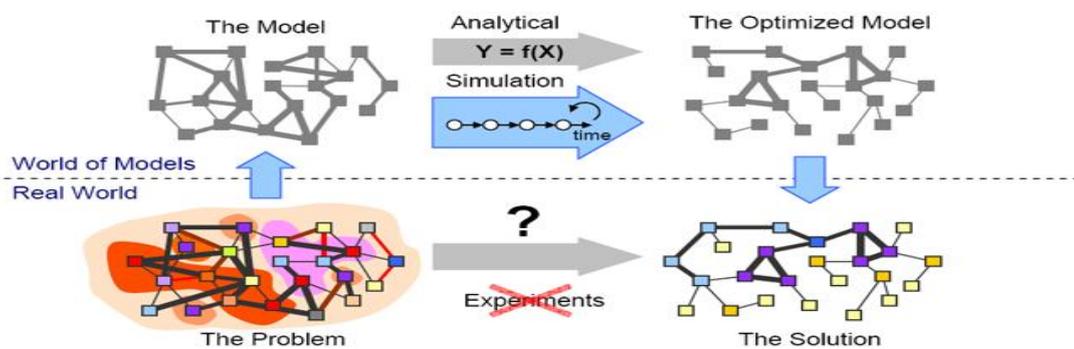


Figure 1: Borschchev and Filipov (2004) analytic (static) and simulation (dynamic) modelling

The modelling process may be analytical/static,²⁶ or a simulation [see practical demonstration in section 4.11]. Modelling can be applied in a research to perform three basic functions: predictive or generative function - with the main objective of looking into future state of a system by observing its past and the present states. Secondly, models can be used to perform diagnostic functions, under which inference into the possible states of a system's past can lead one to reveal its present state and possibly the future state. Thirdly, models can be employed for the purposes of theory building from physical phenomena (Borschchev and Filipov, 2004).

We need to be aware of the dichotomy between qualitative prediction or having foresight (i.e. predicting behaviour modes) and quantitative prediction (i.e. predicting the state of system with respect to time), both of which have been discussed in Troitzsch (1997). It is worth to note that in both quantitative and qualitative modelling, the computer may be employed for making the required foresight/prediction, or for gaining insight (Schieritz and Milling, 2003) into the phenomenon being studied.

Extant literature upholds that different modelling world views (Meadows, 1980) or paradigms (Kuhn, 1970) can cause practitioners to define different problems using different procedures and criteria to evaluate their results. The ability to differentiate among model paradigms and also to select the most appropriate model for application is a success factor in a research. To select a suitable modelling paradigm, Lorenz and Jost (2006) suggest that it should base on the purpose (why), the objective (what), and

²⁶ Functional modelling of results that depend on certain number of parameters based on spreadsheet model

the methodology (how) dimensions. The purpose of the model should centre on the motivation that prompted the research. For example, one may be motivated to solving a given problem, or to finding effective leverage to change, or to optimising a given behaviour, or to gaining insight into a broader and yet to be understood problem in a specified context. It may have become apparent to the reader that, one of the main purposes of this research is to study the interrelationship between the environment, disaster preparedness, and logistics chain's resilience (sustainable performance), so that the problem owner will gain sight into possible consequences of policy interventions (changes) on maritime logistics network.

The selection of an aspect of the real world in a particular context, forms the objective (Lorenz and Jost, 2006) dimension. The objective dimension examines the characteristics of an aspect of real-world and provides key indications for the selection of the appropriate model to use. This part depends on the structure and level of detail of information available about the entity being investigated. For example our literature search on the case study [HPC] shows that most factors that this research sought to investigate were perceived as having potentially high impact on logistics functions and operation of ports in the HE, but low probability of occurrence. The region being apparently stable in terms of large scale regional disasters, coupled with the 'soft' (difficult to quantify) nature of the variables that we wish to investigate, quantitative data was not necessarily available. Thus simulating the impact (influence, or causal relationship) that one construct can have on another may be an appropriate methodological approach to arriving at our research objective (to gain insight into the

interactions between environment stability, disaster preparedness, and resilience in maritime logistics chain as policy interventions are experimented).

Lorenz and Jost (2006) third dimension for modelling speaks of the processes (or methodology) involved in attaining a research objective. According to the Institute of Electrical and Electronics Engineers (IEEE, 1990), methodology is: “[...] *a comprehensive, integrated series of techniques or methods for creating a general systems theory of how a class of thought intensive work ought to be performed*”. This implies that a methodology can comprise of individual methods and/or techniques available for application of a model. For instance, SD methodologies may include techniques such as boundary diagrams, feedback causal loop diagrams, or stock and flow diagrams which can aid in studying the interaction of the behaviour of the research constructs (environment instability, disaster preparedness, and resilience logistics) in the context of HE.

According to Naylor et al. (1967), “simulation” [...] “*is a numerical analytic technique for conducting experiments on a digital computer [or otherwise], which may involve certain types of mathematical and logical models that describe the behaviour of a system over an extended periods of real-time*”. Computers have been programmed in special languages to make them capable of simulating almost anything and are widely accepted as research and analytical tool (Banks, et al., 2005; Shannon, 1998; Naylor, et al., 1966). Simulation models are well suited for “what-if” dynamic scenario decision evaluations. Confirming this assertion, Borshchev and Filippov (2004) state that

‘simulation model is a dynamic set of rules (i.e. dependent on equations, flow charts, states, and cellular automata²⁷), which defines how a system under investigation will change in the future, given its present state’. In other words simulation refers to experimental methods and their analysis using different input values and different model structures (each representing different policies, decision outcomes, scenarios, etc.) which are sometimes treated as black box²⁸ (Kleijnen, 2005).

The execution of simulation model is through discrete or continuous state change over time and is widely used in Operation Research because of the advantages it has over other techniques in terms of flexibility, ability to deal with variability and uncertainty, and also its use of graphical interfaces to facilitate communication with, and comprehension by management (Brailsford and Hilton, 2001) of complex organisation. Simulation experiments are believed to allow the exploration of many more factors and scenarios than are possible in real-life experiments. The grand objective of the modeller is to mimic the observed performance in order to aid in explaining phenomena from a ‘puzzling dynamic world’ (Morecroft and Robinson, 2005). In conclusion, we assert that simulation modelling provides better answer for complex problems where time dynamics is very important (Borshchev and Filippov, (2004).

²⁷ Cellular Automata are discrete, abstract computation systems that have proven useful both as general models of complexity and as more specific representation of non-linear dynamics in a variety of scientific fields.

²⁸ A black box is device which only the inputs and outputs of that box are observed, not its internal operation. Not all simulation models are treated as black box though (Spall, 2003).

2.5.2 Simulation approaches

In a paper presented at the 22nd international conference of system dynamics society in Oxford (in July 2004), Borshchev and Filippov differentiated among four major approaches (paradigms) in simulation modelling. The four paradigms are: system dynamics (SD), discrete event (DE), agent based (AB), and dynamic systems (DS) modelling. According to the authors SD and DE simulations are the traditional paradigms, while AB simulation is an evolution from the traditional modelling Borshchev and Filippov, (2004). Literature suggests that the differentiation in the model approach perhaps stems from key issues such as the level of abstraction, level of detail requirement when a model is being applied, the range of decisions which the model is expected to unravel, and management decision levels requirement. Technically SD and DS deal with continuous process simulations, while DE and AB also focus on discrete time event simulation. Both SD and DS are concerned with designing and modelling of “physical” systems. However, whereas DS focuses on micro modelling and pays attention to details in individual objects (in terms of size, distance, velocity, timing, colour etc.) with low level of abstraction and can be applied at the micro/operational decision levels, SD deals with aggregates (requiring little details to individual objects) and also relies on high level abstraction which has a global (macro) decision perspective usually at strategic level.

DS as a distinction from SD deals with state variables and algebraic differential equations of those variables in various forms (Borshchev and Filippov, 2004). DS involves much higher and more complex mathematical processes that focus on accuracy and details than SD processes and thus DS has been used in part as standard

design processes in engineering disciplines. DS models also deal with integrated variable that have direct “physical” entities such as speed, exact location of event, exact magnitude, and the exact concentration of event (to mention a few), whereas SD treats these entities as aggregates. There is high confidence in SD model especially in terms of representative validity Randers (1980). In terms of model usefulness, SD can be used as learning laboratory (Forrester, 1961) to help management gain insight into business (Morecroft and Sterman, 1994) phenomena. Therefore one can use SD modelling as strategic decision tool since it takes holistic view of systemic performance. Literature acknowledges that SD model can be used in providing full picture (or historical data) of system behaviour within the period simulated. It depicts deterministic behaviour, thus its results are considered as a source of understanding the reasons that cause the change in a system’s performance resulting from counterintuitive effects of the structural behaviour (Morecroft and Robinson, 2005).

In the field of logistics/supply chain management, Kleijnen (2005) identifies four different simulation modelling types: spreadsheet simulation²⁹; business games³⁰; systems dynamics (SD); and discrete-event dynamic simulation (DE). We note that the simulation typology which a modeller may select and use depends on the type of managerial problem that the modeller (researcher) aims to address (Kleijnen, 2005).

²⁹ Spreadsheet is part of production control software which has been used to implement manufacturing resource planning (MRP) (Sounderpandian, 1989) and vendor managed inventory (VMI) (Disney and Towill, 2003). Note that DES provides more realist and power model instead of spreadsheet model

³⁰ Business game is a simulation model that tries to model human behaviour where managers may be required to operate within the interactive ‘world’. It may be useful for the purposes of education (Riis, Smeds & Van Landeghem (2000); Ten Wolde (2000) or for research as is used by Kleijnen (1980) to quantify the effects of information accuracy on return on investment in IBM as well as to study managers’ confidence in their own decisions Kleijnen & Smith (2003); Riis, Smeds & van Landeghem (2000).

From a methodological view point Kleijnen (2005) distinguishes or addresses four key issues underpinning the choice of a simulation model: for research validation and verification; sensitivity; optimisation; and robustness³¹ (risk or uncertainty) analyses. Sensitivity analysis normally yields a list of very important factors in large simulation model from which conclusions can be drawn and decisions made so that best alternatives can be applied (or mapped out) to solving real-world problems. The robustness analysis on the other hand optimises management controllable factors, while at the same time, it attempts to account for noise (Kleijnen, 2005) created by those uncontrollable environmental factors. Examples of some disastrous incidents in the port/maritime transport industry may include; collision of vessels, oil spillage, strike actions, and coastal erosion. However there are some natural events (like faulting, earthquake, volcanism, extreme weather) that cannot be controlled in the short-run. Only their effects on business operations can be managed if adequate preparedness measures are put in place at the appropriate time.

Characteristically, Kleijnen (2005) notes that simulations are quantitative, mathematical, computer generated models. Simulation models may be dynamic with at least one equation and one variable that refers to at least two different points in time (difference equations). Simulation models may not be solved by mathematical analysis per se; they may represent the time paths of dependent (output) variables based on initial states of some exogenous (input) variable. By implication, simulation does not give a 'closed form' solution; rather, the analyst has to experiment with several

³¹ According to Kleijnen's (2005) distinction, a robust supply chain keeps its design fixed yet it is accommodating to many environmental changes while a flexible system has adaptability features that can react to its changing environment of operation

different input values and model structures to come out with the sensitivity of the output (i.e. observing what happens to output under different scenarios), after which depending on the nature of research (experiment), the analyst may perform validity and verification, optimisation, and robustness analyses. Multiple responses (Gunasekaran et al., 2004; Kleijnen and Smits, 2003) are an intrinsic character of simulation models. Generally simulation can help bring understanding of causality as they could give insight into the cause and effect relationships and series of key variables by identifying which factors (or inputs) significantly affect which output/outcome.

For model validity and verification, we adopt Euler's numerical analysis method (technique) to quantitatively evaluate structural behaviour of our stocks variables as we vary certain input values based on field interviews results. For instance we studied the interdependencies in environment instability, disaster preparedness, and resilience in maritime logistics assuming different policy change scenarios. The behaviours resulting from such policy interventions should help management to determine which policy combinations is best as they tackle issues concerning disruptions in the logistics chain in the HPC.

Consequently, we engaged SD modelling to gain both qualitative and quantitative insights into how policy change (intervention) towards disaster preparedness can influences maritime logistics chain's resilience (performance). In other words, we attempt to understand how policy decisions for emergency preparedness amplify resilience (sustained response and bounce-back-ability) of logistics chain of the four major ports in the HE.

Our adoption of SD models (Forrester, 1961; Richardson and Pugh, 1981; Coyle, 1996; Sterman, 2000, many more) to investigate the puzzling dynamics at HPC seem to be consistent with the practice in the field. For example, Higuchi and Troutt (2004) use SD to model the supply chain for the Tamagotchi (pet-toy) in Japan. SD also enhanced the study of closed-loop supply chain of spare parts in Agfa-Gevaerts by Spengler and Schröter (2003), while Ashayeri and Keij (1998) model Edisco's (the European distribution arm of the US Company - Abbott Laboratories) distribution chain using SD. Others who have used SD modelling in SCM are Angerhofer and Angelides (2000), Beamon (1998), Otto and Kotzab (2003), as well as Van der Pol and Akkermans (2000). The general conclusion we draw from all these writers is that 'common sense' strategies may amplify fluctuations in the demand of goods and services by the final customer upstream the supply chain (Forrester, 1961), that perhaps may produce the "bullwhip effects" (Lee et al., 1997) in a logistics system. Therefore SD model could be used to gain insight into the management problem and therefore it is preferred to other modelling techniques when exploring a problem.

2.5.3 System dynamics (SD) model/simulation

According to Forrester (1961) SD is: *"the study of information-feedback characteristics of industrial activity showing how organisational structure, amplification [in policies], and time delays [in decision and actions] interact to influence the success of enterprise"*. SD is a modelling technique that applies engineering concepts and servo-mechanic (electrical control system) theory in social sciences (Richardson, 1991). SD represents real-world processes in terms of stocks

(e.g. material, knowledge, money, people, etc.), flows between stocks, and information that determines the value of the flows (Borshchev and Filippov, 2004; Forrester, 1968b; Tako and Robinson, 2009). The primary assumption of SD is that the dynamic tendency of a system is determined by the internal causal structure of that system (Meadows & Robinson, 1985). However, Robinson (1991) argues that what is responsible for a system's behaviour is not the single decision or the external disturbance, but rather the structure within which decisions are made (i.e. the policy structure within which decision is made). Therefore we propose that the level of disaster preparedness could determine the response and recovery interventions to employ, as well as the sustainability of port's logistics functions and operations in the HPC. Several literature tell us that SD model adopts an aggregate view (Forrester, 1961) which concentrates on policies abstracted from single events. For instance this research studies the behaviour of certain state variables over a period of time as alternative policy interventions towards disruption management and their impacts on HPC's logistics chain are simulated. The mathematics that describes SD modelling as continuous simulation model is a system of integral equations (Forrester, 1968) of the form:

$$N = \int_0^t Stock(\emptyset) d\emptyset; \text{ Where } \emptyset \text{ is a dummy variable of integration ----- eqn (1)}$$

[Specific examples shall emerge under the quantitative analyses of the respective subsystems in section 4.11].

Subject fields or projects that have successfully relied heavily on SD in recent times may include urban development, social, and ecological systems studies. We wish to

explain how disruption (disaster) preparedness influences resilience in port logistics chain, and what influences (or can be influenced by) decisions for preparedness. In applying SD, we will abstract from single events or entities (single organisation) and take aggregate view with a focus on policies regards preparedness towards risks of disruptions and their management in the HPC. We will describe system behaviour as a number of interacting feedback loops [balancing or reinforcing] in consistence with classical textbook model of Sterman's (2000) product diffusion. Under such studies, potential risks may become real disruptions at a rate (speed, or frequency, or size affected by the disaster) that depends on level of preparedness of entity towards the unforeseen event. For instance, if the port is prepared for an anticipated disruption, its response will be quick, which can translate into rapid recovery, leading to improvement in sustainability of port/maritime logistics operations, than it would have been. If on the other hand preparedness is not adequate, response may be slow, disaster can claim more casualties, leading to potential inability to recover from catastrophe and possible systemic collapse.

2.5.4 System dynamics simulation techniques

Risk management studies have been conducted to address various strategies that lead to mitigating risk occurrences (Cachon, 2004; Lee and Billington, 1992; Lee et al., 1997; Levy, 1995; Zsidisin and Ellram, 2003). The complex nature of port/maritime logistics chains and the built – in feedback characteristics of their structure (Wilson, 2005) calls for a consideration of SD model so that one will be able to gain insight into how the interactions between environmental stability (or sustainability), disaster

preparedness and systemic resilience, resulting from policy changes can produce structural behaviour that will aid future decisions towards disaster management. Thus the SD simulation models will help us to study about how different policy changes can cause different responses in the HPC's logistics chain. This may provide room for policy assessment and redesigning, or realignment of maritime logistics activities as well as increase risk managers' motivation towards disaster preparedness.

According to Forrester (1968b) the overall structure of SD is a hierarchically enclosed³² system. SD is the feedback concept whereby outputs go back to become inputs that give a system the capacity to generate behaviour endogenously. Feedback loops show two fundamental characteristic variables: first one is the levels (to represent state of the system) and the second is the rates (to incorporate decision processes which give rise to actions) that cause change in state of the system (Schieritz and Milling, 2003). This can result in two types of loops – the positive feedback loop which have the tendency to reinforce their inputs so that they exhibit an exponential growth or exponential decay, and the negative feedback (balanced) loop which is goal seeking and is self-regulatory. Sterman (2000) shows the difference between physical and institutional structure of systems and the difference between decision rules of participating agents that make decision and those that execute the (decisions) actions. Sterman explains that measurement and reporting processes which produce information cues that can pass on to decision maker are embedded in the physical and

³² Closed bounds implies that all elements relevant for generating the characteristic systemic behavioural pattern have to be modelled endogenously since a system is composed of interacting feedback loops.

institutional structure. It is from these that the decision maker interprets information cues available through the application of policies (decision rules) whose output results in actions that alter the state of the system, which further changes the information. Through such interpretations, complex and informative diagrams can be modelled so that one can clarify problems under investigation in order to gain insight into how these variables interact and influence each other.

SD model will have balanced loops if it contains “odd number of negative signs”, and reinforcing loops (or vicious loops) if it has “even number of negative signs” or is “all positive signs”. Balanced loop is self-regulatory (i.e. system is capable of detecting if a process is just enough so as to adjust automatically). Since SD modelling can be both descriptive and numeric, they can be employed (simultaneously) to study what happens if there is policy or behavioural change in a system. It seems it is this characteristic that Forrester (1968b) describes as learning laboratory. This research will not use SD for predictive purposes because they are not useful tool for prediction and optimisation, instead SD will be used to gain insight into behaviour of research variables.

2.5.5 The justification of modelling in the research

Decision makers have always been sensitive to uncertainties in their logistics chains and are sometimes compelled to tackle risks of disruptions as vigorously as possible. However, it appears that risk management comes with policy changes and also with different costs which many organisations consider as redundancy (Sheffi, 2005), and which they try to avoid. Already some organisations make allocations for “necessary

redundancy” through upgrading staff skills, on-the-job training, and acquisition of standby equipment (and backup services), just to mention a few. Many organisations also design strategic policies or make strategic decisions which may not be needed immediately but which may serve as measures to avoid greater wastage/loss due to systemic breakdown in case something unexpected happens.

We used SD models (as lab) to support logistics chains to finding management policy mix and structures that can lead to greater success (Forrester, 1961) in their own individual organisational contexts. The dynamic theory of this research proposed that the lack of, or, inadequacies in disaster preparedness can increase logistics chain’s vulnerability to risks of disruption and hence reduce supply chain resilience. Generally, it seems that maritime logistics chain’s resilience is the ability to respond to sudden events and having the adaptive capabilities to recover from disruption as well as to sustain operations efficiently. The lack of systemic preparedness could be a function industry’s perception, understanding, and definition of risk vis a vis the environment and its influence on infrastructure as well as the logistics chain’s security and its capacity to cope with significant changes with respect to time. It appears that most systems fail due to accumulation of latent weaknesses or loopholes in the system (e.g. weak security - terrorism, riots/strike, pilfering, vandalism; threats of leakages – spillages, pollution from oil, chemicals and liquid waste; extreme weather elements and many others). Therefore the SD models designed by this research can serve as learning kits which can allow policy makers (in HPC) to perform total systemic vigilance. Through that, they can identify policy changes that are needed towards disaster preparedness and the resilience of the logistics chain plus the potential risks

associated with the changes. Thus thinking outside the box experimentally, management can anticipate the possibilities and extent of disruptions that such policy changes might generate in advance, then based on those speculations, they would be able to make adjustments strategically at the learning lab prior to decision implementation. By this way the research would be able to improve the current understanding of causes, the catalysts, the effects of disruptions in the logistics chain, and how disaster preparedness can ameliorate resilience. Management can learn (through the application models) that risk/disaster preparedness has the potential to improve supply chain performance in terms of its speedy response to, and its recovery from disruptions with minimal, or no interruptions in business functions and operations. Ultimately the research models will serve as a scanning platform that can help the maritime logistics industry (in the HE) to consider all possible events (the separate and/or combined effects of events) as they design, redesign or realign their strategic policies that will make their functions and operations more robust and yet adaptive to changes in business. A change in perceptions towards disaster preparedness that can generate proactive (rather than reactive) attitude is expected to be developed by management and stakeholders after the use of the research models such that resources committed to disaster preparedness can be adequately justified as management juxtapose (through debates) the expected cost of disruption(s) against the costs of risk preventive (security) measures, or compare expected losses if event occurs under prepared condition against those without any preparation for best decision choice.

To wrap up this section, we hope that the research findings can change management perceptions about the capabilities of their logistics chain, as well as change their attitudes towards disaster preparedness such as to enable policy makers to learn in advance about the potential consequences of disruptions, the potential consequences of some interventions, and also provide the risk management teams the opportunity to explore all possibilities leading to improving resilience. Logistics chains can learn from the models, the need to adopt integrated preventive security measures (Zsidisin et al., 2005) as well as the need to be adequately prepared so that they can rapidly respond to disruptions when they occur (Hale and Moberg, 2005; Zsidisin et al., 2005; Sheffi, 2002) and possibly devise many alternative windows for recovery or bounce back from disruptions.

2.6 Chapter highlights and research gap

In this chapter, we defined constructs such as supply chain and its management, supply chain disruption, supply chain vulnerability, risk (classification and management), supply chain security, as well as discussed contemporary issues bordering port/maritime logistics networks not excluding the role, ownership, management, functions, trends and the impact on economic growth. This part of the review enabled us to identify the relationship between the port and its *environment*. We also did a thorough review of “*disaster*” and “*resilience*” and tried to build a relationship between the environment, disaster preparedness, and resilience.

In drawing the above relationship, Bichou (2008) defines accident as a random event whose frequency is influenced by certain factors (empiricists view cited). The immediate cause of accident is hazardous event (safety literature cited). The IMO defines hazard as something that has the potential to cause harm, loss, or injury to entity; the realisation of which can result in accident. Thus hazard has cause and effect (consequence) components which when combined can produce a risk. The classical theorist (cited in Christopher and Peck, 2004) defines risk as “the variation in distribution of possible outcomes [impacts], their likelihood, and [their] subjective values”. Risk has been classified (categorised) differently by various authors (see Juttner, Peck, and Christopher, 2003; Manuj and Mentzer, 2008). It appears that disaster is but only a characteristic level of risk in a system whose severity can range from low to high frequency of occurrence, and in impact. We focus on low (rarely) occurring incidents whose impact on the spokes of maritime logistics chain is high. The occurrence of such low probability but high impact external environmental hazards have the potential to induce myriad of reactions from problem owners (see detail of perception and behaviour of disaster victims in Childerhouse et al, 2003 and Lindell et al, 2012). To avoid such knee-jerk reactions, there is need for a sound strategic risk management to mitigate the impact. It seems that aims of port/maritime logistics system are closely tied to risk identification through risk assessment and risk management, using appropriate safety measures. Harbours, shipowners, and shippers aim at reducing risks to As Low As Reasonably Possible (ALARP). Part of risk mitigation involves adequate planning that can promote quick respond to disaster and also develop self-adaptive capabilities to bounce back from disruptions (resilience). Supply chain literature concede that Ponomarov and Holcomb (2009) identifies three

elements that defines a resilient entity: readiness (preparedness); response (adaptation); recovery or adjustment. Further to the three identified elements, the co-authors also posit that every supply chain activity contains some risk.

Undeniably, the most common risks in the port/maritime logistics industry today include: vessel capsized, grounding, collision, leakage of dangerous cargo, fire, equipment failure, sharp contrasting weather and water conditions, change in political systems, growth of piracy and terrorism. The occurrence of any of these events has the potential to cause disruption in the logistics tunnel. Disruptions in a supply chain may arise from accident (disaster) that can emanate from external natural source or internally induced human errors. As risk levels rise the need to develop superior capabilities also rise. To understand these relationships and to reduce risk in the supply chain, it requires a design that incorporate event readiness, provides efficiency and effective response as well as the opportunity to recover from a disruption.

Lindell et al (2007) identified four stages of emergency [disruption] management: hazard mitigation, disaster preparedness, disaster response, and disaster recovery. Bichou (2008) mentions Event Tree Analysis (ETA), Markov process, Fault Tree Analysis (FTA), Failure Mode and Effects, and Formal Safety Assessment (FSA) as some popular conventional risk assessment (analysis) tools in the maritime logistics terrain. Critiques have found that the calculation involved appear to be subjective apart from it assuming a near perfect condition to hold. This methodological gap we seek to partly fill, by using a dynamic risk assessment model such as the SD to evaluate the impact of certain policy changes on risk interventions (situation, task) in real-time.

This can allow the researcher and the problem owners to adjust response to meet risk conditions.

Technically, one may claim to *assess risk* when s/he considers the probability (likelihood) of an event; models the response or effects of an event on component of a system; or weighs the severity of the outcome of an event on a part or the whole system (Haimes, 2006). The approaches that many researchers have engaged in risk assessment in the port/maritime logistics industry include: rule-based assessment (which dwells on regulations, approved codes of practice, class rules); others use engineering judgement; qualitative risk assessment; semi-qualitative risk assessment; quantitative risk assessment; and value-based assessment (www.HSE.gov.uk). In all these approaches, problem arises when there is insufficient data. In the situation where one is attempting to explain causal relationships between certain key variables of a complex whole, and where one is constrained with access to appropriate data for analysis, modelling (such as the SD) appears to be the best alternative for the research.

To recap the key points in the chapter, we deduced from literature review that hazards are the causes of accident. The two components of hazards are cause and effect (consequence). Hazard can have a range (magnitude) which measures level of an accident depending on whether it is low or high in terms of the frequency of occurrence and in terms of consequential impact. This measure (range) is termed 'risk'. The manifest of a higher range and magnitude of risk becomes a disaster. We also know that accidents have high potential to cause disruption whose impact depends the level of vulnerability, based on entity's size and physical environment (physics). Mitigation refers to measures that reduce vulnerability to certain hazards. Mitigation

measures include both response and development of adaptation capacity for recovery from disaster.

In conclusion, it appears that stakeholder involvement in strategic policy making that leads to seamless transition in risk management (or mitigation) is not very common in the port/maritime logistics industry. The result could be that both those who implement policies as well as those who can be affected by policy interventions may not understand the need and the consequences thereof. Shipping and maritime logistics is more of “order from above” relationship between the supply chain parties, partly due to the long historical connections of port/maritime operations with naval activities. Compliance to instruction is an upheld culture where fragmented thinking is the norm (Bichou et al, 2007). This current approach to risk management may sometimes promote revolt, antagonism, and poor implementation of decision, leading to more grievous consequences. One should bear in mind that risk management does not only help to prevent disaster, it also helps to put into practice what is known as sustainable measures. It is in line with this that various conventional assessment models and procedures have been developed in the maritime logistics industry (see Bichou, 2008). However those models seem to be polarised at the extremes of the quantitative or qualitative methodological continuum. Thus this research is set out to close two major gaps in port/maritime logistics research; firstly, to involve problem owners in model building, analysis, and evaluation such that it may help improve their understanding of the sources of disruptions in the logistics system at ports on the HE; and secondly to break the methodological polarisation that exist in port/maritime logistics risk and security research using the SD model. Furthermore, it appears that there has not been

any research that has establish the influence (causal) relationship between the three stock variables (environment, disaster preparedness, resilience in port/maritime logistics system) whose structural behaviour we attempted to analyse in this research. This research may become useful in that direction as well.

Chapter Three: Research Methodology

This chapter discusses “how we got here” or the steps that were taken in order to arrive at the results. We began the chapter by first explaining the theoretical framework which led to the revelation of the research perspective. We briefly discussed the grounded theory (GT) as supplementary review to a few other theories such as the rational action theory, social functionalism theory, the theories of structuration and stratification which we have reviewed already (pages 48 – 52). These theoretic bases enhanced our investigation into the properties associated with entity, typology, system, and interrelated constructs. We also discussed the research context, designs for data collection, and data analysis techniques which became the foundation for chapter 4 and 5.

3.1 Theoretical background (framework) of the research

“A *theory* is an explanation that is based on scientific study and reasoning” (Webster, 2000, p. 335). McEntire (2004) posits two dimensions for theories: one as an explanation preferred, or an ideal condition for entity in an environment. For instance a society, or an organisation [e.g. the maritime logistics industry], desires to exist and operate in a disaster/disruption free environment, devoid of losses of life and/or resources (revenue, time, or infrastructure). Thus all attempts will be made by the stakeholders for mitigation against disasters by assessing risks and planning towards rapid response in case an incident occurs, and also by formulating strategies for rapid recovery from hazards. The second dimension relates theory to a potentially complex body of knowledge that is available to a given discipline. McEntire seems to imply that

theory on a subject (e.g. disaster) should focus on the entirety of a phenomenon and not just on its specifics. For example in studying disruptions relative to the maritime environment we probe the possible causes and consequences of some phenomena (including geological, meteorological, and anthropogenic events) which might influence logistics activities. Theories also state how interrelated research constructs could be impacted by the mechanisms responsible for creating a phenomenon (Schmenner and Swink, 1998).

A complex system is made of a large number of parts that have many interactions (Simon, 1969). It is a set of interdependent parts which together make up a whole that is also interdependent with some larger environment (Thompson, 1967). Similarly, the logistics system of port on the Humber Estuary can be described as a complex system since it is also made up of a number of activities or subsystems (Daft, 1992) that can be measured by their vertical complexity (i.e. organisational hierarchy), horizontal complexity (in terms of job title/departments across the entire organisation), spatial complexity (i.e. geographical locations of organisations) and environmental complexity.

Environmental complexity relates to the number of different elements that must be simultaneously dealt with (Scott, 1992) by the port (see section (5A)). Such an interrelationship can be described as being nonlinear (Daft and Lewin, 1990), complex (Casti, 1994), and unpredictable. According to Galbraith (1982), organisations try to match the complexity of their structure with those of the environment and the available technology and thus creating a complex interacting parts of web-like system of feedback loops. One can also note that the more complex a system is, the less

knowable it can be, and the more deeply ambiguous is its operations (Perrow, 1967). Models are therefore a means of encoding such naturally complex systems into formal system in order to compress long descriptions into shorter and easily grasped statements (Anderson, 1999).

3.2 Research Methodology

Research methodology is concerned with the methods (techniques) usually adopted in scientific inquiry. The methodology also applies to the ontological and epistemological stands to be followed in a research work. The methodology links the research strategies and the designs that will be used to lead a researcher on to attaining the research objective (Crotty, 1998).

According to Morgan and Smircich (1980), the suitability of the method(s) used in a research is driven by personal assumptions and the social phenomena which the researcher intends to explore. To explain further, it implies that the nature of the problem to be researched, the environment of the research, and the paradigmatic inclination of the researcher dictate the methodology and method/strategy to employ in a research. Most social research inquiries are put into two broad categories - quantitative and qualitative approaches. A third approach which has evolved from the two basic approaches is the mixed-methods (Johnson et al., 2007) or the pragmatic (Onwuegbuzie and Leech, 2005) approach.

The title of this research is:

“Applying System Dynamics Modelling to Building Resilient Logistics: A Case of the Humber Ports Complex”.

The research studies how policy changes (interventions) can influence the interactions between the environment, disaster preparedness, and resilience of the logistics chain of ports on the HE. We investigate what influences disaster preparedness and also how the interdependency between the environment and disaster preparedness can affect port’s resilience or performance [in terms of the perceived capacity to respond to and/or to bounce back from disruptions]. The research focus is to gain an insight into the phenomena under study, to analyse the structural behaviour of the state variables as a consequence of policy changes (interventions) amidst logistics operational uncertainties through which we hope to improve current level of understanding the causes of disruptions in the maritime logistics network.

In order to gain deeper understanding of the phenomena (or the constructs) we adopt the interpretive (qualitative) methods/approach in data collection, then use the qualitative plus quantitative mix (as applied in system dynamics) in data analysis and interpretation. The SD approach in particular is well noted for its ability to provide insight as well as make foresight into a complex management problem. The description in this paragraph about the focus of this research suggests that neither quantitative approach nor qualitative approach alone can adequately yield the expected result. Hence the choice of an integrated, or methodological pluralistic (mixed methods) approach as it emerged later in this chapter.

3.3 The Methodological Design

A research design is synonymous to a blueprint, or the general/specific plan for the study of a research problem. According to Philiber et al. (1980) and Yin (2014), research designs consider at least four basic problems:

1. What question(s) to study. For example this research studies how policy changes can influence disaster preparedness, port stability, and resilience.
2. What type (approach) of data collection to use (whether qualitative, or quantitative, or mixed methods). We adopt the qualitative [personal in-depth interview] approach in data collection.
3. What data are relevant to gather so that one can improve research findings and consistency? This aspect borders on whether one should rely on primary data, or secondary data, or both. We are not interested in issues concerning the size of operation. Rather we are focused on the physical environment and the consequences of policy interventions on maritime operations.
4. What approach to use in the data analysis in order to arrive at best results. We adopt SD models which are both quantitative and qualitative in nature, based on data which is grounded in field interviews from risk managers (CROs) at the major ports on the HE.

Following from the fourth point, we are aware that Morgan (1998) and (Morse, 1991) postulate that a researcher using the mixed method approach may consider the dimension of emphasis to place on the use of a particular research paradigm. In Morgan (1997) the author distinguishes between quantitative/qualitative mixes. One can choose quantitative as the primary approach and qualitative as secondary. By this combination, it implies that the researcher may uses qualitative approach to collect

data, followed by a qualitative data analysis that may finally be crowned with a quantitative analysis and interpretation. Other authors call this approach ‘a qualitative dominant mixed methods approach’ (Johnson and Onwuegbuzie, 2004; Morse, 1991; Tashakkori and Teddlie, 1998) [see figure (2) of this thesis]. Thus we employed the post-positivist (quantitative) view of research process, yet we concurrently recognised that the infusion of interpretivist or hermeneutic (qualitative) tools would benefit the research project (Johnson et al., 2007).

Mentzer and Kahn (1995) observe that logistics research is populated by quantitative or positivistic approach. The new step forward seems to be the mixed methods which, according to many scholars, is an extension of research triangulation (Gioia et al, 1989; Gioia and Pitre, 1990; Lewis and Grimes, 1999). Such research perspective allows one to view a phenomenon from different methodological viewpoints (Brewer and Hunter, 1989) using different lenses (Kelemen and Hassard, 2003), instead of just applying different research methods (or instruments). Mixed methods are therefore a means of bridging the schism between quantitative and qualitative research (Onwuegbuzie and Leech, 2005).

The quantitative part follows formal, objective, systematic process in which numerical data (graphs) are utilised to obtain information about the world (Cormack, 1991) in a sequential order. Following from sequential requirements in quantitative research (Bickman et al., 1998), we reviewed relevant literature (e.g. journal articles, books, annual reports, working papers, magazines and company websites) in order to develop the methodological conceptual framework. Such a frame pointed out the research constructs as well as the expected relationships among them. We built general theories

(Kerlinger and Lee, 2000), out of the information we derived from the preliminary investigations adopting steps in the grounded theory (see Glaser and Strauss, 1967) techniques.

The qualitative part seeks to understand the research phenomena in the problem owners' terms (Hirshman, 1986). For instance, we cannot quantise perceptions and policy behaviour leading to disaster preparedness and resilience. We also note from Creswell (1998) that qualitative research approach is desirable when the phenomenon of interest is new, dynamic, complex, where relevant variables are not identifiable, or the extant theories are not available. Our research exhibits these characteristics. We investigated how CROs perceive risks in the maritime logistics industry and how they respond to disruptions as well as how they plan to bounce back from crisis incidents. Therefore it is appropriate to include the qualitative approach so that we can gain insightful understanding of the emergent complex phenomena. This approach can help us to build inductive (dynamic) theories that are grounded on raw data.

The use of quantitative-qualitative methods for the purpose of gaining better understanding into a single problem is consistent with the principle which suggests that where multiple or pluralistic research paradigms are adopted in order to establish a central ground in a single study, it can be reasonable and more comfortable to employ an integrative paradigm (Bryman, 2006; Johnson and Onwuegbuzie, 2004), or mixed methods approach (Creswell and Plano Clark, 2007; Morgan, 2007; Johnson, 2006; Johnson and Christensen, 2004; Tashakkori and Teddlie, 1998; Patton, 1990). Thus figure (2) below represents the conceptual framework of the research methodology.

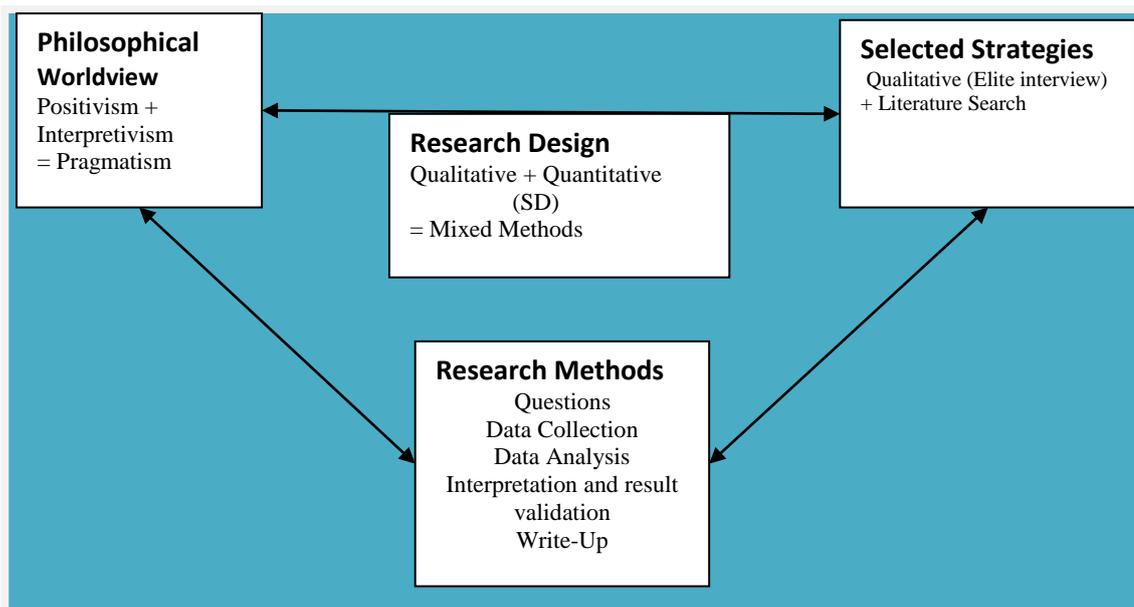


Figure 2: A framework depicting the interconnectivity of philosophical paradigms, research designs, research strategies, and research methods for this thesis. An adaptation from Creswell (2009, p.5)

The above frame (figure 2) depicts the interrelationships between the research philosophy, the methodology, the research design, and the strategies adopted in this research. We merged qualitative and quantitative research at the design, data collection, and data analysis stages in consonance with Seiber's (1973) outline for effective combination of research paradigms. For example, at the design stage, we conducted personal elite interview (a qualitative approach). Steps in Grounded Theory philosophy were engaged as the analytic methodological tools to extract causal relationships from the raw textual data obtained, from which causal loop maps [qualitative models] emerged. Vensim simulation runs [quantitative analysis] was performed to enable us study the dynamic behaviour of the key constructs under different policy interventions (scenarios) from which both insight and foresight can be gained into the structural behaviour of such state variables.

3.4 Justification for choice of mixed methods approach

Onwuegbuzie and Johnson (2004) defines the mixed methods research as:

“The class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts, or language into a single study”

Mixed methods approach follows the pragmatic philosophy; an approach which can be logically inductive (i.e. involves pattern discovery), deductive (i.e. including theory or hypotheses testing), and may sometimes rely on (or uncover) best set of explanations for the understanding of results (de Waal, 2001).

Following from Greene, Caracelli and Graham (1989), we shall employ mixed methods (figure 2) strategy for the purposes of: (a) triangulation; (b) complementing data source for analysis; (c) theory development; (d) theory initiation and uniqueness of research; and (e) knowledge expansion. In an attempt to fulfil the above purposes, we engaged Onwuegbuzie and Teddlie’s (2003) seven-stage data analysis process: (1) data reduction, (2) data display, (3) data transformation, (4) data correlation, (5) data consolidation, (6) data comparison, and (7) data integration. This is also consistent with steps in the Grounded Theory (Glaser and Strauss, 1967) philosophy which was engaged in chapter 4.

For instance, data triangulation (Denzin, 1978; Mathison, 1988; Webb et al., 1981) helped to ensure that biases which are inherent in data source, investigator source, or a particular method (quantitative/qualitative) was neutralized such that the result seem to converge the truth about the interdependencies between port instability, disaster preparedness, and resilience logistics network as different policy interventions are tested prior to change implementation. In conclusion, we adopt the methodological

pluralism (Sechrest and Sidana, 1995) in order that we can improve research validity³³. It seems that such paradigmatic approach offered us a deeper understanding and completeness in the outcomes (Gioia and Pitre, 1990), as well as improved communication (both in the intended and unintended findings) as we attempt to advance knowledge (Maxcy, 2003). It appears that this approach also gave us an opportunity to answer our research questions. As it shall emerge in latter sections of this chapter, the selected strategies for data collection was the personal (face-to-face) elitist interview with CROs and other stakeholder in HE followed by the SD modelling as analytic methodology.

3.5 The Research Methodology

The methodology of a research refers to the overall stepwise and the iterative processes of investigation, by which concepts, philosophies, and theories can be expressed independently of the subject matter of investigation and independently of the problem type to be considered (Wolstenholme, 1985). Elsewhere, Jackson and Keys (1984) define methodology as ‘any kind of advice given to the analysts about how they should proceed to intervene in the world’.

We employ modelling and simulations as the analytic methodology to studying how policy change (interventions) can influence the interdependencies between

³³ Research validity can indicate how sound a research is. Specifically, validity applies to both the design and methods of a research (Winter, 2000). “Any research can be affected by different factors which, while extraneous to the concerns of the research can invalidate the finding” (Seliger and Shohamy, 1989). Validity appears to also stand for research quality, rigour, or trustworthiness (see Davies and Dodd, 2002; Lincon and Guba, 1985; Mishler, 2000; Seale, 1999; Stenbacka, 2001)

environment instability, disaster preparedness, and resilience in logistics chains in the context of ports on the HE. We used causal loop mapping/diagramming (CLM/D) as one of systems methods (tools) to link system insight and system modelling as required in system dynamics modelling (see Richardson and Pugh, 1981; Roberts et al., 1983; Wolstenholme, 1990).

In the field of system of systems methodology (SSM), both CLM and SD are located within “Unitary” domain. However, whereas SD modelling comes under hard systems (quantitative approach) and is categorised as “simple” (i.e. being deterministic or stochastic), CLM gravitates towards “complex systems³⁴” category (Jackson, 1991). Advocates for CLM cite the claim that it is easily accessible even to non-experts (Ford, 1999) and thus is easy to understand by the ‘ordinary’ person. However, CLMs have often been used as foundation for SD. Thus Haraldsson (2004) states that CLM is a useful tool for brainstorming, so that one can upgrade on to SD which can be more quantitative, slightly complicated, and non-accessible to all but a few minority of modelling experts (Greenberger, Crenson, and Crissy, 1976). On the other hand proponents of SD have criticised CLM for the reason that they are ambiguous and lacked detail; they are static models, and perhaps do not create room for simulating the universe. One may recall that Popper (1992) describes the universe as being “partly causal”, “partly probabilistic”, and “partly open”. It seems disaster management can be located within the ‘unitary’ domain under systems engineering concept where certain social activities need to get done at specified time and space in order to be able to

³⁴ A methodology which is rather subjective, non-deterministic, yet it is highly probabilistic.

contain a situation. For instance one does not need the permit from victims in a disaster hit situation (e.g. earthquakes Haiti, Hurricane Katrina and super-storm Sandy or fire outbreak in Brazilian nightclub) before qualified persons go to their rescue. This part therefore will situate this research in the “simple” and “unitary” (Jackson and Keys, 1984) domain, or the domain of “machine metaphor” (Flood and Jackson, 1991) human behaviour. By the “unitary” viewpoint we argue that everything can have causes (Beishon and Peters, 1981) and effects. Therefore rational predictability of cause and consequence of phenomena is possible to some extent in every situation. Here one needs to stoically accept the inevitable events (both natural and anthropogenic disasters) when they are anticipated, and rather prepare for their occurrence. This part justifies quantitative SD modelling which Popper (1959) calls ‘prophecy’. That part can be analysed using dynamic models including difference and differential equations. Based on assumptions, “what if” analysis (using computer simulations) can be made under different scenarios to anticipate logical consequences of such research assumptions. Prior to the quantitative SD, a qualitative SD which relies on CLM/D would have been built to take care of Popper’s (1992) ‘partially open’ part of the world.

3.6 The philosophy, paradigm, and theory behind methodological choice

System dynamicists are naturally inclined towards certain theories and philosophies. For instance there are those who lean towards the isomorphic theory (Churchman, 1971; Hall, 1962; Jenkins, 1969), others believe in adherence to mathematical problem solving approach (Ackoff, 1978), some group also prefer the interpretive cybernetic

approach (Beer, 1972) then there is the computer analytic theorist philosophy (De Neufville and Stafford, 1980). There also exists the structural modelling ideologists (Linstone, 1979), and the purely qualitative [soft system] ideologists (Checkland, 1982). Amidst these ideological divides, some other writers including Denzin (1978) suggest that SD is a positivist paradigm because it attempts to frame casual explanations in terms of universal statements [...] *universal propositions* (p. 130). When viewed from different perspective, SD modelling shows the characteristics of pragmatic research (Onwuegbuzie and Leech, 2005; Maxcy, 2003; de Waal, 2001) paradigm or the mixed methods approach (see representation in figure 2 under section 3.3).

In our attempt to establish link between model and extant theory, we tried to applied the structuration theory (Giddens, 1979) to explain the relationships between policy change and increase in risks (or disruptions) potentials as entities perform their normal social functions in the maritime logistics industry. Policy interventions may be well intended, yet they can also lead to undesirable consequences far different from the anticipated results. Literature has also revealed that there appears to be a link between the use of SD and the traditional structural functionalism theory (Bickerton and Siddiqi, 1992) of social systems; an approach which attempts to provide rational explanation to social issues through generalisations. By the structural functionalism theory, we cannot fail to accept that a change in one of the key constructs (i.e. environment instability, disaster preparedness, or resilience) may result in change in the entire structure of the maritime logistics network. Through such changes there can emerge a theory or at least a set of conceptual categories that can be used ‘[...] to

analyse all societies through history' (Ritzer, 1996, p. 257). For example if policy regulations about the use of the Humber Estuary and its resources are changed to ensure that all port operators prepare adequately for unforeseen disruptions (such as by enforcement of strict environment regulations that can reduce pollution or carbon emission), ports can become more resilient to disruptions caused by disasters (e.g. flooding and extreme temperatures). Therefore studying potential causes of disruptions in the operations of port/maritime logistics chains in the HPC and the antecedents, patterns could be generated which can aid management in designing plans for disaster mitigation and the maritime industry's operational sustainability.

Theoretically, it seems the CLM/SD lack specific assumptions (Lane, 2000), though attempts have been made elsewhere to that effect in Meadow (1980); Barlas and Carpenter (1990); Lane (2006) and Vennix (1996). Recent research however locates CLM/SD as theory within the sociology in the functionalist paradigm (Burrell and Morgan, 1979). Otherwise Lane and Oliva (1998) suggest that SD/CLM and its theory have links with interactionism and the interpretive paradigm.

Lane (2000) suggests that, SD can be offered at different theoretical levels including the structural theory, and the methodological theory levels. At the structural theory level, Lane believes that change in system behaviour over a time period can be explained using causal (feedback) loops and state variables. Social systems frequently behave in ways which are contrary to the intuition of what the actors who are implementing policies aimed at influencing. It seems that this anomaly emanates from the fact that the actors are part of social systems from which they collect information about. Such actors may influence the information gathering process and state of the

system. However the aggregate behaviour of such systems can usefully be explained using the concept of feedback loop, or stocks and flow diagrams. The feedback loops can be a plausible representation of the influencing cycle of activities, and the stocks become a plausible representation of the system state variables. Models which are based on such concepts offer a representation of causal links between variables. Therefore, they allow for a rigorous deduction of the consequence of those links. Such models become theories of the structural source of particular aggregate behaviour and can be used to make deductions about the mode of behaviour that will result from implementing a given policy (Lane, 2000).

The representative theory aspect is exhibited in the concept of feedback loops and state variable during the construction of SD models (Forrester, 1968b). This is what Lane (2000) called “methodological theory”. Such models allow the application of logic to revealing hidden results (Simon, 1969). The theory underlying the representative theory explains that one cannot infer behaviour of systems represented in causal diagrams logically consistently without the requisite deductive pattern aided by computers (or otherwise). Thus there is the need to use simulation with the support of empirical data (Sterman, 1994) which may be computer generated in most cases. Lane (2000) adds that each of such representative models may become a minor valuable content theory on its own. Following from the above discourse therefore, one will accept the reason why we rejected the grand (content) theory approach and rather chose to build the research on grand methodology (or structure) that can be associated with scheme representation.

However, are those causal links and SD tools adequate enough to treat human behaviour or perceptions that may lead to knee-jerk reactions towards policy change (interventions)? This is partly answered in Giddens (1993) under the concept of ‘determinism’ as a social construct where theoretical scheme reduces human action to simple ‘event causality’. Though there are differing views about causality in social theories, the philosophical aspirations of the different views seem to remain the same in what looks like a grand theory (Lane, 2000). One may recall Scott’s (1995, pp. 173-174) statement that:

[...] *“Causal mechanisms both reinforce and undermine one another, they operate alongside other unknown mechanisms, and combination of mechanisms differ from situation. As a result, actual events are never simple consequences of a particular mechanism: they are always “overdetermined”.*

The task of (social) science therefore is to comprehend this over-determination by extending the scope of its knowledge of the causal mechanism operating in the world. This understanding is what we seek to do using simulation modelling.

Other theorists like Craib (1991) argue that some notions of teleological [goal seeking] causality is necessary if we wish to understand human action. However, the same author asserts that:

“[...] the theoretical explanation of how and why people act has an entirely different structure and a different notion of cause” (Craib, 1991, p.23). *“[...] people act because they are swayed by reasons, or because they decide to follow some set rules; not because their actions are causally determined by forces”* Phillips (1987, p. 105).

We wish to add that causal laws of natural sciences may not be able to explain human actions because in social science such laws are never straightforward (Richardson, 1991; Phillips, 1987). Yet we aim to understand managerial actions in relation to crisis situations and their management. It seems the hermeneutic or the interpretive data collection approach through personal in-depth interview with elites in risk management at HPC will be appropriate. We can therefore be justified to include interpretive (or subjective) approach in our data collection, data analysis, and reporting.

Following from the forgoing arguments, it is becoming clear that models which speak about cause and effect relationships such as CLM/D in SD, is appropriate because it deals with aggregates (Forrester, 1961) and not individual actions. Furthermore it appears that through hermeneutic interpretations, patterns may emerge that are observable though with limited prediction (Phillips, 1987). We take a midpoint stance between causality in SD (which treats cause as pressure which produce aggregate patterns of behaviour) and causality as in Beer's (1972) cybernetics, which takes into consideration events, actions, individual stimuli, and decisions (Richardson, 1991) in rather subjective manner.

3.7 The Causal loop maps/diagram (CLM/D) as methodological tool

CLM is a diagramming research methodology (tool, or technique) that is good for conceptualising feedback system model (Morecroft, 1982). Also known as influence diagrams (Roberts et al., 1982), or cognitive mapping (Eden, 1994, 2004; Williams, Ackermann and Eden, 2003), CLM can be used to explain system's behaviour

(Wolstenholme, 1982). It provides a holistic thinking during problem identification and problem solving as the CLMs are known to have advantage over the reductionist³⁵ approach (Churchman, 1968; Von Bertalanffy, 1968; Popper, 1957). According to Morecroft (1982), CLM is a powerful as well as a concise way of conveying the concept of feedback structure, and it can also be used as a tool for behaviour analysis and policy design. Hence Goodman (1974) wrote that CLMs can be most useful during the early stages of model conceptualisation, to helping one identify and organise principal components and feedback loops of the system being studied. CLM simplifies and transforms verbal description (as in interview data) into feedback structure as we shall demonstrate in chapter (4). Such diagramming also readily reveals the loop structure of complex models to people who might be unfamiliar with flow diagrams or DYNAMO notation. CLM improves system's goal seeking capacity by increasing the understanding of the system's behaviour (e.g. how policy interventions (change) and environment instability can interact to influence organisational readiness for crisis and their mitigation).

CLM and feedback loops are normally used to illustrate structure and behaviour of system over a time period (Binder et al, 2004; Wolstenholme, 2003; Senge, 1990; Richardson, 1986). We adopt CLM models as an illustrative methods that can impact on what problem owners think, how they think, and how they communicate their intentions to others (Ossimitz and Lapp, 2006; Ossimitz, 2000). The CLM is a

³⁵ Reductionism is a philosophical position which holds that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to the individual constituents of component parts forming the whole.

qualitative method that is used to show systemic interrelationships (Lapp and Ossimitz (2007) between constructs or research variables, built on cause-and-effect relationships that portray the behaviour of systems in a network of several of such variables. These networks of interrelationships focus on, and are reflected in feedback loops. Such loops may ease communication among stakeholders through causal diagrammatic representations and they can become the building block for SD models (Richardson, 1986). Such feedback loops can allow this research to explain non-linear relationships between key variables and also enhanced the description of the behaviour of the loops as we attempt to describe the CLM. However, CLM fall short when it is employed as tool for organising descriptive data of mental models.

3.8 Selecting SD as research methodology

The SD is a policy analysis and design tool. It involves model building that captures the dynamic structures and processes of complex social, managerial, economic, or ecological systems (Forrester, 1961; Richardson and Pugh, 1981; Sterman, 2000). An apt definition by Wolstenholme (1985) states that SD is:

“A rigorous method for problem identification, system description, qualitative modelling and analysis of change in complex systems; which facilitates and can lead to quantitative modelling and dynamic analysis for the design of system structure and control” (p. 1052).

SD modelling is usually build around particular problem such as those we can find in Forrester’s (1961) Industrial Dynamics and others works in the early 1950s. Richardson (1991) says further that SD approach relies on servo-mechanic theories; where social systems are modelled using computer simulation. The SD model building

involves the researcher working hand-in-hand with owners of a problem to structure debate about long-term policy issues (see Lane, 1998; Forrester, 1990; Randers, 1980 and also Richardson and Pugh, 1981 for detail history and concept of SD).

One conspicuous feature of the SD models is the exhibition of information feedback loops: loops which speak about states of a system and the influencing action that changes the state of system in a closed loop. Such loops involve non-linear causal links and 'delay' that may accumulate in the system (Lane, 2000). Furthermore, SD modelling procedure is described by some authors as a 'top-down' analytic approach where variables are sorted and outlined in Causal Loop Mapping/Diagram (CLM/D) to enhance better understanding of causes and effects (Roberts et al., 1983) in a system. By understanding processes on an aggregate level, it may be possible to gain an overview or insight of the basic system's property (Maani and Cavana, 2000; Ford, 1999; Richardson and Pugh, 1981). Added to the above, SD is also capable to integrate quantitative and qualitative data in its analysis since it has the ability to recognise direction of change for key parameters such that it can guide management to respond accordingly in an adaptive fashion (Winz, Brierley and Trowsdale, 2009). Therefore we adopt SD as a tool for gaining insight into behaviour and evolution of complex systems including the adaptive nature or feedback effects of such systems (Wolstenholme, 1985). These features of the SD approach may be capable to assist this research to deduce the consequent dynamic behaviour (Sterman, 1989) of risk management strategies (interventions) in the HPC with the aid of computer simulations.

Frederick, Deegan and Carman (2008) have acknowledged that SD modelling is capable of capturing policy implementation issues that may cross departments, organisations and industrial boundaries. It also seems easy to extend an initial SD model to enable the modeller to add new questions that may emerge in the research process. Usually information that leads to SD modelling may be complex, subtle, subjective, judgemental, and situational (Doyle and Ford, 1998; Lane, 1999a), or may be described as partly hard (quantitative), or partly soft (qualitative), so as to mimic basic management dilemma. These characteristics of SD will be incorporated in this research to explain the potential consequences of policy changes and managerial strategies governing the conjectured risk/emergency management of ports in the HE.

As stated already, we will engage the SD in two different dimensions - qualitative and quantitative dimensions - which is also akin to the pragmatic paradigm (Onwuegbuzie and Leech, 2005; Maxcy, 2003; de Waal, 2001) or the mixed methods research approach (Creswell & Plano Clark, 2007; Morgan, 2007; Johnson, 2006; Johnson & Christensen, 2004; Tashakkori and Teddlie, 1998; Patton, 1990).

The qualitative section will assist us to develop conceptual diagrams that show relationships between constructs within the systems. Since it is usual for qualitative SD to start with CLM, we will identify causal loops and attempt to explore the dynamics of the loops. This part has the ability to capture the structure and processes of the system when we are constraint by time and resources (Homer and Oliva, 2001; Richardson, 1999). We will represent stakeholders' (respondents') thoughts and assumptions in the form of system structure and function (mental models) such that broader and improved understanding of risk sources and the need to prepare for

disruptions can be established and enhanced. The aim of the qualitative part will be to provide a distinctive set of tools that can easily be used by system owners (port risk managers) and not for analysis alone (Wolstenholme, 1990). The CLM part of the SD model does not necessarily rely on much mathematics, yet it can be useful for analysis of behaviour of systems. CLM (qualitative SD) can also be used as stand-alone methodology because it can be used to structure and analyse ill-defined situations (or ill-posed algorithms) that can be inherent in science-based problem solving methods (Wolstenholme, 1990). The research will develop its diagrams iteratively based on inputs that it will gather from interview respondents or the stakeholders. We will build on the experience and understanding of problem owners (interviewees) to provide accurate and valid CLM. From such a CLM we can estimate the behaviour of the feedback structure (Wolstenholme, 1990).

The quantitative SD models are usually built on “dynamic hypotheses”. Such hypotheses assume that there is a certain causal structure that explains certain dynamic behaviour which can be rigorously testable by model builder through formulation and synthesis of objective, using judgemental data (Randers, 1980b). Such a model then becomes the structural theory for the dynamic behaviour (Lane, 2000). Problem owner can study such mental models, understand them, and then improve the models through repeated experiments with different policy change (policy interventions) under different scenarios till the desired results are obtained prior to policy implementation. We will design stock and flow diagrams (see section 4.10) that will allow the research to analyse its key constructs and the systemic changes over time. We will employ simulation models to further explore the relationships in the systems under focus in

order to provide an added insight into different policy outcomes, or the outcomes of different strategic interventions (Harris and Williams, 2005). This can provide the theory behind the set problem under focus as well as also allow us to examine the interrelationships between variables.

It seems that disaster preparedness is a behaviour driven structure, as such different risk manager in different organisations may adopt different strategies and have different appetite for risk management. However, it appears that policy and the environment can influence risk management strategies that one can adopt, and hence the disaster resilience of the entity in question. We suggest that being aware of the potential risks posed by the environment, knowing the potential sources/causes of risks, and being prepared for uncertainties, can influence the port's ability to response to disruptions as well as its ability to recover from disruptions in real-time. Therefore we propose that for ports to improve their disaster preparedness strategies, management need to improve their current level of understanding the sources of disruptions in their logistics chain and how these interrelate with resilience. Thus we investigate the how policy change can influence the interdependent relationships between environment stability, disaster preparedness, and the resilience of a logistics chain.

Following the steps of Sterman (2000) we will use models [SD] to:

- a. Identify key system components (e.g. disaster preparedness decision options under different scenarios) that will enable the research to examine how the interrelated key variables behave over a time period.

For example what happens to port's preparedness for disruptions if environmental regulations and policies change (i.e. becoming tougher or relaxed);

- b. Define relationship maps among key variables of the systems structure; example, how unstable environment impacts on disaster preparedness and the vice versa; and
- c. Ensure that the models present true representation of how a policy change/intervention can affect the structural behaviour of state variables.

3.9 Justification of the analytic approach

The term 'simulation' generally carries the connotation of quantitative and concrete operational modelling (Richmond, 1993). Thus one may question why we seem to drift elsewhere to include qualitative analytic aspect in the same research. The fact is that we intend to widen the research analytic scope by considering both the qualitative and quantitative aspects of analysis. Arguably, this approach of mixing research paradigms can help the research to still produce valid conclusion even where one approach falls short. Secondly, the research contains soft variables (e.g. attitude and perception, policy change, disaster preparedness and resilience) which may be difficult to quantify. Analysis of such soft variables may produce subjective interpretations which fall within the domain of qualitative research. Therefore it is appropriate that we selected both CLM (qualitative) and simulation models (quantitative) as the analytic tools.

The research could employ econometric approach (e.g. logistics models, survival model, multiple regression analysis, factor analysis, or structural equation models) as the tool for analysis. However it seems by adopting those econometric approach the research will be kerbed to quantitative approach which will make it difficult to quantize soft variables. In reality risk management decision as well as human behaviour especially during complex situation can be fraught with unintended outcomes (Wolstenholme, 1993). We could have also considered applying VSM (Jackson and Keys, 1984; Beer, 1967) as an alternative analytic tool since it can equally treat complex and chaotic situations such as those we can find in disaster management scenarios.

Though numerous analytic tools options exist, we adopt CLM approach because it is a useful tool which can be applied prior to system dynamics (SD) simulation analysis. CLM depicts the basic hypothesised causal mechanism that underlies the reference mode³⁶ of behaviour (Binder et al., 2004) over a certain period of time and could allow us to articulate hypothesised dynamics of the consequences of its feedback structure as an endogenous system (Randers, 1980; Richardson, 1991; Sterman, 2000). According to Coyle (1998) and Eden (1988) CLMs are built with less difficulty yet they can give important insight and understanding that the problem owner wants. As cognitive maps, CLM can be used without computer simulations to represent/express the mind of decision-maker (Jenkins and Johnson, 1997; Bonham and Shapiro, 1986; Weick, 1986;

³⁶ Reference mode refers to a recognised change in behaviour of a structure over time (Richardson & Pugh, 1981, p.19).

Eden, 1994, 1988; Axelfrod, 1976) apart from their ability to connect structure and decisions generated by system's behaviour (Binder et al, 2004).

Many authors including Wolstenholme (1999) and Homer and Oliva (2001) have employed CLM for the purposes of model building, provision of detailed description of system, and also as stand-alone policy analysis tool. We will employ the CLM to test the long-term effects of managerial decisions and strategies (policy changes or strategic interventions) on maritime logistics chain's resilience in the uncertain and complex environment, while facilitating stakeholder involvement, and supporting consensus building towards disaster planning and mitigation.

Furthermore CLM/SD models can help management (CROs, CEOs, CFOs, and COOs) to have a holistic view of the causes of disaster/disruption as they attempt to evaluate their business processes. It appears that a holistic perspective for analysing business processes can foster the view that each process would be understood in the context of its relationship to the people and organisations that execute it, as well as the influence it can have on other upstream and downstream activities (Haimes, 2002). We will examine activities (managerial policies and behaviour) that can generate disruption in maritime logistics chain's functions and operations. CROs can learn and focus on the network of activities that can lead to improvement in disaster preparedness and also promote disaster resilience as they run their port business.

Finally we selected the CLM/SD approach so that in case the research is not able to meet the criteria where all model variables will correspond to the real system being

modelled we can restrict the analysis to the qualitative level; a move which has been arguably justified by Coyle (2000; 1985; 1984b; 1984a; 1983b; 1983a) and Wolstenholme (2004; 1999; 1990) as an equally useful and acceptable tool for research analysis.

3.10 Data Collection and analysis process

Richardson and Pugh (1981) suggest that data source for research that employ CLM/SD as methodological tools may be randomly generated computer data, or documentary evidence (or literature search), or through interview with problem owners. Of the three data sources the co-authors acknowledge that researchers have heavily employed interviews with staff who have in-depth knowledge and great experience about a phenomenon (experts). We purposively selected staffs who are routinely involved with risk management in the industry for interview. Several renowned writers in SD (Coyle, 2000; Hirsch et al., 2007; Levin and Roberts, 1976; Sterman, 2000) have recommended the staff interview approach because it seems to yield better results in terms of high return rate.

The term documentary evidence refers to any written medium by which information can be preserved such that it may enable the researcher to generate data for analysis. This included journals articles, working papers, reports, minutes, magazines, books, charts and websites. By reading extensively, we were able to define and understand key constructs such as risk, security, hazard, disruption, disaster, vulnerability and resilience in the context of port/maritime logistics. Through such documentary source, we identified some gaps in the literature based on which we framed our research objectives, research questions, as well as designed the interview questions that led us

to capture the mental models of the elites in the port/maritime logistics industry. The literature source also provided us with guidance to design, develop, and run research models.

One of the interview questions (#7) presented a hypothesised link among key variables (see figure 3) and sought the opinion of the respondents. CLM that attempts to determine how a policy decision (risk interventions) can reinforce or balance conditions for port disaster resilience over a time period was created (figure 4 and 11) from the textual data produced from the interviews.

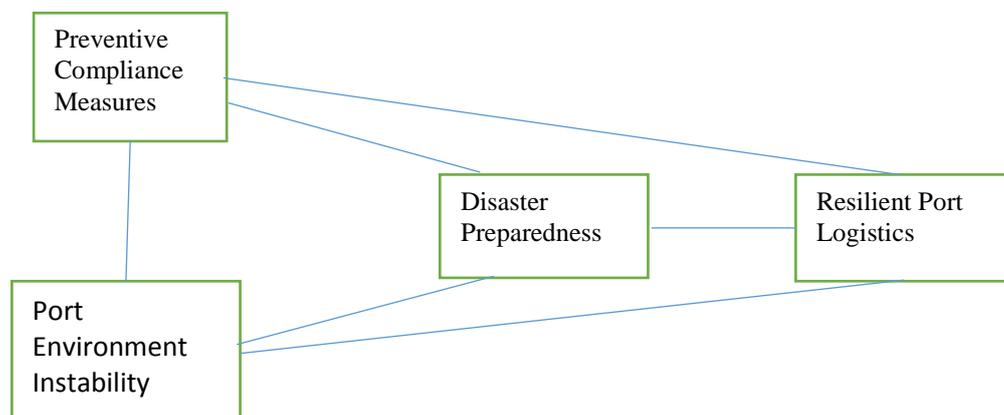


Figure 3: A hypothetic relationship among key research variables

A face-to-face (F2F) in-depth elite interview (Gillham, 2000; Yin, 2009) was conducted within the Humber Ports Complex . The involvement of the elite staff also enabled the research to identify and explore the critical infrastructure at ports and also to identify the potential risks and their sources (e.g. geological, meteorological, and/or anthropogenic sources of disasters/disruptions).

Furthermore, the elites (CRO, CEO, CFO, COOs, and other experts) were purposely selected for interview because we assumed that they hold key information about port

security, emergency, and risk management since such related issues apparently form part of their day-to-day duties. Additionally, they could be key players in policy formulation and implementation concerning disaster planning, crisis and risk management. We put forward seven items (questions) which focused on four thematic areas: risk identification and assessment; current risk/disaster management strategies and procedures; expected changes in the port industry in the next few years (three, five, or ten years) and potential effects that such changes can have on port logistics chain; and the possible consequences of today's planning towards the future events (scenarios of policy change).

The interviews took the form of free conversation with minimum interjections from the investigator. The investigator only interjects when there is need to probe further, or only when it becomes necessary to keep respondent on track to prevent them from veering away from the themes under discussion. Where it was necessary, the investigator requested for documentary evidence to support claims by respondents. Such evidence helped the research to identify threats and similar occurrences of disasters/disruptions in port operations in the past and how they have been managed in the HPC. Scenarios were used to consider a wide range of possible structural behaviour and to explore their potential outcomes on the ports performance so that risk managers can work up mitigation plans for the changes that may ensue from future events by preparing and stress-testing the interventions for disaster preparedness for robustness.

3.11 The Case Study

To paraphrase Gillham (2000) ‘a case study is one which investigates an entity (individual, group, institution, community) in order to answer a specific research question which seeks a range of different kinds of evidence; evidence which is there in a setting, and which has to be abstracted and collated in order to get the best possible answers to the research questions’. Yin (2014) also defines case study as “an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Glatthorn and Joyner (2005) add that the case study research can be undertaken in order to provide a detailed description of a particular situation, organisation, individual, or an event. A case study attempts to illuminate meaning of phenomena using inductive process. The need for adopting case study approach as a form of empirical research has been echoed by many researchers in operations management (see McCutcheon and Meredith, 1993; Ebert, 1989; Wood & Britney, 1989). We engaged the case study approach as we attempt to highlight how policy changes can influence the structural behaviour of the complex interaction between Environment Instability, Disaster Preparedness and Resilient Port Logistics. The dynamic Theory of this research³⁷ states that “*preparedness for unexpected events (or uncertainties) can promote resiliency in port logistics chain*”. The rival theory shows that “*the lack of preparation for disruption can make the port logistics chain more vulnerable to external environmental (exogenous factor) risks, increase the impact of disruptions, induce reactionary interventions (e.g. panic, ad hoc, unreliable, trial/error, uncoordinated) and weaken systemic resilience*”. This theory is capable to establish the requisite analytic generalisation. Where generalisation refers to a general statement or a proposition made by drawing an inference from observation of the particular (Schandt, 1997).

³⁷ Research theory falls within Carrol & Johnson’s (1992) Decision-making theory which also comprises individual, organisation and social group theories (see Yin, 2009, p. 37).

According to Yin (2009), case study is a preferred method of investigation when some, or all of the following conditions hold:

- i) one wants to answer ‘how’ and ‘why’ questions;
- ii) the investigator has little control over research events; and
- iii) the focus of the research is a contemporary phenomenon within real-life context.

Apparently, this research meets all three criteria in Yin (2009). For instance as part of this research, we investigate how certain policy change can influence the behaviour of port environment instability, disaster preparedness, and port’s resilience to disruptions using the ‘extreme conditions test’ in system dynamics modelling. From the structural behavioural results, best alternatives can be designed, or selected, to ameliorate the effects of systemic disruption in logistics chain. Secondly, this research cannot manipulate (control) any of the respondents interviewed. These are deemed to be experienced and knowledgeable personalities at the high echelon of management positions whose decision can make a difference in both the long-term and the day-to-day running of the ports in HE. It is also obvious that we do not have any control over the perceived disruptors within the scope of study. We are looking at catastrophic events or potentially catastrophic events (natural or anthropogenic source) which maritime logistics industry may not have any direct control over. Such external environmental (disruptive) incidents may be rare or have low frequency of occurrence but they have very grievous consequences on the port and its critical infrastructure. Thirdly the phenomenon under investigation (HPC) is a contemporary one; there is growing perception that the frequency of disruptions in global logistics chain is

increasing (Coleman, 2006). Furthermore, literature shows that there had been increase in disruption potentials, multiplicity, and the magnitude of destruction resulting from catastrophic events in the past decades (Blackhurst et al., 2005; Craighead et al., 2007)). Thus we believe that the choice of case study approach for data collection over other alternative approaches such as questionnaire survey or ethnographic research is appropriate.

3.11.1 The type of case study applied in this research

We have selected the HPC or Ports on the HE as the case study. Seven individuals (CROs and academics, all of whom live and work within the case study area) were interviewed. The reader should note that this individuals do not represent a sample size³⁸, rather they serve as multiple experiment (data) source for the research. A further location of the multiple data source (experiment) suggests that we relied on personal interviews and documentary evidence (e.g. journal articles, letters, minutes, annual reports, charts, books, magazines, company website, etc.) to improve our knowledge about the maritime logistics industry in general and the case study in particular. We also used the documentary evidence to augment data from interview or the verbal exchange (Ritchie and Lewis, 2003; Gillham, 2000) between the selected respondent and the investigator. It seems the documentary evidence (or literature

³⁸ The dilemma of whether a research should carry out a questionnaire survey, or personal (face-to-face in-depth) interview serve entirely different purposes. According to Gillham (2007), questionnaire survey are required if large-scale or preliminary data is sought for. We did not choose to validate our results on the basis of large data (large-N). We wanted to gain insight into some phenomena based on 'the eye witness's accounts' in a "naturalistic" context.

research) can make the research data more compelling and robust (Herriot and Firestone, 1983). We are aware about the need for good communication between the respondent and the investigator during the interview proceedings (Clough and Nutbrown, 2007). This was not a problem in this research because the investigator seems to possess good skills that enhanced effective communication with the respondents. For example the investigator possesses: good listening skills (Clough and Nutbrown, 2007); skills for clear questioning structure (Cohen et al., 2007); skills for pausing, probing, and prompting the respondent at right time (Ritchie and Lewis, 2003); as well as has good rapport that encouraged respondent to talk freely.

Additionally, the choice of personal in-depth interview was also based on its characteristic flexibility, relationship promotion, capacity to generate rich and thick data that may lead to analytic generalisations, as well as making interview process livelier apart from it closing the gap between theory and reality. Through his form of interview, abstract theories were given concrete meaning in specific case context. We were able to see, understand, and reflect on the abstract secondary [textual] data from documentary evidence (Gillham, 2007). Ricoeur (1971) argues that the text is a model for action and that we can get to a better understanding of the structures of action by analysing the action as a text. It is apparent therefore that the personal in-depth can play the role of an illustrative report to what will otherwise have been an artificial, or purely abstract report from documentary evidence and simulation. Furthermore direct quotations from the respondents seem to be more powerful, authentic, and have more impact than mere abstraction from documents. Therefore the hermeneutic approach of an in-depth interview, which deals with the search for ideal-typical structures

(Rendtorff, 2015) such that it may contribute to the deeper understanding of the principle and structure of the port/maritime logistics industry is most appropriate.

3.11.2 Justification of the interview type

We engaged the F2F personal interview with a few purposely selected elites from the port industry within the HE. This type of interview was preferred because we anticipate the possibility of work interruptions, and problem with accessibility to company premises if many people were involved. Secondly, we require in-depth knowledge about the phenomena (port environment stability/sustainability, disaster preparedness, and resilience port logistics) we are studying; knowledge which seem to be in the possession of few people in the high echelon of the industry. Another reason for selecting few elites for the F2F personal interview was that the dialogues may last long (between 1hour-3hours each), which can interrupt with business activities of the respondents or the functional enterprises they represent. In consistent with Gillham (2000) and Ritchie and Lewis (2003), we state that the prime objective for adopting F2F personal interview data collection approach at this stage is to gain insight, in-depth knowledge, and understanding in the context of the respondent. Thus we focused on a few managers or directors (CROs or persons in charge of risk management in the

functional enterprise within the case study area), and preferred the personal interview approach to telephone, or mail interviews³⁹.

The preference of personal elite interview to the mail, or, telephone interviews is that it suited the open-ended questions that were designed and administered. Furthermore, this approach may give room for an extended response from the respondents by providing opportunity for follow-up questions (probes and prompts) when necessary. Through this F2F personal interviews, we will be able to note non-verbal communications during the interviews which may not be possible to observe in the mail, or, telephone interviews.

A small number of people (small-N) (see Gillham, 2007) was involved because we were concerned about establishing trust and confidence between us, the elites and the data. It seems that the small-N can make each individual or unit that was involved to feel that s/he was key source of information and cannot afford to be left out of the data collection process. Usually, there are no many people in companies (port industry) who have possession of the potentially sensitive (classified) data, which might not be available in public domain. Castillo and Saysel (2005), Burrell and Morgan (1979), Easterby-Smith et al (1991), Gill and Johnson (1991), and Gummesson (2000) have all spoken about when a research can adopt small number of respondents as source of data and appears to suit this studies. Hence the involvement of few [7] individuals who are

³⁹ No one will like to pass on personal and/or sensitive details via the mail of any kind. For example Nash & West (1985) studied adult women's experience of sexual abuse when they were children. The response was more positive in the F2F interview than in questionnaire answered by the same people. Therefore this research prefers the F2F interview to other the forms interviews.

in the higher echelons of the functional enterprises within the case study (the HPC) seem to be appropriate.

Another reason why elitist interview was preferred is that different individual industrial perspectives are been sought about the phenomena of our research interest within the case study. Thus we could not use focus group approach where people will have to gather and try to brainstorm others about their own views and ideas. We wanted to gain insight and deeper understanding into the potential consequences of the interactions between port stability, disaster preparedness and resilience in maritime logistics operations in the ‘naturalistic context’. These constructs are close to real-life management dilemma and problems (Rendtorff, 2015) which require philosophical approach to solution. These phenomena, as constructed human cultural expressions, can be properly understood only through interpretation (Morrison 2010 reviews Rendtorff, 2009). Understanding these constructs can be accomplished only when the texts can be changed into possible actions (Gadamer, 1960).

In concluding this section, we argue that, it is the search for such in-depth (insightful) knowledge about the constructs in a contextual real-life account that a purposive, F2F, elite form of semi-structured personal interviews were conducted⁴⁰. Such an approach may help the research to develop a more consistent and a reliable account of issues that

⁴⁰ Elite interview can provide: i) distinctive view/perspective of the individual interviewee to which research can relate to other kinds of evidence (e.g. simulation and documentary evidence); ii) wider and deep (rich and thick) information that others in the system may not fully be aware of due to their background in the context of position and work experience; iii) guidance on things to look out for and questions to ask in order to fill research gaps; iv) answers to where and what kind of document and records to look for to support evidence; and v) the permit to gain access to the sources of additional evidence (Gillham, 2003, pp. 82-3).

we wish to discuss as well as provide firm grounding that will lead to an empirical conclusion (Eisenhardt, 1989; Yin, 2009) and possible theory generation that is grounded on field data. Several writers (e.g. Ellram, 1996; McCutcheon and Meredith, 1993; Stuart, et al., 2002; Voss, Tsiriktsis and Frohlich, 2002; Seuring, 2008) have applied similar personal interviews in different aspects of supply chain and operations management research. Many other authors including Randers (1980), Richardson and Pugh (1981), Roberts et al (1983), Wolstenholme (1990), and Sterman (2000) have applied similar qualitative data collection methodology in system dynamics modelling. Therefore this research methodology is consistent with what pertains in the field.

3.12 The Analytical Design

As defined earlier, a research design refers to the general or specific plan for the study of a research question. Elements of a research design may include: the research perspective; the type of research; the context of the research; the participants studied; the method/instrument used in data collection; and the data analysis tool. However unlike section (3.3), the current subsection focuses at giving a vivid account of exactly what took place before, during, and after the fieldwork (data collection) so that the reader may appraise the validity of the data.

3.12.1 Number of Cases and the selection criteria

Data was collected on the four (4) major ports that are located on the Humber River Estuary (HE) or what is also known as the Humber Ports Complex (HPC) in the UK. As it will have been a fruitless effort to attempt interviewing the entire work force of

23000 in the logistics industry in the region (according to www.hull.co.uk), we narrowed our data source to involve only the Chief Risk Officers (CROs) for the functional enterprise that we officially gained access to conduct the interview. We targeted twelve (12) people for the interview, however, circumstances which we cannot control (as researcher) made us to end up interviewing a total of seven (7) individuals to feed us on the single case study (the HPC). The composition of the seven respondents was made up of six (6) CROs [or head, or member nominee, of the risk management team] and one (1) academia. The interviews were conducted at the premises of each of the respondents at an appointed time (most of which took place between the hours of 1300 and 1600) and at the convenience of the respondent. This category of respondents was purposely selected because we assume that they would have an in-depth knowledge in port/maritime security, risk, and disaster management relative to the ports in the Humber Estuary (HE) in general, and particularly relative to the functional enterprises which each candidate represents. We also assumed that these categories of respondents might have encountered at least one crisis situations in their life time, in the course of executing their duties as CROs or as members of risk management team and could therefore give a vivid account of exactly what happens in the port/maritime logistics industry. The prime aim of the research is to highlight on the need to prepare for disruption in the maritime logistics chain. It is in the view of the research that through adequate preparations, real time to respond to disruptions, real time to safe life/property, as well as real time to bounce back and restore (basic requirement for resilience) operations in the port/maritime logistics chain can be improved.

A more detail description of the elite group show that they were drawn from logistics agencies, port operators, transporters, and manufacturers who operate within the HE. The academia who is an expert in coastal and estuarine studies [a marine biologist] was included so that we can have a balanced view particularly about environmental issues. Apart from the deep knowledge and information that these group of elite are assumed to possess, we also believe that they can be in the position to direct the investigator to appropriate sources of supplementary data to augment the interview data for analysis if required. It is apparent that these seven respondents coupled with the documentary evidence may provide a rich data that can enhance result comparability and possible generalisation.

In another direction, we wished to cut down cost (e.g. time and resource costs) therefore we could not involve large number of respondents. The researcher will personally conduct the interviews (and if necessary), one additional person shall accompany the investigator on the trip to the agreed place (the office, boardroom, or interview rooms on the respondent's premises). The research team will also acquire interview recording devices so that we can capture the respondents' story for the research to understand the phenomena in real-world context. The medium for communication with the respondent shall be verbal; however research will note and recount the non-verbal expressions by the interview respondents as well.

3.12.2 Method of the interview

Barriball and White (1994) cite several reasons ascribed by different authors to support the need for personal interviews as a means of data collection for the researcher using

semi-structured interviews. We copied some of the advantages that the approach brings to the data collection process below:

- i. This form of data collection has the potential for high response and return rate as opposed to other methods such as the questionnaire survey (Austin, 1981)
- ii. Personal [semi-structured] interviews are well suit when attitudes, values, beliefs, motives, and [behaviours] are being explored in a research (Richardson et al, 1965; Smith, 1975)
- iii. They provide the research with an opportunity to evaluate the validity of the answer given by the respondent as the researcher can observe and account for non-verbal expressions especially, when the topic involves sensitive issues (Gordon, 1975)
- iv. Personal [semi-structured] interview can facilitate comparability of the answers provided by respondents on particular themes or questions (Bailey, 1987)
- v. This form of data collection ensures that the view of respondent is devoid of assistance and makes his/her views less biased by outside influence (Bailey, 1987)

The above discourse about personal interviews [F2F semi-structured] makes it more favourable and more suitable to this research especially in the context of its high rate of response as acclaimed by authorities including: Cormack (1984); Treece and Treece (1986) and Bailey (1987). For example, Barriball and White (1994) cite Kidder (1981) to have suggested that there is between 70% to 80% response rates in personal interviews such as the semi-structured face-to-face interview as compared to the poor rates that can be registered under survey questionnaire. Perhaps one reason for high

response rate could be that, even people who might not have confidence in written language can still participate in personal interviews by stating their views verbally or non-verbally. Arguably, our respondents were motivated by the face-to-face contact and thus became more willing to participate in the personal (semi-structured) interview than it would have been if we had used the questionnaire survey method (Gordon, 1975).

Access to respondents was done through personal interactions and advertising of research topic at CILT membership meetings, dinners, as well as academic seminars, forums, workshops, and conferences. It is worth mentioning that the research committee chair's (supervisor's) personal contact made accessibility to the identified respondents less difficult than we have anticipated. The interaction sessions as mentioned also deepened the writer's knowledge as well as increased the motivation for the research.

3.12.3 Types of questions for interview

This research is set out to explore the perceptions and opinions by a group of CROs (respondents) in the HPC (case study) about the causes of disruptions (disaster); then analyse the impact of certain managerial decisions on the complex phenomena we are investigating including the sensitive unintended outcomes of managerial policies on the port/maritime logistics network within the region. A study of the category of the elites interviewed shows that they have varied background, experience, and expertise. In order to ensure that any differences in opinions in the answers that the respondents provided do not come from differences in the questions (Gordon, 1975), we selected the semi-structured interview approach. It seems that the use of semi-structured

interview questions provided a standardised stimulus (Mann, 1985; Abrahamson, 1983; Smith, 1975) that led to the respondents sharing common vocabulary and common meaning to each and every question (Denzin, 1989; Nay-Brock, 1984). One can also observe that the semi-structured interview questions offered the investigator the opportunity to change the wording of a question in order to suit the respondent's understanding without changing the meaning (Treece and Treece, 1986). According to Denzin (1989), semi-structured interview questions can enhance data validity and reliability that is not based on repetitive questioning, but rather, based on equivalent meaning that the question conveys to the respondent. It is this equivalence of meaning which the semi-structured interview brings about that leads to standardisation and facilitation of comparability in data results.

We sought to extract people's experiences and what they feel or think about the interdependency in the following research constructs: environment instability, disaster preparedness, and resilience in the context of the logistics chain of ports on the HE. The semi-structured interview approach may lead to discoveries that will enhance theory building (that is grounded in raw qualitative data) and possible generalisation. We allowed the interview to flow as in a natural conversation (or a dialogue) but based on an agenda (themes) that was presented by the investigator such that it enabled the research to learn more from respondents⁴¹.

⁴¹ Actually it is preferred that the research presents just an agenda for the meeting comprising of a list of topics which will give guidance and direction to the conversation. This is presented as a kind of brief for the interviewee/informant about the purpose of the research. The conversation rolls on till all the topics are exhausted.

We noticed that the elite group could be sophisticated and officious (Gillham, 2007). Several authors including Gillham also warned that it is possible that this category of people may know certain technical dimensions of the subject matter more than the investigator and may often be alert about the implications of certain questions and the way to answer them, especially if they have had the experience of granting interviews somewhere in their life time. For these reasons we employed short, loosely structured open-ended questions [see appendix A] that were as concise as possible such that they seem to carry no ambiguities so that respondents had the opportunity to express themselves more.

Prior to the field interviews, we had some pre-conceived ideas and responses that we expected from the elite group. We also anticipated a professionally authoritative view about the subject matter. For instance we are of the view that complex human experiences are not issues that people can slickly speak about in an organised fashion, hence they need to be ‘teased out’ of the box. That is why we intermittently employed prompts and probes during the interview proceedings. Treece and Treece (1986) support this approach by stating that probes when used in an interview, they may ensure that data reveals “what we think they reveal” because they offer the opportunity to clarify ambiguous words and phrases [jargons] that the respondent might use during interview proceedings. Such probes that semi-structured interview allows, provided the study with some form of flexibility to validate the meanings to answers as given by each respondent. Thus the probing questions ensured data reliability as espoused by

several authors (Hutchinson and Skodol-Wilson, 1992; Smith, 1992; Bailey, 1987; Nay-Brook, 1984; Austin, 1981; Gordon, 1975). Drawing from Patton (1990) as a conclusion, probing helped the research to maximise the potential for interactive opportunity between the respondent and the interviewer; a move which enhances the establishment of rapport, and rather reduced the risk of socially desirable answers.

3.12.4 The interview schedule and development

The next important phase of this chapter is the interview schedule. This phase both abstracts the research constructs as well as facilitates comparability between respondents' answers during analysis.

To begin with, we wanted to gain a deeper understanding of the research area, thus we did an extensive literature review which enhanced the delineation of areas of interest and relevance to the scope of the research. A large number of potentially interesting questions popped up during the interactive processes at meetings, study tours, workshops, seminars, conferences as well as from the literature reviewed. We processed the questions; we group them under common ideas or themes; and ordered them into a sequence of topics and subtopics to tally with the research objectives and problem. The questions so formulated were "internally tested" (Mann, 1985) on colleagues PhD research candidates. This was done so that colleagues can assess the interview questions for phraseology, ambiguity, signs of leading questions, and general critique in relation to the correctness of questions.

We also trialled the questions on people who have worked in similar settings such as where the actual research was going to be carried out (i.e. people who have worked in maritime logistics environment, or with an emergency response organisation). This step gave the investigator a feel of real interview process, as well as created the alertness about the range of factors to expect on a given interview day. Additionally, this step allowed the investigator to learn about how the questions can be managed. The trial also made the investigator focus on how to frame the questions such that they become productive, and thought stimulating enough so that it can lead to the extraction of requisite facts from the respondents. Another advantage of the trial is that it allowed the research to highlight key questions as well as indicate the redundant ones that need rethinking or reframe. One very important reason for testing the research questions at this level was to enable the research to concentrate on the structure of the interview (e.g. introduction, development, and closure), and also to learn about the possible behaviour of respondents (e.g. non-verbal language, tone, emotions, and others). Finally this stage of the trialling therefore gave the investigator the style to adopt during the actual interview process.

After trialling [as described above] the next stage is piloting. Piloting forms part of the development stage that is close to the actual interview (Yin, 2009; Gillham, 2007). At this level, the interview questions (or research agenda) have become clearer with regards to getting the right frame. The investigator had practised the trend of questioning and had adjusted the content of questions and own behaviour including

time management. That led the writer to draft a final pilot interview⁴² questions which were assessed for content validity by an expert⁴³. This assessment tested for the appropriateness and the completeness of the content of the question. It also exposed the draft question to the rigours comparable to what is anticipated at the field. According to Barriball and White (1994) this assesses whether the respondent could answer the question when they are to be administered. The investigator also got feedback from the expert which was taken into consideration for further correction and final adjustment to the agenda (research questions for discussion) before the actual interview was carried out. The pilot interview was recorded and listened to for several times to help investigator readjust as well as to strengthen the research themes. Additionally, the piloting offered the investigator the opportunity to test the duration (i.e. between 1-2 hours per case – interviewee) for the actual interview. These steps were taken in order for the research to be in line with Mann's (1985) recommendation that the respondent should be considered throughout the construction of an interview schedule 'since s/he will be doing the work by supplying the answers to the questions'. This protocol provided the needed structure for the analysis which shall emerge clearly in the analysis chapter.

⁴² Piloting is a rehearsal stage that was done in two phases: 1) with students who have knowledge on disaster relief operations; 2) with people who have held such portfolio in similar organisations (as the case study) as well as academics who have conducted similar research.

⁴³ In this occasion we involved the CRO, or the safety and risk manager at the University community. These people advised whether the questions were standard, ethical, and conformed to standard practice in the field of risk and safety management.

3.12.5 Equipment required for field interview

There is the need to replicate the content of each interview session such that it will facilitate analysis. An argument raised by May (1989) states that: [...] *“Given the dynamic nature of interviewing and the subtle problems of topic control and data interpretation, the procedures used to log data must be given considerable attention”*.

Following from the above statement, we procured and used the following field equipment: audiotape recorder for recording interview conversation/proceedings and a transcription machine. We did not need such equipment as photocopier and scanner because we did not need to make copies of any documents. We relied on interview data and literature search from relevant journal articles, books, websites, magazines etc. Every interview session was tape recorded and the transcription begun as soon as we returned from a field trip. Taping was chosen because it provides a detailed insight into the performance of the one doing the interview and the respondent (Barriball and White, 1994). It seems that the use of audio tape recording reduced the potential errors that would have been associated with long-hand writing. Any additional information was taken from the extensive literature review that was done prior to, and after the interviews (i.e. documentary evidence or literature search).

Eisenhardt (1989) recommends that interviews of this nature [such as personal, or semi-structure interview] require at least two people per interview team per interview session so that one of the team members introduce the topics to the interviewee while the other one records the proceedings. However we did not find it necessary to do so since we did not need to write. Rather, we used only one investigator who sought permission from each respondent and recorded the conversations as they dialogue

rolled on. We listened to the audio recording after each interview for two or three times in order to understand the issues raised by the respondent after which we transcribed the proceedings. We also listened to the tape and compared it with the transcript again in order to make correction and if possible make the report available to the interview respondent for clarification of misunderstood statements as well as for insertion of omissions [if any were found].

At the end of every interview the we requested for further help and advice with regards to other people that the respondent would like the investigator to speak to; or other organisations that can also provide useful information; or the dimension of the research which the researcher might not be aware of; or for general guidance on how to proceed (if these have not been addressed already in the course of the interview). This part was important because it helped the research to gain access to the network of elites and also to gain access to information that might not be publicly accessible.

To give enough time for preparation for the next interview, and also in order not to lose memory of the previous data, we adopted a three-day time space between two consecutive interviews. This allowed the researcher to listen to the tape as many time as possible to be able to transcribe the conversation, as well as to reflect over any pitfalls in the interview schedule before the next session comes off. The import of this step was that, it enabled the research to fill in gaps that were identified in the data. Such lapses that might be identified may form part of the probe questions in the next interview session. We labelled each specimen, evaluated, and content analysed each transcript in turn. Substantive statements were highlighted so that we ignored repetitions, digressions and irrelevant materials (see Gillham, 2000, pp. 62-66).

3.12.6 Potential limitations of the process selected

Few researchers have critique the approach we adopted for data collection. Some have said that:

- It can be fraught with inaccuracies, non-factual statements and self-aggrandisement especially if the interviewee is bossy and full of self-praise [experienced in the field].
- It does not give enough room for extensive inferences (Gutek, 1978)
- Opinions might be quite subjective and different from objectivity. People may say one thing but behave quite differently (Gillham, 2000)
- Proceedings of the agenda can be hijacked by elite interviewee [experienced on the field].

3.13 Research Data Reliability, Validity, and Generalizability of Results

Patton (1990) states that “the quality of information obtained during an interview is largely dependent on the interviewer”. Factually, one cannot ascertain 100% control, or plan against all incidents that might take place during field work. Respondent’s motivation to participate in a research interview depends on a number of reason (Morse, 1989) some of which include how interesting and challenging the topic may be to the respondent or his organisation. However, Barriball and White (1994) acknowledge that interviewer’s friendliness, interview approach, and one’s general manners towards the respondent can help the investigator to overcome the above

limitation so that one can ensure data validity and reliability (concepts which are more of positivist epistemology than the phenomenologist).

Reliability of research refers to “the extent to which results are consistent over time and are an accurate representation of the total population under study. Also, if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable” (Joppe, 2000). Thus reliability seems to emphasize repeatability of results of an observation after testing and evaluating in a quantitative study. However in a qualitative study, reliability relates to the quality of a research. It helps one to “understand a situation that would otherwise be enigmatic” (Eisner, 1991, p. 58). Apparently this research can be deemed to be reliable because the ideas we wish to communicate to the respondents were clear, and transparent, such that they allowed the respondents to express their opinions about the research constructs to the extent they enhanced interpretation and fair analysis.

Validity is mainly judged against certain external criteria (Gillham, 2007). We attempt to correlate preparedness with crisis response and the ‘bounce-back-ability’ of an impacted port/maritime logistics chain. From the information, influence relationship were deduced from the interviews and data from documentary source. It seems generally common that different respondents may express different opinions about the same construct. However, Gaskell & Bauer (2000) points out that:

[...] ‘it is axiomatically acknowledged in psychometrics that the reliability of an instrument sets the upper limits of validity’ but ‘in interpretation, validity may indicate that the material being analysed/categorised invites a number of different and legitimate understandings’ (pp. 340-1).

The suggestion is that though results may vary depending on the subjective view of each respondent, yet their diverging opinions may converge at certain instances where we can claim external validity. Research “validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. Validity allows you to “hit the bull’s eye” of your objective. Researchers generally determine validity by asking a series of questions, and will often look for the answers in the research of others” (Joppe, 2000, p.1). Therefore a research is said to be valid if it is firmly grounded in the processes and intentions of a particular methodology [e.g. the pragmatic or the mixed methods approach]. Research reliability is therefore a consequence of validity (Paton, 2001). We have ensured high quality, rigour, and trustworthiness (Davies and Dodd, 2002; Lincoln and Gupta, 1985; Mishler, 2000; Seale, 1999, Stenbacka, 2001) by following the appropriate research protocol including: conducting purposive in-depth interviews with top level risk managers in order to give us divergent views; we performed trialling; we asked clear and concise questions; we selected appropriate analytic tool etc., hence we can claim both reliability and validity.

External validity which Stanley (1963) calls generalizability, seems to measure the extent to which an experimental findings make us better able to predict real-world behaviour. According to Calder et al (1982) external validity checks “whether or not an observed causal relationship should be generalised to and across different measures, persons, setting, and times”; in this case meaning different port complex on another environment, different organisation, and situation. The argument about research

generalizability appears to raise great controversy across many fields. Mintzberg (2005) argues that “If there is no generalising beyond the data, no theory, no theory, no insight. And if no insight, why research?” (p.361). In their research in 2008, Gilbert et al. found out and concluded that of the four criteria for assessing rigor in a research (i.e. internal validity, construct validity, external validity or generalizability and reliability), case study research is likely able to produce data that can be more generalizable. Chreim et al (2007) seem to imply that it does not matter the number of cases studied. They argue that “naturalistic case studies should not be judged on the basis of generalizability, but on the basis of transferability and comparability” (p. 1535). It is the naturalistic context which provides the research with rich information that helps to develop a theoretical explanation to the phenomenon being investigated (Yin, 2014). Gomm et al (2000) as well as Sharp (1998) distinguished between theoretical and empirical generalisations, where the latter relies on statistical evidence usually with large-N representing the portion (fraction) of the population which was represented in the sample. Theoretical or analytic generalisation (according to Yin, 2014) on the other hand, develops explanations for the relationships between observed variables in a studies (Sharp, 1998). Tsang (2014) argues that case studies have greater advantage over quantitative methods in terms of theoretical generalisation, identification of disconfirming cases, and in providing useful information for

evaluating the empirical generalizability of result. Tsang argues that theoretical generalisation can be built from both quantitative and qualitative researches. We have conducted a “naturalistic case study”; engaged mixed methods approach; we have followed the necessary rigorous research procedures. These steps were taken so that we can ascertain research generalizability (especially theoretical generalizability) in terms of transferability of our methodology to other similar situations to yield the same results.

Quality (reliability) of research focuses on how an audience can become convinced about a research findings (Lincoln and Gupta, 1985, p. 290). The quality of case study research is judged by its trustworthiness, credibility, confirmability and data dependability (US Government Office, 1990). This research tests its quality based on the four commonly used methods as established in empirical social research (see Yin, 2009, p.41) and as defined in Kidder & Judd (1986, pp. 26-29).

In terms of construct validity, we related that to identification and correct operationalization of concepts. To meet construct validity, we ensured that we met two steps (Yin, 2009): firstly the research attempt to define its constructs in terms of specific concepts relative to the research objective. Thus in the study of the HPC as a case, we related “resilience in port logistics” to the capacity for a port to cope with unexpected events, or as the ability to handle emergencies without systemic collapse, and also as the potential for port logistics network to recover to their original or to a better state after perturbation (operational disruptions). Secondly, we attempted to

identify operational measures that match the concepts in the literature and cited studies that make the same matches⁴⁴ in terms of preparedness, response, and recovery [see sections 2.2-2.4 of this thesis].

Gillham (2001, p. 21) discusses six (6) sources of evidence for typical case study research. Of the six sources, this research considers applying two – documentary evidence (e.g. journal article, books, websites, etc.) and evidence from interview data so that we will be able to overcome problems associated with construct validity. The said documents were used in corroboration with interviews to augment any other sources of evidence. Furthermore documents helped the research to verify spelling, provide specific details that may be omitted in the interview as well as clarify contradiction we may find in the interview data so that the respondent can be contacted for further verification of facts. The test for maximum validity resulting from reliability in qualitative research may produce a more “credible and defensible result” (Johnson, 1997, p.283) that may culminate in high quality research and can lead to generalizability. According to Patton (2005) generalizability of quality case studies depend on the case selected in a context. Whereas validity in quantitative research is the testability, qualitative research relies on triangulation methods; a process which may be attained by applying various techniques to arriving at the final results as we have reported in chapter 5.

⁴⁴ For example, preparedness for disruptions/disaster depends whether the source is natural, or anthropogenic; whether the nature is slow on-set, or sudden/rapid events and so on.

3.14 The Research Ethics

3.14.1 Data storage and confidentiality

We made it clear to each respondent about who will have access to information, for what purpose, and also pledged to respect issues of anonymity (if that is preferred). For security reasons, we shall lock up all hard copy data (if any) in filing cabinet. Electronic data on the other hand, have been secured using pseudo names and password; there was no mailing of sensitive material (if any). The research report shall either appear in thesis or published in journal articles but will be devoid of information that can be deemed as sensitive and revealing identity of individuals involved in the interview. Summary of publications shall be made available to respondent/organisation if that was agreed on. If video excerpts of the data shall be used for any other presentations, explicit permission shall be obtained from respondent/organisation. Data shall be destroyed as in accordance with the HUBS's allowable data lifespan and it shall be done by the researcher, or it will be sent back to the respondent, or done by the appropriate methods according HUBS regulation.

3.14.2 Intended durations

The time schedule for each respondent to be interviewed was between 1 – 3 hours. As said earlier, the research allowed at least three days interval between consecutive interviews to allow time for listening to the tape, and the transcription of the recorded data. Seven (7) individuals were interviewed thus giving a total of about 21hrs for interviewing, plus 21 days transcription all within 6 - 7 month time period.

In case a respondent is not available to be interviewed, we shall reschedule the date. If this happens for two consecutive times, we shall seek permission from, or suggest to the respondent, or the functional enterprise to nominate another person who is equally capable, willing, and readily available to “step into the shoe” of the absentee participant.

In order to gain access to any of the organisations and/or the respondents, we sent an official letter to request access to premises and information. In the letter, we stated clearly that the investigation was purely for academic research purpose and nothing more (see appendix D for sample). The research findings will help ports in the HPC (case study) in managing emergencies/disruptions in their logistics network. The kind of information the research is looking for, the expected time it hopes to spend and how the information gathered will be secured so that confidential reports will not leak out were clearly explained to the respondents before the interview proceeds. We were however aware of the fact that documentary evidence may not be sacrosanct, they have been written for specific purposes and for some specific audience (Yin, 2009). Therefore evidence from such sources could have some limitations. Thus, though we relied on such literature evidence, we placed more emphasis on the interview data and used such data only to augment field data if there were any gaps to be filled.

3.14.3 Access and control of data

Elite respondents are people in high position of authority and can be particularly helpful if they decide to lend their support on a research. The support can open up

avenues for acquisition of supporting information and materials that could augment evidence gathering.

Reporting elitist interview data requires full detail of what the respondent said. Hence we quoted verbatim, those statements we deemed very relevant to the research for modelling purposes and also to enhance cross-referencing. This was done in consultation with respondents and also in accordance with requirements of UKDA (1998) as well as HUBS's research ethics requirements.

The right of respondents to review the transcript is very important under elite interview. Gillham (2009) says that this serves as a form of confirmation for the investigator that the respondent acknowledge ownership of what was written down. It also gives the respondent the opportunity to correct inaccuracies that may be detected later in the report as well as to fulfil the condition that might have been set for acceptance to be interviewed. We did not anticipate any gender or social class issues. However arrangement was made so that in case they arise (especially racial issues and differences in slangs and communication difficulties) we would have asked for support from the department or from the University to assist in conducting the interview on behalf of the researcher. For the issue of vulnerability of the respondent, consent was sought and guidelines to data protection explained before the interview commences. We did not use any minor, or anybody outside the HUBS research community for data collection. All safety procedures at the sites for interview were learnt and adhered to by the research team. The team complied totally and was guided by the UK Data Protection Act 1998 as well as HUBS research ethics guidelines and we conducted the research with a fair motive and only for academic purposes.

Chapter Four: Research Analysis

This chapter details how chapter 3 was applied and the results thereof. The reader will find how the philosophical paradigms mentioned in the previous chapter were blended using the SD modelling as the analytic tool. At the end, we summarised the quantitative (simulation) results that were crafted from qualitative (raw textual) data which we derived from interviews.

4.1 Chapter preamble

What occupies the thought of geographers and environmental scientists [CROs inclusive] is how they can understand the vast interacting systems comprising of all humanity with its natural environment on the surface of the earth (Ackerman, 1963). The deficiency in understanding the world therefore calls for the need to develop appropriate techniques for the purpose of understanding the complex interactions in the world.

Disruptions are commonly occurring problems in any logistics/supply chain system. However, due to their global nature and the vastness of their environment, maritime logistics operations can become highly unpredictable and more prone to hazards and disruptions of all kinds. Disruptions in maritime logistics chains can cost the ports and the stakeholders several billions of currency units per year. An MIT forum in 2012 acknowledged that the cost of [*logistics*] disruptions has always been increasing at an astronomical rate. For instance, the Japanese earthquake/tsunami in March 2011 was estimated at \$309 billion. Typhoon Haiyan of the Philippines in 2013 was estimated at

\$14 billion. The cost of 9/11 and Katrina was estimated at \$3.3trillion (New York Times, 2011) and \$96-\$125 billion respectively.

The source of these disruptions can be traced to natural, or anthropogenic, or a combination of the causes. It appears that the sources (causes) of such events are not very clear, since the concept “*disaster*” in itself seems to be definitionally blur, apart from it involving a series of events. By improving the current understanding of the causes of disruptions in port/maritime logistics chains, measures can be taken to mitigate their impact, or to avoid the losses that follow their aftermath. We further argue that policy change can influence port’s preparedness (or alertness) towards operational disruptions, and that the interdependencies (or interactions) between port environment instability, and disaster preparedness can influence port’s resilience to disruptions that result from disaster situations, in a maritime logistics system. Placing high emphasis on the influence relationships between the above state variables requires that we engage a long-term policy analysis tool such as the SD modelling.

Following Wolstenholme’s (1985) definitional argument (see section 3.8 of this thesis), we presented a conceptual model at the interviews, to the respondents, in order to extract some CROs’ (experts) opinions about the potential influence (causal) relationships between a pair of variables (see #7 on appendix A). In collaboration with the CROs, a CLM (figure 4) was developed from the CROs’ mental database that was derived from figure 3. Three basic variables whose structural behaviour we wanted to analyse were selected as stock (state variables) for simulation modelling. Nevertheless, the research involved soft variables (Checkland, 1982); the future state of such variables depend more on social judgement (subjective), and are mostly perceptual

rather than matters of scientific fact. Thus a case of forecasting the future trajectory of the system depends on the way in which the modelled system and its confidence levels fit the research anticipation (Bennet, 1980) since the values of soft variables also involve great measurement error.

System dynamicists have used soft variables in the field of ‘system thinking’ to resolving ‘social systems’ problems (Luna-Reyes & Anderson, 2003). The ‘systems thinking’ approach (or process) uses formalisation and analysis of feedback loops, but it does not result in mathematical simulations. Arguably, all authors perceive the SD approach as an iterative process in which the modeller tests a dynamic hypothesis in the form of feedback theory or causal structure theory that generates series of system behaviour over a specified period of time. Such tests (see section 4.11 of this document) allow the modeller as well as the problem owners to understand the problem at hand such that it can lead to redesigning policy guidelines for effective policy change management where necessary. It seems that structural theories can also be generated from out of such policy changes.

4.2 Modelling: Some common terminology and typology

Literature has revealed that human beings are not able to cope with dynamically complex systems (Dorner et al., 2006; Moxnes, 2000, 2004; Sterman, 1989; Sterman and Sweeney, 2002, 2007). Two reasons were ascribed to this assertion. Firstly, it seems that humans are unable to infer mentally the dynamic behaviour of accumulated processes such as what the stock and flow structure exhibits (Brunstein et al., 2010; Cronin and Gonzalez, 2007; Sterman, 2010) under the SD modelling. Secondly,

it is apparent that humans fail to recognise causal feedback relationships that are distant in time and space (Moxnes, 2004; Sterman, 2008) from the present. It appears that these are some of the reasons why many system dynamicists recommend the use of mental models (including the use of feedback loops, stock/flow diagrams) to explaining dynamically complex systems so as to bring practical understanding to the real-world's complex phenomena.

Different authorities have categorised models in their own ways. For instance Barlas (2007) has grouped models into physical models⁴⁵, symbolic models, static [fixed] models, and dynamic models. We discussed and applied symbolic, and dynamic models. *Mental* (symbolic) *models* are abstractions of situations which individuals maintain in their minds (Forrester, 1961). Symbolic models consist of abstract symbols such as verbal descriptions, diagrams, graphs, and mathematical equations. Citing Craik (1943) as the origin of the concept “mental model”, Groesser and Schaffernick (2012) upholds that *‘thinking is the manipulation of internal representations of the world’*. Various authors have defined the term ‘mental model’ variously. For example Maani and Cavana (2007) speak of ‘mental model’ as something that reflect the beliefs, values, and assumptions that one personally holds. Therefore, ‘mental model’ underlie one’s reasons for doing things the way one does it. For Senge (1990), ‘mental models’ are *‘internal images of how the world works’*. Argyris (1982) simply says that ‘mental models’ are *‘theories-in-use’*. As a normal practice in the field of SD, and as a

⁴⁵ Physical models consist of physical objects including physical structures that have been drawn to scale (e.g. the port’s physical infrastructure).

tool for this research, we combined verbal description, diagrams, graphs, and mathematical equations to explain effects of the interdependencies (interactions) in the state variables (i.e. environment instability, disaster preparedness, and port resilience) including possible unintended outcomes.

In 1983, Johnson-Laird developed a theory of human reasoning (in the field of psychology) which uses mental models. That model investigates how human beings resolve their problems using mental representations of what they believe to be true (Johnson-Laird, 2001). It was found that human beings represent relationships between known facts in logical assertion (Seel, 2001). However such kinds of model representations as in psychology are said to be 'static models'. Apparently they might not be applicable in system dynamics models where closed-loop processes are required (see Grösser and Schaffernicht, 2012).

Amidst the controversy surrounding static mental models as used in the field of psychology, Bryson et al (2004) as well as Ackermann and Eden (2011) argue that cognitive mapping/diagram approach seem to be close to what is applicable in SD. In dynamic situations, diagrams can be used to structure complex problems, and then the modeller strives to articulate the causal relationships as per the understanding, or the narration by the problem owner(s). It appears that this approach relies on construct theory rather than content theory. The prime objective of such mental modelling is to extract constructs and behaviours from a set of data, using causal links, but not necessarily to extract variables.

Causal links or arrow-head arcs (figure 9), are the fundamental elements of mental models (Grösser and Schaffernicht, 2012). Causal links have been studied by Langan-

Fox et al (2001; 2000), Markoczy and Goldberg (1995), as well as Langfield-Smith and Wirth (1992). Groesser & Schaffernick (2012) went further to study the polarity of the causal links, the strength of the causal relationships, and the variable connections in a causal link. Groesser & Schaffernick explains that variables are represented as the end nodes in the structure of a mental model, while the links (arcs) represent cause-effect connectivity linkages between the end nodes (variables). The links may carry a polarity (positive [+], or negative [-] sign) to indicate the directional relations between the variables they connect.

To be 'Dynamic' implies to continually 'change over time' (Barlas, 2007). Dynamic problems lead to dynamic continuous managerial action. A dynamic model is a simplified real-world system which changes with time and space (Moffat, 1991). It includes the wide array of behavioural changes of such models that can be discovered through the application of SD (Forrester, 1961). Risk [hazard, disaster, disruption, emergency, crisis, or whatever the local nomenclature] can be a very difficult problem to study and to manage in the global logistics chain. Yet the decision whether to be prepared, or not to prepare for unforeseen events that emanate from such crisis can be considered as static - once the decision is made, it binds and cannot change regularly or easily. However today's disaster management policies need monitoring and frequent adjustment of the risk/disaster management plan in order to be able to meet business dynamics in specific contexts. According to Barlas (2007), dynamic management problems seem to be parallel to feedback problems. The solution to such management dilemma (dynamic management problem) can be an iterative spiral loop that may involve decision taking, result observation, and result evaluation. Barlas argues that

dynamic managerial problems are ‘systemic’ because they originate from the complex interactions between the system’s variables such that they necessitate a spectrum of dynamic policy interventions. Nonetheless one should note that system’s behaviour in an SD model must be endogenous for management to be able to control it with policy decisions. Therefore, common scientific tools such as modelling can be used to investigate problems and then arrive at their solution. However, if the behaviour is exogenous there will be no much space for managerial control.

Concerning the term ‘system’ as applied in this research, we defined it as a collection of interrelated elements of reality that form a meaningful whole (Barlas, 2007). Due to the interconnectivity between elements of a system, it is apparent therefore that any attempts to solving one problem in a system can contemporaneously generate another problem in another part of the system. The environment can be a good example of a system which comprises of a series of inputs, outputs, and the interdependencies between the elements which make up that environment (Moffat, 1991 cites Bennett and Chortey, 1978; Jorgensen, 1986; Jeffers, 1978, 1987). With the SD as the discipline that is concerned with addressing such long-term dynamically ‘wicked problems’ which are normally associated with policy change, and change management, it can be the best tools to use in finding solutions to chronic and complex problems in systems. Readers will recall from the literature the various definitions of model including that from Barlas (2007) which states that a model is ‘a representation of selected aspect of real system with respect to some specific problem’.

Apparently most dynamic problems are systemic. Therefore the purpose of adopting system dynamics model as the analytic method for this research is to lead one into

gaining understanding (or insight) about some problematic behaviour (or the causes of undesirable dynamics) in the port/maritime logistics system in order that policies or strategies can be designed for improving the system's performance over time (Sterman, 2000; Richardson and Pugh, 1981). It is known that the SD model techniques can be used to formulate, explain, and effect long-term complex policy changes (Barlas, 2007) with little or no resistance from the effector (stakeholders) because of its capacity to offer a platform for debates and idea sharing. SD is a powerful approach (tool or technique) to dealing with dynamic complexities (Newsome, 2008; Wankhade and Dabade, 2006; Santo, Belton and Howick, 2004; Forrester, 1961), thus several researchers including Kopainsky and Luna-Reyes (2008) and Sterman (2000) have engaged it to structure the behaviour of complex dynamic systems through modelling, simulation, and feedback mechanisms within the field of systems thinking. Barlas (2007) notes that “[.....] *continuous SDs models are mathematically equivalent to differential [or integral] equations, whereas discrete models are difference equations....typical SD models are descriptive continuous or discrete dynamic models that focus on policy problems involving feedback structures*” (Barlas, 2007).

In Lane and Schwaninger (2008), theory building appears to be the core aim of SD, particularly in the social sciences as affirmed in Forrester (1990). Perhaps this is because SD is flexible (being capable to making understanding of complex social phenomena easy), its models are said to offer a theory that explains an observed behaviour over time in terms of a hypothesised (yet plausible) underlying casual mechanisms (Richardson and Pugh, 1981; Randers, 1980). The nature of the theories

created by SD (Lane, 2000; Meadows, 1980) can be subjected to rigorous scientific testing (Homer, 1996; Bell and Senge, 1980; Forrester and Senge, 1980) and have often yielded results. We have noted that, SD simulation can test for model structure, test for boundary adequacy, as well as for dimensional consistency (Sterman, 2000; Forrester and Senge, 1980). Being a rigorous method, such models can be used to identify a problem, to describe a system, to qualitatively model and analyse changes in complex systems; which facilitates and can lead to quantitative modelling and dynamic analysis for the design of system structure and control (Wolstenholme, 1985). We took advantage of all the above features, especially the verbal descriptions, symbols, graphs and algorithms to understand the structure of the problem. Thus it became apparent that SD was the most appropriate analytic tool for this research.

4.3 Event-Structure-Behaviour of SD

The structure of a system is ‘the totality of the relationships that exist between the system’s variables’ (Barlas, 2007). The structure may concern itself with issues such as what material/information flows through a network; how they flow; how stocks accumulate; and how stocks are depleted. The structure may also represent the aspect of reality that one believes (or hypothesis) to be of interest for investigation relative to a specific problem. In an SD model, the structure represents a set of relationships between certain variables. Such relationships can be expressed mathematically as differential [*integral*] functions or difference functions which can be solved analytically (see Barlas 2007). However the solution can become nearly impossible if the functions are nonlinear and complex. Hence computer simulations (section 4.11 of this research) can be employed, to unfold the behaviour of the structural reality.

The behaviour of a structure on the other hand, determines or produces the dynamic patterns of the system's variables. Common dynamic behavioural pattern of systems can be described as: constant, growth, decline, growth-then-decline (collapse), decline-then-growth, or oscillation. It follows (by inference) that an event may represent the activities or the scenarios that have the potential to trigger of the behaviours of interest. What we reported as stock of the structure in this research (such as disaster preparedness, or port environment stability, or resilience port logistics) is the cumulative effects of behavioural change of the variable of interest, during the period we are considering. Therefore our measurements will be the averages instead of instantaneous values of the flows affecting the stocks.

We consider simulation as one of the SD “tools used in testing policy outcomes resulting from organisational change (Sterman, 2000; Forrester, 1961) [*due to a disruption*], which can lead to improving design in a process (Pidd, 2004, 2003; Robinson, 2004; Law and Kelton, 2000), or for reporting the impact of a past change” (Ackermann et al, 1997). Simulation can also be thought of as representing some mathematical models that combine evidence from research and other sources to approximate how real-life systems behave under particular conditions. The usefulness of simulations in accounting for past events makes them suitable tools for accounting for the future change of organisations (Pidd, 2004; Robinson, 2004; Forrester and Senge, 1980) as well. Simulation processes can help researchers and policy makers in several ways. They can help to translate research and other evidence into a form that decision makers can readily understand. One can experiment virtually with policy levers or other interventions to understand how they affect outcomes of interest.

Simulation can be a tool for discussion, collaboration, and “big picture” thinking among researchers, analysts, and policy makers throughout the policy-making process. Simulations can help entities to identify policy-relevant holes in the in a system as well as to understand the subtle dynamics that are involved in alternative change options available through genuine debates which they can generate among experts during data collection and analysis. Such debates enhance model validity which is normally attained when problem owners are deeply involved in the structuring process of the model to the extent that sometime they can use their own ways to demonstrate their understanding of the model or the problem at stake. Nonetheless, Forrester (1961) and Sterman (2000) argue that simulation as a model building process can sometimes become vague and meaningless to problem owners. However their usefulness have compelled several research to adopt SD simulation model processes in different fields, and for various purposes. For example Forrester (1961), Bell and Bell (1980), Forrester and Senge (1980) Richardson and Pugh (1981), Barlas and Carpenter (1990) dealt with philosophical aspect of SD model validation. Other authorities have called for the need to use simulation models for confidence building and model testing (see Coyle and Exelby, 2000; Sterman, 2000, 1984; Barlas, 1996). According to Howick et al (2008), the purpose of model validation in most cases is to gain confidence in the model by problem owners. This fit can be obtainable by the modeller through qualitative methods, or quantitative methods, or through the use of both approach. We attained model validity through the use of thick and rich description of how the ‘world’

works (qualitative modelling) and then followed it up by assessing the model behaviour through quantitative simulation models (numerically) using Euler and Runge-Kutta numerical integration methods⁴⁶.

4.4 System dynamics as mixed model

We employed both qualitative (CLM) and the quantitative (simulation) modelling methods in our analysis. Causal loop diagrams allowed the research to identify systemic feedback loops while the simulation models helped it to investigate the dynamic behaviour of research stock and flow structure over a period of time. As a start for dynamic modelling, Sterman (2000) states that CLM:

[...] “They are well suited to represent interdependencies and feedback processes. They are used effectively at the start of a modelling project to capture mental models – both those of the client group and those of the modeller(s). CLMs are also used to communicate results of a completed model project effort”. (p. 192).

Despite the advantage stated in Sterman above, many authors also claim that CLM cannot capture the dynamic structure of stocks and flows as in system dynamics. Perhaps this and other limitations warrant the upgrading of CLM by introducing stock and flow and feedback structures or models.

The dynamic behaviour of dynamic systems can be represented in four ways (the bathtub, stock and flow diagram, integral function, or differential function) to contain or to disseminate the same information. The choice of which one to adopt in a research

⁴⁶ Note that in numerical analysis Euler’s method is used for first order, while Runge-Kutta is used for higher order integration methods.

depends on the client's background and that of the modeller as well. Authors like Sterman (2000) recommend that diagrams are better understood by many people, especially those who have low interest in mathematics, while some others prefer mathematical (functional or numeric) modelling. We attempted to balance these views, hence the use of diagramming and integral functions in the analysis of data as depicted in section 4.11.

4.4.1 The qualitative aspect of SD modelling

The qualitative SD aspect involves the use of mental (symbolic) models to articulate the minds of the clients and the modeller. They represent the interdependencies and feedback process of a dynamic system being studied. Forrester and Senge, Richardson and Pugh, Howick et al, Stermen, Coyle, and many other apostles of SD have advised that CLMs can be used as foundation for modelling projects to enable one capture mental models of both the client(s) and modeller(s).

We selected environment instability, disaster preparedness, and resilient port logistics operations as our stock variables whose structural behaviour we wish to model and analyse with respect to various policy changes in the port/maritime logistics industry. For example, a cursory look at the CLM figure (4) below suggests that increase in port environment instability is contingent on port activities, disaster preparedness, and policy/preventive compliance measures. Apparently, port environment stability can improve when sustainable management practices are observed over a period and the vice versa.

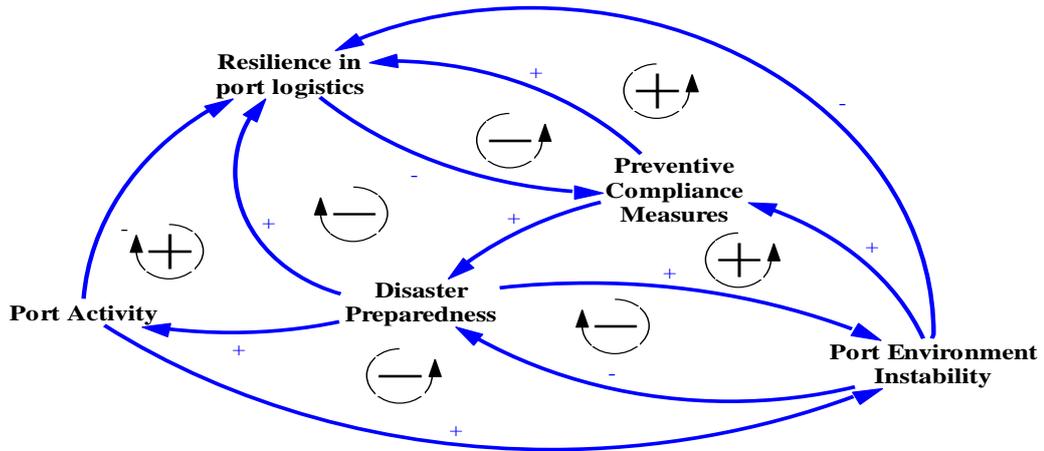


Figure 4: An influence/causal loop diagram derived from interview response and literature search

A study of the loops in figure (4) suggests that the total number of times that Port Activity for instance, feeds back onto itself is four (see summary on table 3). On table 3, the length of loop one is two; implying that there are two elements (or variables) in that loop which is composed of Port Activity → Port Environment Instability → Disaster Preparedness → Port Activity. The net polarity of that feedback loop is negative (−), or it can be said to be a balancing loop. Furthermore, the length of the longest feedback loop formed by Port Activity is four elements, and is composed of Port Activity → Port Environment Instability → Resilient Port Logistics → Preventive Compliance Measures → Disaster Preparedness → Port Activity. The net polarity of the feedback loop is positive (+) which represents a reinforcing loop.

In a summary, the arrow-headed arcs and the polarities as in figure 4 (extracts from interview data) can be explained as:

- An increase in Port Activity can cause a rise in level of Port Environment Instability more than it will have been (+);

- Increasing in Port Instability can reduce levels of Port Resilience to disruptions less than it will have been (—);
- We also assumed that a highly Resilient Port can cause management and port users to feel invulnerable (or have state of exaggerated safety) and thus they may relax vigilance, reduce supervision and thus reduce Risk Preventive Compliance Measures less than it would have been (—).
- It can become apparent from the CLM above that when hazard (Risk or disaster) Preventive Compliance Measures are increased, directives (laws and regulations) may be enforced such that port operators, agencies, shippers, CROs, and all port facility users may become more alert, thus increasing the potential Preparedness for disruptions in the port/maritime logistics network (+).

Figure 4 is summarised into table 3 below, and the detail feedback analysis can be found on appendix B.

Variable	Number of Feedback Loops	Length of Longest Loop
Port Activity	4	4
Resilient Port Logistics	5	4
Disaster Preparedness	8	4
Risk Preventive Compliance Measures	7	4
Port Environment Instability	6	4

Table 3: A summarised analysis of feedback loops extracted from figure (4)

To further analyse figure 4, (apart from the analysis of the loops) we employed some additional Vensim analysis tools such as causality diagrams (i.e. the Causal Tree and Use Tree) and simulation models as described below.

a) Causes Tree Analysis of figure 4

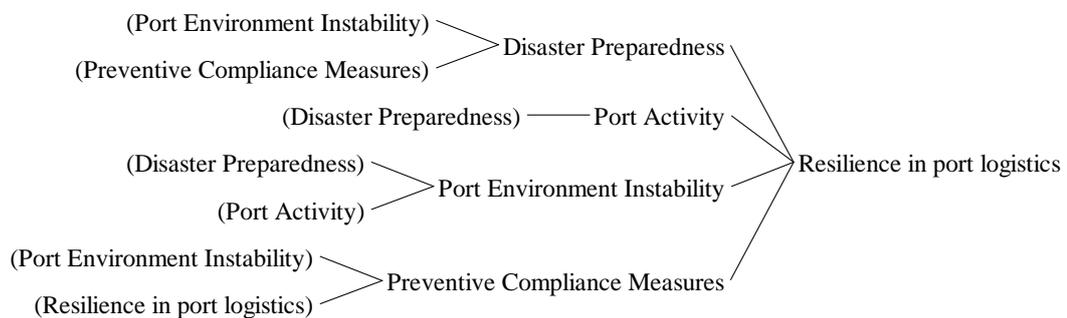


Figure 5: Causal tree analysis derived from CLM in figure 4

The causal tree diagram represents key variable as the head of the tree and includes all the elements (subordinate variables) that influence it. The causal tree allows one to answer questions such “who (or what) influence what” or “what causes a change in behaviour identified in a particular structure”. For example, figure 5 above is the causal tree analysis for Resilient in Port/maritime Logistics. Tracing the diagram backwards, the reader will find that there are four (4) variables that have direct influence (cause) on Resilience in Port Logistics (effect). These comprises of Disaster Preparedness, Port Activity, Port Environment Instability, and Risk Preventive Compliance Measures. One can also see that Disaster Preparedness is influenced by Port Environment Instability, Risk Preventive Compliance Measures, and others that followed as shown in the diagram (figure 5). The inference is that any change in the

circumstances of any of the causal variables can change the behaviour of Resilience in Port Logistics (the effect variable) as it shall emerge in the simulation section (4.11.3). The reader may refer to appendix B for the remaining causal tree diagrams representing the other variable of figure 4. The explanations follow the same argument as the above.

β) Uses Tree Analysis

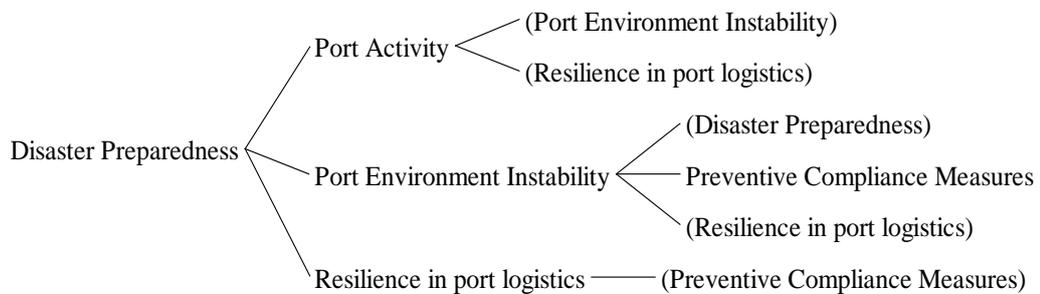


Figure 6: The use tree diagram representing what elements can be influenced by disaster preparedness

The use tree diagram (figure 6) has a main variable as head and shows all other variables influenced by the same key variable. The use tree diagram helps to explain how one variable affects others in the CLM. The above suggests that the level of DP can [directly] influence Port Activity, Port Environment Instability, and RPL, as well as remotely affect the other variables at the second level. The reader may turn to appendix B for diagrams that represent the remaining variables as represented on the CLM (figure 4). In causality diagrams, variable (element) which are found in a parenthesis indicate that that variable has occurred at least twice in the tree and is therefore contained in a loop formed with the key variable at the head.

4.4.2 Diagramming stock and flow plus the integral functions

Quantitative analysis in SD modelling usually relies on one or a combination of the following processes: stock and flow structures, integral functions, or simulation processes. We attempted to engage all three as we described in the remaining sections of this chapter.

The stock of an SD is that quantity which is measurable at a particular time. Stocks do not have any time dimension, they are the existing quantities at time t . The stock accumulate over period of time. For example, the inventory level in a warehouse at the time of a disaster incident. Conventionally stocks are represented as a rectangular block in a stock and flow diagram. Flow in SD model (on the other hand) is the quantity that is measurable within a specified time period (e.g. hours, days, months, years etc.). Thus flow has time dimension and varies per time unit. For example we can talk about the rate (speed) at which quantity of material in a warehouse is issued out during an emergency operation. SD modellers represent flows as pipes with control valve attached. There are two types of flows (the inflow and the outflows). Inflows have arrowheads that point towards the stock while the outflows have arrowheads pointing away from the stocks. As represented on figure (7), the clouds at the tail of inflow pipe represents the inexhaustible source from which the inflow pipe draws its resources, and those at head of the outflow pipe signifies the bottomless tank into which resources from the stock drain (see Sterman, 2000, pp. 192 – 193, and also <http://www.economicdiscussion.net>).

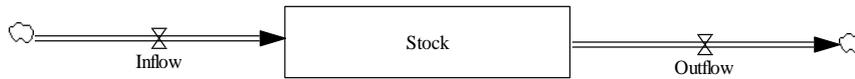


Figure 7: Conceptual stock and flow diagram

The stock can be transformed into more unambiguously precise mathematical statements such that it may create room for simulations runs. Mathematically, stocks may be featured as the integral equations (2)

$$Stock(t) = \int_{t_0}^t [Inflow(s) - Outflow(s)] ds + Stock(t_0) \dots \dots \dots Eqn (2)$$

We can also write as:

$$Stock_{(t)} = INTEGRL (Inflow - Outflow, stock_{t_0}) \dots \dots \dots Eqn (3)$$

Eqn (2) and (3) represent the value of stocks at time **S** between the initial time **t₀** and final time (**t**). Both equations can be interpreted as meaning that stock accumulates at the rate of the inflow less (or minus) the rate of outflow, beginning with an initial value of stock_{t₀}. The specific equations and structures have been discussed in section (4.11) under the respective state variables being modelled.

By the dynamic systems theory, stock levels can change only by their flows; particularly at the rate of the outflow. Since outflows can be a drain on the stock they can be expressed as derivatives, or differential functions like the general equation (4) below:

$$\frac{d(Stock)}{dt} = Inflow(t) - Outflow(t) \dots \dots \dots eqn (4)$$

We may interpret the equation as the rate at which the stock is consumed (depleted, or issued out) at time t .

According to Mass (1980) cited in Sterman (2000, p.195), Stocks inform the decision makers about the state in which their system is. For instance, CROs and management at the case study (HPC) may ask: How prepared are we if disaster X or Y occurs now? How resilient (capacity to bounce back and adapt when impacted by crisis) are we? Or how stable is our ports' environment relative to disasters/disruptions? Questions of these kind may enable management to do thorough risk assessment then plan mitigation against potential disruption incidents in the logistics network. An informed decision can be made on key variables that may affect risk intervention processes and change management in the system.

Stocks usually accumulate past event, and the only way they can be changed is by their corresponding flows. It seems that stocks are source of delays in a system and by such delays they enable management to determine how long it will take to effect a change in policies and strategies of operations as well as the length of time it may take to overcome the effects of an incident in the logistics network. We may be aware that delay output of systems often lag behind the system's input. For example there is always a time lag (or differences in time) between the time an event occurs and the time to respond to that event. Specifically, there will be time lag between port activity and its effect on the environment, just as the time between preventive compliance measures (policy regulations, directives, laws, and sanctions) and the expected effect on logistics sustainability (resilience).

Furthermore, stocks decouple rates of flow and rather create disequilibrium dynamics. One will learn that the inflow – outflow imbalance (or disequilibrium) may be due to the different decisions that govern each process. For instance, the decision to prepare for disruption in the logistics chain may be contingent on the rate of resource supply, the capacity to carry out and sustain essential functions, available technology, forecast accuracy, policy and preventive compliance measures and many others. Nonetheless, how much redundancy to keep, and how much should be released during an event are examples of two different decisions which can result in imbalance in a system and thus reduce or aggravate the effects of a crisis. In other words, these can be linked to demand-supply imbalance or the famous ‘bullwhip effect’ in logistics networks, particularly during instances where prompt action is required to carry out certain functions.

4.5 Processing the interview data into SD modelling

Personal interviews and Grounded Theory (GT) can be two of qualitative data collection and data analysis methods (or techniques, or approaches) that many system dynamicists have employed. For example Newman and Benz (1998) note that these two tools could be used in a single research both to build, and to test theories. In this research we attempt to build structural theories using SD models. One may note that the key variables in this research involve constructs which cannot be measured accurately without measurement errors (soft variables). We look for a methodological hybrid that can enable us to measure such intangible/soft variables both qualitatively and quantitatively. Therefore we applied interview methods as data collection tool

(section 3.12.4), thereafter we employed steps in the GT approach for data analysis from which quantitative measurements were derived. We selected some steps in the GT because it has the capacity to generate mathematical models from raw qualitative data. Details of the GT and equation derivations emerged in sections (4.7) of this document.

4.5.1 Usefulness of qualitative data in SD model building

Qualitative data collection has been recognised as a rich data source for building simulation models in SD modelling (Kim and Anderson, 2012). It has been acknowledged in Forrester (1992) that numerical data alone may contribute little to the type of information that is needed in order to create a meaningful model in SD. Forrester adds further that a larger amount of information for an SD model can be gotten from written (textual) and mental database. This perception has already been advanced in Richardson and Pugh (1981) when the co-authors state that ‘qualitative data can provide a more reliable dynamic view in SD modelling than quantitative data’.

Arguably, we can state that when qualitative data is left out in SD modelling, there can be some biases in data analysis and reporting. One of such biases may include ‘measurement bias’ which can result when certain important qualitative (Sterman, 2000) constructs, or soft variables (Checkland, 1983) have been left out. Due to such occurrences, Luna-Reyes and Anderson (2003) recommend the need to use qualitative data in all stages of SD simulation modelling process, especially where soft variables are involve.

In spite of the extensive use of qualitative data in SD modelling, Luna-Reyes and Anderson (2003) also note with concern that the field has not yet developed guidelines to show how data can be collected and analysed. However Kim and Anderson (2012) suggest that qualitative data can enhance the generation of reference modes, the estimation of model parameters, and also the generation of table functions. All these can help to elicit the basic causal links underlying model structure. Furthermore, qualitative models can represent the various ways by which the client team can confirm and/or modify existing model structure, or a model's behaviour. For example Luna-Reyes and Anderson (2006) and Ackermann et al (2010) used time graph approach to engage their clients in model building during the conceptualisation phase of their model which investigates the benefits of group involvement in model building. Ford and Sterman (1998) used task based approach to elicit non-linear graphical functions of their simulation model. Though the examples cited here were typical group model building cases where the stakeholders were grouped at one place to develop the model, we did not directly gather problem owners around a table to build the model structure. Rather the clients' mental models (as represented in the text) were translated into complex structures that became testable using scenarios.

It appears that Kim and Anderson's (2012) approach where well-structured text-coding methods were used to systematically extract causal structures from textual data, from which they developed causal diagrams that could be used for model validation and simulation is appropriate. Earlier to that, authors such Axelrod (1976) and Eden et al (1992) proposed and used word-and-arrow diagram from qualitative data to construct cognitive maps. Such cognitive maps derive structural relationships among a set of

causal assertions that might have been made by individuals, or a group during data collection. In the cognitive mapping process, each word or phrase represents a concept which is then linked to one or more other concepts in a cause and effect conceptual frame that can specify a relationship arrow which may carry polarity.

We therefore engaged Kim and Anderson (2012) approach/method of data collection in this research. Therefore, we presented a conceptual relationship diagram (see figure 3) to the respondents. We requested the interview respondents to critique the diagram (or express their opinion about the diagram) by indicating the perceived causal relationship between the key research variables (port environment instability, disaster preparedness, policy/preventive compliance measures, and resilient port logistics). The respondents were tasked to state the possible polarity of the causal relationships that they might identify in the diagram [see details of item #7 in the appendix A]. The process of data collection and transcription have been discussed already in chapter (3). Data analysis approach is detailed in subsections (4.5–4.11). Several authors have used similar qualitative methods to elicit causal structures. For example we found that Kopainsky and Luna-Reyes (2008), have engaged a similar causality relationships diagrams to develop a conceptual model in the field of system research and behavioural science to strengthen empirical rigour in the relationship between data and structure. Eden and Ackermann (1996) and Ackermann et al (2005) on another occasion used a similar strategy to support decision on the software ‘Decision Explores’. Howick et al (2008) employed a closely related approach to report procedures for using ‘Group Explorer’ to elicit causal relationships that supports the construction of formal simulation model. In Richmond (1997) the approach was

embraced in order to aid in explaining the causal structure from a management team in a 'Strategic Forum'. Additionally, Ackermann (2011) presents a 'Scriptmap' using similar method as a way to recognising the use of qualitative methods to explain model structure and behaviour for easy access (grasp) by those planning group model-building sessions.

4.5.2 Applying the data collection methodology (approach/technique)

Subsequent from the methodological blend according to Newman and Benz (1998), the research conducted semi-structured interviews with CROs at the major Ports in the HE and also with an expert in Coastal and Estuarine Studies (academia). All respondents live or work within the Humber Region of the UK. Because it intends to unearth issues that might be counterintuitive, the research implemented face-to-face in-depth elite interviews approach (see detail in section 3.12.2). This path offered the research an opportunity to seek clarification for technical terms and definitions that popped up during data collection. Additionally, the approach gave both the investigator and the respondent the chance to elaborate on the points raise for each theme under discussion. Thus, the interview data became the respondents' own words that can be quoted verbatim by the research to support its arguments during data analysis and thesis write-up stages. This dialogue approach of data collection was carried out in a free and friendly atmosphere. Hence it appear that the usual confusion that ensue in other data collection approaches due to communication gap was addressed right at the interview session.

The investigator remained as neutral as possible throughout the process of the dialogue with each respondent so that their accounts are not biased by the behaviour of the researcher (McCracken, 1988). The investigator sought for permission at the beginning of each meeting to voice record the interview proceedings. All interviews except one data source (CS3) did grant the permit to record. CS3 told the investigator that for security reason, the company does not allow recording of interviews on their premises. Each interview data was transcribed as soon as the research returns from fieldwork. The textual data forms what the research quote copiously (under anonymity) to support its arguments at data analysis and report stages.

Alternatively, we could have used workshops or focus groups to review, assess, and build the causal links/diagrams (Eden and Ackermann, 1998) that emerged from the conceptual diagram (figure 3) into a CLM (figure 10) which was later expanded to produce a more complex model (figure 11). However we anticipated that getting the experts (i.e. the respondents) together on a particular day, venue, and time, out of their busy schedules may be very difficult if not impossible. We also failed to use skype or teleconferencing since the use of such technologies will undermine the beauty and relevance of the physical presence that can be experienced from a face-to-face interview. Therefore we adopted the interview protocol as described in section (3.12.2) at the premises of each of the respondents. The data from each of the interviews were coded, causal links (figure 9) were formulated, from which models were constructed (Bryson et al., 2004) to provide clarity of thoughts by the problem owners and the modeller as shown on figure 4.

The above approach can be a powerful tool for creating feedback theories (Luna-Reyes and Andersen, 2003) from raw textual data. Gurus in SD (Randers, 1980; Richardson and Pugh, 1981; Roberts et al., 1983; Sterman, 2000b; Wolstenholme, 1990) have used such approach to develop guideline processes for model building. Others (Forrester and Senge, 1996; Sterman, 2000) used such tools to enhance confidence building in the model they have created. However, Luna-Reyes and Anderson (2003) posit that SD models can also be mathematical representations of problems and policy alternatives where data available to the modeller is mostly qualitative. Forrester (1994) assert this by suggesting that ‘qualitative data resides in the actors’ mind (mental database), in written or in ‘textual’ form. Thus Forrester acknowledges that to a larger extent, data source for SD modelling can be derived from qualitative data. This assertion is shared by many mainstream SD writers such as Randers (1980), Richardson and Pugh (1981), Roberts et al. (1983), Wolstenholme (1990), and Sterman (2000).

4.5.3 A detailed composition of interview respondents

Through previous interactions such as visits and study tours and literature search, we learnt that the administration of the four major ports in the HE is under the ABP. It also became apparent that the CRO in Hull is also the person who is in charge of affairs in Goole, whiles that of Immingham port is the one and same person who doubles as the CRO in of Grimsby. We further learnt that the central administration (ABP) in the HE is located in Hull. Therefore the respondents at Hull were more or less playing a central administrative role that covers the other ports in the Humber Estuary.

We originally targeted between nine (9) to twelve (12) respondents. However the representatives of two companies withdrew their participation at the last minute for apparently genuine reasons. For one of those who withdrew, it was due to change of job, or duty reschedule just a few days prior to the appointed time for the interview. Whiles the other one withdrew from the exercise because the project (or company) he represents was only at the feasibility stage in the Humber Estuary. This second person states further that his company has established their presence in other ports on the East Coast like the Teesside, but they have not yet established in the HE. So the participation in discussions concerning the Humber, especially in the area of risk, security and operational disruptions will be premature and unrealistic. Nevertheless, we still tried to engage at least one person from the port of Immingham with the view to getting different perspective from the officials in Hull. However the potential respondent whom we contacted via the phone, followed by two visits, said that his/her views may not be different from those expressed earlier by the colleagues at ports of Hull. The person explained further that CROs in Hull and Immingham are bounded by the same administrative (ABP) rules, regulation, and policies. The potential respondent said that the representatives at the ports of Hull are senior colleagues, they have more experience and possibly more knowledgeable in the field than that representative in Immingham. The nominee therefore indirectly declined to participate in the exercise. Time was running out for the research student, hence we ended up settling on seven (7) respondent's view for data analysis. Details of the composition has already been discussed in section (3.12.1) of this document. All the respondents live and work within the catchment area of the HE. The transcripts that were derived from the interview proceedings provide good example of purposive textual data.

Since data was captured in conversation (or dialogue) form on the tape recorder, one may be right to believe that the data reflects the frank and unfeigned views of the respondents. Research therefore assumes a reasonably high confidence that the mental models of the respondents are a revelation (or the representation) of the facts as pertained in the field at the time of data collection. The number of interview questions and how the interviews were conducted including how we corresponded with respondents (e.g. via the telephone, e-mail, personal visits, and study tours to ports) was detailed in section 3.12

Interview item #7 was purposely designed such that the response from respondents will elicit the interactions between environment, preparedness, and resilience. It contains a conceptual model (figure 3) which requested each of the respondents to. We used the data generated from the hypothetical model to conceptualise, to validate, and simulate the models. Kim and Anderson (2012) called this approach the ‘purposive textual data collection’. By this approach the transcripts were deemed to represent the mental model of the clients, perhaps with just very little data manipulation so as to suite the research purpose at where we found available information to be inadequate. However, in as much as we could, we did preserve the statements in verbatim in the original form, undistorted by data collection method. Therefore causal relationships such as figures (8 or 9) emerged from the raw textual data.

4.5.4 Processing the data in GT fashion

Immediately after the field work (data collection) and data transcription, we engaged some steps in the GT methodological philosophy (detailed in section 4.7) to guide us

in structural identification, and structural formulations through the creation of various connectivity via the meanings provided in the relationships that the research established from the textual database. Luna-Reyes and Anderson (2003) assert that one of the common ways to extract parameters, especially nonlinear relationships from problem owner, is through the use of interviews and group sessions. For instance, we developed initial characterisation of the problem through interactions (include; CILT meetings and conferences, study tours at some of the ports on the Humber River, academic seminars, and conferences) with practitioners in the field of port/maritime logistics operations in the HE. We supplemented this information gathering sessions with a thorough literature review. However field interviews with the top risk managers (CROs) in the port industry within the HE become the main data source for the SD modelling, taking cue from Reagan-Cirincione et al. (1991), Vennix et al. (1992), Morecroft and Sterman (1994), Richardson and Anderson (1995), Vennix (1990), and Anderson et al. (1997). We particularly followed the advice by Babbie (1992), and Bernard and Bernard (2013). These authors recommend that data collection process should be updated stage by stage from group interaction to interviews. For instance, we update interview items (questions or agenda) after every interview session where necessary; we usually build on a previous data collected. It seems this helped to fill potential gaps that we identified in the previous interview sessions. The data updates also helped the research to seek confirmation (or otherwise), from the current respondent about information which has been provided by a previous respondent, thus making it possible for the investigator to get more explanations for issues that have not been clearly explained in the previous interviews.

4.6 Qualitative data analysis method (approach/technique)

Various techniques are available for use and have been adopted in qualitative data analysis. For example, Forrester (1975a) used hermeneutic approach when he describes the need for observation and conversation (dialogue) methods that should involve problem actors in data collection and model building. In Bernard's (1999) work, he cites how the use of discourse analysis method helped Waitzkin et al (1994) to understand how aging, work, gender role, and socio-emotional problems are treated in older patients and primary care internists. Others advocate for ethnography and content analysis approaches. However we engaged steps in Strauss and Corbin (1990) and Corbin and Strauss (2008) GT approach (methodology) to aid us in identifying themes and concepts across the text that we had obtained from the transcribed interview data. The main objective for the adoption of the steps in GT analytic methodology resides in the linkage of concepts that can results in meaningful theory generation. SD dwells mainly on linkage of variables to generating structural theories (figure 9) which seems to be analogous to the tools in GT.

The Grounded Theory (Glaser and Strauss, 1967) methodology is a qualitative data collection and analysis method (or process) that can be used in developing system's structure in SD modelling. According to Strauss and Corbin (1998) techniques in GT keeps the researcher looking for a balance between objectivity and sensitivity throughout the data collection and analysis process. We note that this approach matches with the recommendations by Babbie (1992), Bernard and Bernard (2013) that was mentioned earlier in this document. One will infer that there is no control

experiment in the attempt to reach objectivity under the GT approach. However, listening to the respondent (or ‘being in the voice’ of stakeholders, or the problem owners), and picking the sensitive, naturalistic, but hidden meaning in a set of data, becomes the hallmarks of the GT, and is deemed as prove for objective reality. Luna-Reyes and Anderson (2003) posit that data gathering techniques such as the interview, and qualitative data analysis tools such as GT methodology can play a strong and critical role in attaining rigour in SD modelling efforts. Therefore to ensure rigor in data collection and data analysis, we adopted the interview technique and steps GT including those we have described in the sections (4.6.1 – 4.8) below.

4.6.1 Data filtration

We engaged the qualitative approach purposely, in order that the different views from the respondents can be captured including all the necessary details. However the analyst cannot use all the data in the raw state as they were presented by the respondents. Therefore we filtered out or reduced the content so that we can form the influence diagrams. Filtering the data removed unwanted and repetitive statements or ideas such that what was left became the basis for the causal loop maps from which simulation models emerged later in the work. Data filtering also reduced the number of auxiliary variables to a manageable level so that model complexity was effectively reduced.

In the opinion of the research, the data describes thoughts and the state of affairs (mental models) as narrated by the respondents. We filtered out the most relevant information for the purpose of building an SD that subsequently paved way for the

simulation runs. Although we collected data purposely for our model, the technique might have been employed elsewhere and it could still be applicable in other situations. It seems that this character gives the research a reliable causal structure and helps to support its conceptual model as well as builds the needed confidence in the structure of the research models that follow in the subsequent sections below.

4.6.2 Model building process

Following the cascade model of Howick et al (2008) we conducted a total of seven (7) interviews with elites from a wide range of backgrounds within the case study. The interviews were preceded by series of interactions with practitioners in maritime logistics industry through seminars and meetings (CILT) that led to the kind invitations and study tours at some of the major ports on the Humber River Estuary. These activities were carried out in order to acquaint the research with port/maritime logistics operations and practices, and also to help the research understand the relevance of the topic to the problem owners. By tapping the wealth of knowledge of the group of elites, we developed the conceptual diagram (figure 3) for the interview respondents to critique and also the interview questions that followed (see appendix A). This approach is consistent with Eden (1988), and Eden and Ackermann (2004). See also Howick et al (2008) cascade model, and Corbin and Strauss (2008) grounded theory approach to modelling in SD.

Analogous to the cascade process (for instance) we provided a structure (figure 3) that is transparent and formalised from ‘real world’ interviews, from which the qualitative CLM (figure 4), and the stock and flow models/diagrams including the quantitative

(simulation) models emerged (section 4.11 of this thesis). The models in each stage reinforce the argument (Howick et al., 2008) by the respondents. These arguments when put together, presents a rich picture in the form of CLM (figures 4 and 11) that transforms into Stock and Flow diagrams and then finally the simulation models that provided grounds for quantitative analysis. These iterations that represent the same argument about the system's behaviour in different format support, test, and make the research models trustworthy (Howick et al, 2008).

4.7 Model conceptualisation through the Grounded Theory⁴⁷ technique

According to Lane (2001), the SD approach combines the positivist and interpretive paradigms. As a positivist approach, SD recognises the existence of objective reality. However it holds on to the subjective reality as well in the form of mental models. Kim and Anderson (2012) explain that the misalignment between the objective and the subjective realities can be the source of ineffective decisions that appear to plague most management dilemma. SD modellers attempt to make the subjective mental models explicit and testable through simulation processes by using conceptual frames [an interpretive approach]. One may argue that mental models of the same system can be modelled differently by different modellers. This phenomenon appears to attest to the fact that different people perceive the world differently, and that plays a part in the SD modelling process in which different subjective responses were composed into

⁴⁷ Grounded theory method (GT) is a systematic methodology that can be used to discover theory through data analysis (Martin and Turner, 1986; Faggiolani, 2011). The grounded theory approach seems to work using a bottom up approach in a reversal fashion counter to the traditional research method as in social science. It starts with data collection using various means and ends up generating theories from the raw data. The GT approach begins by extracting meanings, and assigning codes to raw (textual) data usually from field. Similar codes are grouped together to form concepts, the categorised concept build into theories.

relationships to be analysed. However buried in the heart of SD modelling is theory generation from raw textual data, which maps with the GT (Glaser and Strauss, 1967) approach. The GT method aims at generating inductive theory from raw data, rather than theory testing (Charmaz, 2006). For instance, Kopainsky and Luna-Reyes (2008) elaborates on how GT methodology can strengthen theory-building in SD. In the next few paragraphs we demonstrate how we built causal theories of the SD (conceptually) from raw data to explain the observed behaviour of the port/maritime logistics network relative to crisis management.

We adopted Straus and Corbin's (1990; 1998) and Corbin and Strauss's (2008) steps for data analysis as in the work titled '*Basics of Qualitative Research*'. Such steps in GT enabled us to attached labels to segments of data to depict what each segment is about (Charmaz, 2006). Based on meanings extracted, codes can be assigned to the textual data. Similar codes can be grouped together to form concepts which build into theories. Coding distils data, sorts them into groups, and gives the writer a handle for making comparison with other segments of data. Drawing from the coding types of GT [including open, axial, and selective coding] key concepts in the data can emerge leading to theory creation.

4.7.1 Practical application of grounded theory using purposive textual data (#7)

As narrated earlier, we derive causal structures from the "purposive data", using extracts from the transcribed (verbatim) data from item #7 as per the narration by each of the respondents. This gave the research a wide range of opinions from the respondents about the possible causes of disruptions in maritime logistics chain. The

end result is that the research findings are expected to improve the current level of understanding the sources (or potential cause and effect) of disruptions in port/maritime logistics network. We uphold that through the understanding, strategic (policy) changes that will lead to the creation of a more stable (or sustainable) port/maritime logistics network can be enhanced without much resistance from the stakeholders.

In order to build confidence in the structure of the model in this research, we matched the causal structure to the original data source by adopting Kim and Anderson (2012) approach for coding (table 4 below) to explain how we derived the model structure.

Description of the process	Main tool	Input	Output
Identifying themes in the data	Open coding	Raw text data	Definition of problem and system boundary; selection of relevant data segments
Identifying variables and their causal relationships	Open coding; causal links	Data segments (each segment = one segment + supporting rationales)	Forming coding charts (e.g. figure 8)
Transforming text into word-and-arrow diagrams	Causal links or causal maps	Coding charts	Simple word-and-arrow diagrams (e.g. figures 8 and 9)
Generalising structural representations	Axial coding; causal maps	Simple word-and-arrow diagrams	Final causal map (e.g. figures 8 and 9)
Linking maps to the data source	Map/data ID numbers	Coding charts and final causal map	Data source reference table (discarded in this research)

Table 4: A summary of coding process, an adaptation from Kim and Anderson (2012) Copy right 2012 system dynamics society

Step 1: discovering the themes in the data through open coding

The main tool under step one was to perform open coding. According to Strauss and Corbin (1998), open coding dissects the text and exposes thoughts, ideas, and meanings obtained from the raw data. Therefore applying the process of open coding, we decomposed the raw (transcribed) data into themes, paragraphs, sentences, phrases, and key words. We closely examined the data break-down for similarities and difference in constructs, and labelled them according to source such as CS1, CS2...CS7. Through such labelling and coding process, there emerged clear definition of the research/system's boundary, which also led to the identification of the key research variables. The open coding process also led the research to identify causal arguments that relate to the mental models of CROs within the case studies. For example we summarised opinions based on the purposely designed interview item #7 as follows:

“...the more prepared” one is, the “more resilience” one can be; or

“...increased risk preventive compliance measures” can improve “port stability”

“...increased risk preventive compliance measures” can “improve disaster preparedness”; or

“...more policies, sanctions, directives, laws and regulations (risk preventive compliance measures)” can lead to “improvement in port environment sustainability [i.e. reduce port instability]”; or

“.....increased disaster awareness and preparedness” consequently “increases resilience in port logistics chain”.

....etc.

These extracts from the raw textual data helped the research to create themes and sub-themes that enhanced the creation of links and structures such as figure (8 and 9).

One will note that the codes were chosen on the basis of the context of the research (Strauss and Corbin, 1998), hence the codes identified and classified various phenomena in the data in the perspective of this research. We manually grouped the transcribed data into themes that suite the research purpose. The manual coding was cross – checked using NVIVO software for the purposes of comparability, confirmability, and also to ensure rigour in the data analysis. For example the codes ‘disaster ready’, ‘disaster preparation’, ‘crisis alert’, or ‘crisis readiness’, were categorised as disaster preparedness. Others terms such as ‘directives’, ‘regulation’, ‘rules’, ‘laws’, ‘sanctions concerning the environment’, were coded as policy on risk preventive compliance measures. Furthermore, codes such as ‘recovery’, ‘reconstruction’, ‘sustainable operations’, ‘bouncing back from disruption’ were grouped into resilience and so on. These terms were derived from the field data from the interviews and/or the interactions as described under the data collection process prior to the actual interview process, or from literature review and existing theories on disaster, resilience, and preparedness. We iteratively grouped and regrouped the codes (or categories) till dominant patterns of the themes emerged (such as in figure 9) to enable the research to develop causal loop maps (figure 10), as well as stock and flow structures, from which we carried out simulation processes or to perform “extreme

condition tests” (section 4.11). For example, the multiple coding revealed among several factors that *resilience* at the port can be influenced by the *level of preparedness* for unforeseen events; policy issues; technological capabilities; and stable (sustainable) port environment (based on location effects).

From the discourse above, it can become apparent that the research boundary (scope of the research) is limited to studying causes of disruptions in the logistics chain at the four major ports that are located on the Humber River Estuary. We will analyse the cause-effect relationships of the key variables extracted from the field data. Through the models, stakeholders can design policy changes (interventions, or strategies) that may enhance better preparedness, improve port environment stability/sustainability as well as improve lead-time to respond to, and/or bounce back from operational disruptions (resilience) in the logistics chain.

Step 2 and 5: Identification of variables and their causal links

At this steps, we micro-analysed the open coded data so that we were able to identify the possible causal structures embedded in the data. We used the respondents’ mental model about the structure or behaviour of the unit of analysis (i.e. the key constructs). Examples of the unit of analysis includes: port environment (in)stability, disaster preparedness, resilient logistics operation, technology change, location effects and port activities, risk preventive compliance measures, and others. We support the argument(s) that follow the single argument made about a particular structure or a system’s behaviour as per the narration by the respondent. For example CS3 argues that ‘.....*increase in disaster preparedness can cause increase in resilience*’ in port logistics operations. Whiles CS4 says that: ‘.....*increases in policy on risk preventive*

compliance measures can improve the stability in port environment' relative to potential risks emanating from location effects.

Step 3: Transforming text into Word–And-Arrow diagram

We transformed the variables that were extracted from the data (such as those in step 2 above) into word-and-arrow diagrams, as in figures (8 or 9), from which we developed the stock and flow diagrams as in the conceptual models [figures P1, S1, R1⁴⁸]. From the word-and-arrow diagrams we identified such variables as “disaster preparedness”, “resilient port/maritime logistics”, and “port environment (in)stability” to represent stocks. These were derived from statements in the text such as: ‘level of preparedness.....’, or ‘level of resilience.....’, or level/state of port instability....’ or the equivalents of such words (or phrases) expressed implicitly or explicitly were enough to inform the analyst to identify whether the respondent perceived the variable as stock. From these word-and-arrow relationships, we built up the composite diagrams (dynamic system structures) such as figures P2, S2, and R2 in section 4.11.

Step 4: Axial/Selective Coding

In step 4, we moved on to perform axial coding (or the reassembling of fragmented data) where similar ideas (codes) were grouped together to form concepts, and the categorised concept built into dynamic theories which were grounded in the raw textual data. For example, a theory might state that:

⁴⁸ For the sake of consistency in labelling of figures, we will use P, S, R and G to represent figures derived from Vensim simulation model for the subsystems preparedness, instability, resilience and general models respectively.

“Disaster (risk/hazard) preparedness promotes resilience in port/maritime logistics chain”

or

“The levels of disaster preparedness is dependent on port’s location effects in terms of port size and physics”

or

“Resilient port/maritime logistics operation is contingent on environment stability and level of disaster preparedness” [this theory seem to have been satisfied in figure G16].

These theories might not be generic, but they may guide a research to focus on solving problems, in the kind of the dynamic theories above. According to Glaser and Strauss (1967) such a substantive theory can become *“a springboard to the development of a formal theory”* (p.79). The substantive causal diagrams that can be generated may later be used to construct a generic model for the entire system being modelled.

For example, from the theories generated through axial coding we built the causal relations such as figure (8) below.

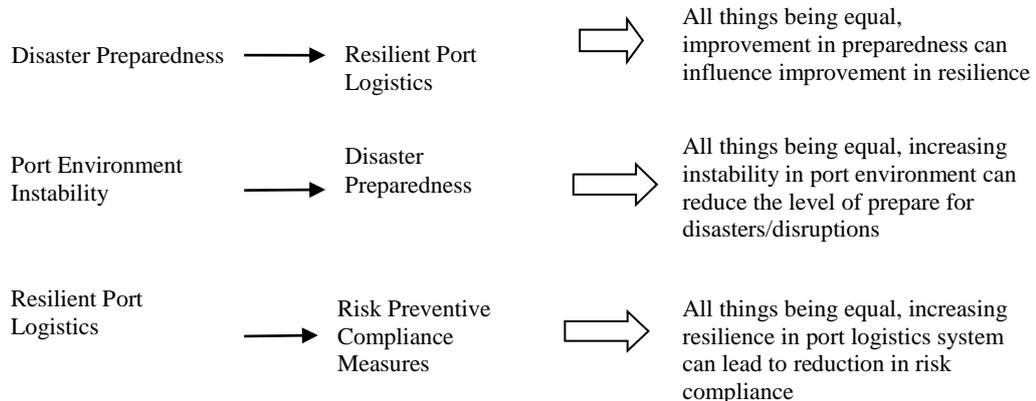


Figure 8: Causality relationships derived from raw textual data

Causality in this sense could stand for either covariance, temporal precedence, or production (Pringle, 1980). For instance in figure (8) above, when one assumes that increasing disaster preparedness can result in associated predictable improvement in a logistics chain's resilience, then the causality type can be classified as covariance. Temporal precedence causality occurs when one activity must come first, followed by the next activity. For example, an entity must be risk/disaster prepared first in order to be able to respond to crisis/disruption in the logistics chain; or a technology must exist in the first place before an entity can suffer its effects (harmful, or beneficial). It may not be possible to respond to an event before preparing for its occurrence. Hence the causal relationship between disaster preparedness and port resilience can also define temporal precedence causality. The third causality is more of a functional relationship type and actually is sometimes quite difficult to prove.

Throughout the analysis process, we used the Vensim® software package for diagramming and simulation runs. First the analysis identified the research variables through the process of filtration (section 4.6.1) and also through coding processes as described in section (4.7.1) above. Variables that were identified were connected to each other to form cause-effect links such as those in figure (9) below. For example we formed the link between:

- a) '*Disaster preparedness*' and '*resilient port logistics*';
- b) '*Port activity*' and '*Port environment instability*';
- c) '*Technology change*' and '*Risk preventive compliance measures*'; to illustrate just a few.

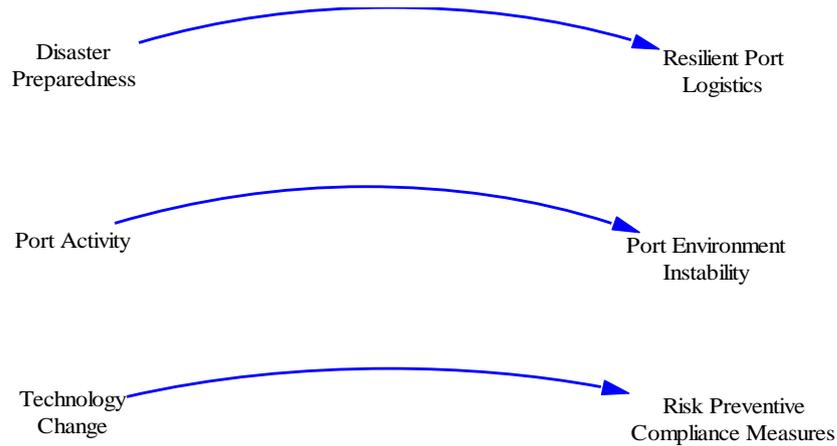


Figure 9: Basic causal links between variables

We note from Howick and Co that in SD modelling, it is usual and acceptable that the modeller determines which variables in the influence diagram to model as stock and flow variables (Howick et al, 2008) as well as which variables not to include in the model at all. Other variables may be used as supporting variables that can help the research to determine the behavioural relationships in the SD model. These may be categorised as auxiliary variables and parameters. Some authors (Burns, 1977; Burns and Ulgen, 1978; Burns et al., 1979) proposed that qualitative models such as the CLM in figures (10, and 11) could be automated to formulate SD such that it can enhance the understanding of the underlying structure of a SD (Olivia, 2004).

4.8 Model formulation

We recall from Luna-Reyes and Anderson (2003) that the stages of modelling where qualitative data may be required include: model conceptualisation, model formulation, model testing and implementations. At the conceptualisation stage, we attempt to understand the dynamics of port/maritime risks and disaster (or disruption) management, particularly how the environment and disaster preparedness interact to

influence port's resilience to disruptions in its logistics system. We focused on the causes of disruptions in the logistics chain within the HE (a real world situation) and how port managers attempt to overcome them. The general response from all respondents echoed one key word "be prepared". All the respondents appeared to relate continuous preparedness, sustained response to crisis, and recovery from crisis in real-time to "resilience". This motivated us to investigate the relationship between preparedness for disruptions and resilience in port/maritime logistics environment.

It is the investigations that led us to conduct the interviews as detailed in section (4.5), followed by data processing which has been discussed in section (4.6). The data processing gave us an opportunity to compare and revisit, or review database from the previous interview such that we were able to refine the conceptual understanding about the research problem. This iterative process safeguarded 'process biases' so that the data collected facilitates better model explanation. The grouping and regrouping of ideas that we described above (coding process) led to the emergence of themes from the content of the raw textual data. The emergence of themes from the content of data is what many scholars term as 'content analyses'.

At model formulation stage, we presented a structure of the concepts that we wish to represent (see figure 3) to each respondents during the interview session. Even though some authors (Nuthmann, 1994; Richardson, 1996) speak against models that rely on social judgement (or 'qualitative systems thinking') approach, we preferred such subjective approach at this stage instead of providing units for measurement. This has helped the research to avoid omission of certain key variables, taking cognisance of Sterman (2000) which states that:

“Omitting structures or variables [that are] known to be important [just] because of numerical data unavailable is actually less scientific and less accurate than using your best judgement to estimate their values” (Sterman, 2000, p.854).

The research involves soft variables which also appear to be nonlinear. Hence numerical data cannot be of much value to us at model formulation stage. Sterman (2000, p.585) further argues that numerical data are often not able to cover a wide range of extreme values or saturation points. Moffatt sums up by stating that:

[...] “it is sufficient to comment on the fact that in complex, nonlinear, multi-feedback dynamic systems, conventional statistical techniques are NOT the only form of model verification, nor are they the most appropriate ways in which SD models can be evaluated” (Moffatt, 1991).

This appears to be in line with what authorities such as Forrester (1992) Richardson and Pugh (1981) spoke about in favour of the use of textual data as a major source of data for SD model building (see section 4.5). Model verification was attained in the research through series of iteration, which by itself is sufficient verification. The ultimate goal is to identify the alternate policies [or strategic interventions] that can lead to improving performance [resilience] of the real system (Forrester and Senge, 1990). This encouraged the research to use the judgemental or qualitative approach which led to the reliance on data from interaction with experts and practitioners, literature search, and interviews in model building. The issue about model testing, and implementations shall emerge in section (4.11) of this document.

4.9 Forming specific stock and flow structures from textual data

We remind the readers that all the variables that we selected to model were drawn from the literature we have reviewed which were further confirmed by the respondents at the

interview. Thus discussions in this section throws more light on the different categories of variables and the roles they are expected to play in the modelling process.

a) Stock (or State Variables)

State variables (Stocks) describe the current conditions of a dynamic system. Stocks are accumulations, or they represent the state of systems that generate the behaviour (information) upon which management decisions and actions are based. Because they create natural delays, stocks are said to be the source of disequilibrium dynamics in a systems (Sterman, 2000) that help management in decision making. In this research we select: disaster preparedness (P), environment (in)stability (S), and resilience (R), as the state variables whose behaviour we wish to investigate; behavioural outcomes which can influence management decisions regarding the choice of best alternative policy interventions that can improve risk (hazard, disaster, disruption, or emergency) management.

By the dynamic systems theory (van Geert and Steenbeek, 2005; Fischer and Rose, 2001; Thelen and Smith, 1994), a researcher is allowed to take state variable approach in the models. The dynamic systems theory is a flexible framework for analysing how many factors can act together in a natural system. It uses abstractions that can be based on thermodynamics and nonlinear mathematical concepts. It can be applicable in many fields where behavioural change is expected. The dynamic systems theory posits that “the only way by which stock levels can change is through the stock’s rates of flows”. The system in this research consists of inflow/outflow networks, and information feedbacks from the stocks that connect with the flows. Under the dynamic systems theory, any variable which the research chooses not to model can be considered as

constants⁴⁹. Otherwise they can also be considered as exogenous variables⁵⁰. In this research, we considered the: cost of resource; specific use of the resources; policy making; and disaster incident as exogenous to our studies. [For the purposes of diagramming stock and flow notation, see Sterman (2000, p. 192-3)].

According to Ogata (1998), you need at least one variable in a dynamic system model whose state must change over time by means of a transition function. Mathematically, stocks can be represented as integral functions, and flows written as derivative functions [as in eqn (1) and eqn (2)] respectively. The transition function (Flow) describes how a system's state changes (behaves) with respect to time. The change depends on a combination of endogenous variables and some exogenous parameters. In this research, the transition functions (flows) are: increasing preparedness due to resource accumulation (IPRA); decreasing preparedness due to resource supply/usage (DPRU); rate of change in instability (RCI); increasing resilient port logistics (IRPL); and decreasing resilient port logistics (DRPL). One needs at least one state variable for the formulation of a transition function (Arrowsmith and Place, 1990) such as those in figures P1, S1, R1.

Let the letters P, S, R stand for Preparedness, Instability, and Resilience models respectively. For the sake of convenience and consistency in the numbering of figures, these representations shall apply throughout the thesis particularly in chapters 4, 5 and

⁴⁹ Constants in SD are said to change so slowly such that they cannot be considered within the model's time frame.

⁵⁰ Exogenous variables are those that the research has chosen not to model because they lie outside the model boundary or scope.

6. For example, figure P1, P2, P3...stands for figure 1, 2, 3...of preparedness model and so with S or R models.

b) The auxiliary variables and parameters

The Auxiliary variables (some call them intermediate variables) are variables which are neither stocks nor flows, but they can be used to formulate the flows. We considered the following as auxiliary variables: technology change, risk preventive compliance measures, port activities, extent of damage, forecast accuracy, frequency of rescue/relief missions, and resource flexibility. These variables were drawn from literature on disaster management and strategies adopted in the various fields (see Quarantelli (1991b); Smelser (1991); Rossi et al (1983, p. 4-9); Milliman (1982, p. 5)). These intermediate variables explain the rate of flow in our dynamic equations (as in the documentary analysis) as well as in the causal structures. One might have already known that only flows can cause changes in stock levels (Forrester, 1968a). Thus the functions of auxiliary variables lie in the conceptualisation and formulation of causal relationships. They provide clear, non-technical meanings to general audience. The auxiliary variables can be eliminated in a stock/flow structure by embedding them in the flow variables as in figures P1, S1, R1. This assertion is supported by Groesser and Schaffernick (2012) who postulate that when auxiliary variables are collapsed into the flow variables, the resultant SD converges into a dynamic systems theory that can be represented as differential equation or integral functions. It seems that auxiliary variables can always be eliminated and the model be reduced to a set of equations (eqn 5 – 9) consisting only of stocks and their flows (figure P1, S1, R1). However SD modelling generally does not appreciate embedding auxiliary variables (Richardson

and Pugh, 1981; Richmond, 2001) since that makes the meaning of the structure a bit “blurred” to those that might be less enthusiastic towards mathematical algorithms.

c) The behaviour of feedback structure

The concept of SD posits that a system’s behaviour emerges from its underlying causal feedback structure (Forrester, 1961; Richardson, 1999). According to Groesser and Schaffernick (2012), CLM structures (figure 4 and 10) and stock/flow (figure P1, S1, R1) can be used to represent underlying causal structures of an SD. For example, for the stock Disaster Preparedness, we selected IPRA and DPRU as the inflow and outflow respectively. For the Port Environment Instability (disequilibrium) the flow is RCPEI. Finally for the stock Resilient Port Logistics, the inflow is IRPL and its outflows is DRPL. The SD representations and behaviour is provided for in section (4.11) of this chapter. Such representations helps to explain the relationships between variables of the causal links since they contain the stocks, flows, and the auxiliary variables as well as show the relevant causal relationships.

d) Simulating the Behaviour of the Research Variables: An SD Approach

This section describes the models and how they work. As a methodological tool, SD applies computer simulation modelling techniques to aid in the understanding and analysing the behaviour of complex systems. The key idea of the model adopted is to analyse the structure of the interdependencies in a system which has multiple interacting objects; such that an insight can be gained into the behaviour of the system (Murphy et al., 2010). Generally the basis for adopting the SD methods is the recognition that the structure of any system is just as important in determining its behaviour as the individual components themselves (see system dynamics method: a

quick introduction, 2010; Road maps: a guide to system dynamics, 2010). In the view of a SD, the behaviour of individual interacting parts of a system cannot explain the whole. Following the steps as used by system dynamicists, we identified certain variables whose behaviour can potentially change with time (the stocks). The research then identified the interrelationships or interdependencies among those variables and how a change in one variable can influence changes in series of interconnected variables forming the chain (loop). At the end, the ripple effects that a change in one variable had on itself across the feedback loop (or the causal loop) were revealed [figure 10]. The overall behaviour of the system is then determined by the aggregate of all loops interacting together. The steps that we adopted are as follows: we first identified the CLM (figure 10); we then developed the stock and flow diagrams for each sub-system (figures P1; S1; R1), we developed the conceptual models into the various dynamic models (figures P2, S2, R2 and G1) from which we performed the corresponding simulation runs for each of the models; the results from the simulation were used to explain (predict) the behaviour of the structure studied (detail is in section 4.11 below).

4.10 Developing feedback loops and causal relations

Feedback loops enable a model to endogenously represent the dynamics of a system (Forrester, 1968a; Richardson, 1999). They are logically closed causal chains where initial change in a variable is fed back on to its origin. The philosophy of systemic feedback recognises the active involvement of problem owners in finding the root cause of a dynamic problem so that policy change to mitigate (avoid, or solve) the

problem can be designed. This philosophy appears to take its root from the ‘General Systems Theory’ of von Bertalanffy (1968), or ‘Systems Theory and Science’ Boulding (1956) and Simon (1960), or ‘Systems Approach’ by Churchman (1968), or Wiener’s (1948) ‘Cybernetics’, or of Gordon Brown’s (1951) ‘Feedback Control Theory’.

Causal relationships on the other hand, can be described as the connections linking end notes (or variables). They may carry an arithmetic operator to give them the attributions of causal relationships between the variables which they connect. SD scholars (Grösser and Schaffernicht, 2012; Sterman, 2000) have explained that such polarity in causal relationships carry meaning. For example, in the relationship between disaster preparedness and resilience, the sign being positive (+) indicates that, *ceteris paribus* (all things being equal), an improvement (increase) in disaster preparedness correspondingly improves (increases) resilience above what it would have been. On the other hand, a negative (-) causal relation between environment instability and disaster preparedness signifies that *ceteris paribus*, an increase in environment instability may reduce the level of disaster preparedness below what it would have been. In other words, the more risk environment poses to the maritime logistics network, the less stable the port becomes less than it would have been. Therefore that port becomes more prone to disasters and operational disruptions. Table (5) below is an example of the meaning of the causal relationships between some variables.

SN	Arc Linking	Polarity	Implication (Explanation) at ceteris Paribus	Mathematical Representation
1	Disaster Preparedness <u>to</u> Resilience in port logistics	(+)	Increased (improvement) in disaster preparedness (perhaps) due to rise in rate of resource accumulation and supply can improve the state of resilience to disruptions more than it would have been	$\frac{\partial[RPL]}{\partial[DP]} > 0$
2	Environment Instability <u>to</u> Resilience in Port Logistics	(-)	Increased in instability can cause decrease in systemic resilience possibly due to rise in magnitude of destruction and rise in outflow from resilience	$\frac{\delta[RPL]}{\delta[PEI]} < 0$

Table 5: Explaining some causal links, their polarity and equations based on figure 4

It seems that the relationships described above exhibit nonlinearity. Nonlinearity may occur when a change in one output exhibits a more (or less) than proportionate change in the corresponding input. Nonlinear relations may show up when there is interdependencies between variables especially when a system involves soft variables. Barlas (1989) and Ogata (1998) assert that nonlinear relationships are rather difficult to analyse both intuitively and mathematically, particularly if they occur in implanted closed causal relationships. According to Sterman (2000), nonlinear relationships can be linearized (or normalised) when analysing such relationships/variables.

In this research, three sub-systems were discussed as we attempt to analyse their structural behaviours through linearization. The models were constructed through linking a few variables with arcs to form influence diagrams. First we linked two

variables (figure 9), then three, and so on, till we formed a chain such as the causal loop diagram in figure (10) below.

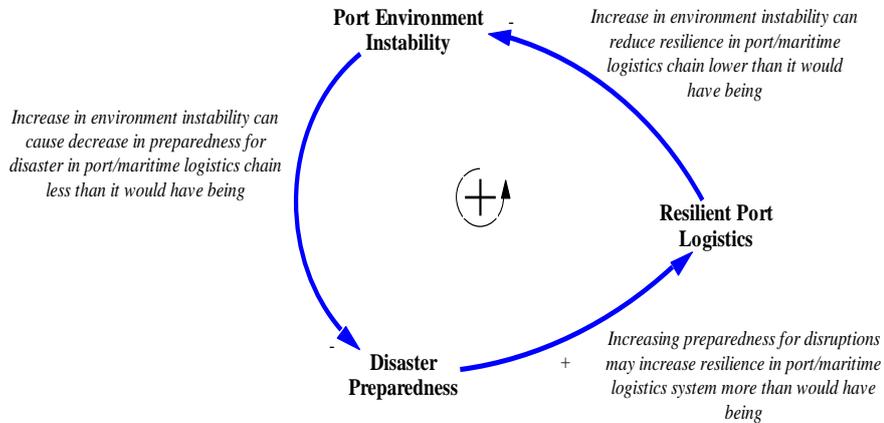


Figure 10: The causal loop diagram connecting Resilience, Preventive Compliance, and Preparedness

Two or more loops were joined together to build a cognitive map(s) such as figure (4) which we extended to form the general CLM structure in figure (11) below.

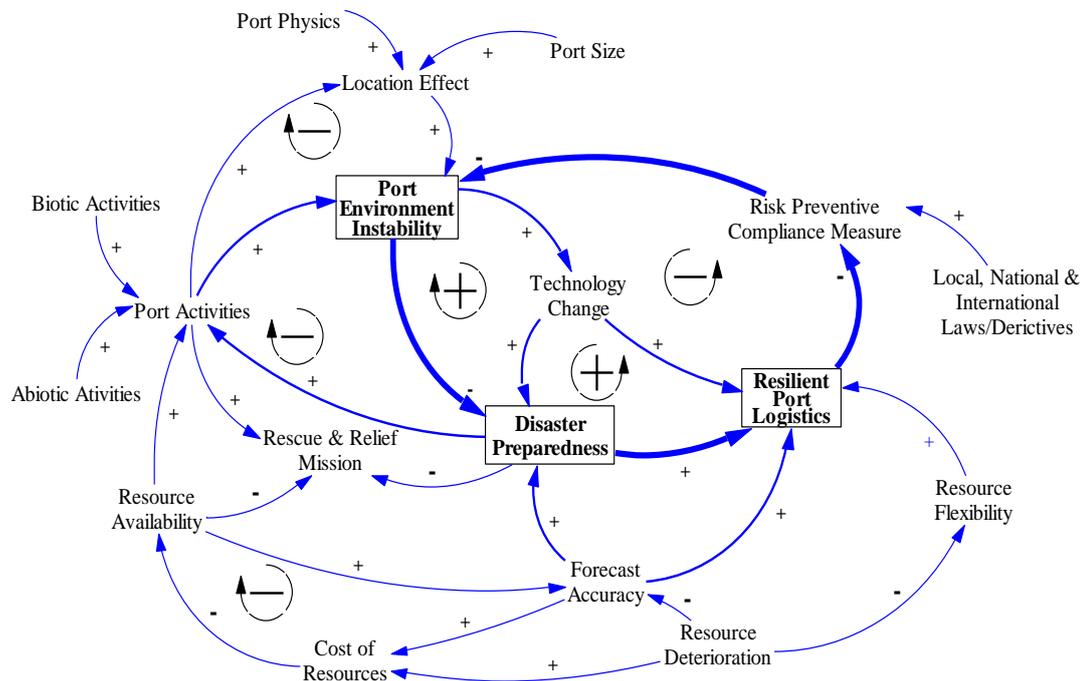


Figure 11: The general integrated CLM/D indicating interdependencies in research variables extracted field data

We further transformed a portion of the CLM/D into stock and flow models (figures P1, S1, and R1 respectively). The work ended up by running a few simulation runs (as in section 4.11). The simulation runs serve as test that enabled us to analyse the structural behaviour of each of the sub-systems and finally the one for the general model for disruptions in the logistics chain. Below are the model results and analysis for each of the three sub-systems we considered in this research: Disaster Preparedness [DP]; Port Environment Instability [PEI]; and Resilient Port Logistics [RPL].

4.11 Model testing

This subsection of chapter 4 deals with the simulation models representing the three stocks (state variables). We performed the “extreme conditions test” on the stocks (DP, PEI, and RPL) to enable us observe the structural behaviour and the potential sustainability of each strategic intervention (auxiliary variable) prior to decision implementation.

The time horizon for the simulation models is 100 days (i.e. approximately 3 months). We selected this time horizon on the basis of the responses we got from the respondents concerning the expected duration of some disruption incidents they illustrated. The responses suggested various time horizons that are event dependent. In fact, by the nature of their activities, ports cannot endure any major disruptions in their logistics network even for one hour. Several modelling gurus (Meadow et al., 1974; Backus, 1996; Bunn and Larsen, 1997; Sterman and Richardson, 1985; Sterman, Richardson and Davidsen, 1990) have warned beginners that time horizon should be selected on the basis of the concept they are about to model and also based on the

resources that need to be measured. The rule of thumb is that ‘time horizon should be set several times as long as the longest time delays in a system’ (Sterman, 2000). Sterman adds that time horizon should extend far enough back into history as well as far ahead into the future in order to show how the problem emerged and to adequately describe the symptoms of the effects of strategic policy interventions.

However, one defect of mental modelling is the presumption that cause and effect are local and immediate. This does not allow one to think into distant and space. Thus a long time horizon may be a critical antidote to the event-oriented worldview so that patterns of a behaviour and the feedback structures that generate them can be identified. It seems therefore that 100 days is long enough for the system we are modelling to be able to learn whether the planned mitigation activity (policy intervention) has failed or otherwise. We presume that any time less or more than the 100 days may not yield a desirable result. See Sterman (2000, pp.90-94) for further details about the selection of time horizon. Also in the said pages, Sterman cited Hubbert’s (1966-1971) model that predicts a decline in the USA oil industry. Sterman advised modellers against accepting problem owners’ initial assessment for time frame since most of such time horizons are usually based on milestones that may have nothing to do with dynamics of key problems.

4.11.1 Modelling the Sub-System Disaster Preparedness (DP)

This sub-system represents the stock and flow structure for disaster preparedness. All labels (figures) in this series shall carry the prefix “P” to indicate that they represent DP model. Stocks as applied in this research may represent mental images, or

perceptions, or physical stock such as handling equipment, port infrastructure and emergency response equipment, which may be used to enhance port/maritime logistics chain's operations. The construct DP can be measured based on how resourceful and agile the logistics system is able to respond to crisis and also how quickly it can be perceived to contribute to speed of recovery from crisis if they happen at time (t). Apparently this can also measure safety and stability levels of port logistics chain against operational disruptions.

In this structure, material that flows through the network is the information about the actual or perceived state and availability of resources which can be channelled into port/maritime disaster response at time (t). This information can be conserved physically as necessary redundancy, in the form of backup and/or reserved equipment. Other resources can be stored in the form of intangibles such as skills and techniques that one acquires during training, drills, as well as experiences such as special natural talents that one has, which can be unleashed during periods of crisis management. The dynamic systems theory (van Geert and Steenbeek, 2005; Fisher and Rose, 2001; Thelen and Smith, 1994) applies. Therefore we assume that the only way by which the stock (DP) can be depleted (or reduced) is by using up the resources that have accumulated over a certain period of time for the purposes of emergency response operation. Furthermore we assume that there is no obsolescence and waste such that there is high level efficiency in the logistics chain within the period under investigation. If these assumptions hold, then all resources can be channelled into emergency response operations only at any particular time (t) as we have represented in figure P1 below.

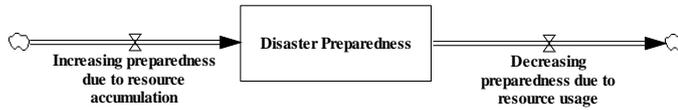


Figure P1: A collapsed conceptual model for DP

The mathematical representations of the structure in figure (P1) is eqn (4) and eqn (5) below. Let:

- Disaster Preparedness (DP) = Stock
- Increasing Preparedness due to Resource Accumulation (IPRA) = Inflow
- Decreasing Preparedness due to Resource Usage (DPRU) = Outflow

$$DP(t) = \int_{t_0}^t [(IPRA)(s) - (DPRU)(s)] ds + DP(t_0) \text{-----eqn (4)}$$

This equation represents the quantity of stock (DP) at time **S** between the initial time **t₀** and final time **t**. Equation (4) can be interpreted as meaning that DP grows at the rates of the difference between IPRA and DPRU, beginning with the stock prior to the onset of response to a crisis incident (DP_{t0}). See specific definition in eqn (02) of documentary analysis for DP (p. 239).

By the dynamic systems theory, stock levels can only be changed by their flows; particularly at the rate of the outflow. Since outflows can be a drain on the stock they can also be expressed as derivatives of a function such as in eqn (5).

$$\frac{d[DP]}{dt} = IPRA(t) - DPRU(t) \text{ ----- eqn (5)}$$

We interpret eqn (5) as meaning that, the rate at which resources are depleted [used up] from a stock of preparedness (DP) at time (t) is the difference between what flows in (IPRA) and what flows out (DPRU) of the stock. Consequently, it appears that the level of DP at time (t) can increase (or improve), or decrease (level reduce) dependent on the following endogenous variables: port activity; policy on risk preventive compliance measures; technology change; forecast accuracy; resource flexibility and so on. For example, increased awareness of location effects [in terms of port size and physics] and the accompanying change in port activities can lead to increased preparedness (risk awareness) and improvement in real-time response through advanced planning. It is expected that when any of the above listed endogenous variables experienced favourable change, management team would be enabled (through the disaster management plan), to strategize how to avoid, or how to mitigate the impacts of disruptions in all the key phases (pre-disaster, disaster, and post-disaster phases). Together, those auxiliary variables feed into the inflow (IPRA) of figure (P2). The result is that it may increase the stock (DP) levels. We considered natural environmental dynamics and policy formulation as exogenous variables since they appear to be out of control by port/maritime logistics managers. The structural illustrations of the above arguments gives rise to figure (P2).

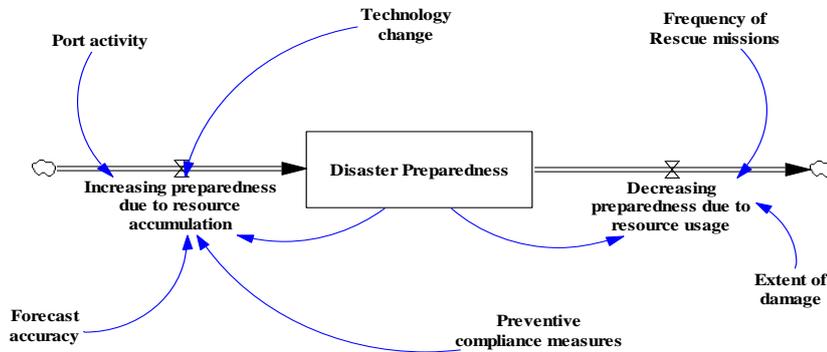


Figure P2: The dynamic conceptual model of DP

In figure (P2), assumes that the only way by which the level of DP can reduce is by the rate of decrease in preparedness as a result of resource usage (or large scale resource depletion) for the purposes of disruption management in the logistics chain. Such change may rather increase the rate of outflow or constrain the inflow; a phenomenon which tends to reduce the amount of already accumulated stock and subsequently makes the system more vulnerable to risks; slow to respond to disruptions; become non-responsive to future incidents of disruptions; especially if the needed resources are scarce, or if the resources are non-replaceable in the short-run. Figure (P2) summarises the discourse as well as makes figure (P1) clearer to any audience, by the inclusion of the few necessary auxiliary variables.

We also conceive DP as a state of readiness (or alertness) leading to acting promptly and decisively accurate at a particular time in order to save a crisis situation. The concept is a mental state (or perceptual) because the actual state of preparedness cannot be valued or ascertained with any certainty prior to the occurrence of event, neither can it be quantified. Therefore the stakeholders can only assume a state of

readiness at a particular time as confirmed by a large majority of the respondents during the interviews statements such as the one below:

‘By our work efforts and also by our standards we are probably fairly prepared, we are fairly well protected in our own sense theoretically but we have not tested our readiness in a real life scenario’.

In other words, management appears to trust their current state of DP; a perception which seem to be normal in the way people perceive risks/hazard in their environment. Lichtenstein et al (1978) observe that people tend to overestimate their ability to control or prevent accidents, leading to an under-estimation of risks [hazards] in a system. Since entities have the tendency to over-estimate safety conditions around them when they get used to it, it seems that their beliefs and perceptions will remain the same until the system is tested by real life scenario. However, experimenting with real-world scenario can be highly catastrophic in terms of costs (i.e. financial, and casualty). Therefore models of this research have been set out to mimic the real-world scenarios that can help to stress test the level of disaster preparedness of ports in the HE.

4.11.1.1 Analysis of DP and results

a) Qualitative analysis of disaster preparedness using causes tree

To analyse the subsystem qualitatively, we used the causality tree diagrams as represented in figure P3 below. Reading backwards, the model suggests that DP is directly caused (influenced) by IPRA and DPRU and indirectly caused by the other variables including DP itself (reading from left to right).

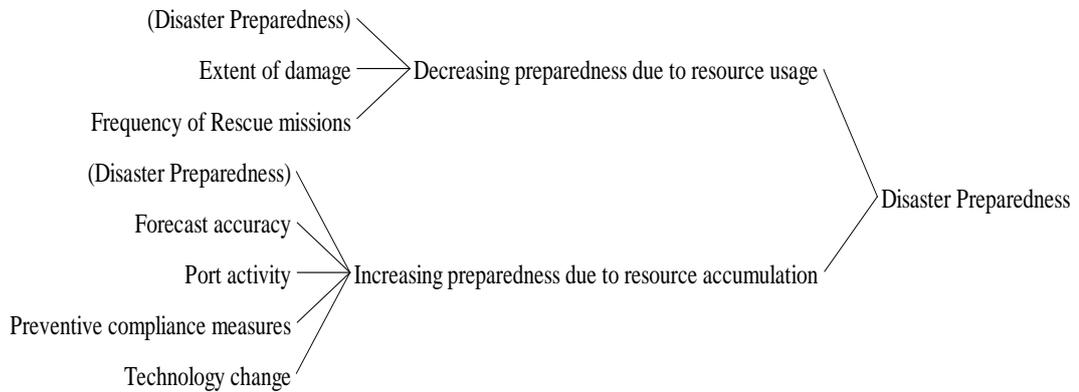


Figure P3: The causal tree diagram representing different variables that can influence DP

b) Quantitative Analysis

We randomly (arbitrarily) generated some initial values for the parameters (constants) to allow manipulation and estimation for the next values as permitted in Euler's numerical approximation. For example we assumed a high value of 70% (0.7) technology application in all port/maritime operations, a low incident of damage at 0.3, and a 0.5 forecast accuracy. See the equations for the documentary analysis under each subsystem for the initial values of other parameters. We used these initial values to run the simulation processes for the other state variables (PEI and RPL) as well. Similar approach has been applied in Shin et al (2014) to analyse safety attitudes and behaviours among some construction workers in the USA, while Georgiadis et al (2005) adopted a similar technique to model strategic management of food supply chain in Greece. Furthermore, the numbers 0, 1, 10 and 100 seem to be the most

common basic units that Euler's numerical method⁵¹ as well as the Vensim® software uses as initial values for modelling; though the modeller may choose other values to suit the problem of the day (Sterman, 2000, pp. 90-94).

1. Documentary Analysis (set of equations)

(01) Decreasing preparedness due to resource usage =
(Frequency of Rescue missions*Extent of damage)/Disaster
Preparedness
Units: **undefined**

(02) Disaster Preparedness = INTEG (Increasing preparedness due to resource
accumulation - Decreasing preparedness due to resource usage, 10)
Units: **undefined** [10,100] (*specific case of eqn 5*)

(03) Extent of damage = 0.3
Units: **undefined**

(04) FINAL TIME = 100
Units: Day
The final time for the simulation.

(05) Forecast accuracy = 0.5
Units: **undefined**

(06) Frequency of Rescue missions = 0.2
Units: **undefined**

⁵¹ Euler's numerical methods is a basic explicit mathematical or computational procedure for solving by approximation, the ordinary differential equations (ODEs) given some initial value and is the simplest Runge-Kutta method

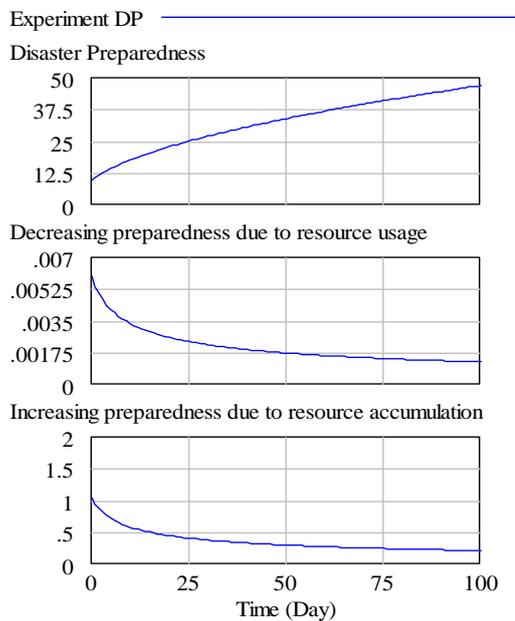
- (07) Increasing preparedness due to resource accumulation =
 (Technology change*Preventive compliance measures*Port activity*Forecast accuracy)/Disaster Preparedness
 Units: **undefined**
- (08) INITIAL TIME = 0
 Units: Day
 The initial time for the simulation.
- (09) Port activity = 50
 Units: **undefined**
- (10) Preventive compliance measures = 0.6
 Units: **undefined**
- (11) SAVEPER =
 TIME STEP
 Units: Day [0,?]
 The frequency with which output is stored.
- (12) Technology change = 0.7
 Units: **undefined**
- (13) TIME STEP = 1
 Units: Day [0,?]
 The time step for the simulation.

The 13 equations yielded the below dynamics of disaster preparedness

2. Structural Behaviour of Disaster Preparedness

The set of curves (figure P4) represent the dynamics of DP change over a 100 day period. They represent the corresponding graphs of the dynamic structure of DP when simulation run was performed on figure P2. We have already mentioned the relationship between figure P2 and figure P1 as well as the mathematics behind, as represented under the 13 equations in the documentary analyses for DP above.

Figure P4: The dynamics of DP over 100 days



In figure P1, the stock (state variable) is DP. The flux (flow) variable or the rates which are capable of changing the stock levels when they are altered are IPRA (inflow) and DPRU (outflow) respectively. To make the structure a bit complex; to allow the audience the needed understanding; and also to reflect the actual mental model by the respondents plus evidence from literature review, we added those few auxiliary variables to figure P1 to form figure P2. Next, we quantitatively analyse the structure in figure P2 which has been defined in the thirteen equations represented in the documentary analysis above. Following from the documentary analysis, we performed

simulation runs (using Vensim software) which produced the set of graphs on figure P4. To get the model results, we re-run the simulations (performed the synthesim) and the outcomes is shown on figures represented in the scenarios that follow.

All the graphs of the dynamics of DP over 100 days suggest an apparent sustainable port/maritime logistics chain at the initial conditions (0). DP builds up (grows) exponentially at an increasingly slow rate by each day, while the trajectories of both IPRA and DPRU decline exponentially contemporaneously and finally appear to be asymptotic to the time axis as described in the set of graphs on figure P4 as well as the subsequent ones that follow under the scenarios tested.

The goal of the system is to improve real-time response to disruptions in a port/maritime logistics network. In real life situations, the apparent goal of many risk managers (CROs) is aimed at continuous improvement in their capacity to respond to emergency (crisis situations) above what they can do at the present conditions (or to improve on current state of preparedness) at any time (t). Hence it seems the curves mimic real life behaviour of risk managers' objective function (or decision) and disaster management plan by their continuous growth over the period.

3. Testing the Consequences of Risk Interventions (Policy Change) on the Structural behaviour of state variables

The diagram below (figure P5) represents the conceptual model of DP and its corresponding set of graphs (P6). To test for sensitivity (behaviour change) of the state variables (stocks) with respect to time, we re-run the model (i.e. performed synthesim). When the micro-levels (or sliders) attached to the constants were varied, the model defined the dynamic behaviour of DP in real time. For instance, when technology is

reduced, DP_2 falls below DP_1 , implying that the level of DP declines when technology falls (figures P5 and P6).

When Technology is reduced

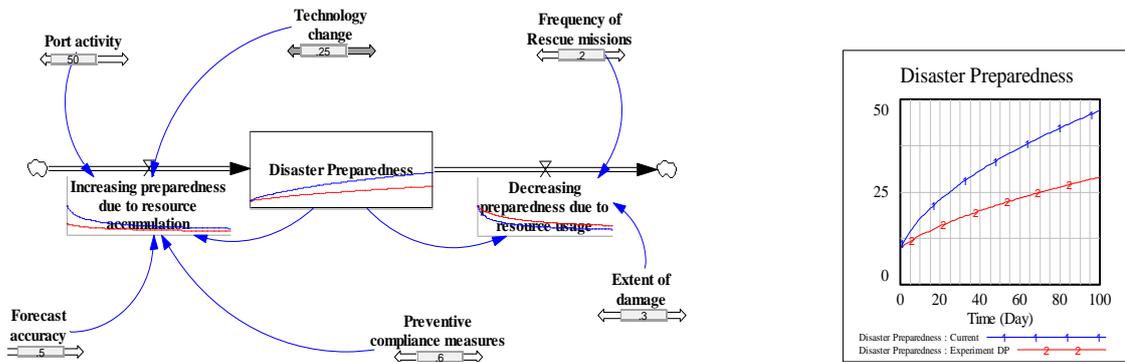


Figure P5: The conceptual model of DP and its corresponding dynamic graph in response to decrease in technology

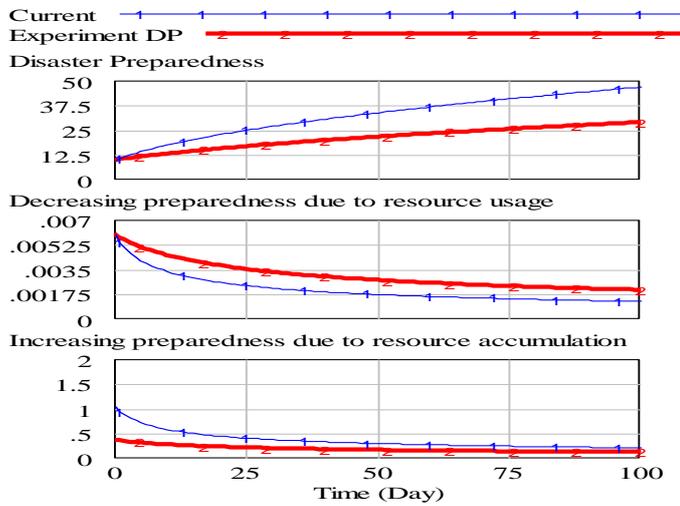


Figure P6: The real time change in DP over 100 day in response to decrease in technology

When Technology is increased

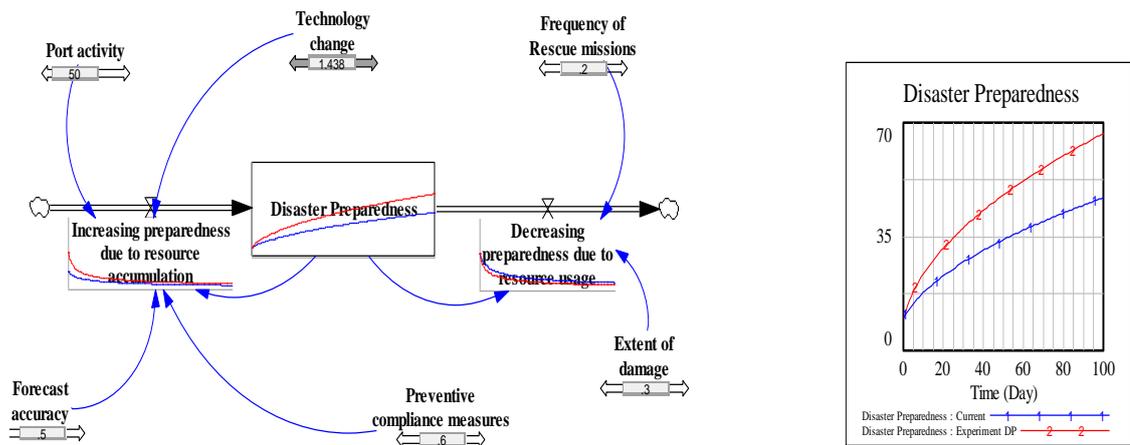


Figure P7: The conceptual model of DP and its corresponding dynamic graph in response to increase in technology

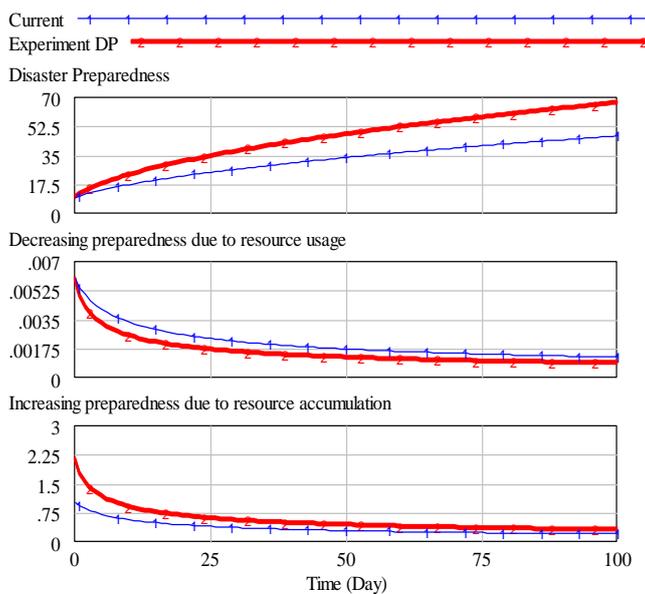


Figure P8: The real time change in DP over 100 day in response to increase in technology

Figures (P5 and P6) describe the real-time change in DP assuming that management decides to reduce the level of technology application (quantity/quality of technology of all kinds) in the port/maritime logistics network or if efficiency in technology falls. From the set of graphs (figure P6), one can be right to allude that the fall in DP is due to a higher marginal increase in $DPRU_2$ as opposed to the marginal decrease in $IPRA_2$.

When the level of technology changes from 70% to 25% (i.e. $0.7 - 0.25$) per operation, the trajectory of DP_2 drops below that for DP_1 . It appears that DP_1 rises faster than DP_2 and hence the gap between the two curves keep widening up per day. It suggests that real-time response to disaster and disruption in port/maritime logistics chain may take longer in the absence of the requisite technological capabilities than if the required technology were available. There may be a lot of “noise” and waste in the logistics system. Thus it seems more number of day units may be needed to accomplish a particular task if the appropriate technology was not available and therefore logistics operations may not become sustainable at the long-run. For example, if there was no technology available to clean oil spills, response to such an incident may be slow or impossible and thus leading increasing maritime environmental pollution. Management can therefore debate to procure, and keep such technology handy (the concept of as necessary redundancy) if that was deemed more viable and sustainable.

Contrarily, figure (P8) is a scenario where technology is increased to above 70% of assumed current level; DP_2 rises faster than DP_1 . Contemporaneously, the trajectory of $IPRA_2$ lies above $IPRA_1$, implying that resources accumulate faster when technology increases more than it will have been. Furthermore, the trajectory of $DPRU_1$ lies above $DPRU_2$, suggesting that improved technology allows efficient use of resources so that they do not drain away easily as waste. This also suggests that improved technology application can improve efficiency in the logistics chain and hence DP improves according to figure (P7 and P8). A rising DP_2 suggests a shorter ‘real-time’ for risk management team to respond to crisis, such that output of crisis management plan may

yield returns more than proportionately and hence make port logistics operations more sustainable in the long-run.

Arguably, the gap between DP_1 and DP_2 appears to be narrower in figure (P7) than in figure (P5). This suggests that technology overload (or technology over-crowding, or over specialisation, or “over-technologisation”) can also affect the level of preparedness for a particular event by increasingly reducing real-time for response to crisis. $IPRA_2$ appears to intersect $IPRA_1$ (figure P8) indicating a possible congestion and reduced efficiency in resource accumulation when there is excessive technology change in logistics system.

When compared with the causal tree diagram, the set of graphs confirm that DP is directly influenced by IPRA (inflow) and DPRU (outflow). One may conclude from the results above that DP is significantly sensitive to technology change. This also confirms the CLM polarity (+) of the connective arc between technology change and DP as well as the interview results which suggest that an increase in technology can improve DP. We conclude the argument by stating that technology improvement to an extent can make logistics chain more sustainable to disaster (disruption, risk) management.

When Port Activity is reduced

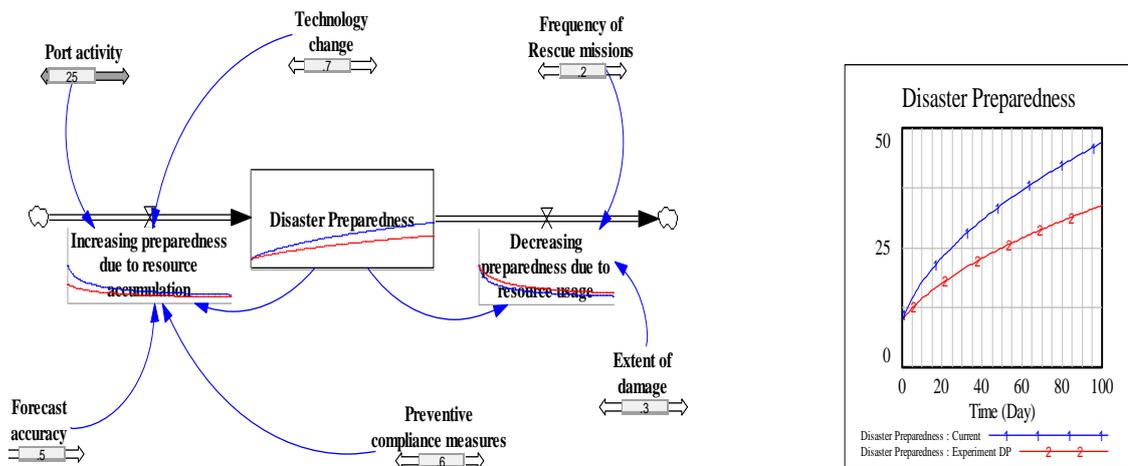


Figure P9: The conceptual model of DP and its corresponding dynamic graph in response to decrease in port activity

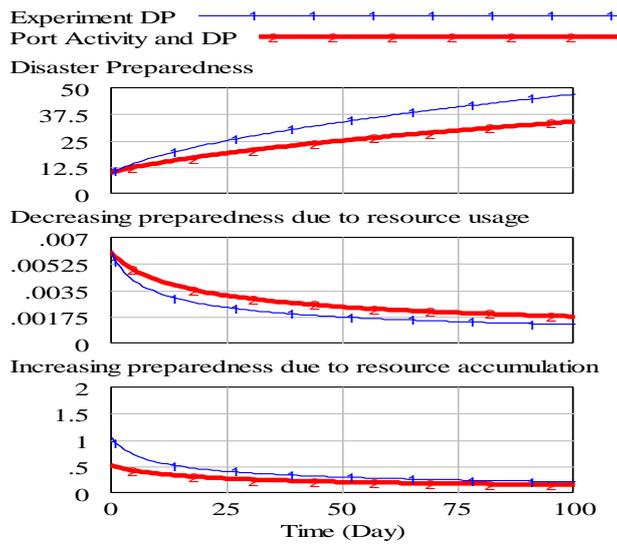


Figure P10: The real time change in DP over 100 day in response to decrease in port activity

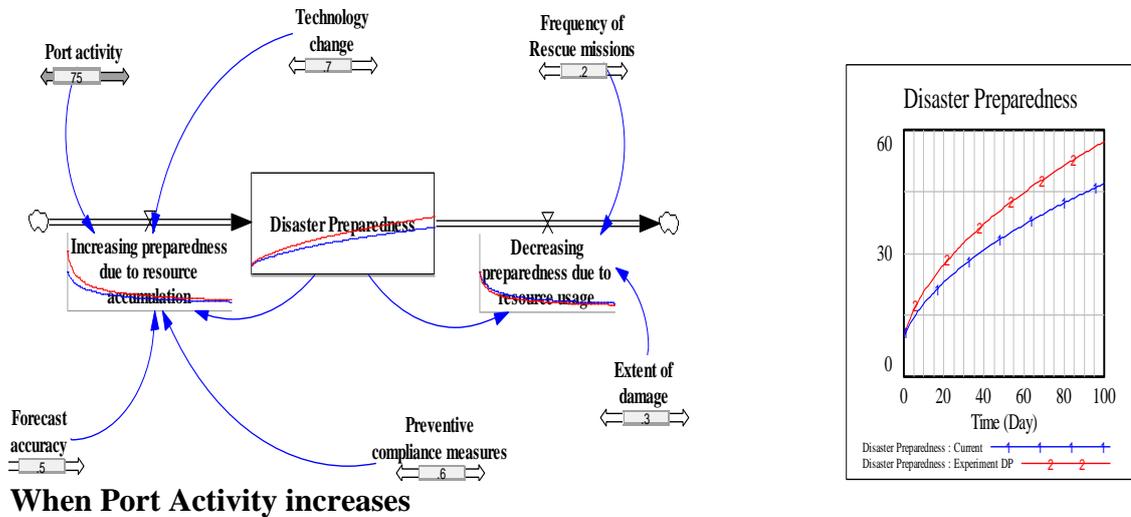


Figure P1: The conceptual model of DP and its corresponding dynamic graph in response to increase in port activity

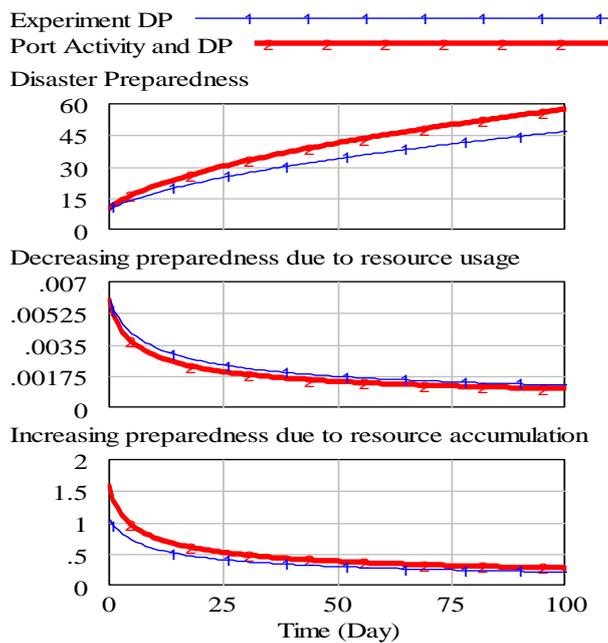


Figure P2: The real time change in DP over 100 day in response to increase in port activity

Figure P9 – P12 represent dynamic behaviour of DP with respect to change in port activity over 100 day period. From the set of graphs, DP_2 falls below DP_1 (figure P9) whereas $DPRU_2$ lies above $DPRU_1$ and $IPRA_1$ is found above $IPRA_2$ (figure P10) when number of port activity is decreased. A reverse condition is observed when port activity increases (figure P11 and P12).

It seems that when number of port activities decline, resource usage for disaster/disruption mitigation and restoration ($DPRU_2$) reduces which mimics real-world condition. There is the likelihood that flow in redundancy stock ($IPRA_2$) will increase and there may be a lot of reserve resources to support future emergency operations in the logistics chain. Hence one will observe that the trajectory of the DP curves grow exponentially. However DP_2 falls below DP_1 (figure P9 - P10) suggesting that for the same amount of resources dedicated to a disaster response, it may take more days for the stock level to get depleted if the number of port activities were reduced lower than it is at the moment. For instance, the graphs (figure P10) suggest that at any time (t-days), the logistics chain appears to be more sustainable at DP_2 than DP_1 , assuming that port activities are reduced from 50 to 25 activity unit per day.

On the other hand, by increasing port activities to approximately 80 activity unit per day (figure P12), one will observe that the trajectory of DP_2 rises above that for DP_1 . It seems that management's spending on safety needs to increase proportionately as the number of port activities increase per day. It also appears that increasing port activities can make the emergency management unit unable to meet resource demand for operations. The port can become vulnerable to risks from disruptions emanating from even less catastrophic events.

If resource accumulation (IPRA) does not match demand requirements for essential resource supply for the sustenance of emergency operations that could be a recipe for frequent disruptions in the logistics network (or “shadow bullwhip effect”). Port may therefore identify activities that they think will not be necessary and reduce them. For example traffic congestions, storage of unwanted resources, and any negative practices can be identified (through thorough risk assessment programs), followed by scientific debates that may lead to reduction or outright stoppage of less productive activities at the port facilities.

When Forecast accuracy decreases

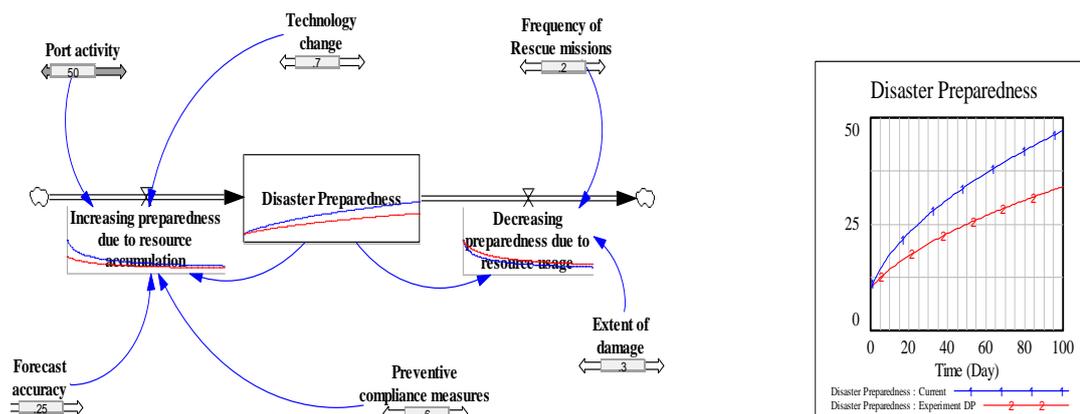


Figure P3: The conceptual model of DP and its corresponding dynamic graph in response to decrease in forecast accuracy

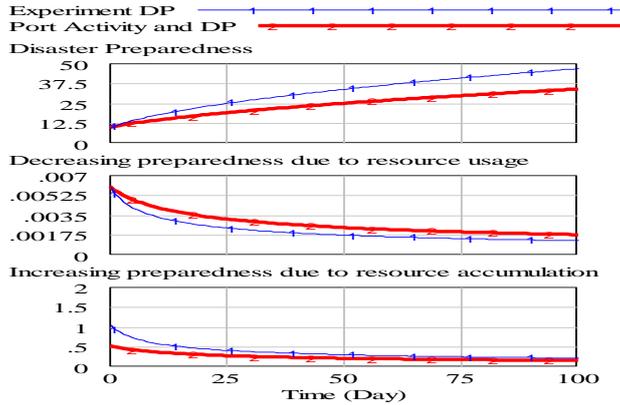


Figure P4: The real time change in DP over 100 day in response to decreased forecast accuracy

When Forecasting becomes more accurate

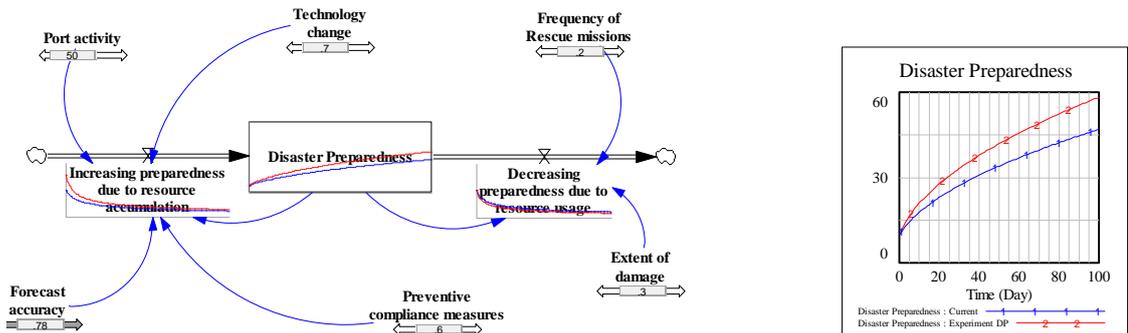


Figure P5: The conceptual model of DP and its corresponding dynamic graph in response to improved forecasting

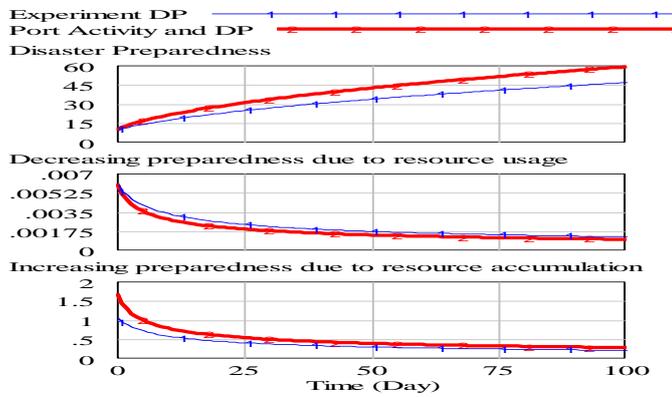


Figure P6: The real time change in DP over 100 day in response to improved forecasting

The structures and their corresponding curves under this section verify the behaviour of DP at variable forecast accuracy. In the models represented in figures (P13 – P16), forecast accuracy refers to the ability to predict event (such as flood, storm surge, power and equipment failure, IT failure etc.) occurrences and the possible effects that the incident may have on port/maritime logistics chain with high degree of certainty. Forecast accuracy is one of the key requirements to disaster management. Without knowing the likelihood, the type of disruptions, as well as the resources that would be required, mitigation and decisions for specific interventions cannot be made well. Planned mitigation and speculative outcomes of response may also become difficult as a result. In the real-world, wrong relief resources have sometimes been supplied during crisis periods; some of which have been rejected, or have been left unused (especially in humanitarian logistics operations). One will agree with the Vensim simulation runs that as forecast accuracy gets close to 100%, the logistics network's level of DP improves more than it would have been (figure P16). It seem when management can improve forecasting (procure, and maintain equipment plus improve methods), information generation and dissemination may become quite reliable such that response motives may yield sustainably positive results in the long-run.

When port users become less risk prevention compliant

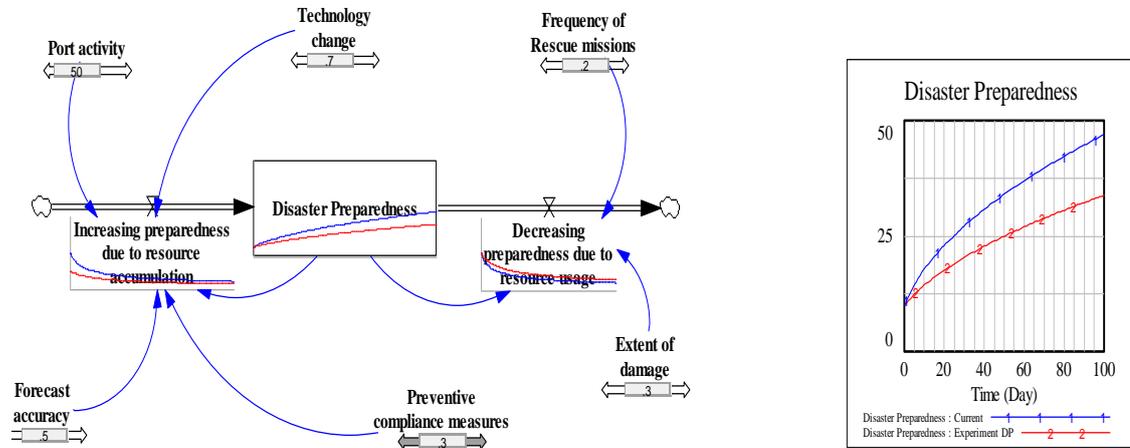


Figure P7: The conceptual model of DP and its corresponding dynamic graph in response to decrease in risk preventive compliance measures

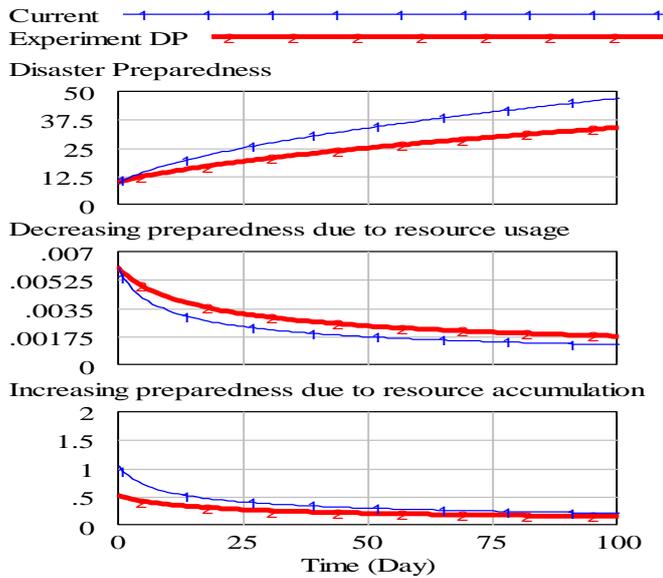


Figure P18: The real time change in DP over 100 day in response to decrease in risk preventive compliance measures

Under this scenario, we assumed an initial risk preventive compliance of 60% (0.6).

When the level is reduced below the current level, the trajectory of DP_2 falls below DP_1 as exhibited in the exponential curves in figure P17 and P18 above.

When facility users become more risk preventive compliant

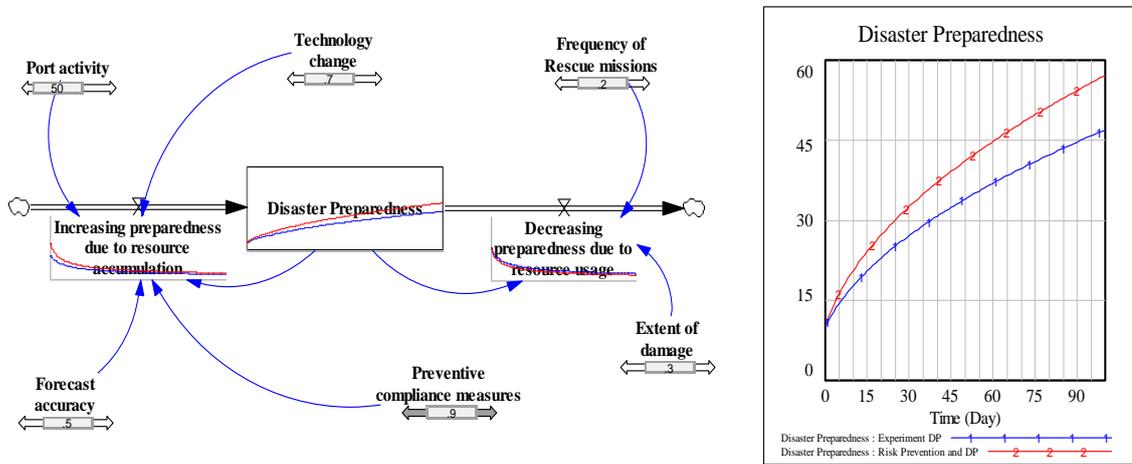


Figure P8: The conceptual model of DP and its corresponding dynamic graph in response to increased risk preventive measures

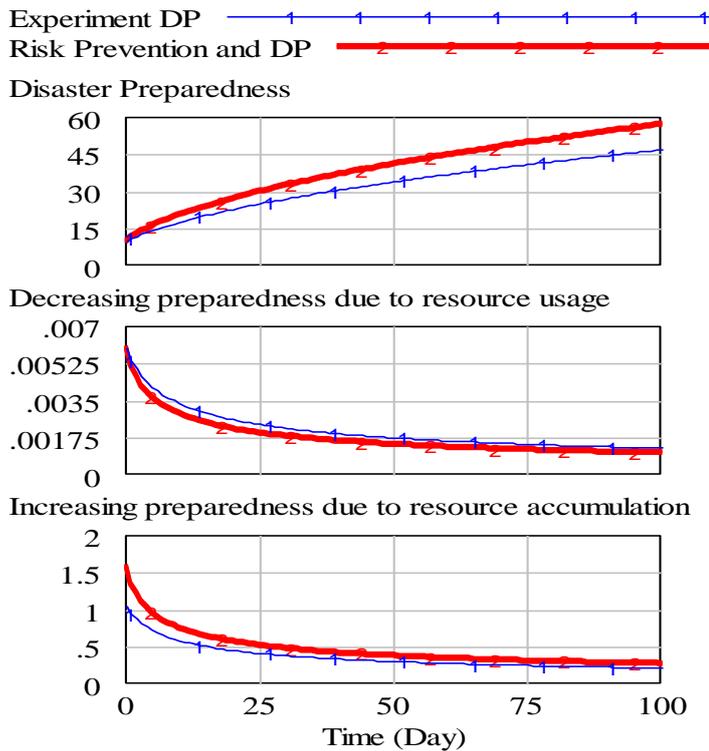


Figure P20: The real time change in DP over 100 day in response to improved risk compliance measures

On the other hand, it appears that excessive preventive compliance measures can have adverse impact on port/maritime logistics chains such that the probability of not yielding the intended results may rise. This is shown in the exponential curve in figures (P19) and (P20). As suggested by the graphs, one can observe that even though the trajectories of both DP_1 and DP_2 rise simultaneously, the gap between the two curves appear to be closer than it is expected as opposed to what happened in figure (P18) above, as risk compliance increases towards 100% (or 1).

The suggestion from the curves is that when there is low policy (directives, regulations, laws) awareness and compliance, the level of readiness to respond to disruptions in port/maritime logistics network may fall. It appears that logistics chains might become highly vulnerable to risks of disruption and thus becoming increasingly unattractive to logistics facility user. There may be chaos in the logistics network; customers and other stakeholders may carry out operations haphazardly without regards to sustainability of logistics operations. Real-time response may take longer than it would have been required for mitigation efforts to be realised perhaps due to chaos and disorderliness that may be experienced in a logistics chain.

When team carries out fewer rescue missions in the system

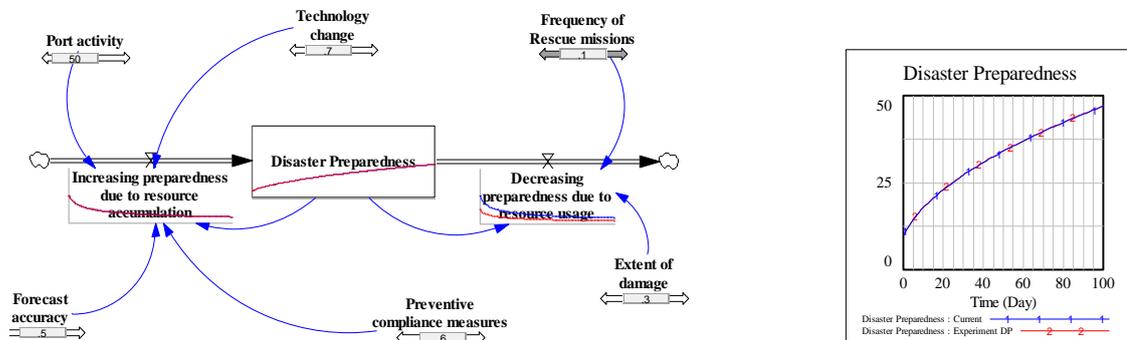


Figure P9: The conceptual model of DP and its corresponding dynamic graph in response to decrease in rescue missions

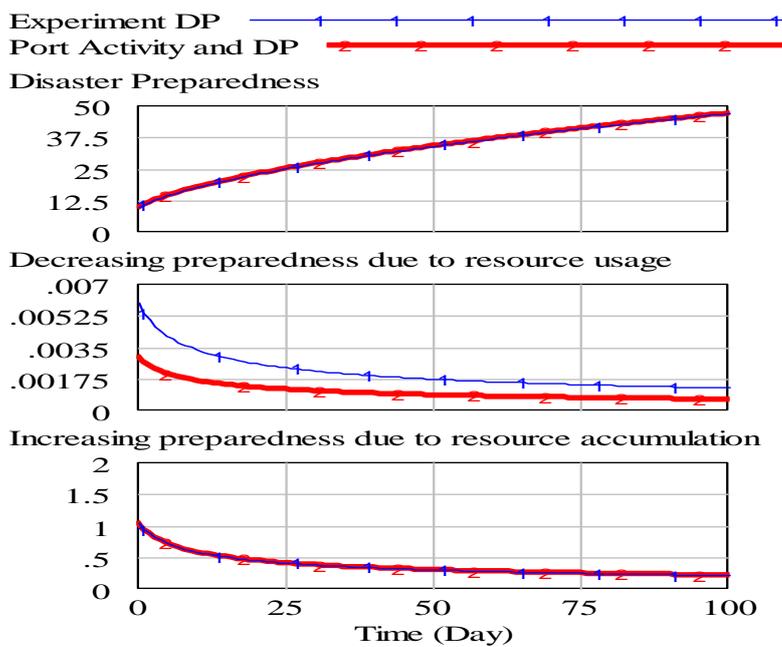


Figure P10: The real time change in DP over 100 day in response to decrease in number of rescue missions per period

When rescue missions increase in the logistics network

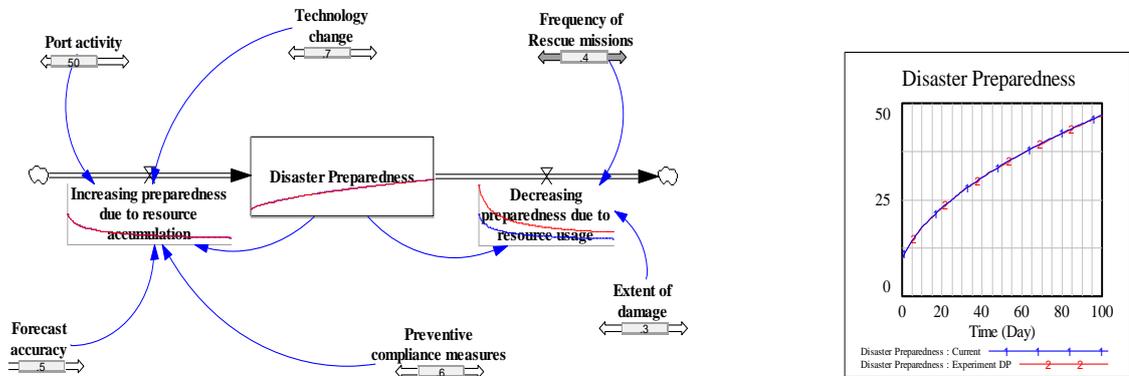


Figure P11: The conceptual model of DP and its corresponding dynamic graph in response to increase in number of rescue missions

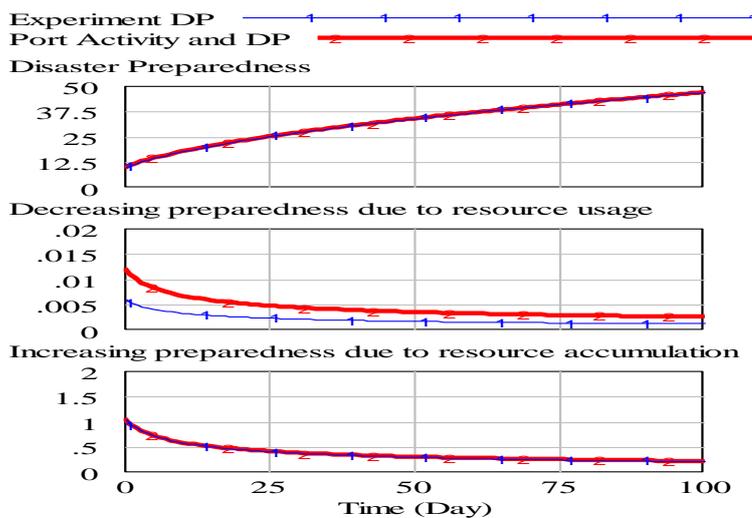


Figure P12: The real time change in DP over 100 day in response to decrease in number of rescue missions per period

The real-time change in DP in reaction to change in “frequency of rescue mission” as described by the set of curves (figures P21 – P24) suggesting that DP does not respond significantly to changes in these variables (at least for the period under review). Details of the graphs indicate that $DPRU_2$ lies above $DPRU_1$ suggesting an increase (figure

P24). However the trajectories of $IPRA_1$ and $IPRA_2$ as well as those for DP_1 and DP_2 appear not to change. The result suggest that the level of DP cannot be significantly affected by changes in rescue missions in the logistics chain. Figure P21 and P23 represent the structures and trajectories of curves for DP when rescue missions alters. One will observe that the rate of DPRU (or resource usage) goes up in both scenarios (when rescue increases and decreases), yet there seem not to be any significant change in DP.

When event results in less damage to the logistics network

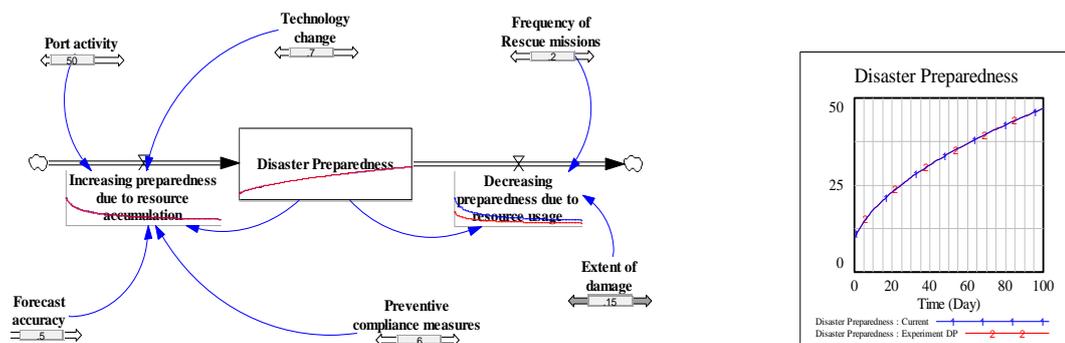


Figure P13: The conceptual model of DP and its corresponding dynamic graph in response to decrease in extent of damage in the logistics network

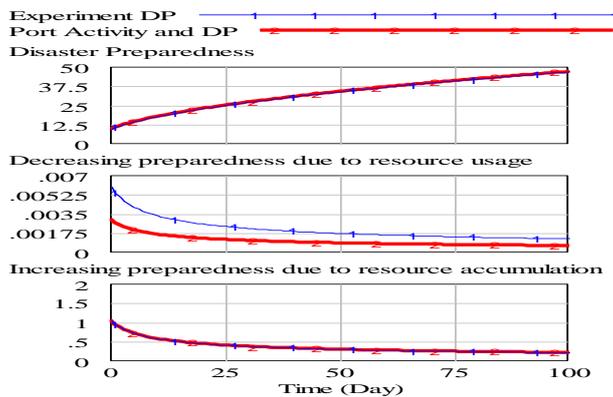


Figure P14: The real time change in DP over 100 day in response to decrease in extent of damage to logistics network per period

When the extent of damage increases

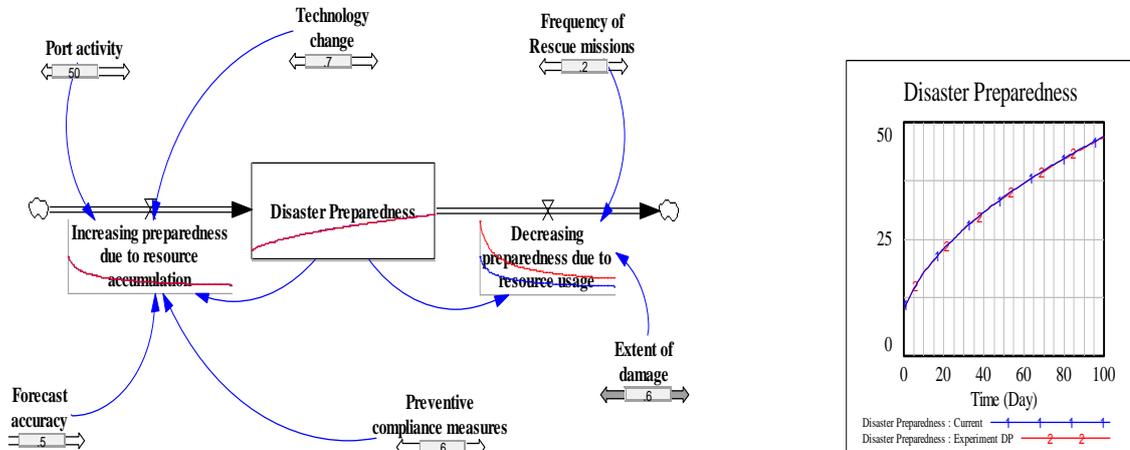


Figure P15: The conceptual model of DP and its corresponding dynamic graph in response to increase in physical damage to logistics network

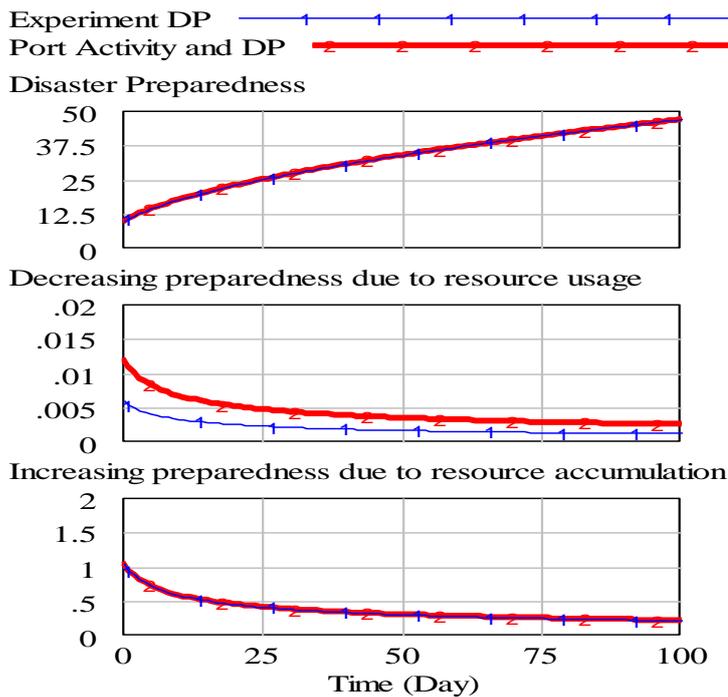


Figure P16: The real time change in DP over 100 day in response to increase in extent of damage to logistics network per period

Based on the structural behaviour of the graphs (figures P25 - P28) above, one may argue that significant change in “extent of damage” done to a logistics network, do not significantly change level of DP, though DPRU increases more than it would have been. In real-life situations, some events may overwhelm risk management such that no matter the level of preparedness, the entity may still not be able to cope with the magnitude of destructions from a disaster (disruption) incident. Real-world examples include 9/11, Japan earthquake/tsunami, Philippines storm in 2013, and many others. It seems that catastrophes of these kind are independent of an entity’s level of preparedness. It also appears that the levels of preparedness often chases after (or lags behind) response to event in most cases (i.e. preparedness is a cause and response is an effect) and not the other way a typical precedence relationship. Therefore though $DPRU_2$ might rise above $DPRU_1$, if IPRA does not instantaneously increase significantly, DP_1 and DP_2 might not change. Hence the trajectories of DP_1 and DP_2 appear to coincide in P25 and P27.

A scenario where policy requires that all variables increased

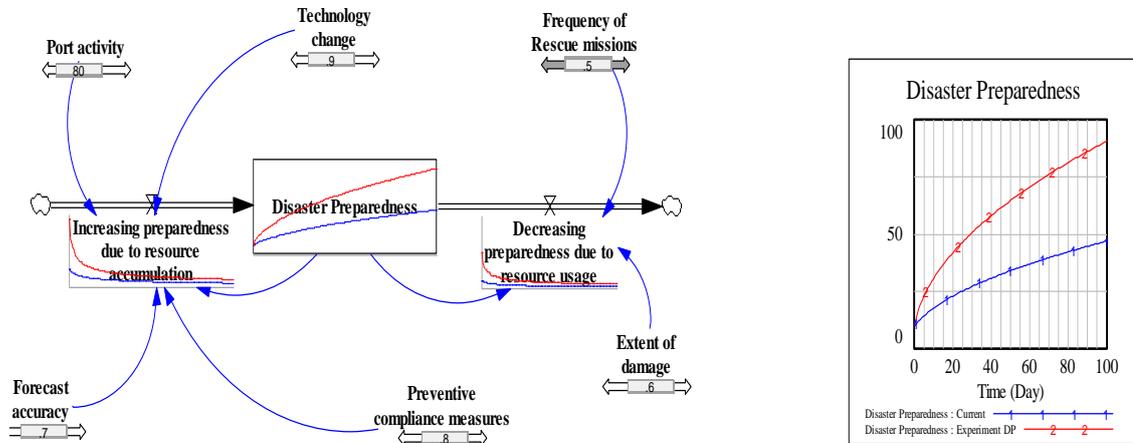


Figure P17: The conceptual model of DP and its corresponding dynamic graph in response to increase in all key variables

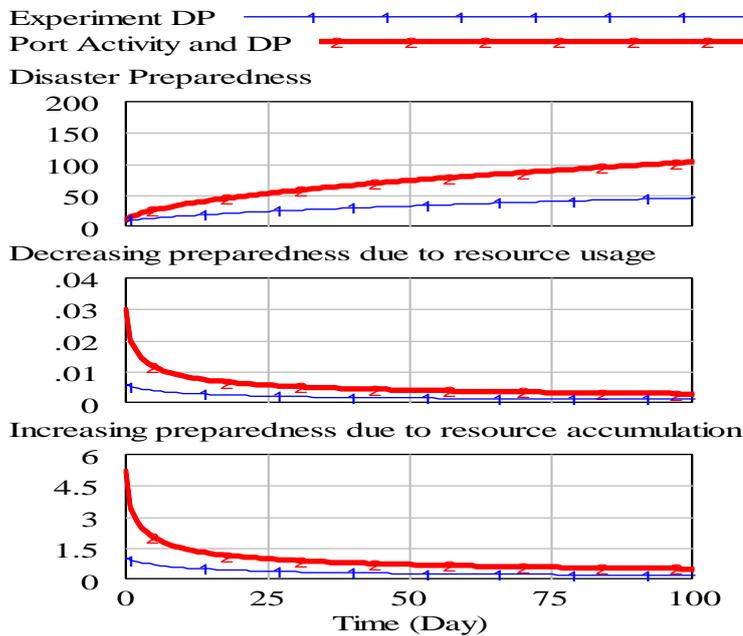


Figure P30: The real time change in DP over 100 day in response to increase in all key variables per period

A scenario where policy requires that all variables reduced

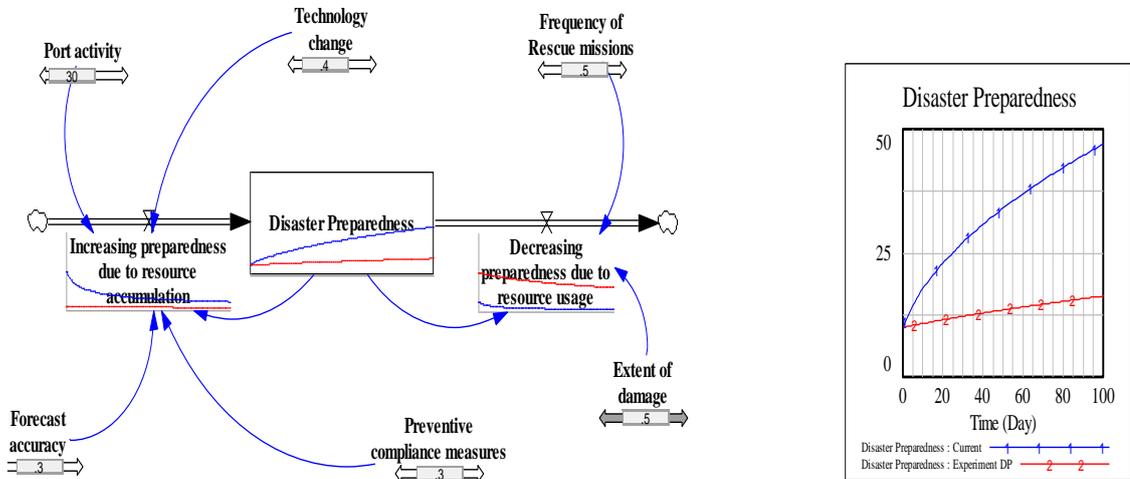


Figure P18: The conceptual model of DP and its corresponding dynamic graph in response to decrease in all key variables

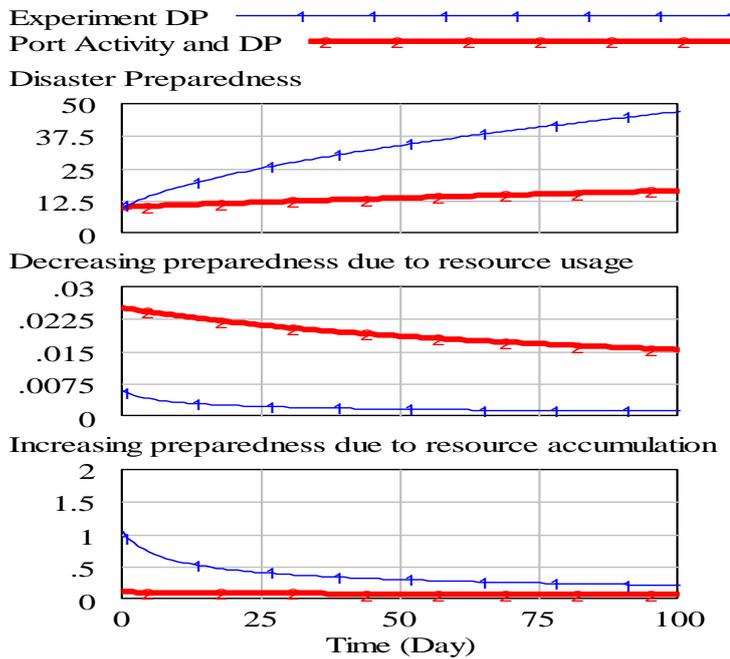


Figure P19: The real time change in DP over 100 day in response to decrease in all key variables per period

The composite graphs (figure 29-32) show that when all variables changed, DP becomes highly sensitive to change in key variables considered in the research. However, one will remember that ‘Frequency of Rescue Mission’ and the ‘Extent of Physical Damage’ have insignificant direct influence on the change. We may conclude from this analysis that, the levels (or state) of DP depends on periodic resource accumulation (IPRA), less the periodic usage (DPRU) of the same resources for disaster/risk management in the logistics chain. In real-life conditions, it seems that if the rate of IPRA increases faster than the rate of DPRU, or if IPRA increases and DPRU decrease, DP will increase more than it would have been and hence logistics operations may become more sustainable (all being equal).

Arguably, one will observe that the mean value of the DP curve increases at a decreasing rate over the 100 day modelled. We may explain that the level of disaster preparedness (the stock) increases less than proportionately by each day for the period considered. One might be aware already that exponential growth does not increase ad-infinitum. Therefore it may not be good predictor for distant future growth in DP. However the growth reveals an ideal state of disaster preparedness for the immediate future (i.e. at operational and tactical decision stages) interventions to be taken, which seem to be the target of many risk managers as long as such policy change is sustainable at the short and medium term decision levels.

In general, the results suggest that DP responds to changes in technology, risk preventive compliance measures, and forecast accuracy. However DP appears not to respond significantly to changes in ‘Frequency of Rescue Mission’ and the ‘Extent of Damage’ done to the logistics network (at least) within the real-time period of

consideration. Management can focus on how to improve the sources that feed into those variables that can cause change in DP.

4.11.2 Modelling the Sub-System Port/Maritime Environment Instability (PEI)

Figure (S1) below represent the stock and flow structure for the sub-system Port Environment Instability [or port stability]. To distinguish the labels we used the pre-fix “S” to denote model for the sub-system PEI. The stock could be the actual state or the perceptions that management and facility users have about the state of equilibrium of the port’s environment and the perceived change in safety levels.

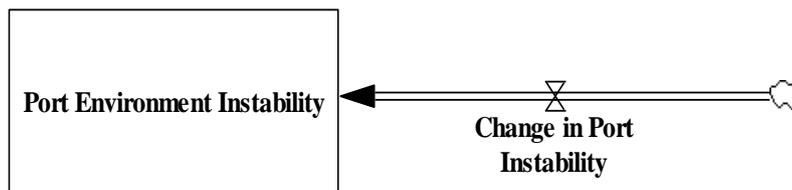


Figure S1: A collapsed model for port environment instability

Mathematically, we represent the above structure (figure S1) in equations (6):

Given that:

Port Environment Instability (PEI) = Stock

Rate of Change in port Instability (RCI) = Inflow

$$\mathbf{PEI(t) = PEI(t_0) + \int_{t_0}^t [RCI(s)]ds} \text{-----eqn (6)}$$

This equation represents the aggregate value of PEI at time s between the initial time t_0 and final time t (i.e. day 0 – 100 as the test period). Equation (6) means that PEI grows at the rate of RCI, beginning with initial environment conditions based on location effects, and independent of the port's existence (PEI_{t_0}). Elements considered as aggregate components of the location effects may include whether the port was built on floodable area, earthquake zone, erosion prone area, or is vulnerable to natural hazards of any kind. See specific example of eqn (6) in equation (06) under the documentary analysis of PEI (p. 267).

We assume that PEI exogenously depends on location effects and policy formulation, but is endogenously influenced by technology change, risk preventive compliance measures, and port activities as well as the effect of PEI on itself (figure S2). For example a change in technology or any other variables, may accelerate or decelerate the RCI. It appear that the type of change may be a function of the perceptions that the problem owners (or management) have about location effects. If the stakeholders overestimate the safety levels, that can influence the type of operations that the port system will undertake and how they comply with environmental policies/directives, as well as the type of technology they will adopt when performing their functions as a port, and also in their preparedness for uncertainties. Some of the respondents' illustrations about the impacts of port location on maritime logistics activity can be found in section 5.1A on pages 315 - 316 and 335.

For instance in an illustration, CS2 cites academic literature to support the claim that man's quest to dominate the environment leads to the siting of structures [including ports on the HE] at the wrong place. This created additional problems apart from

increasing risk potentials, peculiar to each individual establishments. According to CS2, the reconstruction/extension of the Immingham docks and terminal for instance, brought about change in river dynamics (e.g. increased siltation, accretion and biotic activities) in that section of the Humber River. Thus it became difficult and more risky for vessels to navigate over, or to circumvent the silt. Besides the siltation and the concomitant risks posed to navigation the sediment is highly rich in organic matter. These organic laden matter starts to produce methane and some hydrogen sulphide gases which can expose workers to health hazards with time. We may conclude that the geographical location of the port can have either positive or negative impacts on the operation and sustainability. These are a few geological hazardous effects that the port and its environment mutually produce. The above illustrations go to buttress the relationship diagram in figures (S1) and (S2) especially in relationship with the flows and the auxiliary variable – Port Activity.

Granted these illustrations, now assuming that the only way that material can drain out of the stock of this sub-system depends on the rate at which disruptions occur in the logistics network. Then as long as there are no disruptions, the port may be perceived by its stakeholders as being invulnerable and stable relative to major disasters. The occurrence of a disaster can reduce the confidence that businesses have on the logistics chain, which rather may increase the port's reputational risk. However disaster occurrences and the frequency of a particular type of disruption [e.g. flooding, or icing] in the logistics network is capable to reducing the uncertainties about the unknowns that may be associated with that kind of incident but not necessarily the risk of disruptions. A pattern can emerge out of these occurrences that may lead to change

in strategic decisions in the network. It seems that modelling (such as the ones below) can help management to test the consequences of such policy decision options so that best alternatives can be selected for change management prior to decision implementation.

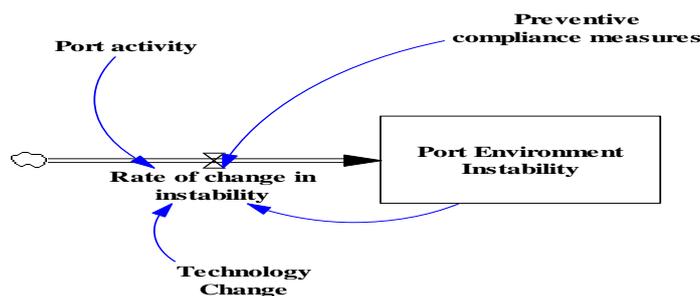


Figure S2: The dynamic model of PEI

The model (figure S2) above describes the dynamic behaviour of environment instability. The model was developed from figure S1 by adding a few auxiliary variables to make it a bit complex but clearer to the audience.

We considered Port Environment Instability (PEI) as one of the variables to model as stock (figure S1). The material that flows through the PEI is primarily the general logistics risks and the information about disruption occurrences in logistics chain. Some of the variables that can trigger disruptions in the logistics system according to the interview data were attached as in figure (S2). Policy change that can affect any of these variables can influence the occurrence of catastrophic events and thus create instability in the port/maritime logistics network.

Already some operational activities including handling and storage of dangerous goods, the emission of carbon, sulphur, nitrogen, and other gaseous substances from exhausts and other sources [according to literature interview] make the port/maritime environment quite volatile. In addition, some biotic (microbial) and abiotic (geological) processes can also increase the port's vulnerability to risks of disruptions. However, there may not be the appropriate technology change to sustain the logistics systems, or the technology available may have become obsolete and unable to cope with the speed of changes. There may also be increasing demand for implementation of new marine laws and regulations as an attempt to protecting the port environment. It seems that these developments have the potential to convert controllable risks to uncontrollable risks. These feed into the dynamic structure (figure S2) to increase the rate of flow into (or out of) the stock. Unfortunately the conceptual flow in the stock of instability (PEI) means that there is going to be more disasters/disruption incidents in maritime logistics operations. Increase in PEI means reduction in sustainability of port/maritime logistics functions which can potentially lead to reputation damage and economic losses. A summary of the above relationships among the variables is represented in figures S2. A clearer picture about the effects of changes in the various policy decisions (risk interventions) emerged in the analysis that follow after figure S2 onwards.

4.11.2.1 Analysis of PEI and results

a) Qualitative analysis of PEI using Causal Tree diagram

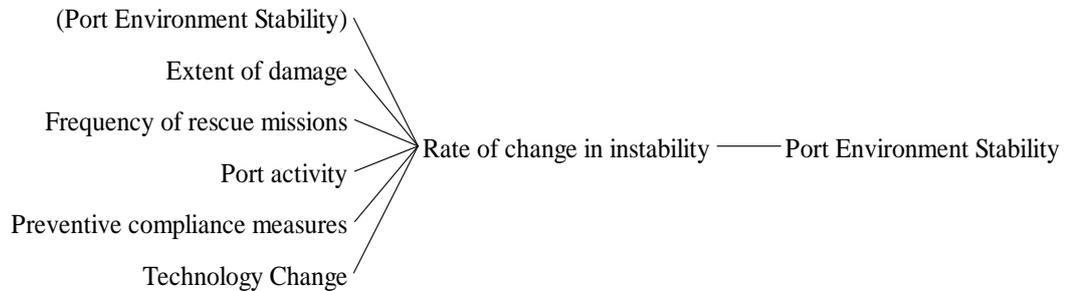


Figure S3: The causal tree diagram representing different variables that can influence PEI

The causal tree diagram in figure (S3) above shows the cause and effect relationships between PEI and the neighbouring variables. Figure (S3) reveals that PEI is directly influenced by the rate of change in instability (RCI) whose flow into the stock may cause rise (or decline) in incidents such as disasters, disruptions, hazardous situations and many other crisis that can interfere with port logistics operations in the HE. The reader can see (figure S3) that the extent of damage, frequency of rescue missions, risk preventive compliance measures, port activity, as well as the state of port stability, indirectly influence the current levels of PEI. It suggests that a change in any of the auxiliary variables can influence the state of PEI. How PEI will behave when these variables change is what we attempt to test so that planners can ascertain the sensitivity of PEI to systemic changes. The flow (RCI) is double headed (supposed to be) arrow to signify that whether the resources flow in or out of the stock it still pose security threat to port logistics network.

b) Quantitative Analysis

1. Documentary Analysis on PEI

The PEI was analysed based on a total of 11 equations as below:

(01) Extent of damage = 0.4

Units: **undefined**

(02) FINAL TIME = 100

Units: Day

The final time for the simulation.

(03) INITIAL TIME = 0

Units: Day

The initial time for the simulation.

(04) Number of rescue missions = 0.3

Units: **undefined**

(05) Port activity = 50

Units: **undefined**

(06) Port Environment Instability = INTEG (Rate of change in instability,10)

Units: **undefined** [10,100] (*specific case of equation 5*)

(07) Preventive compliance measures = 0.4

Units: **undefined**

(08) Rate of change in instability =

(Extent of damage*Number of rescue missions*Port activity*Preventive compliance measures*Technology Change)/Port Environment Instability

Units: **undefined**

(09) SAVEPER =

TIME STEP

Units: Day [0,?]

The frequency with which output is stored.

(10) Technology Change = 0.7

Units: **undefined**

(11) TIME STEP = 0.5

Units: Day [0,?]

The time step for the simulation.

2. *Structural Behaviour of Port Environment Instability*

The structure and curves to be discussed under this subsection, represent the Vensim® simulation models for the sub-system 'Port Environment instability'. The initial values for the constant variables and parameters have been represented as indicated on the sliders attached to the constants (e.g. figure S5). The trajectory of the graphs describe the shape of exponential curves that grow at decreasing rate over the period of studies, suggesting that the environment will continue to become unstable by the day as long as the port executes its day-day logistics functions, and also that the likelihood of

disaster/disruption incidents may increase correspondingly even though RCI seem to decline.

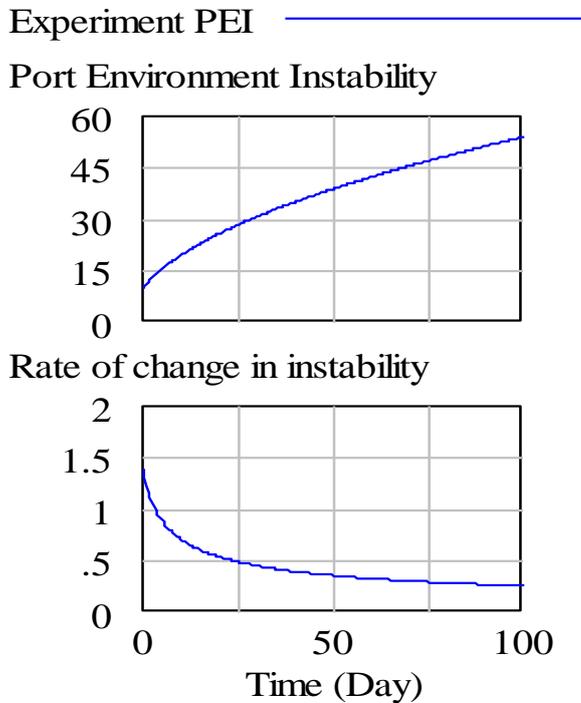


Figure S4: The dynamics of PEI over 100 days

The real-time change in PEI is described by the trajectory of the graphs in figure S4 above. The historical data of the graphs indicate that PEI grows exponentially at a decreasing rate for the 100 day period for which the test run. At the same time as PEI grows, implying that port environment is becoming more risky/hazardous and more vulnerable to operational disruptions, RCI also declines sharply at the onset, flattens up, and appeared to remain asymptotic to the time axis. The set of graphs (figure S4) suggest that logistics networks can become more unstable (less sustainable) at the start of operation, then as the business matures, solutions may be found to some of the

sources of the (controllable) risks of disruptions such that port operations can become normal and assume a relative stability (equilibrium state) at the long-run though the environment (uncontrollable) risks may continue to increase. In other words, the system will learn to accept the situation and rather adapt its logistics functions to match the port's size and physics. By extension from figure S2 and S4, the set of curves that follow under this subsystem tests the impact of port activity, technology change, and risk preventive compliance measures, on the dynamic structural behaviour of PEI. All the curves seem to exhibit the shape of nonlinear graphs representing increasing PEI, and decline in RCI respectively. Since it appears that the trajectories of the set of graphs belong to a family of curves, the reader will accept the explanations to follow the same line of argument as the scenario under change in port activity.

3. *Testing the Consequences of Risk Interventions (Policy Change) on the PEI Structure*

When Port Activity is reduced

According to figure S5, when Port Activity is reduced, PEI_1 lies above PEI_2 . In this instance, a lower PEI trajectory implies a more stable environment. Therefore the graph on figure S5 suggest that a reduction in port/maritime logistics activity can improve stability (sustainability) of the ports' logistics network more than it would have been. This is further explained in figure S6.

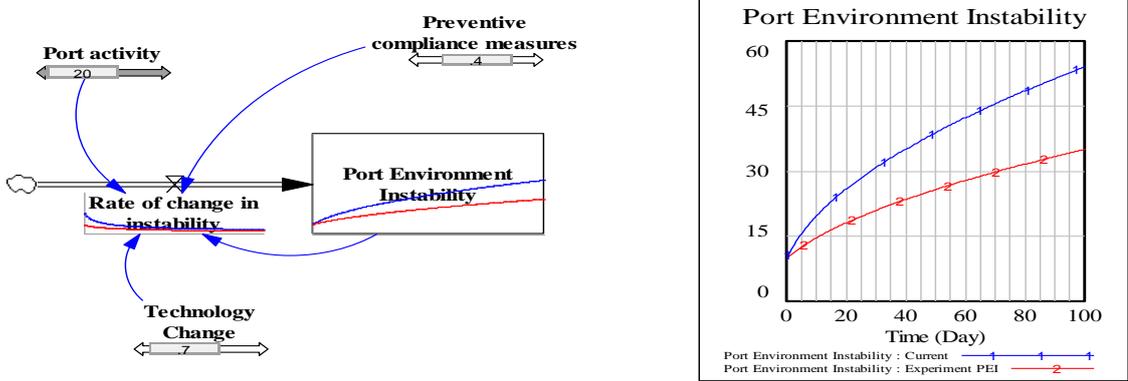


Figure S5: The conceptual model of PEI and its corresponding dynamic graph in response to decrease in port activity

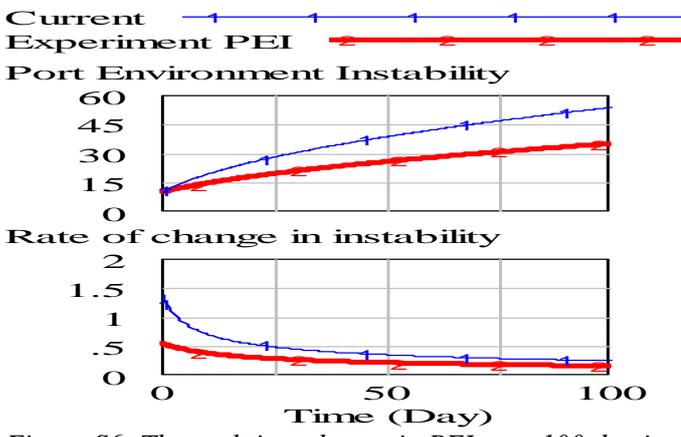


Figure S6: The real time change in PEI over 100 day in response to decrease in port activity

From the set of curves (figure S6), one can observe that the trajectory of PEI₂ falls faster than that for PEI₁. One can also observe that RCI₂ falls below RCI₁ which suggest that reduction in port activity can cause decrease in flow into PEI, hence the fall in PEI₂. Also a decline in RCI implies an improvement in stability of the logistics network. One will expect that a declining RCI can make a logistics system less vulnerable and thus reducing risks of disruptions. Arguably one can say that given the resources available, the logistics chain may become more stable if the amount of

unfavourable port/maritime logistics activities such as carbon and greenhouse gas emission can be reduced or when the port system is gotten rid of dangerous goods and obsolescence.

When port activity is stepped up

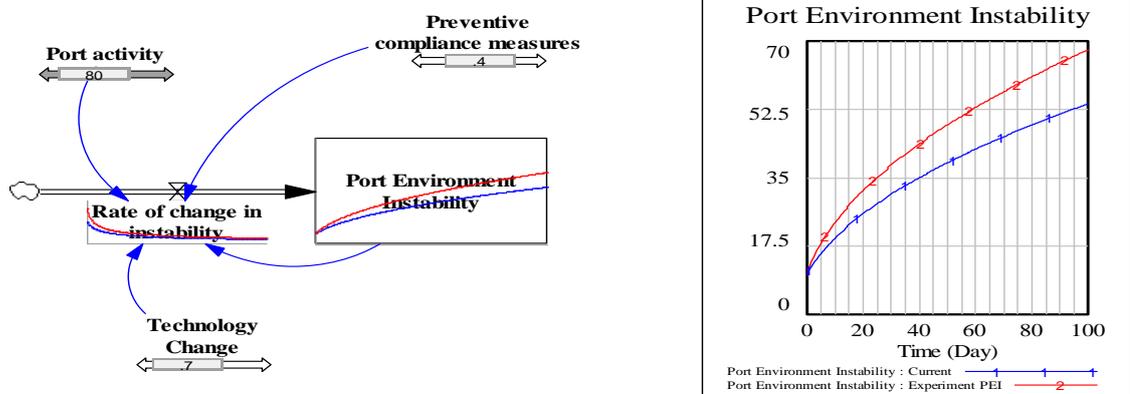


Figure S7: The conceptual model of PEI and its corresponding dynamic graph in response to increase in port activity

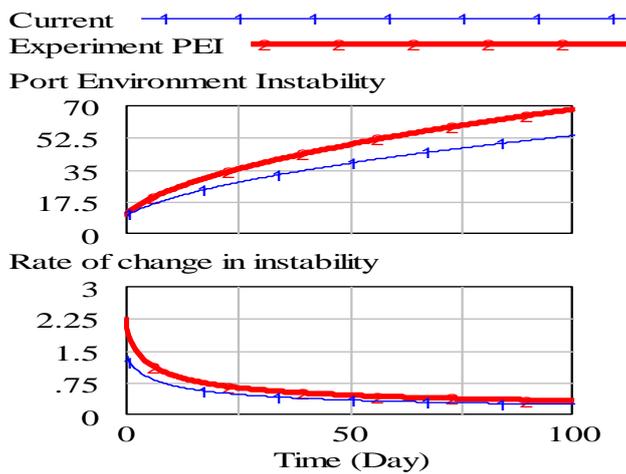


Figure S8: The real time change in PEI over 100 day in response to increase in port activity

An increase in port/maritime activity causes PEI_2 to stay above PEI_1 implying an increase in level of instability, or implying that the logistics network is becoming less stable (or sustainable) than it would have been. Though RCI_2 falls sharply, then followed by a slow fall and flattening, it is still high above RCI_1 and possibly strong enough to cause PEI_2 to increase faster than PEI_1 . A higher RCI indicates that the port environment is becoming more vulnerable to risks of disruption or increase in number of hazards that can cause disaster in the logistics network. For example when port activities are increased from 50 to 90 unit activity per day (figure S7 and S8), the trajectory of PEI_2 rose higher above that for PEI_1 . We find that both PEI_1 and PEI_2 rise throughout the period considered, however PEI_2 rises faster than PEI_1 . It implies that operations in the logistics chain can become more unstable when port activities are increased more than it would have been given that all other conditions are held constant.

A crust of the above discourse is that it seems PEI is sensitive to change in port activity. A rise in the trajectory of the curve signifies a rise in disruption or the logistics network becoming risk prone, and more vulnerable to disaster incidents. Therefore it behoves the CRO or the risk management team to design interventions (or find the mix) that will keep port activities that can increase instability at check so that PEI_2 is kept below PEI_1 such as in figure S5 above.

When technology reduces

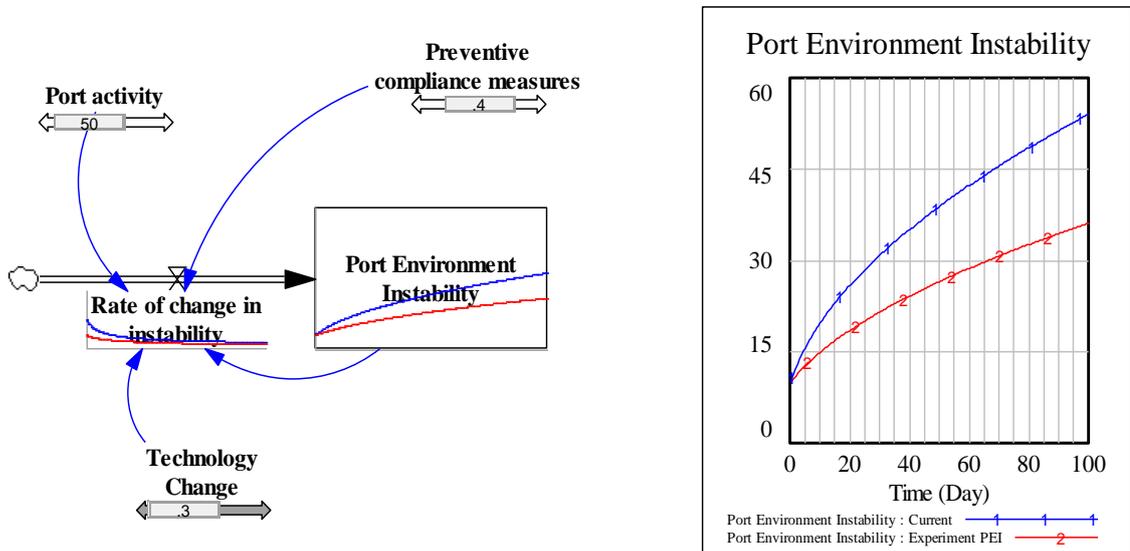


Figure S9: The conceptual model of PEI and its corresponding dynamic graph in response to decrease in technology

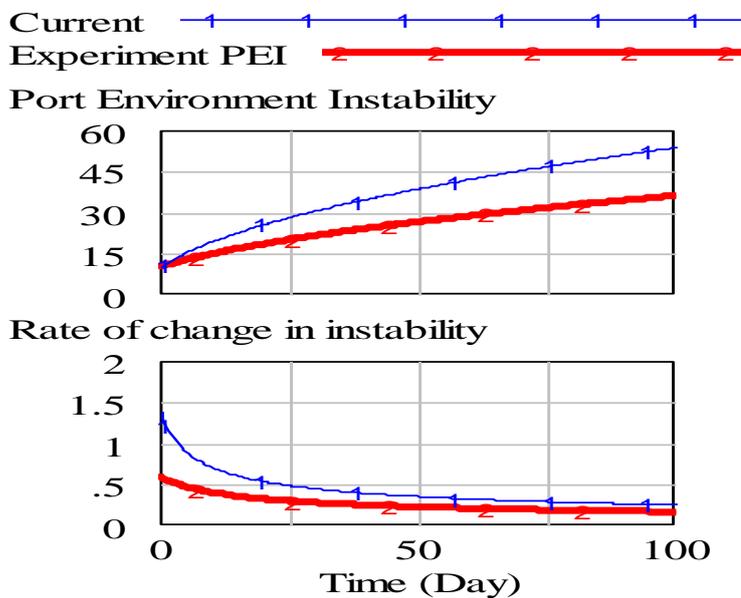


Figure S10: The real time change in PEI over 100 day in response to decrease in technology

When technology is increased

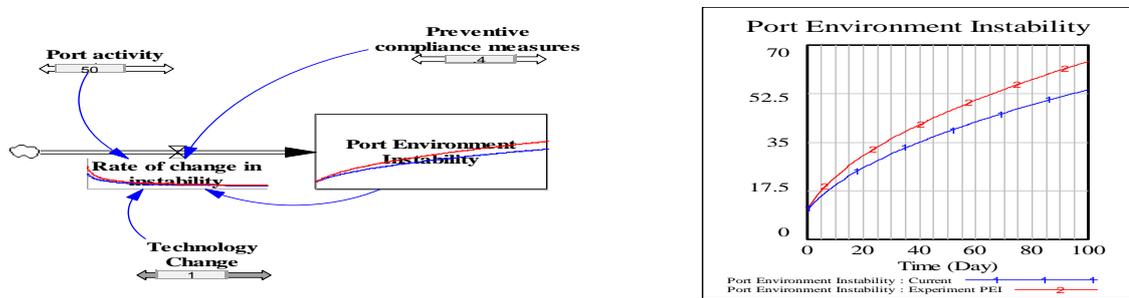


Figure S11: The conceptual model of PEI and its corresponding dynamic graph in response to increase in technology

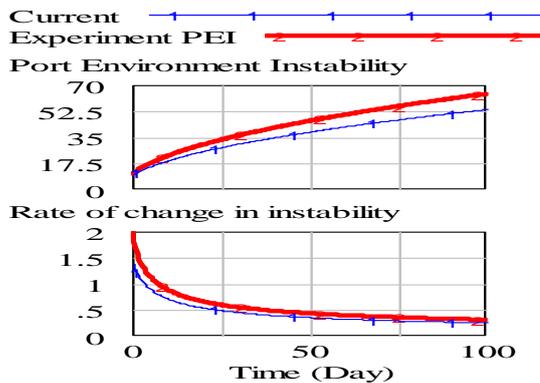


Figure S12: The real time change in PEI over 100 day in response to increase in technology

In figure S10 and S12, the set of graphs suggest that PEI is sensitive to change in technology application in port logistics chain. Whereas low technology can cause a fall in PEI (or make the logistics chain more stable), over application of technology can also cause instability in the logistics network perhaps due to a rise in technology related risks/hazards and accidents. This argument seems to be confirmed by the positive polarity of the arc between technology change and PEI on the CLM (figure 5).

In figure S9 – S12 above, we find that ‘technology change’ plays very important role in how stable the port environment can become for effective and efficient logistics chain operation. One can observe from the graphs above that as technology capacity falls, the trajectory of PEI₂ drops below that for PEI₁. Arguably, this could imply that if appropriate change technology is made available and adopted, port environment can become stable enough to sustain logistics operations.

When risk preventive compliance measures is reduced

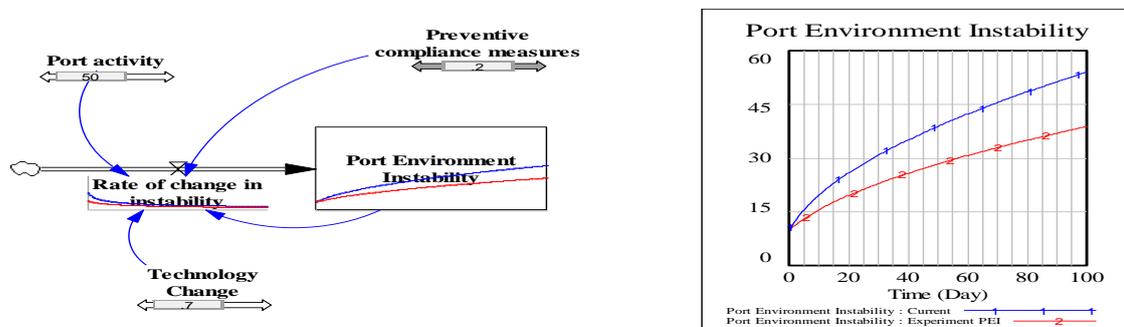


Figure S13: The conceptual model of PEI and its corresponding dynamic graph in response to decrease in risk preventive compliance measures

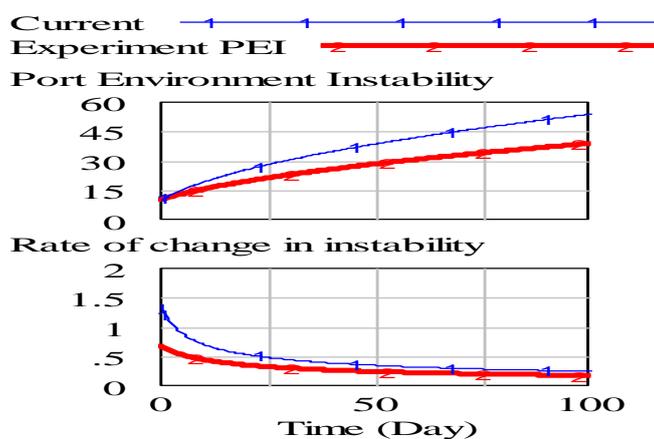


Figure S14: The real time change in PEI over 100 day in response to decrease in risk preventive measures

When risk preventive compliance measures increased

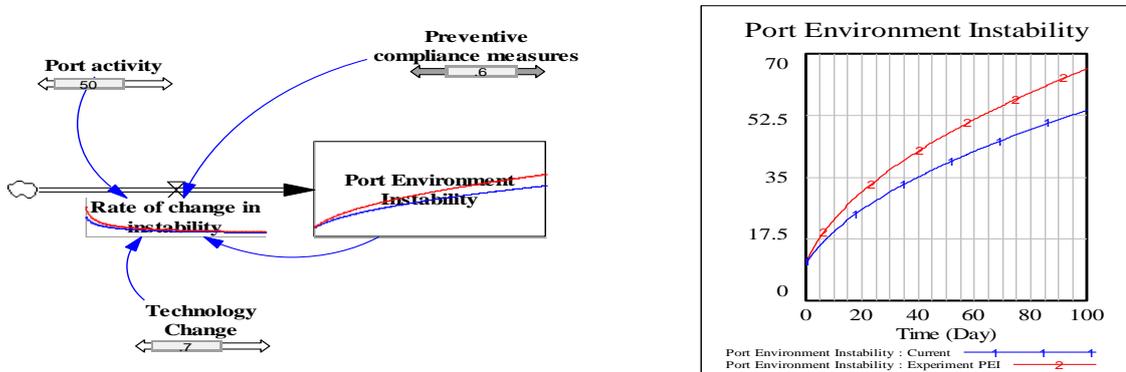


Figure S15: The conceptual model of PEI and its corresponding dynamic graph in response to increase in risk preventive compliance measures

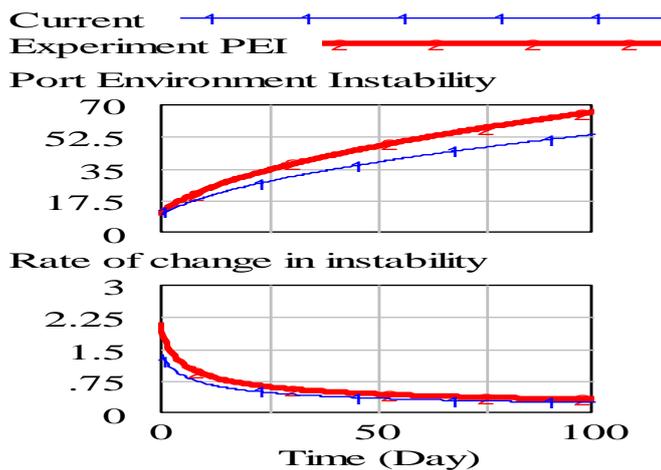


Figure S16: The real time change in PEI over 100 day in response to increase in risk preventive compliance measures

When policy on risk compliance is reduced, the graph suggests that it may take more days to establish port stability and subsequently to attain sustainable operations [if an event occurs] perhaps because the logistics chain would have become more unstable and more exposed to risks.

The graphs (figure S15 and S16) describe the structural behaviour of the effects of an increase in risk preventive compliance measures on the sub-system. We follow the same line of analysis (or argument) as in the effects of port activities figure S5 and S6 respectively. We infer from the structure and the graphs that port environment stability improves (or state of instability reduces) as ports comply more with policies that lead to the prevention of hazardous operations in the logistics chains.

Composite impact of change in all auxiliary variables on PEI

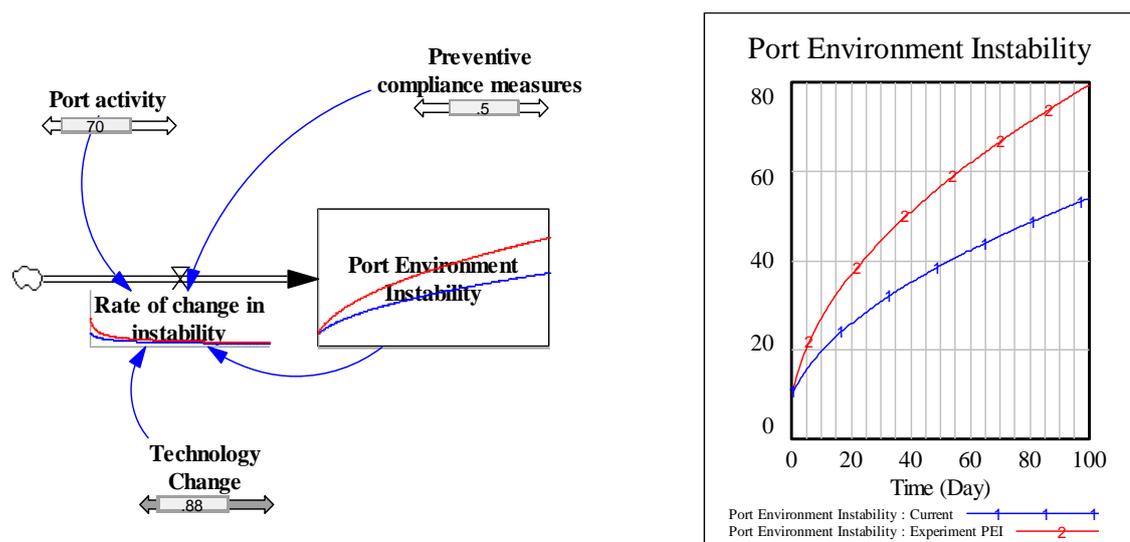


Figure S17: The conceptual model of PEI and its corresponding dynamic graph in response to increase in all key variables

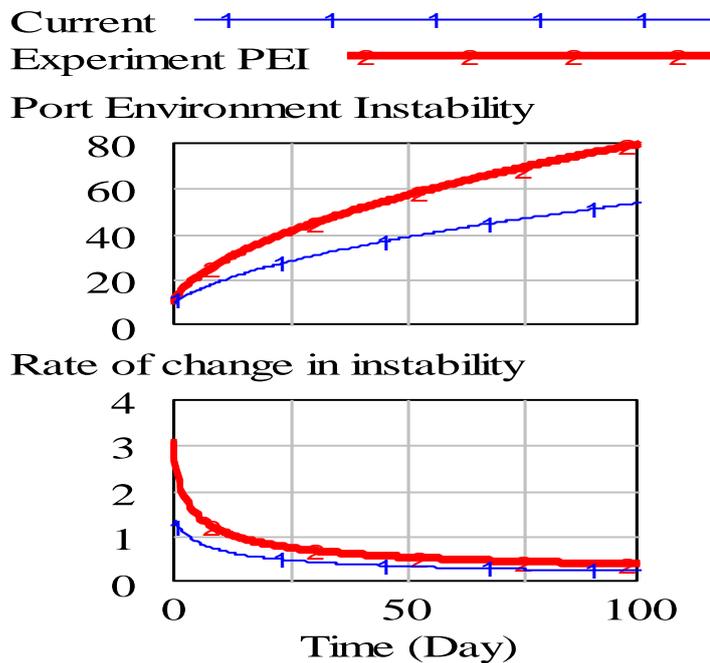


Figure S18: The real time change in DP over 100 day in response to increase in all key variables

We are reminded that the research did not set out to provide solutions to risk in the maritime logistics industry, rather, we set out to improve the current level of understanding the potential causes of disruptions in the logistics chain (particularly how policy change can influence the structural behaviour of a logistics chain). It seems that when all stakeholders understand the consequences of policy change (both intended and unintended consequences), it can become easier for team members to work together to arrive at solutions rather than become antagonistic to strategic interventions and implementations of mitigation plans. In our opinion, when the understanding of the dynamics of disaster (risk) antecedents in the logistics network is achieved, then the next question of how to resolve the problems may follow naturally.

4.11.3 Modelling Resilient Port Logistics (RPL)

The sub-system in figure R1 represents the stock and flow structure for Resilient Port Logistics (RPL) chain. The pre-fix “R” will be used as distinction label for models representing RPL. Material that flow through the network is the continuous supply of appropriate resource and the requisite information about the actual state of demand and supply requirements for disaster (emergency) management. The stock (RPL) accumulates at the rate of resource supply to the sub-system [Increasing Resilient Port Logistics (IRPL)]. We assume that resource accumulation in the RPL is dependent on outflows from disaster preparedness [Decreasing Preparedness due to Resource Usage (DPRU)] which transforms into available usable resources and have the capacity to change the level of resilience in port logistics chain. The diagram also suggest that resources exit the stock through resource usage (demand) for response or for recovery/reconstruction purposes (DRPL). Other usages may include operations that aim at preventing disaster from happening as well as fortifying the logistics network for sustainable operations. The above conditions were compressed into the conceptual model in figure R1.

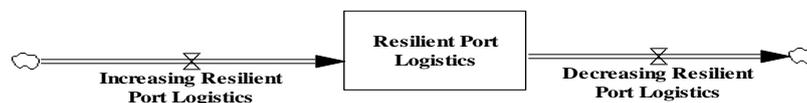


Figure R1: A collapsed model for resilient port logistics

The level of resilience (figure R1) can also be determined analytically (mathematically) as the net change in stock levels (behaviour of the system) such as the expressions in equations (7 and 8). We assume zero waste, and also that material supply is inexhaustible so that what can influence the stock level should be only the endogenous variables that have been considered in the research as shown in figure R2.

Let:

- Resilient Port Logistics (RPL) = Stock
- Increasing Resilient Port Logistics (IRPL) = Inflow
- Decreasing Resilience Port Logistics (DRPL) = Outflow

$$\mathbf{RPL(t)} = \mathbf{IRPL(t_0)} + \int_{t_0}^t [\mathbf{IRPL(s)} - \mathbf{DRPL(s)}] \text{----- eqn (7)}$$

Equation (7) represents the value of RPL at time **S** between the initial time **t₀** and final time **t**. We may interpret equation (7) as meaning that, RPL grows at the rates of the difference between IRPL and DRPL, starting from an initial level of resilience independent on existing policies that govern port operations based on location effects (RPL_{t0}). Aggregates of elements considered in RPL_(t0) were whether the port was built on marshy/floodable land, earthquake zone, erosion prone coastline, harsh weather, vulnerable to natural hazards/catastrophes, or human induced hazards/disasters.

Let us also set the rate at which the stock (RPL) levels change as a derivative function as eqn (8). We can interpret eqn (8) to mean that, RPL at time (t) is the difference between what flows in (IRPL) and what flows out (DRPL) of the stock.

$$\frac{d(\text{RPL})}{dt} = \text{IRPL}(s) - \text{DRPL}(s) \text{ ----- eqn (8)}$$

Subsequent from figure (R1), there emerge figure (R2) when auxiliary variables and the constants have been attached to the collapsed structure (figure R1). From research data source (interviews and literature search), we deduced that the stock changes can be influenced by risk preventive compliance measures, technology change (advancement), forecast accuracy, and nature of destruction (damage).

If we assume that all other variables can be held constant within the period of consideration, then according to figure R2, the outflow (DRPL) is influenced by “frequency of rescue missions” for the purposes of response and disaster recovery/reconstruction, and also the “extent of physical damage” to the logistics network and infrastructure. If the rate of outflow is greater than that for the inflow, the system will be described as being less resilient and it can be susceptible to disruptions, or it may be unable to recover from crisis in real time (all things being equal). We have also not lost sight of the fact that some incidents can overwhelm the logistics network’s capacity to respond immediately to crisis [e.g. Japan earthquake 2011, or 9/11 terror attack]. Such occurrences can drain RPL more than is desired, hence making the logistics network potentially incapable to bounce back from disruption in real-time. The above discourse has been summarised in figure R2 and the consequent impact analysis of the subsystem follows from figure R2 downwards. Let us be reminded that the description of the shape/behaviour of curves is similar to those for the subsystem DP (section 4.11.1 above).

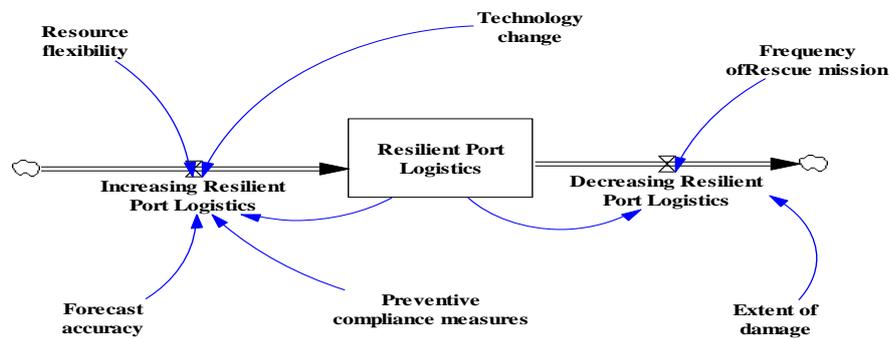


Figure R2: The dynamic conceptual model of PEI

a) Qualitative analysis of RPL using Causal Tree diagram

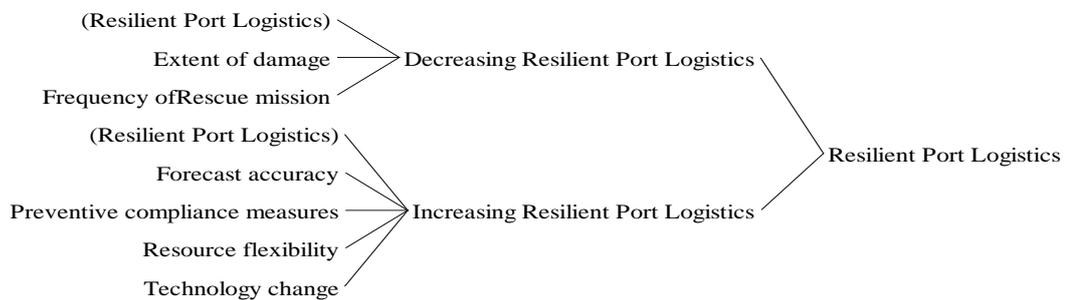


Figure R3: The causal tree diagram representing different variables that can influence RPL

The causal tree diagram (figure R3) allowed the research to answer questions such as “what influence what”, or “what causes a change in behaviour identified in the structure”. Accordingly, figure R3 reveals that RPL is directly influenced by IRPL and DRPL. Further down backwards, DRPL (for example) is caused by “extent of physical

damage”, and “frequency of rescue mission”, as well as state of resilience at time (t). Since these variables have influence on RPL, it suggests that a change in the value of any of those variables can change the state and behaviour of RPL. The quantitative analysis in the next couple of steps below can help the reader to gain further insight into the consequences of some of these policy interventions on RPL.

b) Quantitative Analysis

1. *Documentary Analysis on RPL*

This section defines the equations upon which the quantitative/graphical analysis of the dynamics of RPL were derived. There were a total of 13 equations representing functions and the necessary constraints from which the graphical analysis could be performed.

(01) Decreasing Resilient Port Logistics =

$$\frac{\text{Rescue mission} \times \text{Extent of damage}}{\text{Resilient Port Logistics}}$$
 Units: ****undefined****

(02) Extent of damage = 0.2
 Units: ****undefined****

(03) FINAL TIME = 100
 Units: Day
 The final time for the simulation.

(04) Forecast accuracy = 0.5
 Units: ****undefined****

(05) Increasing Resilient Port Logistics =

(Technology change * Resource flexibility * Preventive compliance measures * Forecast accuracy)/Resilient Port Logistics

Units: **undefined**

(06) INITIAL TIME = 0

Units: Day

The initial time for the simulation.

(07) Preventive compliance measures = 0.6

Units: **undefined**

(08) Rescue mission = 0.2

Units: **undefined**

(09) Resilient Port Logistics =

INTEG (Increasing Resilient Port Logistics-Decreasing Resilient Port Logistics,
1)

Units: **undefined** [1,100] (*a specific case of eqn 7*)

(10) Resource flexibility = 0.5

Units: **undefined**

(11) SAVEPER =

TIME STEP

Units: Day [0,?]

The frequency with which output is stored.

(12) Technology change = 0.7

Units: **undefined**

(13) TIME STEP = 1

Units: Day [0,?]

The time step for the simulation.

2. Structural Behaviour of Resilient Port Logistics

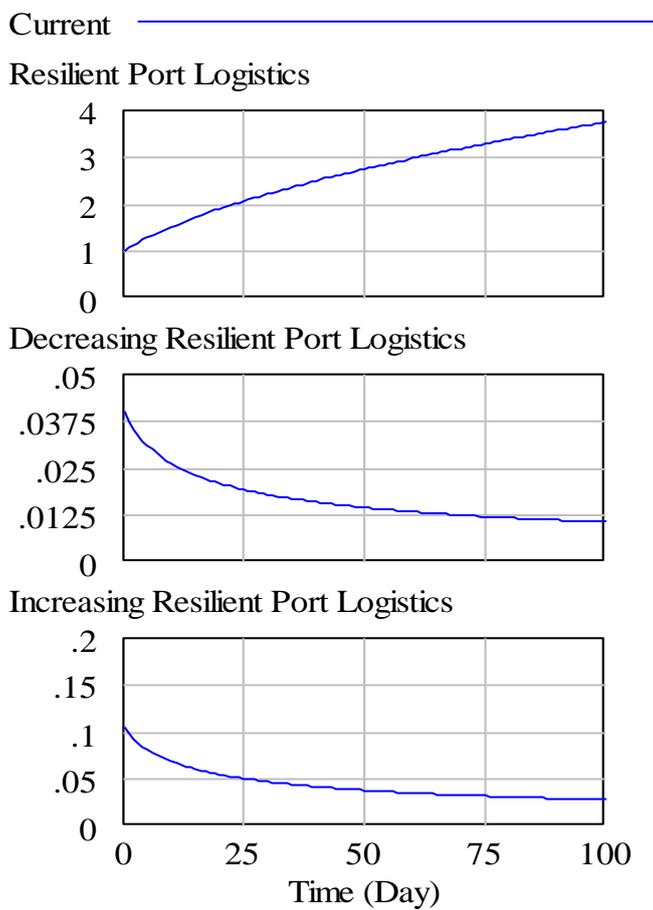


Figure R4: The dynamics of DP over 100 days

Figure R4 was derived from figure R2 based on the documentary analysis of RPL above. The set of graphs in figure R4 may be described as follows; that RPL increase exponentially at a decreasing rate within the period under focus. Contemporaneously, both DRPL and IRPL also decline exponentially at decreasing rates. Since these two elements have direct influence on RPL (figure R3), we can attribute the dynamic structural behaviour of RPL to the fall in rates of the flows.

We performed sensitivity analysis on RPL (figure 3) to evaluate the impact of change in policy decisions on the structure. A total of Thirteen (13) well defined equations were developed with the necessary constraint under the documentary analysis. The simulation serves as a kind of test/experiment evaluating the intended policy change prior to the implementation as we find in the next sub-section.

Subsequent from figure (R4) the family of curves that follow describe the dynamic structural behaviour of the sub-system RPL. The trajectories of the curves appeared to be nonlinear. RPL_1 represents the current level of RPL system and RPL_2 reflects the experimental RPL when any of the constants and parameters is varied through adoption of alternative policy (intervention) mix. If the policy requires that we reduce (decrease) the variable whose effect on RPL is being tested the slider is adjusted to the left, and the opposite holds if one wants to test for the effects of an increase in the same variable.

3. Testing the Influence of Risk Interventions (Policy Change) on the Structure of RPL

When technology is reduced

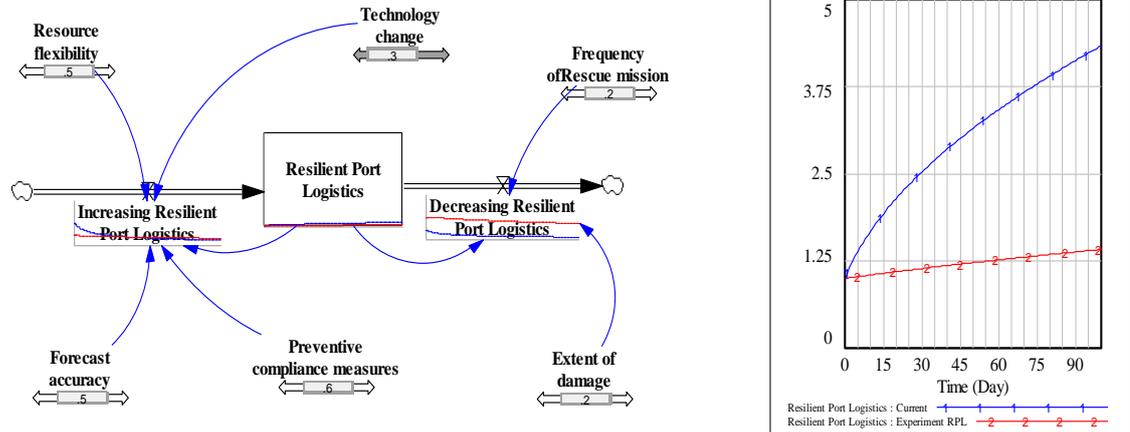


Figure R5: The conceptual model of RPL and its corresponding dynamic graph in response to decrease in technology

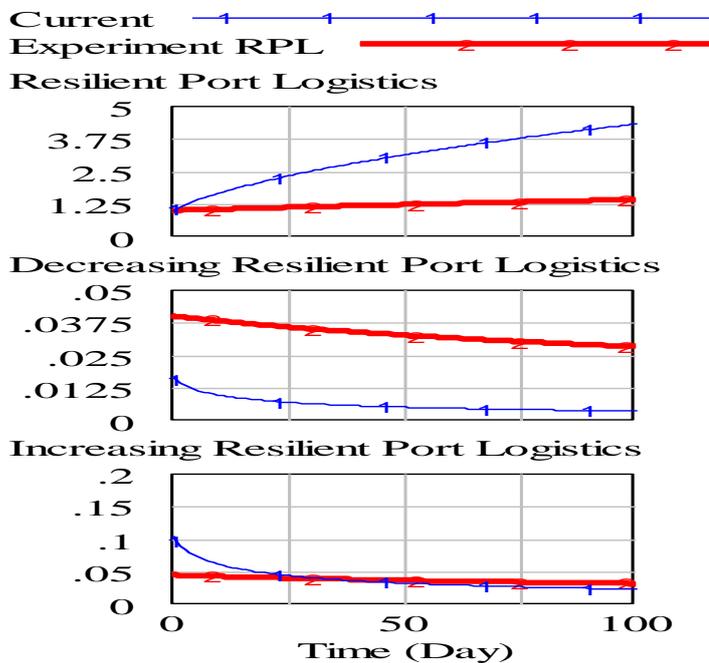


Figure R6: The real time change in RPL over 100 day in response to decrease in technology

When technology increases

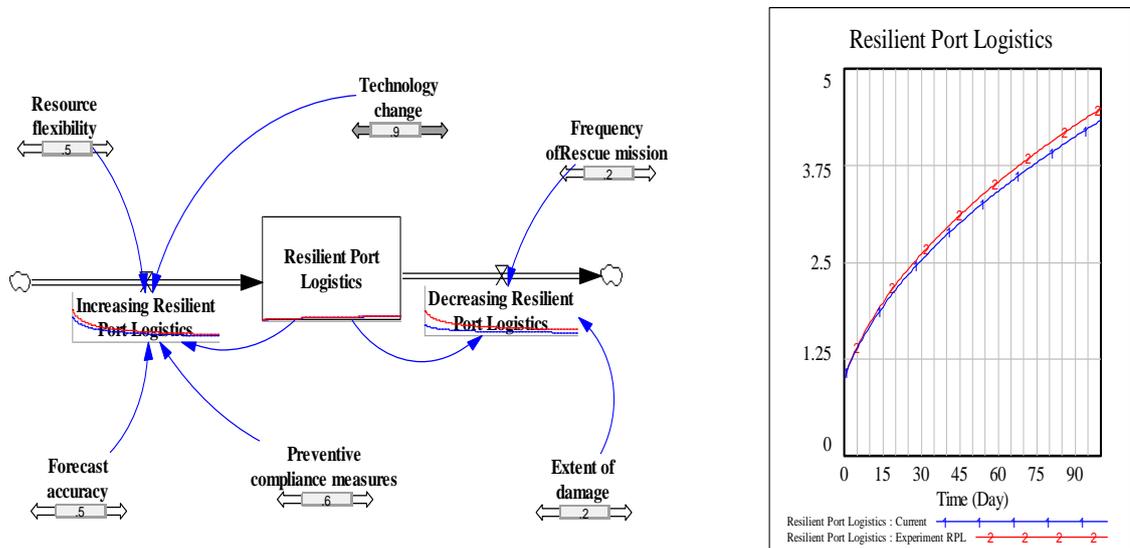


Figure R7: The conceptual model of RPL and its corresponding dynamic graph in response to increase in technology

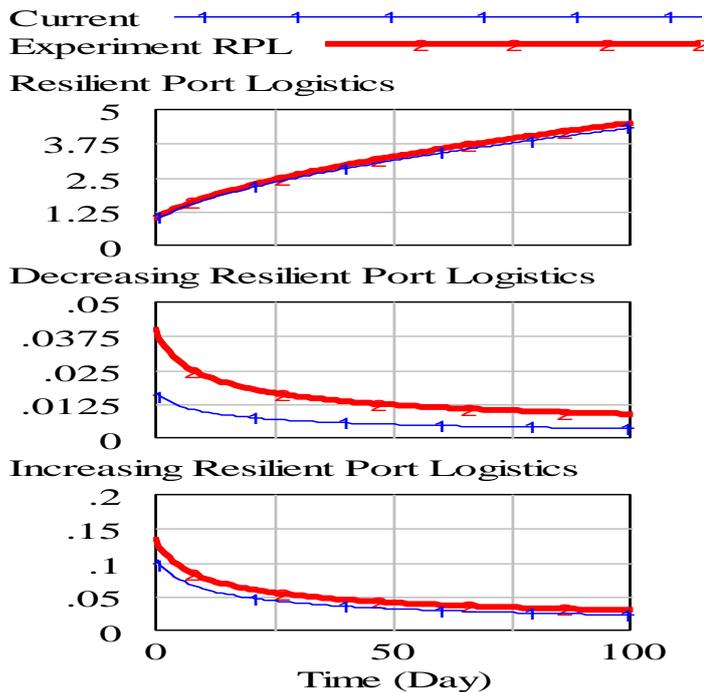


Figure R8: The real time change in RPL over 100 day in response to decrease in technology

The family of curves produced when technology is varied suggests that RPL is sensitive to technology change. According to figure R5 and R6, when technology decreases, $IRPL_2$ lies below $IRPL_1$ initially and appears to remain constant whereas $IRPL_1$ continues to fall and even goes below $IRPL_2$. $DRPL_2$ lies way above $DRPL_1$ and both curves seem to decrease at steadily slow rate. Since DRPL is an outflow out of RPL, it can be argued that DRPL might have contributed to the big fall in RPL_2 way below the trajectory of RPL_1 . One other significant observation in the model (figures R7 - R8) reveal that an increase in technology beyond a certain point does not improve RPL significantly as compared to the scenario where technology is reduced, though the trajectories of both RPL_1 and RPL_2 continue to rise slightly within the period under consideration. Both $IRPL_2$ and $IRPL_1$ fall and became asymptotic to the time axis, however RPL_2 lies slightly above RPL_1 . The trajectory of $DRPL_2$ appears to fall faster than $DRPL_1$ but the former remained above the later curve. In spite of these changes in the curves of IRPL and DRPL in response to increase in technology, RPL_1 and RPL_2 seem not to have any significant difference (figure R8). Arguably these behaviour can be attributable to effects of “over technologisation” or technology overcrowding which can be a setback rather than an advantage to logistics operations.

When resources become less flexible

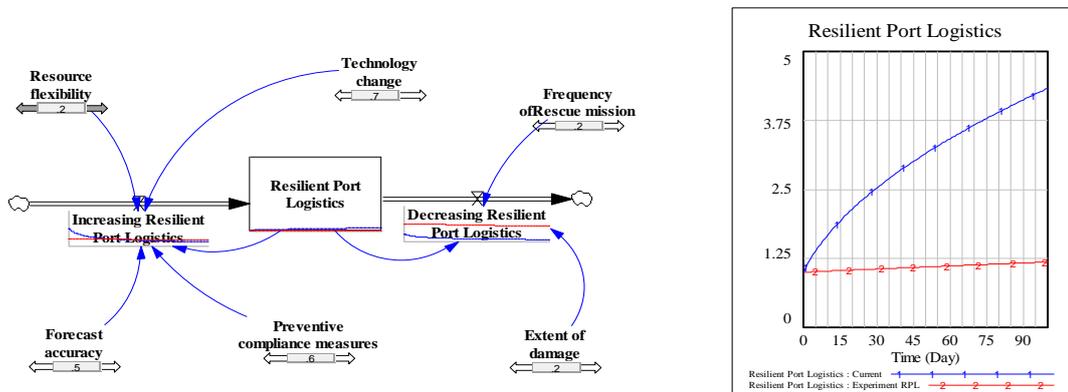


Figure R9: The conceptual model of RPL and its corresponding dynamic graph in response to decrease in resource flexibility

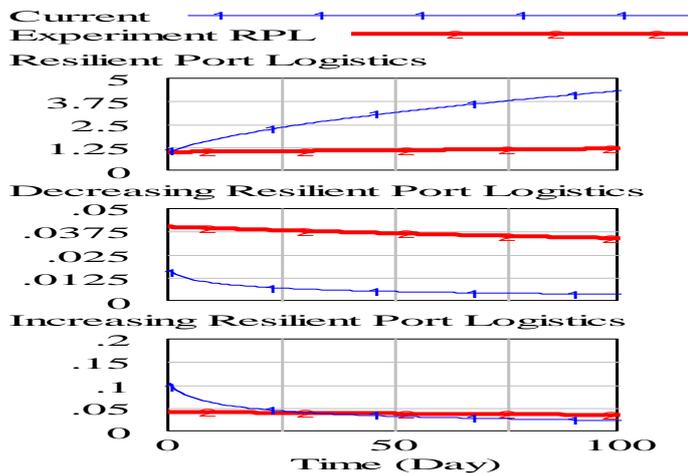


Figure R10: The real time change in RPL over 100 day in response to decrease in resource flexibility

From the set of graphs (figures R9 and R10), RPL can be said to be significantly sensitive to change in resource flexibility. It seems the outflow from RPL (DRPL₂) is quite high enough to pull down the trajectory of RPL₂ faster and lower than that for RPL₁. The graphs suggest that when port/maritime logistics risk management resources become less flexible it may translate into incapacity to move (substitute)

operational resources from one logistics operations to another, or resources may not be adaptable to changing situations to suit the needs of facility user at a time. Alternatively, figure R11 and R12 suggest that when resources become more flexible, it can improve entity's risk management capacities leading to bouncing back from disruptions. The marginal increase in resource supply ($IRPL_2$) coupled with a marginal decrease in rate of usage ($DRPL_2$) can cause resource accumulation to increase and hence the rise in RPL_2 faster and above RPL_1 as in figure R11 and R12.

When resources become more flexible

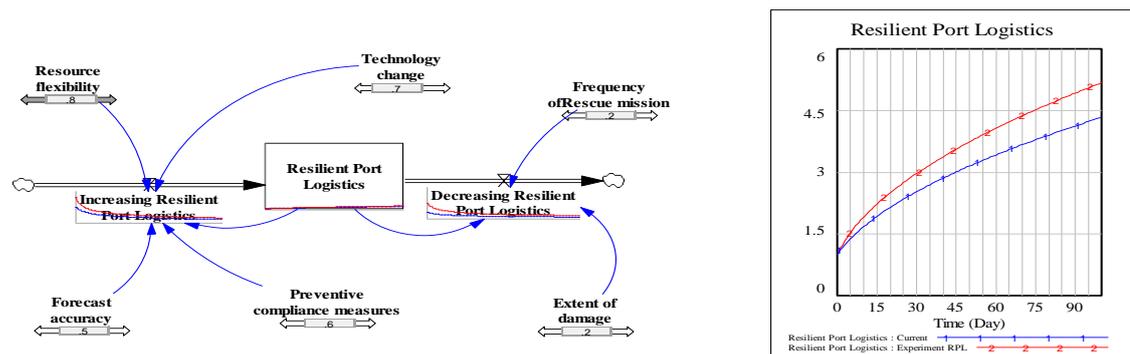


Figure R11: The conceptual model of RPL and its corresponding dynamic graph in response to increase in resource flexibility

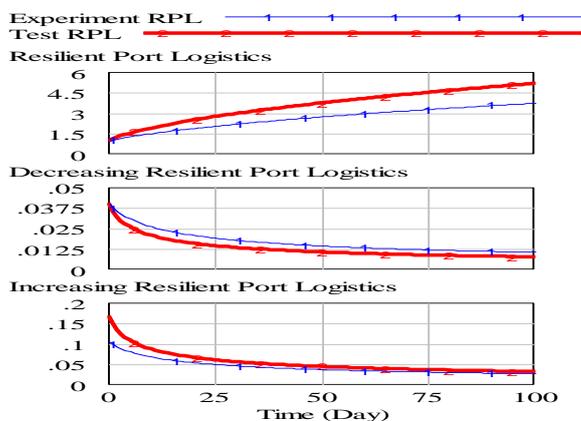


Figure R12: The real time change in RPL over 100 day in response to increase in resource flexibility

When forecasting becomes less accurate

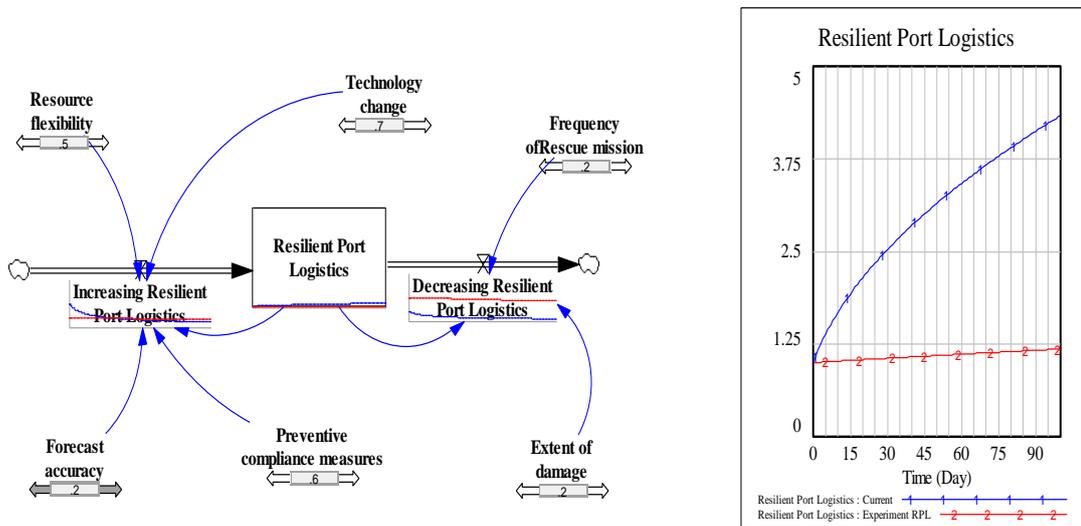


Figure R13: The conceptual model of RPL and its corresponding dynamic graph in response to decrease in forecasting

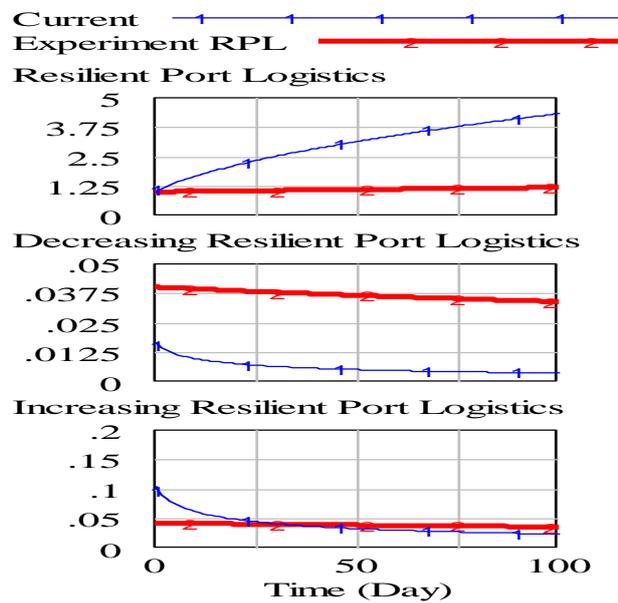


Figure R14: The real time change in RPL over 100 day in response to decrease in forecast accuracy

When forecasting becomes more accurate

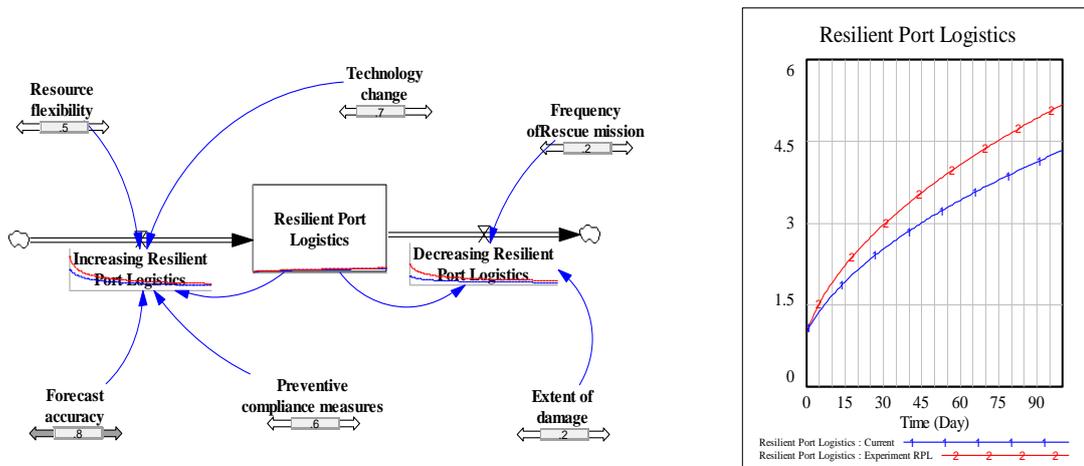


Figure R15: The conceptual model of RPL and its corresponding dynamic graph in response to increase in forecast accuracy

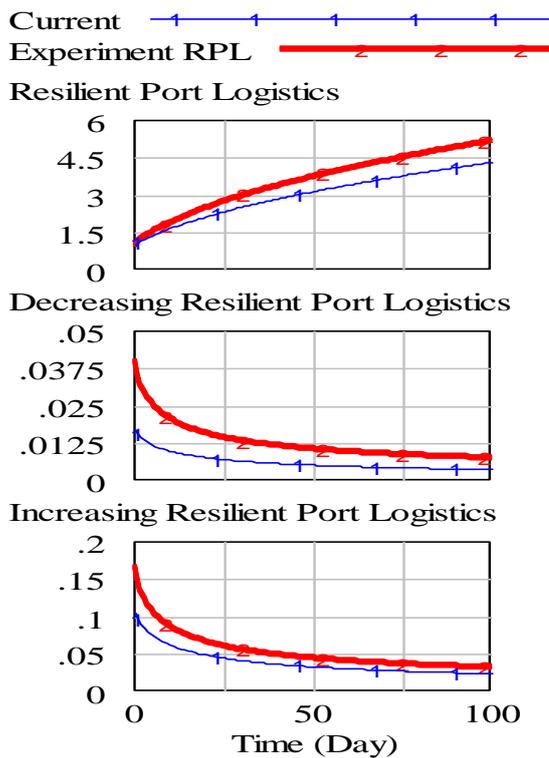


Figure R16: The real time change in RPL over 100 day in response to increase in forecast accuracy

When risk preventive compliance measures improved

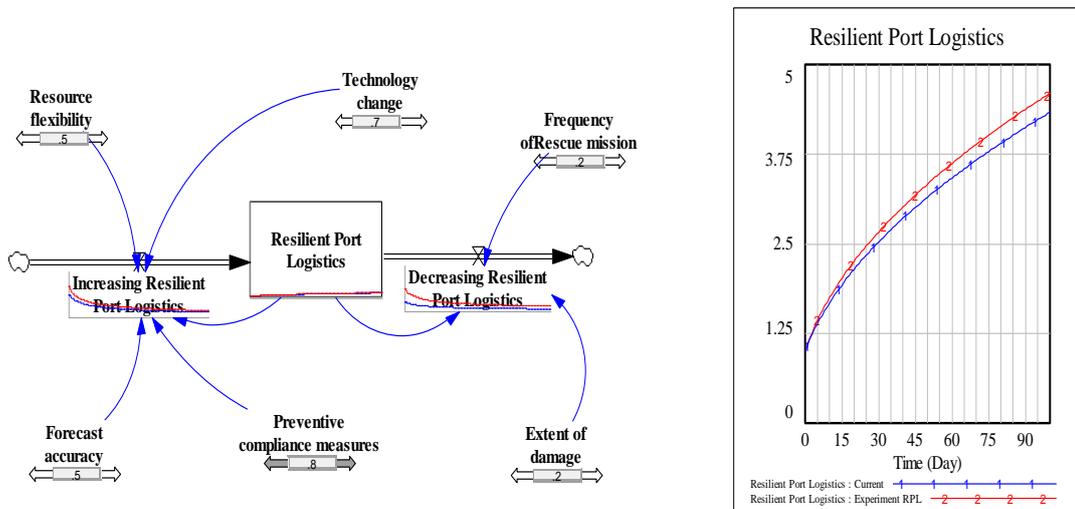


Figure R19: The conceptual model of RPL and its corresponding dynamic graph in response to increase in risk preventive compliance

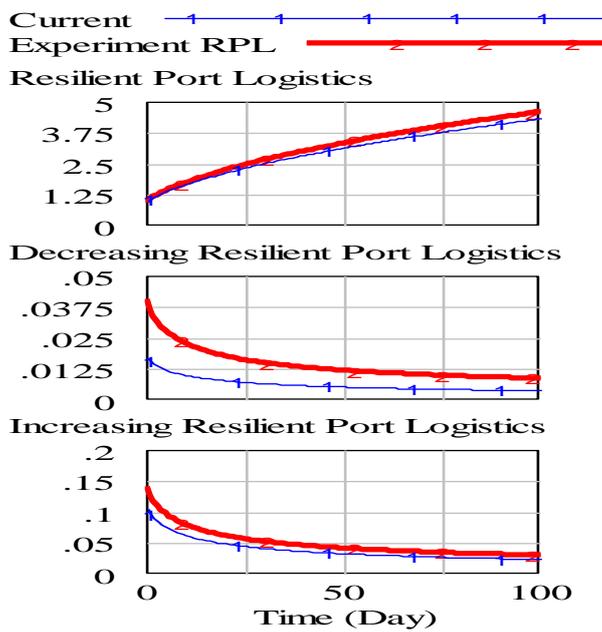


Figure R20: The real time change in RPL over 100 day in response to increase in risk preventive compliance measures

In this section, we examined the effects of risk preventive compliance on RPL. Let one assume that risk preventive compliance has decreased from 0.5 (or 50%) to 0.225 (22.5%) as in figure R17 and R18. Consequently one can observe that the trajectory of RPL_2 drops below that for RPL_1 indicating that RPL reduces when risk preventive compliance reduces. It can also be seen that $DRPL_2$ rose high above $DRPL_1$ while $IRPL_2$ falls marginally below $IRPL_1$ but $IRPL_2$ appeared to gradually merge with $IRPL_1$. The decline in RPL_2 faster than RPL_1 suggests that the system can become less resilient than it would have been when risk preventive measures are reduced (given the same level of resources and operations). This can also signify that if every variable is held constant, then a reduction in risk preventive compliance measures can result in longer time being taken to respond to crisis and/or recovering (bounce back) from emergency situations.

Contrary to the above argument figure R19 and R20 suggests that when risk preventive compliance measures are increased, the trajectory of RPL_2 rose very slightly above that for RPL_1 . The graphs suggest that RPL seem not to be significantly sensitive to increase in risk preventive compliance measures as one would have thought. A study of the set of curves shows that $IRPL_2$ rose slightly above $IRPL_1$ but seem to decrease faster such that the two appear to meet. At the same time $DRPL_2$ lies above $DRPL_1$. Since the causal tree diagram (figure R3) confirm the influence that the two variables have on RPL couple with the fact that the outflow ($DRPL$) appears to be higher, that could have been one of the causes of the behaviour of RPL. It seems that too much sanctions on risk compliance can restrict significant innovations into logistics operations or cause the observed behaviour in RPL.

When frequency of rescue mission increased

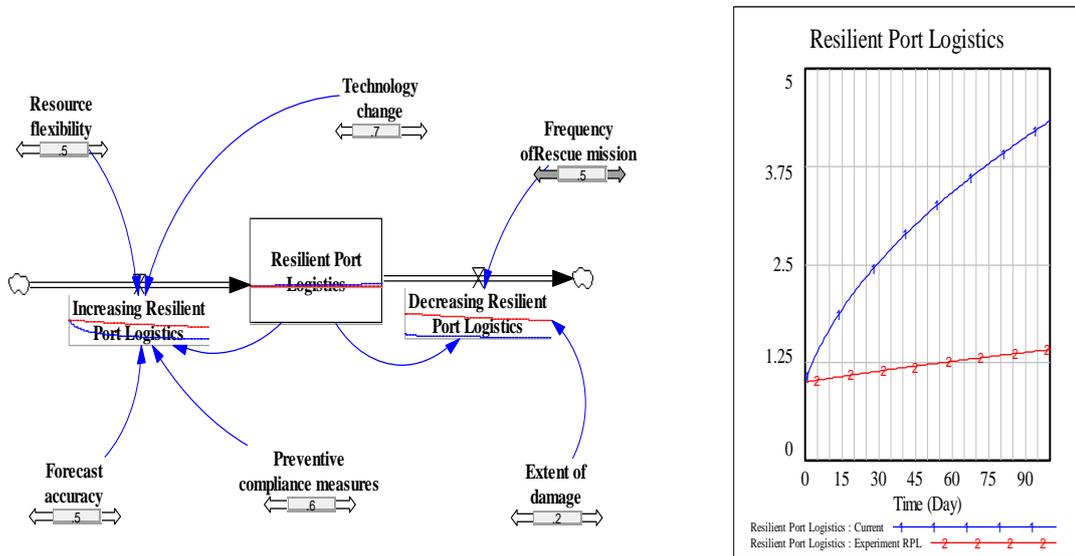


Figure R21: The conceptual model of RPL and its corresponding dynamic graph in response to increase in number of rescue missions

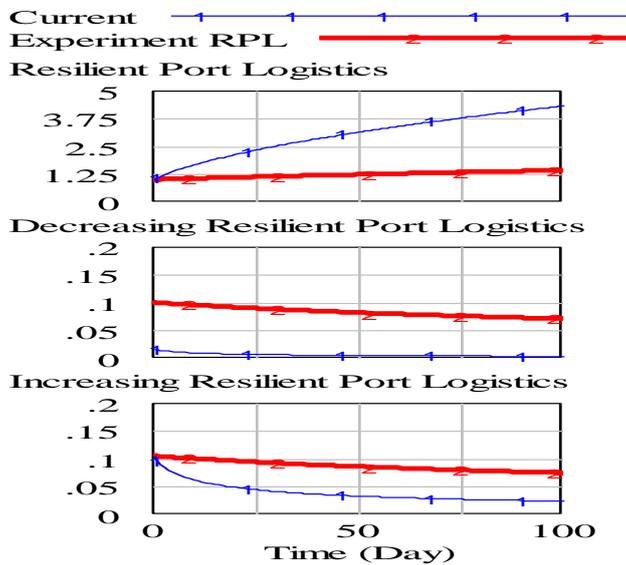


Figure R22: The real time change in RPL over 100 day in response to increase in number of rescue mission

When frequency of rescue mission reduced

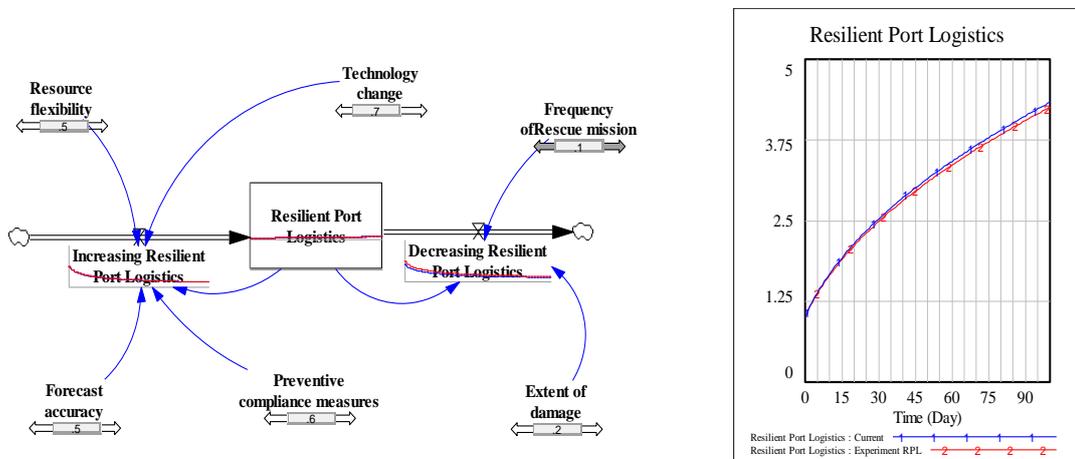


Figure R23: The conceptual model of RPL and its corresponding dynamic graph in response to decrease in number of rescue missions

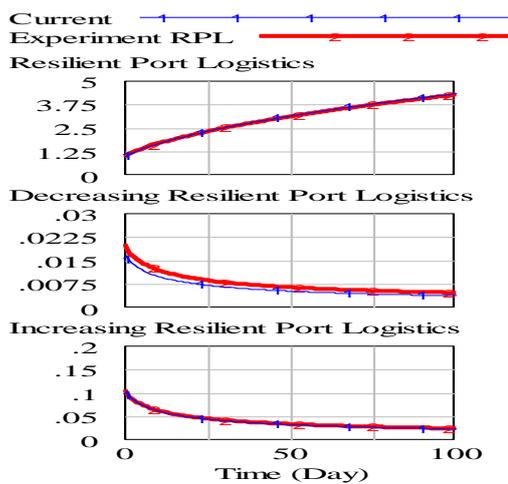


Figure R24: The real time change in RPL over 100 day in response to decrease in number of rescue mission

The set of graphs (R23 and R24) suggest that a decline in the frequency of rescue mission increases the rate of outflow (DRPL) marginally but not the rate of inflow (IRPL). Therefore RPL can be said not to be influenced significantly by decrease in frequency of rescue mission.

When extent of damage is high

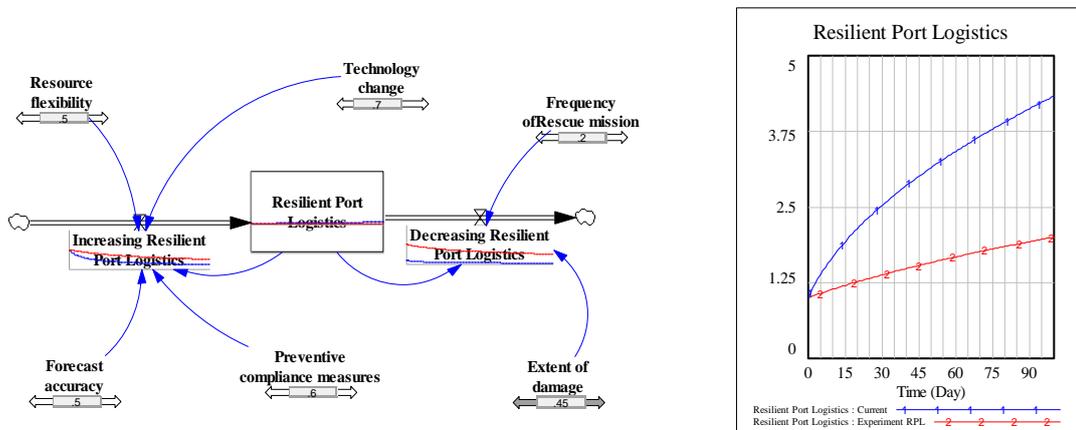


Figure R25: The conceptual model of RPL and its corresponding dynamic graph in response to increase in physical damage to logistics network

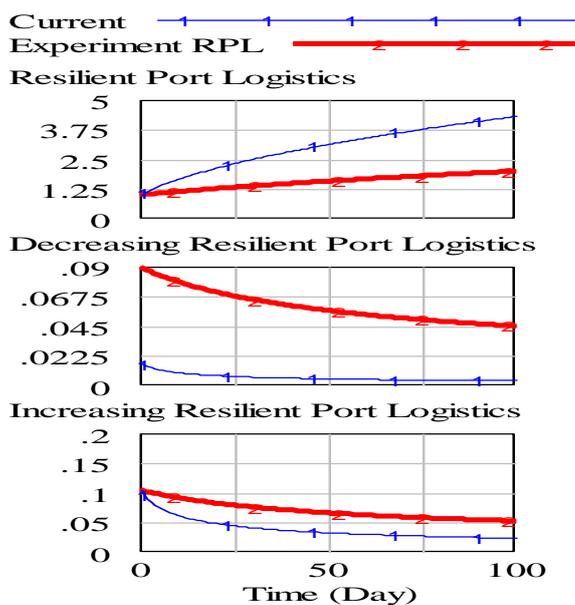


Figure R26: The real time change in RPL over 100 day in response to increase in physical damage to logistics network

Figure R26 above suggests that $DRPL_2$ is displaced quite high above $DRPL_1$, it is apparent that the rate at which resource drains out of the stock is higher than it used to be and perhaps also more than the rate of resource accumulation ($IRPL_2$). It seems the

imbalanced inflow/outflow mix causes the trajectory of RPL₂ to fall faster and hence be displaced below RPL₁.

When extent of damage is low

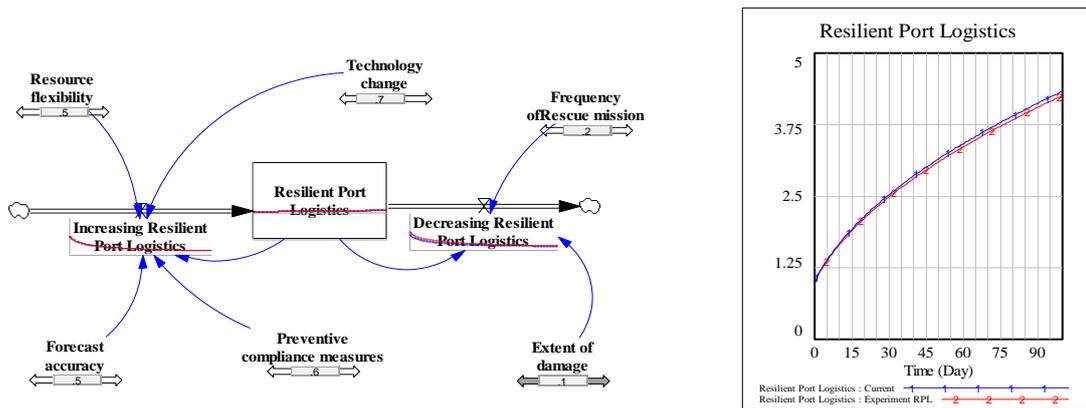


Figure R27: The conceptual model of RPL and its corresponding dynamic graph in response to decrease in physical damage to logistics network

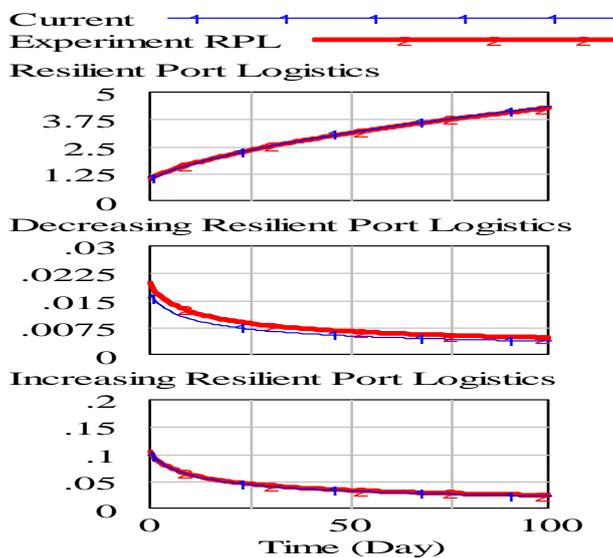


Figure R 28: The real time change in RPL over 100 day in response to decrease in physical damage to logistics chain

The set of graphs (figures R27 and R28) representing the dynamic structural behaviour of the sub-system RPL indicate that when less damage occurs in a logistics chain, the system's capacity to respond to, or to recover from disruption, as well as the capacity to reconstruct itself (capacity to bounce back) after a disruption does not change significantly within the period of investigation. It seems the level of damage done to the logistics network can significantly determine the system's capacity to bounce back from operational disruptions according to figure R25 and R26.

4.11.4 Stock and Flow Diagram for the interdependencies in DP, PEI and RPL (General Structure)

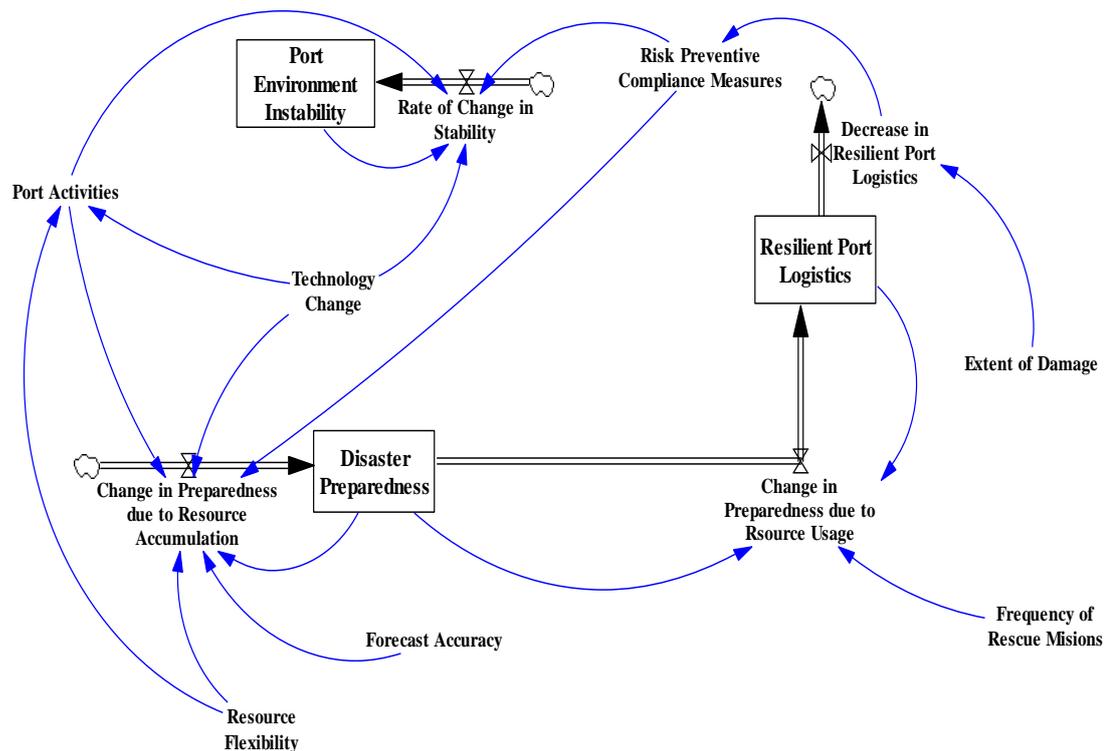


Figure G1: The dynamic model for the general structure

The model above (figure G1) represents the dynamic behaviour of RPL taking into account the state of port stability (PEI), and the level of DP. The labels for this model shall be pre-fixed with the letter “G” to signify ‘the simulation model representing the general structure’. The structure describes a system that is consisted of a flow in PEI “rate of change in stability (RCI)”. It also has DP whose inflow is “change in preparedness due to resource accumulation (CPRA)”⁵², and an outflow of “change in preparedness due to resource usage (CPRU)” which also drains into RPL. The outflow of RPL is the “decrease in resilience” (DRPL). The tail end of the arrows linking the auxiliary variables to the state variables represent that which causes an effect in the variable at the arrow head. The causality tree diagrams in figure G2 and G3 below explain the conceptual relationships among variables. For instance, the ‘use tree’ diagram (figure G3i) suggests that CPRU has direct influence on the levels of disaster preparedness and resilience in port/maritime logistics chain.

To examine the dynamic behaviour of the model (quantitatively), sensitivity analysis was performed which produced the set of graphs (figure G4 – G29) based on 18 equations produced with the Vensim® software. To test the state of resilience, we change the positions of the sliders (or the micro-levels) attached to the constant/auxiliary variables.

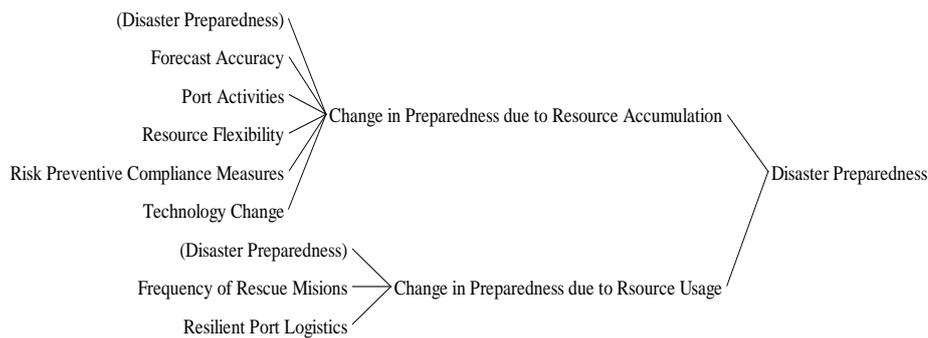
⁵² For the sake of simplicity and convenience, we replaced increasing in preparedness due to resource accumulation (IPRA) with change in preparedness due to resource accumulation (CPRA) and decreasing preparedness due to resource usage (DPRU) with change in preparedness due to resource usage (CPRU) for the general structure model.

a) Qualitative analysis of RPL using Causal Tree diagram

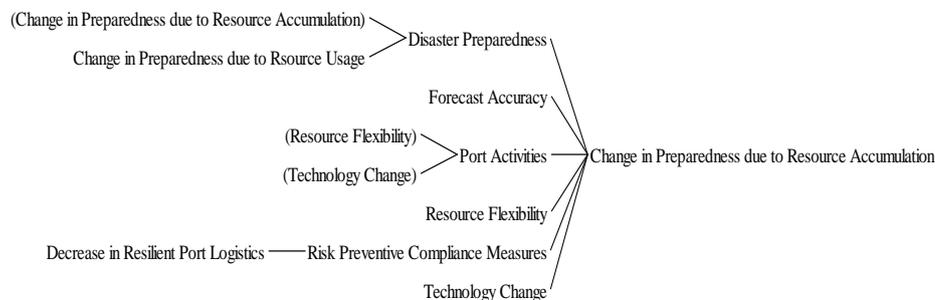
i) Causal Tree Diagram

The causal tree diagram (figure G2) aims to allow the research to learn about which variables cause the behaviour in another. Accordingly one can observe in figure G2d (for instance) that RPL is directly influenced by CPRA and DRPL. Further down, DPRU is caused by DP, RPL, and frequency of rescue mission. Since these variables have influence on RPL, it suggests that a change in the value of any of them can change the state of RPL.

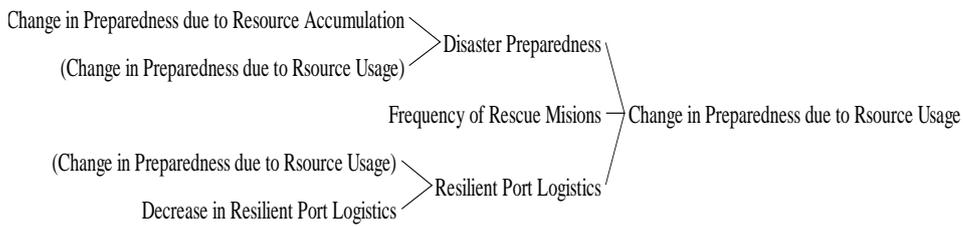
(a) Disaster Preparedness: Causes Tree



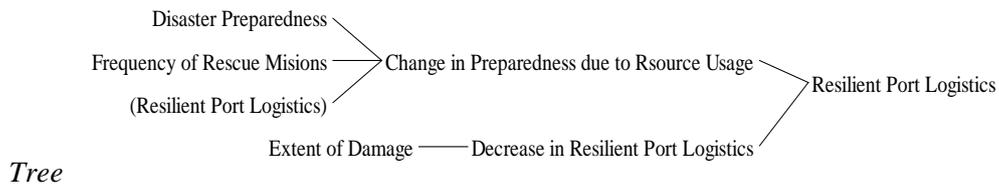
(b) Change in Preparedness due to Resource Accumulation: Causes Tree



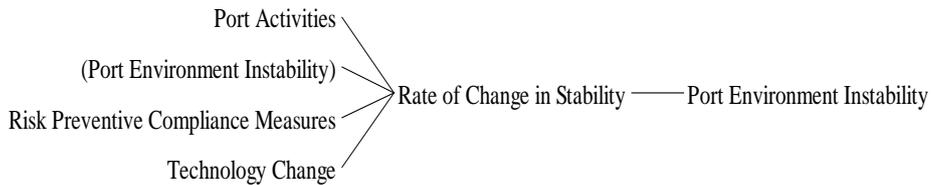
(c) Change in Preparedness due to Resource Usage: Causes Tree



(d) Resilient Port Logistics: Causes



(e) Port Environment Instability: Causes Tree



(f) Rate of Change in Stability: Causes Tree

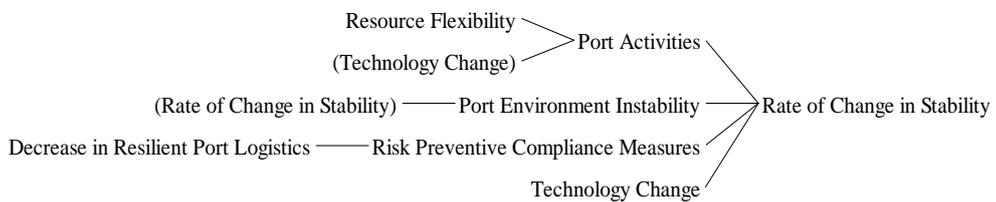
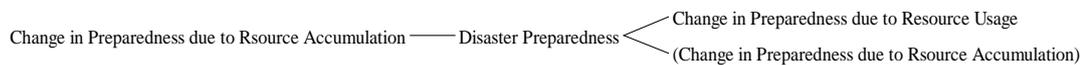


Figure G2: The causal tree diagram representing the influence relations in the variable the affect the general model

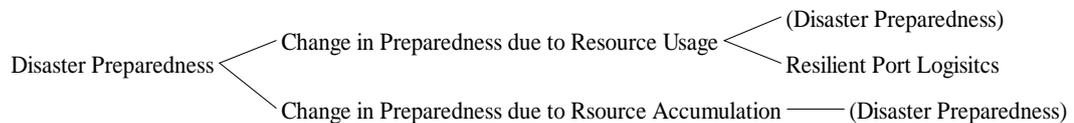
ii) Use Tree diagram

The ‘use tree’ diagram (e.g. figure G3i) suggests that CPRU influences Disaster Preparedness, and Resilient Port Logistics, each of which also influences other variables in that chain. Let us recall (figure G1) that CPRU is the outflow of DP which doubles as the inflow of RPL. It therefore suffices to say that the rate of CPRU can significantly influence the levels of both stocks (DP and RPL).

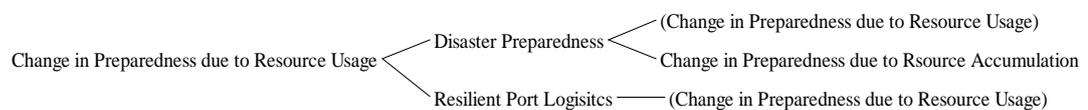
(g) Change in preparedness due to resource accumulation: Use Tree

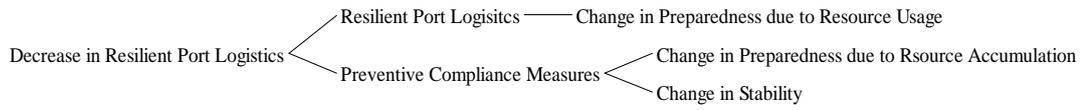


(h) Disaster Preparedness: Use Tree



(i) Change in preparedness due to resource usage: Use Tree





(j) *Decrease in resilient port logistics: Use Tree*



(k) *Port environment stability: Use Tree*



(m) *Change in stability: Use Tree*

Figure G3: The use tree diagram representing different variables that can influence the general structure

b) The Quantitative Analysis figure G1

1. Documentary Analysis of the general structure

(01) Change in Preparedness due to Resource Usage =

(Disaster Preparedness*Frequency of Rescue Mission)/Resilient Port Logistics

Units: **undefined**

- (02) Change in Preparedness due to Resource Accumulation =
 (Technology Change*Resource Flexibility*Preventive Compliance Measures*Port Activity*Forecast Accuracy)/Disaster Preparedness
 Units: **undefined**
- (03) Change in Stability =
 (Port Activity*Preventive Compliance Measures*Technology Change)/Port Environment Stability
 Units: **undefined**
- (04) Decrease in Resilient Port Logistics =
 Extent of Damage
 Units: **undefined**
- (05) Disaster Preparedness =
 INTEG (Change in Preparedness due to Resource Accumulation-Change in Preparedness due to Resource Usage, 1)
 Units: **undefined** [10,100]
- (06) Extent of Damage = 0.2
 Units: **undefined**
- (07) FINAL TIME = 100
 Units: Day
 The final time for the simulation.
- (08) Forecast Accuracy = 0.7
 Units: **undefined**

- (09) Frequency of Rescue Mission = 0.2
Units: **undefined**
- (10) INITIAL TIME = 0
Units: Day
The initial time for the simulation.
- (11) Port Activity =
Resource Flexibility*Technology Change
Units: **undefined**
- (12) Port Environment Stability =
INTEG (Change in Stability, 1)
Units: **undefined** [1,100]
- (13) Preventive Compliance Measures =
Decrease in Resilient Port Logistics
Units: **undefined**
- (14) Resilient Port Logistics =
INTEG (Change in Preparedness due to Resource Usage-Decrease in Resilient Port Logistics, 1)
Units: **undefined** [1,100]
- (15) Resource Flexibility = 0.7
Units: **undefined**

(16) SAVEPER =

TIME STEP

Units: Day [0,?]

The frequency with which output is stored.

(17) Technology Change = 0.7

Units: **undefined**

(18) TIME STEP = 0.25

Units: Day [0,?]

The time step for the simulation.

2. Structural Behaviour of DP in Reaction to CPRU and CPRA

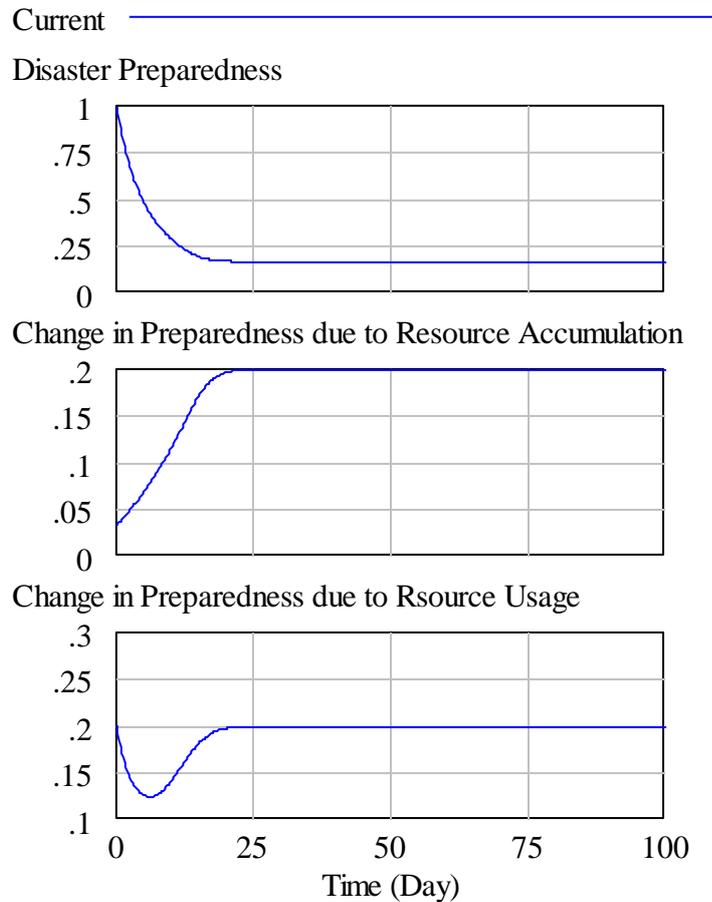


Figure G4: The dynamics of DP over 100 days

Figure G4 is the graphical analysis for dynamics of DP that was derived from a Vensim® simulation run of figure G1 by applying the 18 equations under the documentary analysis. The set of graphs show that DP falls rapidly in the first 25 days, then gradually appears to remain parallel to the time axis after the 30th day. The graph of CPRU on the other hand falls very sharply within the first 5 days (approximately) to reach a minimum turning point, then rose fast to reach a maximum (at approximately 0.2 units), and remained constant thereafter. Contemporaneous with the dynamics of DP and CPRU, CPRA rose rapidly, reaches a peak (also within the first 25 days), then

remained constant for the period under review. The behaviour of the set of graphs describe the behaviour of a port/maritime logistics' DP, CPRU and CPRA during a crisis incident especially in the periods following resource mobilisation and usage. At the interval when the trajectory of CPRA rises while that for CPRU declines, it suggests that resource demand cannot meet supply at that stage. The combined effects could be the cause for which DP falls exponentially. However, at the time when resource demand equals the supply, all three graphs appeared to reach an equilibrium point and hence all three graphs appeared to remain constant and parallel to the time axis.

3.1 Structural Behaviour of RPL in Reaction to CPRU and DRPL

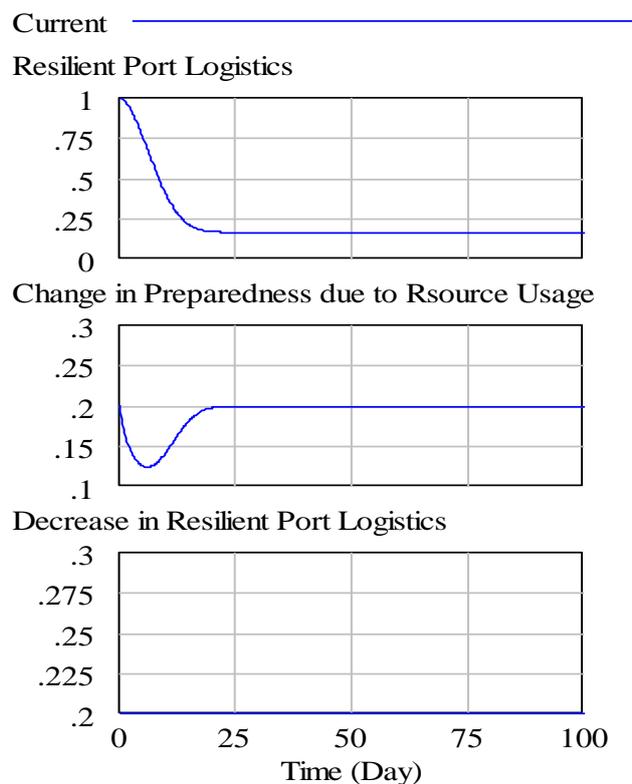


Figure G 5: The dynamics of RPL over 100 days

The trajectories of the set of graphs (figure G5) suggest that at constant rate of outflow (DRPL), the stock (RPL) and the inflow (CPRU) decline contemporaneously at the onset, but the latter (which represents the inflow) reaches a minimum point and rises fast while the former (the stock) keeps declining within the first 25 days of the crisis period. Both two graphs flattened and seem to remain parallel to the time axis, apparently when resource demand equals supply (equilibrium). This also suggests that factors (elements) that influence resource usage can significantly determine the state of resilience in a logistics network. Therefore this tool can assist management to critically examine how such variables can be mixed in order to influence systemic capacity to bounce back from crisis. The risk management team can design a response to mitigate the impacts of change (both intended and unintended consequences) prior to the occurrence of an incident. We reiterate that the model is not being used as a predictive tool, but rather as a tool to aid in gaining insight into the dynamic behaviour of the port/maritime logistics system as a result of policy change (strategic risk interventions) are tested prior to decision implementation.

3.2 Structural Behaviour of PEI in Reaction to RCI

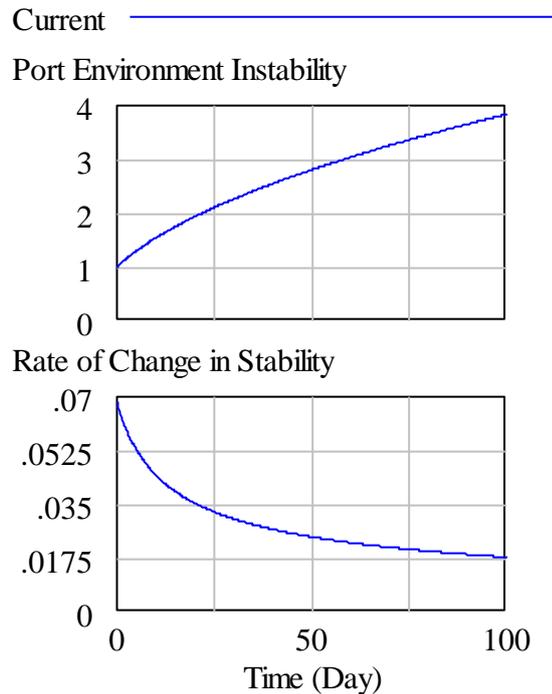


Figure G6: The dynamics of PEI over 100 days

The set of graphs (figure G6) indicate that PEI grows exponentially at a decreasing rate contemporaneously as RCI declines. A fall in RCI implies that port/maritime logistics operation is becoming more stable, sustainable, and less vulnerable to risks and disruptions. On the other hand, the growth in PEI suggest an increasing impact of the location effects. Therefore policy interventions that will encourage further falls in RCI can be vigorously pursued by management.

4. Testing the influence of policy change (e.g. technology change) on the general structure

This section tests for the impact of a risk intervention on the state variables and their flows, assuming that all other variables were held constant except technology capacity.

We performed the “extreme conditions test” on figure G1 to observe the structural behaviour (sensitivity) of the state variables in the system. The test produced a family of curves that look similar to those discussed above (figure G4 – G6). We shall use numbers 1 and 2 to distinguish between the trajectories of current (initial) and the experimental graphs respectively.

Effects of increase in technology on the resilience of the logistics network

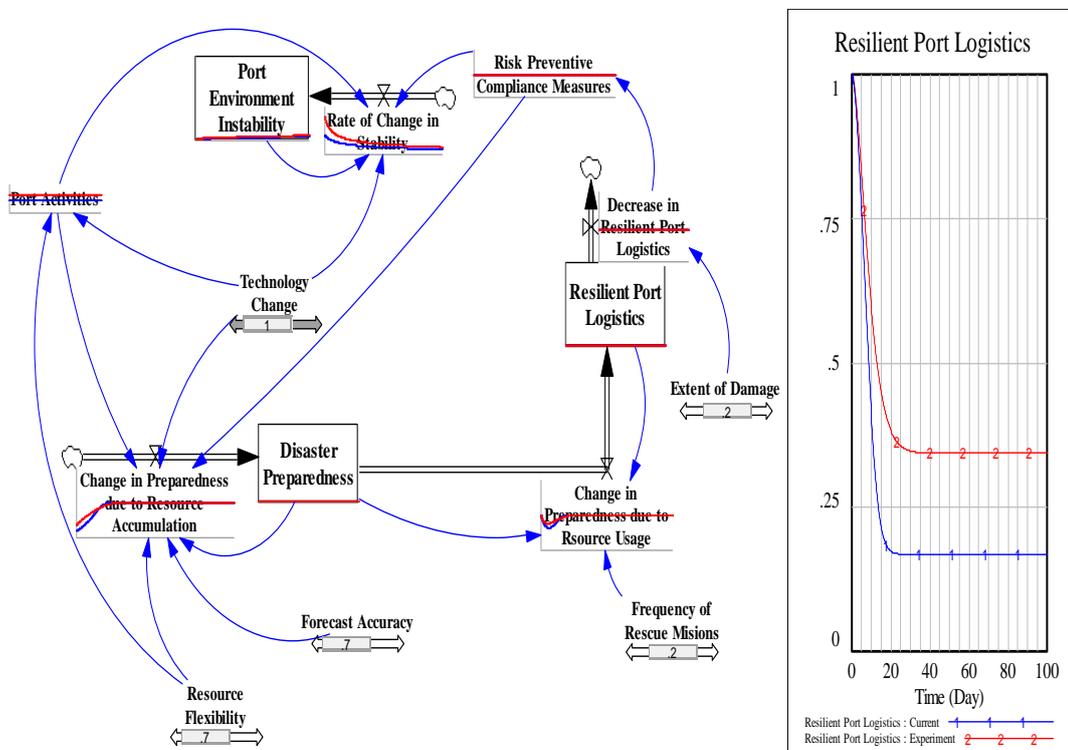


Figure G7: The conceptual model of general structure and the corresponding dynamic graph in response to increase in technology as policy requirement

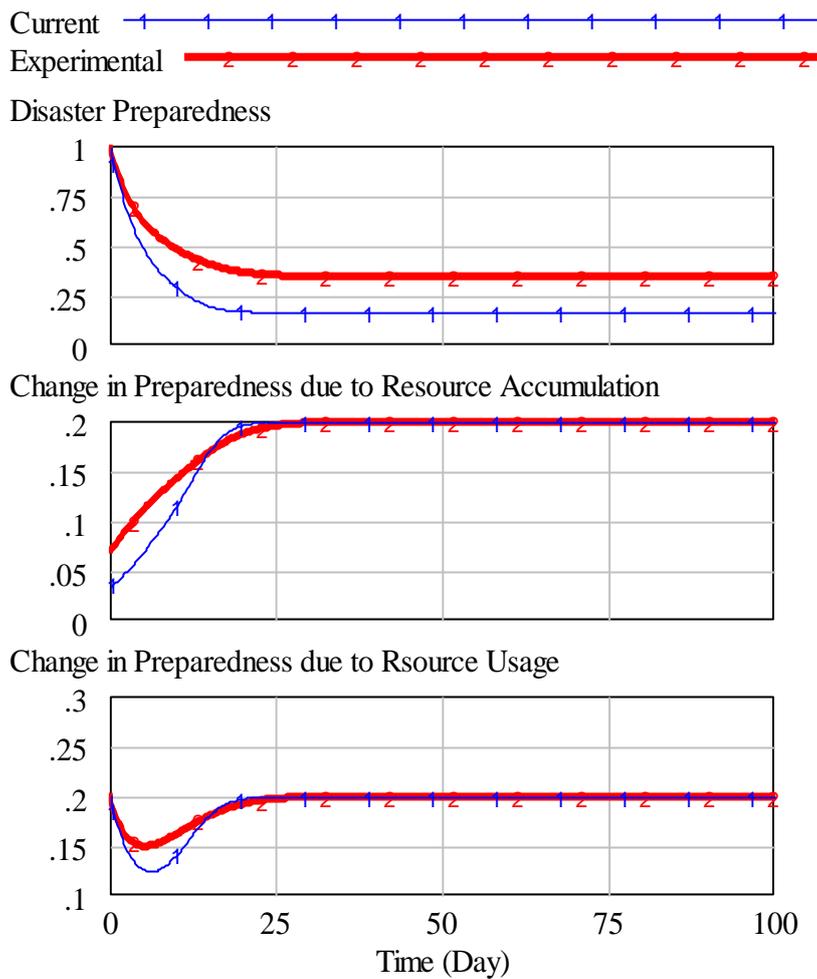


Figure G7: The real time change in DP over 100 day in response to increase change in technology capacity of the logistics chain

The trajectories of the set of graphs (figure G8) show the impacts that increase (improvement) in technology capacity at the port/maritime logistics industry can have on the dynamics of systemic disaster preparedness (DP) and its flows. In addition to what has been explained already under figure G4, we observe from figure G8 that an increase in technology raises the trajectory of DP₂ above DP₁ as in figure G9 below.

Change in Preparedness due to Rsource Usage

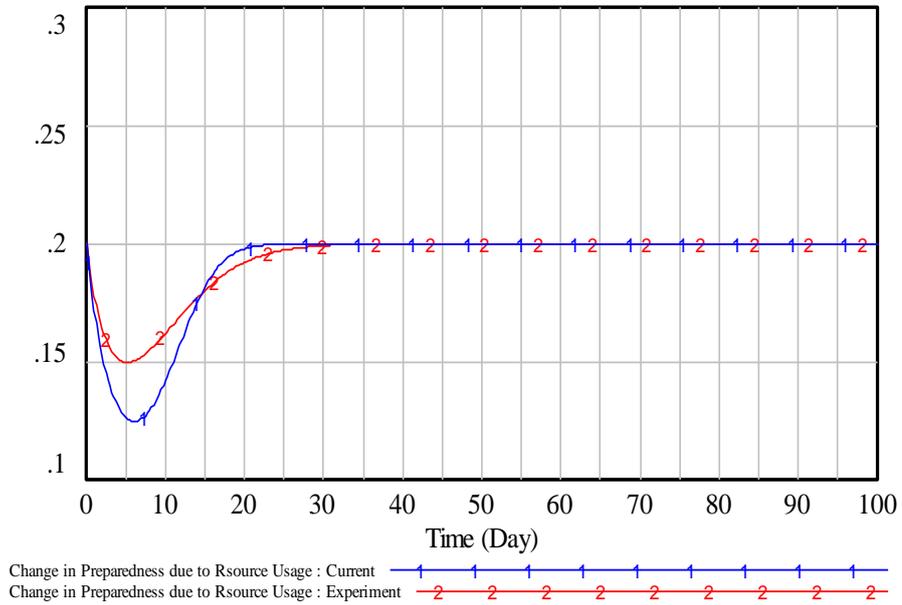


Figure G8: The real time change in CPRU over 100 day in response to increase in technology in logistics chain

Change in Preparedness due to Resource Accumulation

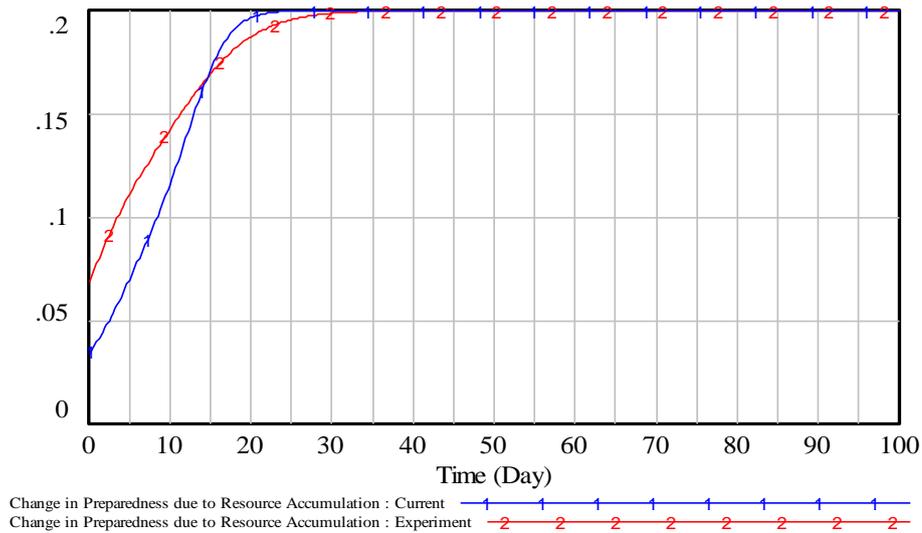


Figure G9: The real time change in CPRA over 100 day in response to increase in technology in logistics chain

The trajectories of the graphs above (figure G9 - G11) suggest that technology improvement can actually improve resource supply and efficient usage which can lead to building sustainable port/maritime logistics operations faster than it would have been. Generally, figure G2a reveals that CPRA is influenced by several factors including disaster preparedness, forecast accuracy, port activity, and many others, which affects levels of preparedness directly. Though resource accumulation increases, DP is still falling at the same period.

In another instance, the fall in CPRU (figure G10) could be in response to the lapses that usually follow the introduction of new technology to a system. It takes a certain period of time for the system to learn and adjust before the output begins to pick up. Resource usage flattens when every resource had adapted well enough, operation is in full session, and also when resource demand equals supply. System would have studied itself and all resources are being used appropriately. Additionally, resources need to be gathered, whereas information flow does not get through to targets immediately. It may also take some time to accumulate resources well enough in order to be able to perform (respond to) a particular operation. It seems that these can explain (to some extent) the dynamics in the trajectory of resource usage (CPRU) as depicted in figure G4, G5 and G10 as well as the other graphs relating to DP in the G models.

Resilient Port Logistics

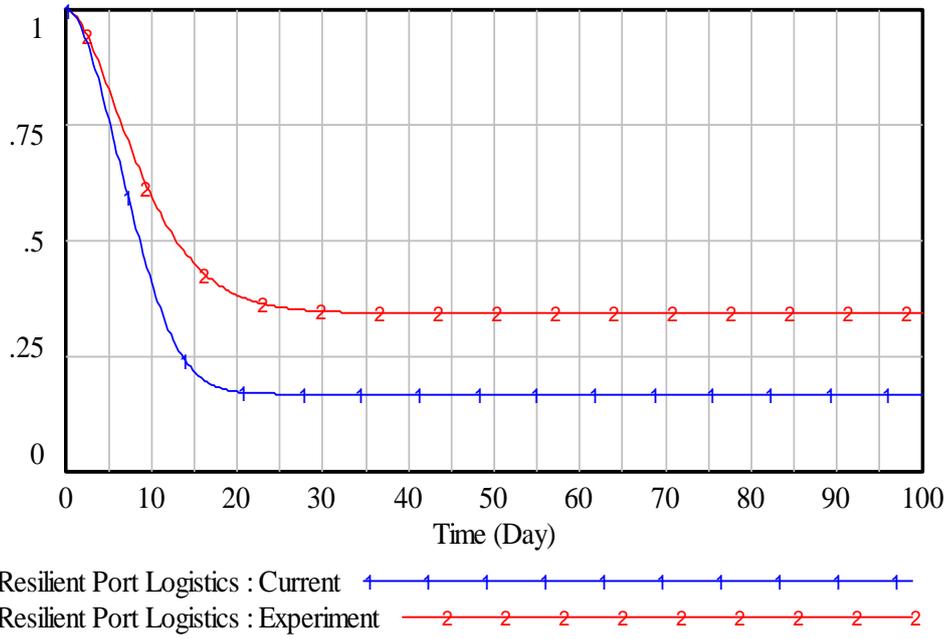


Figure G13: Real time change in DP as technology increased

Decrease in Resilient Port Logistics

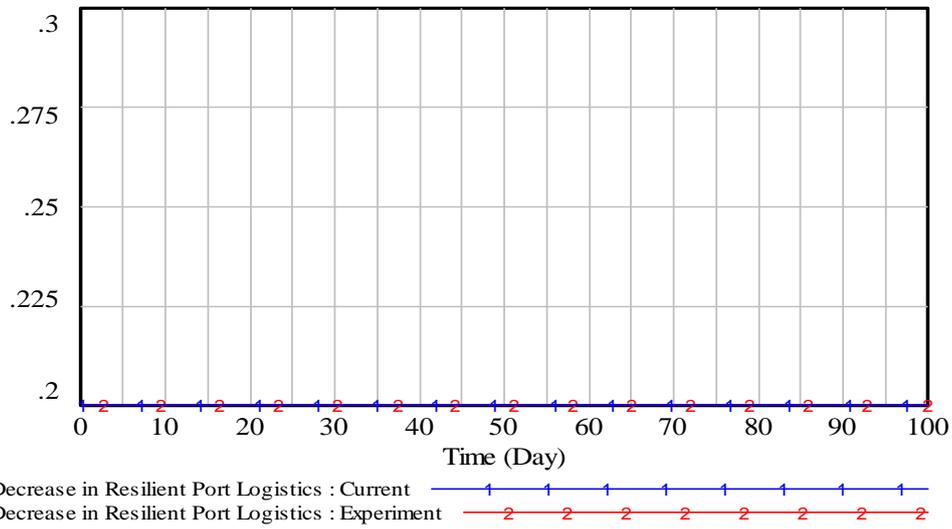


Figure G14: Real time change in DRPL as technology increased

The trajectory for CPRU follows the explanation as in figure G10. We note that the same CPRU is the inflow for RPL. Another significant observation is that DRPL is

constant and does not change (within the research time frame) whether technology capacity increase or not (figure G14).

The trajectories of the above graphs (figure G12 - G14) suggest that technology capacity improvement may actually improve resource supply and efficient usage before/during crisis management which can also lead to building sustainable “bouncebackability” or recovery of port/maritime logistics operations from systemic disruptions faster than it would have been. This phenomenon is confirmed by the use tree diagram in figure G3i which clearly shows the link between CPRU, DP and RPL. However figure G14 above suggests that DRPL may not have significant influence on RPL but CPRU does.

The third factor we considered is the PEI. Building from figure G6, we can observe that the trajectories of the set of graphs (figure G15) show the impacts that increase (improvement) in technology capacity at the port/maritime logistics industry can have on the dynamics of systemic PEI, its flow and the factors that are directly linked to the flow. We can observe that an increase in technology places the trajectory of PEI₂ above PEI₁, RCI₂ and line 2 of Port Activities have also rose above the current levels (figure G15 – G18).

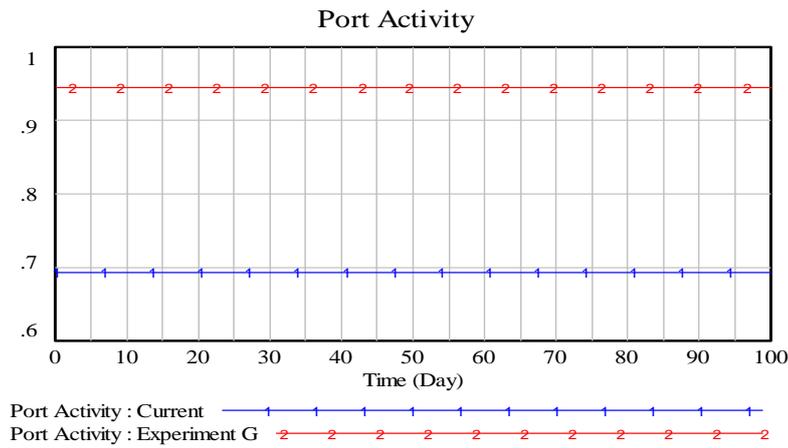


Figure G18: Real time change in port activities as technology increased

Furthermore, the graphs in figure G18 show that port/maritime logistics activities will increase higher and above what it used to be as a result of technology improvement. This relationship seem to suggest that change in technology can cause change in port activity which can further influence the logistics network’s vulnerability to disruptions such that it may lead to decline in resilience in a continuous cycle.

The interactions in these variables appear to have pulled the trajectory of resilience downwards followed by flattening. In all cases compared, the test/experimental graph (line 2) laid above the initial/current condition (line 1) which suggests that improvement in technology capacity can indeed improve conditions in all element that influence resilience. Even though RPL_2 falls, it reaches a turning point higher than RPL_1 according to the trajectories of the curves in figure G13. One can also explain that the decline in DP (figure G9) plus the rise in PEI (figure G16) had a significant influence on the RPL (figure G13), as such that could be one of the main causes of the observable behaviour of RPL.

Effects of technology decrease on the logistics network

The trajectories of the set of graphs (figure G19 – G28) represent the real time change in RPL as technology decreases over a 100 day period. All curves exhibit the shapes, flows (exponential increase or decline structure) and relationships as explained under figure G10. However, we observe that curves produced from experiment declined faster and are placed below the current conditions. We can observe some random (erratic or unstable) behaviour in the experimental conditions when technology capacity is reduced. For example in figure (G20 – G25) all line2 lie below line1.

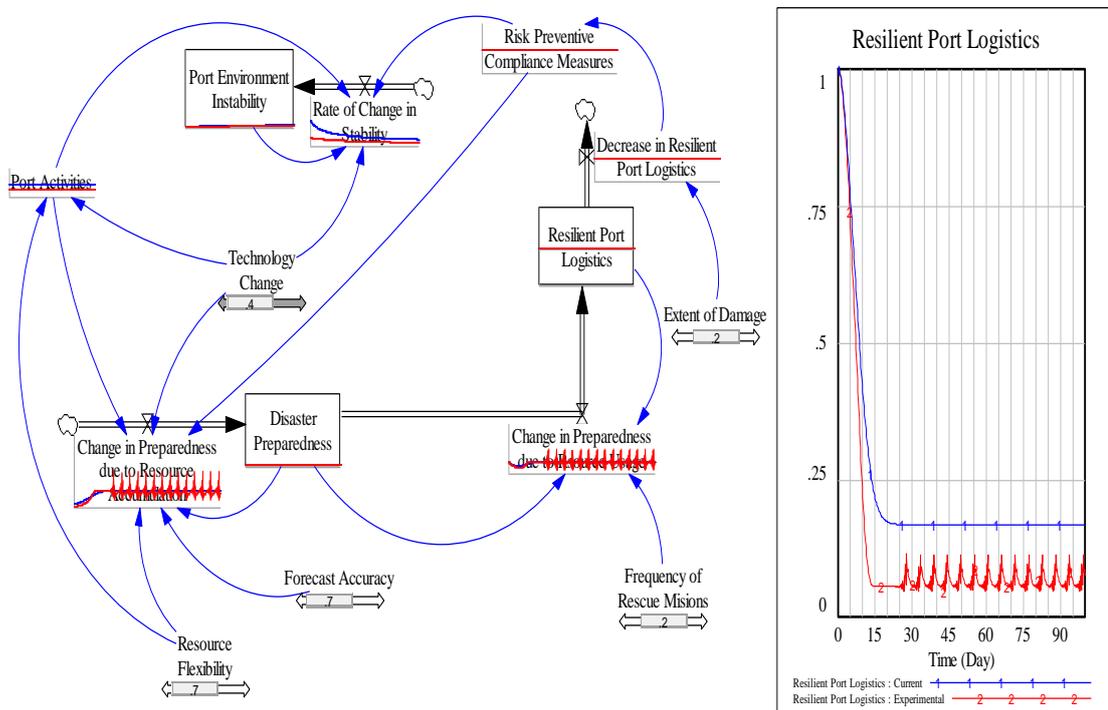


Figure G19: The conceptual model of general structure and the corresponding dynamic graph in response to decrease in technology as policy requirement

Change in Preparedness due to Resource Accumulation

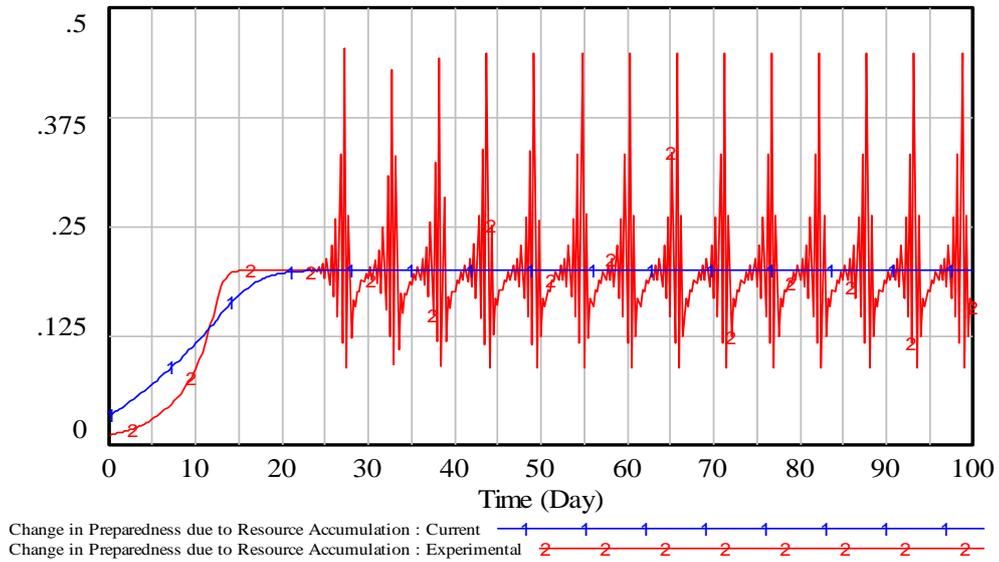


Figure G22: Real time change in CRPA when technology capacity decreased

Change in Preparedness due to Rsource Usage

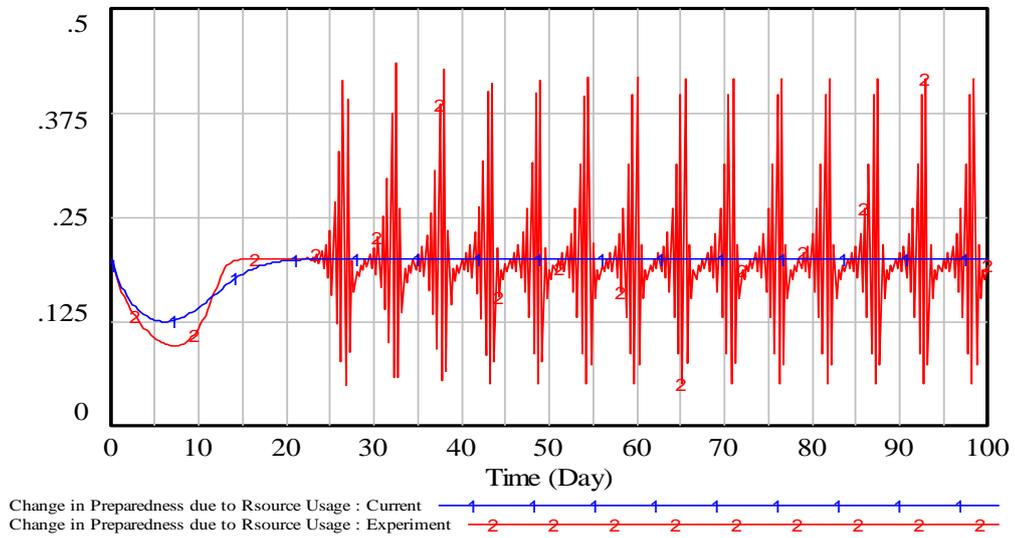


Figure G23: Real time change in CPRU when technology capacity decreased

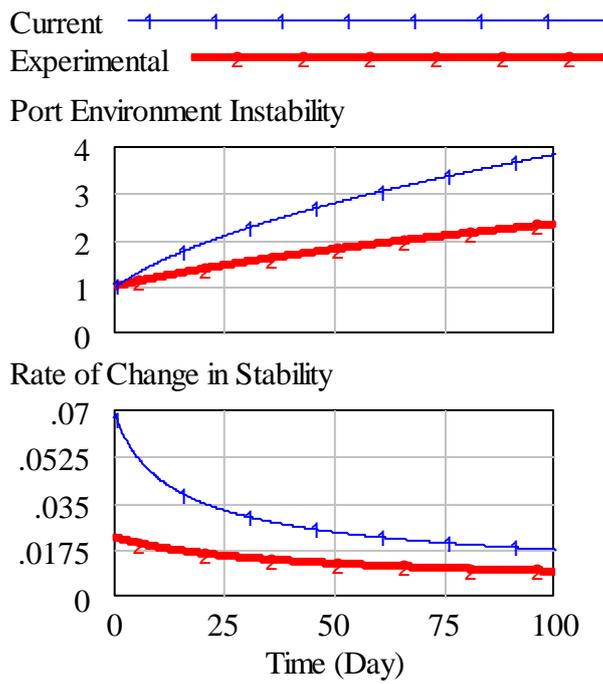


Figure G26: The real time change in PEI and RCI over 100 day in response to decrease in technology capacity of the logistics chain

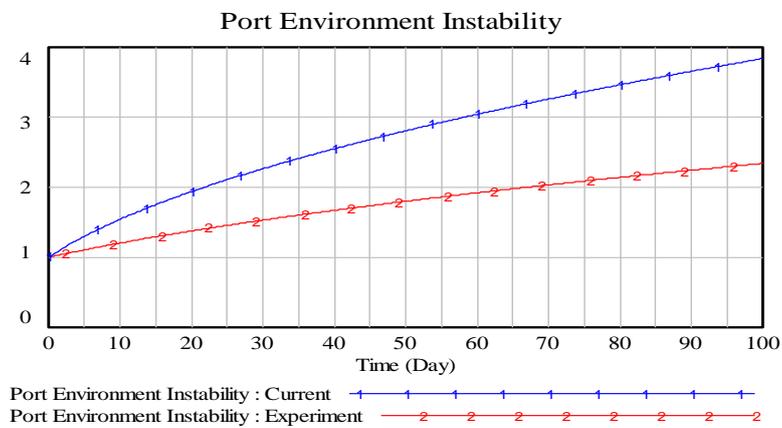


Figure G27: Real time change in PEI when technology capacity decreased

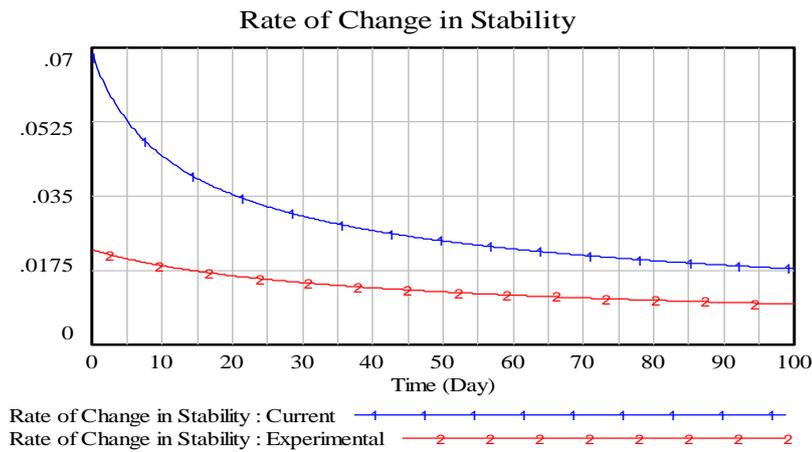


Figure G28: Real time change in RCI when technology capacity decreased

Though PEI_2 and RCI_2 were below current levels showing an improvement in the logistics network, $CPRU_2$ became erratic (random) perhaps due to irregular resource supply as a result of lack of requisite technology. This behaviour also seems to confirm that preparedness has very significant influence on resilience of logistics network since $CPRU$ depends significantly on levels of DP . Furthermore when technological capability is reduced, one will observe that the trajectory of RPL_2 falls and lies below RPL_1 . The behaviour of RPL_2 mimics $CPRU_2$ (also became erratic or random) as technology capacity is reduced further. Apparently, because resource usage (supply of necessary resources for sustenance of operation) becomes unpredictable, it reflects in the behaviour of RPL_2 as well. One can explain that such situations have the potential to make mitigation plans, response, and recovery from disruptions very difficult, or probably impossible.

The graphs of $DRPL$ (figure G24) seem to be stable and unchanged because it is being influenced mainly by a constant (extent of damage). From the causal tree diagram (figure G2c), resource usage is directly influenced by level of preparedness, level of

resilience, and the frequency of resource usage for rescue missions. If DPRU is not stable, it could be an indication that DP is low which also implies apparently that CPRA is also low or not stable. Under such conditions, if the frequency of rescue mission is high, that can also influence resource usage to behave the way it did as in the above curves leading to a very unstable port/maritime logistics network.

Response of the logistics network to general policy change when all variables increased

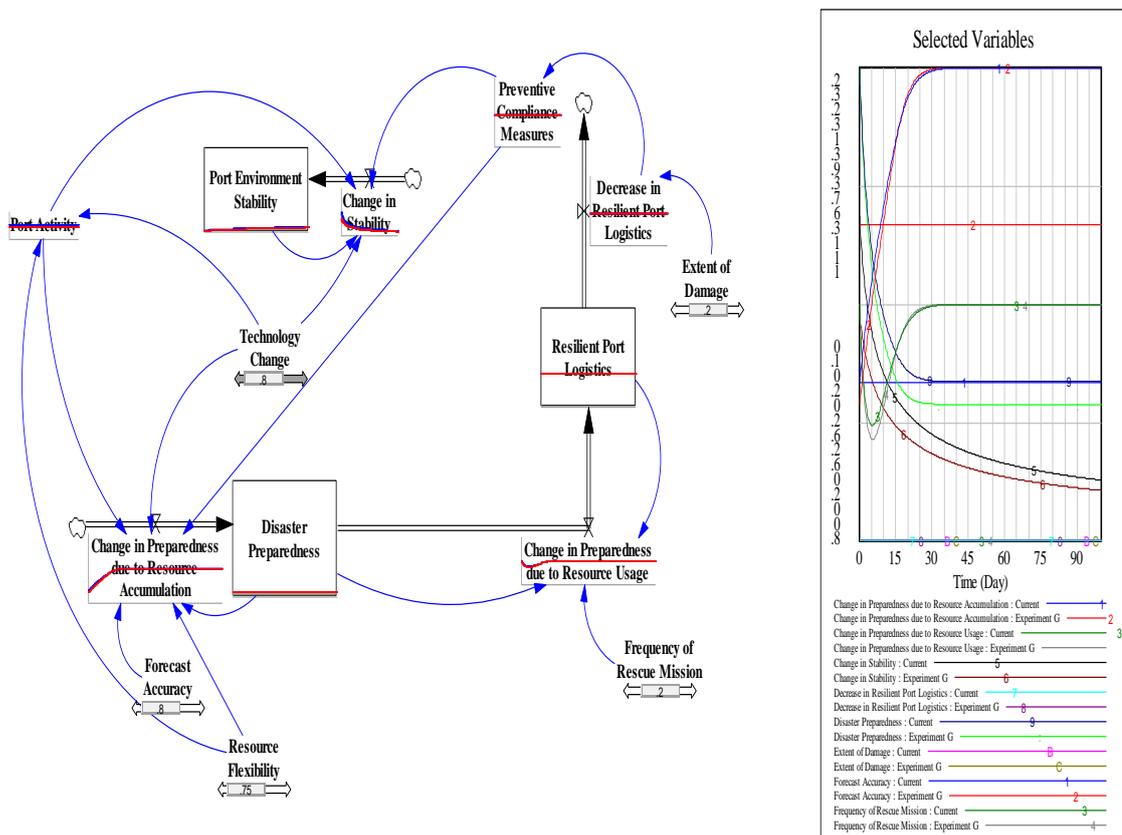


Figure G 29: A summary of the conceptual models and the corresponding dynamics as policy changes

The stock/flow diagram and the corresponding graphs in figure G29 is a summary of what has been explained in the various subsystems in the preceding sections. It represents the real-time change in RPL when policy requires that all variables change contemporaneously. We argue that resilience seem to be influenced by changes in the level of environment instability and the preparedness of the port/maritime logistics system towards a particular disruption incident. The more unstable the environment becomes, the more unable it will be for the logistics chain to respond to disruptions, and even the more difficult it will become for the system to bounce back from disruptions if they occur.

The structure (figure G29) tests the general influence relationships (or interactions, or interdependencies) between DP, PEI, and RPL. It seems the graphs mimic the real world situation where entity's ability to responds to emergency (as well as the ability to bounce back from disruptions) appears to be largely dependent on the location effects, subordinated by how prepared the entity is.

The nature of the graphs in the general model (figure G29) seem to have revealed the research philosophy that *'the level of disaster preparedness and the subsequent resilience of a logistics chain is contingent on the size and physics of the logistics network'*. For example, by the nature of the location effects of a port, the authority may recommend high redundancy (hold inventory of essential resources), or take some preparedness (risk prevention) measures as an attempt to overcome the impacts of some anticipated hazards. Such inventory which may sometimes include dangerous and obsolete materials may rather make the environment more hazardous for operation. Specifically ports rely on hard engineering (e.g. constructing concrete, hard

surfaces, floor walls, and all-weather facilities) as flood preventive measures in their quest to dominate the difficult terrain. However, such constructions and extensions can lead to land reclamation/squeezing which may result in floods, and/or disruptions in the natural ecological processes at the port's immediate environs, or even far away from where the construction took place. Generally the construction of massive structures such as the port, have the potential to cause 'spatial dimensional effect' and 'temporal dimensional effect' such as the illustration in the case regarding the proposed expansion of the port of Rotterdam (seaward) by about 1000 hectare (see Klink and Klink, 1995). A case specific illustration was narrated about the extensions of some terminal at the port of Immingham:

“.....the spatial dimension refers to the expected effects of a project at one end of a region/country on the other end of another region/country and possibly that part of the continent.....the temporal dimension speaks about the expected life-span of a projectwell, if the port is going to be there, you got to think of probably 100 year time scale or something more [most projects currently target 50-80year time scale]. Now I guess Immingham has been there for more than 100years and I can't see why it won't be there for another 100years. So the temporal and spatial extent is becoming a big problem after the extension/reconstruction of the terminals at the port of Immingham” (CS2).

The above result arguably suggest that in order to attain port resilience, management need to stabilise the environment by adopting good environmental management policy interventions and also ensure change compliance. Perhaps PEI can be controlled if factors that can influence the RCI are not allowed to escalate. In that case the logistics network can be made or can become more sustainable.

The description of the structure above fit into the current policy change (intervention) in the European port/maritime industry; particularly those directives that deal with River usage, and environment/pollution control regimes such as the MARPOL conventions (Wright, 1999) that are being promulgated and enforced at major sea ports

the world over. Other policies in the Humber Estuary include: environmental impact assessment (EIA); NATURA 2000; Habitat and Species Directive; Wild Birds Directive; the Appropriate Assessment (AP); Marine Strategy Directive; Integrated Pollution Prevention Control (IPPC); Flood Management Control Directive; to mention just a few. It seems that most of these preventive measures in the HE are supervised by the TIDE project. According to some interview respondents with regards to EU policy and the risk preventive compliance measures:

“...The EIA is done based on the European directive or European laws set up in Brussels to be implemented by all EU member states. In the UK the EIA Directive is implemented by the National Regulation Orders. Apart from the EIA we also have the Harbour Empowerment Order which requires that if anyone is going to build a harbour, or going to extend the port facility, certain requirements must be met. The EIA sets out what you need to do, the information you need, in order for things to get done the right way. This is linked to the Coastal Protection Act, which also outlined what the investor must do in order to minimise the problems that the activity to be carried out can generate in the environment. These are some of the measures that have been put in place to try to control the impact of port activity on the environment...” (CS2).

“... The import of the directives is that there is a law which says that if any of your activities is going to affect anything for which a site has been designated, then an Appropriate Assessment (AP) must be done to ensure that the activity will not affect the environment in any negative way. If it will do, then enough mitigation, or compensation for the damage must be put in place, including the creation of new ecological sites and wetlands to accommodate the displaced population and the land that can be lost elsewhere...” (CS2).

It appears that when the above regulations/directives are adhered to by all stakeholders, the growth and impacts of PEI on the port logistics network may reduce due to a decline in RCI. This can potentially cause DP to influence the trajectory of RPL to rise instead of the current decline.

4.12 Summary and discussion of the simulation results

This section summarises the analysis done under the quantitative simulation techniques. The interview protocol has been vividly narrated (section 4.5). From the purposely designed conceptual diagram we presented to the respondents, opinions were extracted from their mental database to explain the research problem. Simulations were run to elucidate the impact of the influence relationships between environment instability, disaster preparedness, and resilient port logistics.

Steps in the Grounded Theorists methodological philosophy (iterative data collection leading to possible theory building) required that the investigator involved problem owners till model yields satisfactory results. However, we chose the “one-off interview” approach because of the limited time to complete the studies. Apart from time factor, it may not be convenient to both the investigator and the problem owners to continually interrupt with the busy work schedules of the respondents (CROs) who were involved in the data collection for that lengthy period (approximately 8months) of data collection, model building, and analysis. Furthermore we envisaged that future continuous access to some of the companies’ premises will be difficult obviously for security reasons. However we do not believe that these can affect the results in any significant way because we filled those gaps we identified in the interview data with literature search. The “one-off interview” approach has been employed by MacLean and Behnam (2010) to study the dangers of decoupling organisational compliance program from the core business activities of a large financial services firm, and also by Dacin et al (2010) to examine the role of rituals on institutional maintenance in the University of Cambridge. The data was processed (sections 4.5), structures were

designed from raw data, and then simulation runs (sensitivity analyses or extreme condition tests) were performed to analyse model behaviour over a 100 day (similar approach can be found in Sterman 2000, pp. 585-595). Next, we tested for model behaviour following Forrester and Senge (1980). In spite of these few constraints, we found a high level of agreement in the connection (nonlinear relationships) between most of the variables we analysed in the models.

We selected this approach based on Randers's (1980) strong support for the use of qualitative data in SD model building. Randers states that:

“[...] the modeller should not restrict himself to the small fraction of knowledge available in numerical form that is fit for statistical analysis. Most human knowledge takes a descriptive non-quantitative form, and is contained in the experience of those familiar with the system, in documentation of current conditions, in description of historical performance, and artefacts of the system. Model testing should draw upon all sources of available knowledge”, (Randers, 1980, p.129).

Guided by the above sources of data leading to model building and testing, the next step was to avoid methodological criticisms (Legasto, 1980; Forrester et al., 1974; Nordhaus, 1973). Hence we subjected the prototype model and interview questions to thorough review for verification⁵³ and validation⁵⁴ by experts [i.e. experienced researchers in SD, Operations Research (OR), and practitioners in port/maritime logistics operators]. The essence of these reviews was to help the research to ascertain whether the assumptions made (through the interactions at CILT meetings, seminars,

⁵³ This refers to model comparability with the real world system. The model represent the mental database of the CROs and the academia we interviewed at the field. We therefore assumed that their narrations may be picturesque prototype of the real world.

⁵⁴ Implying the logical consistency of model's internal structure. We gained this by presenting models to an authority in OR and one of the originators of the SD model for critique.

conferences, coupled with a thorough literature search prior to the field interviews), describe the actual relationship in the industry and also to gain model acceptance. The verification by experts (experienced people in the field) also ascertained rigor in the model structure.

In summary, we carried out the tests in order to ensure that the basic mechanisms assumed, actually created the reference mode, and also to ascertain if the relationships among variables that we assumed were really reasonable. It seems that this approach can solve the biases that might originate from the researcher as a result of ill-posed model. For example we faced problem running the general model initially even though the Vensim software tells us that the model was “ok”. It took the scrutiny by an expert in OR and a further advice by a guru in SD (Emeritus Prof George Richardson) to cause the simulation process to run. Specifically they advised that some variables be deleted in order to make the model simple and its analysis a bit manageable. When that was done we were able to run the model successfully. However, we note that these few alterations did not affect the main ideas as we got from the interview. They only enhanced a successful running of the simulation processes.

As explained earlier, we presented a specific piece of model structure (Luna-Reyes & Anderson, 2003; Rich, 2002) to interview respondents (or problem owners) and figure 4 was built from the mental database. The diagram challenged each respondent to suggest the theories and possible counter theories underlying the model structure. For example, respondents state which variable in a matching pair is the potential cause and the other an effect of a relationship. See detail of this protocol under methodology (section 3.5) and in appendix A #7 of this document. We also provided a ‘5 point

Likert scale', as part of item #7, for the respondents to indicate the strength, direction, and possible polarity of the perceived causal relationships between variables. Unfortunately the 'Likert' questions were poorly attempted by the respondents during the dialogues. Majority of the respondents focused their attention on the main items explaining the interdependencies in variables and their expected behaviour instead of filling the Likert responses. Arguably, this may be seen as one of the weaknesses of the approach of data collection methodology (elite interview) that this research selected.

It seems the model gained acceptance by the elites (CROs) as it mimicked the real world in port/maritime risk management, judging from the feedback and enthusiasm with which respondents discussed the diagram. Nonetheless a small number of the respondents did not understand exactly what the structure (figure 4) stands for and its relationship with emergency/crisis management in the port/maritime logistics systems, particularly in relation with their functional enterprise which they represent. For example, when the investigator asked this follow up question: WHAT CAN YOU SAY ABOUT THE DIAGRAM UNDER #7? CS6 says:

“Yea it is a good one but ehh..... it is a little bit difficult and [quite] technical. But I think everything is affecting the others correct”.

The above constraint by which not all respondents understood the structure of a concept in SD modelling has been acknowledged in Vennix (1996). However the issues about the strength, direction, and polarity of the causal relationships between research variables were implicitly or explicitly addressed elsewhere during the interview proceedings which make our approach very consistent with guidelines in chapter 6 of Vennix (1996).

The above steps were taken by the research so that we will be enabled to build CLM (such as in figure 10, or 11) from the mental database (transcribed textual data) of the respondents. The importance of the approach is that it helped the research to extract key issues that confront the respondents from which the dynamic structural behaviour of key variables could be determined such that it can promote policy change without possible interruption and resistance (by the investors and other stakeholders) to the potential changes that might occur in the maritime logistics system. It seems that by understanding the causes of disruptions in the industry, specific insightful policies can be generated through debates/discussions among team members such that it may lead to improved port/maritime logistics system's operations.

Arguably, there can be no causal simulation model that contains entirely all the known and empirically verified relationships (Moffat, 1983). The art of simulation itself is a means to highlight on, or to give insight to causal relationships which have not yet been subjected to further research and empirical testing. According to Forrester (1958; 1961) and Senge (1979) an SD model can be validated by testing the 'extreme conditions'. Such a test can check whether the model still behaved normally or otherwise when extreme values such as zero, (0) or infinity (Lee, 2006) are inputted for numerical analysis. Model test as implied in this research consist of imaginary minimum and maximum values of interconnected variables which were deemed to have the potential to influence the rates which can bring change in the structural behaviour of the state variables in a causal loop. By these tests we were able to scrutinise the model behaviour under 'extreme conditions' as well as able to explore

the usefulness of policy interventions beyond the historical range of behaviour (Forrester and Senge, 1980).

The Input/Output structure that was derived from 'Vensim work bench' attached some micro-levels (adjustable scales) to the constants and parameters, the values of which can be varied to enable one to observe the behaviour of the stock over a specified time period. In order to verify the accumulated variables at any time (t), we take each micro-level (as indicated at each of the constants) in turns and observe what happens if we moved the levels slightly to the left (decrease) or to the right (increase) on the scale (testing the extremities) which appears to be parallel to performing a "sensitivity analysis".

Starting from 'Disaster Preparedness (DP)', through 'Port Environment Instability (PEI)' to 'Resilient Port Logistics (RPL)', we tested the 'extreme conditions' for each sub-system for validity. The structure of the General (G) model is a merger of all three sub-systems into one giant structure so that one can analyse and validate the interdependencies in PEI, DP, and RPL based on the 'extreme conditions test'.

The main objectives of the simulations is to mimic the effects of mitigation interventions (or policy decisions) prior to policy implementation and the occurrence of disruptions in port/maritime logistics system. Therefore we assume that the test results represent the possible outcomes that can result when these variables are incorporated into each of the sub-systems.

4.12.1 Scenario-based modelling framework for the sub-systems

The scenarios that were analysed represent the interrelationships among the various variables. Few auxiliary variables were arbitrarily considered vis-à-vis their influence on each of the sub-systems over the 100 day period. The input data that represents each sub-system was presented in the respective documentary analysis. The equations and constraints under the documentary analysis was followed by few simulation runs, to enable the research to observe the behavioural change (or deviation) in the trajectories of the curves produced for each of the sub-systems (i.e. DP, PEI, RPL) as a response to policy changes. In all the graphs, line1 represents the initial condition and line2 is the experimental graph whose behaviour is compared with the initial outcome.

The trajectories of the set of curves produced by the “extreme condition tests” suggest nonlinearity between each pair of variables tested as well as with others in the system. Furthermore, flow of the curves apparently exhibit either growth (rise), or decline in the sub-system that they stood for, within the 100 days period examined. There could be many other factors that can cause the dynamic behaviour (increase, or decrease) in the stock (DP, PEI, and RPL) levels. However the nonlinear dynamic behaviour of the graphs could be explained using the functionalism theory (Parson, 1903 – 1979) and/or the structuration theory (Giddens, 1979). These theories acknowledge that society (organisation) is complex and must fulfil its four basic functional prerequisites – adaptation, goal attainment, integration, and pattern maintenance. Any attempt to maintain an equilibrium may produce certain unintended results that can yield a more (or less) than proportionate outcome. Hence the nonlinear (exponential) trajectories of the graphs. A rising graph suggests an improvement in the phenomenon being

measured except the graph for PEI in which a decline is preferable. A rising trajectory of PEI implies that the environment is becoming more unstable and may lead to increasing frequency, or magnitude of risks, or disruptions in the logistics network.

Such interdependencies between factors result in causal links between the various variables in the sub-systems as well as the entire port/maritime logistics network. Understanding these systemic interrelations among factors can motivate management to develop possible alternatives that have the potential to help them to ameliorate crisis situations. It appears that if stakeholders can learn from the resultant behaviour of the models due to the influence by the alternative interventions, it can lead to systemic adjustments that may result in sustainable logistics operations.

The interviews as well as the simulation results show that all the endogenous variables that we have considered indeed affect the behaviour of each of the sub-systems (stocks) in various ways. Particularly, “Forecast Accuracy”, “Technology Change”, “Port Activities”, and “Risk Compliance Measures”, seem to have significant influence on the behaviour of each of the sub-systems as indicated by the nature of the graphs generated from the sensitivity analysis (or the extremity condition tests). From the insight gained about the potential causes of disruptions in port/maritime logistics network, management can understand better the consequences of the chosen policy interventions. Subsequently, this can influence how management plan to implement policy changes such that it may lead to a holistic and sustainable disaster management plan implementation in maritime logistics chain.

Chapter Five: Research Findings and Discussions

We dedicated this chapter to the reporting of our general findings resulting from the application of the various research designs as described in chapter 3, followed by the practical applications as explained in chapter 4. Summary of the findings were put into part A and part B as below.

5. Section A

This part discusses the question by question findings from interview respondents, starting from item one to item six (i.e. #1- #6). Each question seems to address a specific theme based on the research problems in relation to the research aim and objectives. However, the reader may find some themes cutting across some questions.

(#1) Findings and Discussions from the general question

#1 of section A investigates the general risks (hazards) that have been identified in the HE (through risk assessment), and how such risks are currently being managed. Figure (12) below is a summary of some of the potential risks/hazards that the respondents identified. Readers may be familiar with some of the risks/hazards on the menu in relative contexts, in extant literatures on port/maritime logistics. We have categorised the risks/hazards into natural and anthropogenic risks as represented in the diagram. Those that may be difficult to fit well into these two major categorisation as pertains in most literature were put in the oval between the two extremes of the risk continuum. Elsewhere, those risks/hazards that can neither be classified as natural nor

anthropogenic have been classified as hybrid risks/hazards. Such risks/hazards appear as natural (or anthropogenic) but which were remotely caused by human (or natural) activities. One such common hybrid hazard/risk is the phenomenal global warming and its harmful effects such as flooding, draught, hurricane, and others.

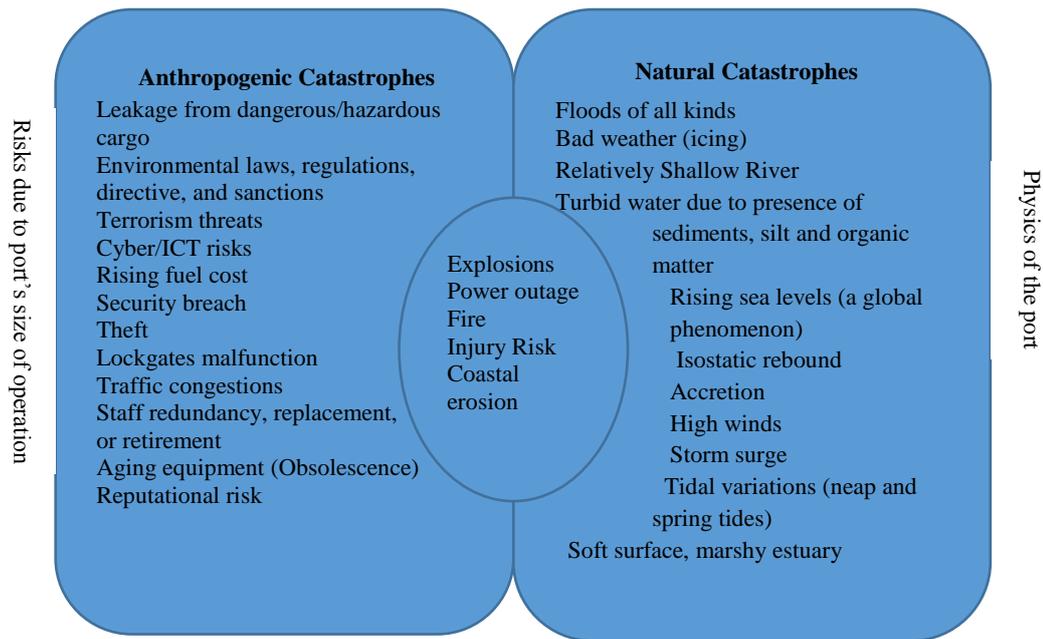


Figure 12: Some risk/hazards categorisation according their perceived source/course source

Elsewhere this classification can fall under human induced (or anthropogenic) catastrophes and natural catastrophes. Other researchers might classify the same risks/hazards in different ways to suit their own research contexts.

The above risk list suggests that logistics activities in the HE appear not be as smooth as an outsider to the port industry might imagine. There are a few potentially identifiable risks/hazards in the region which have manifest in the various incidents as

per the narration by respondents, some of which we quote verbatim in the discourse that follow. For example, CS7 acknowledges that:

“...This [port/maritime logistics industry] is a high risk industry: the plants [equipment] we work with, the people we work with, the site on which we work can be a risk or a source of risk...Perhaps the consequence of an event happening is the temporal interruptions we suffer in our operation....”

This research examines the “actuals”, by reflecting on the twin impact of port vs environment relationships vis-à-vis the location effect. Location effects can fall under:

- a. Size of operation (port capacity, number of vessels, vessel/cargo type, call rate, etc.)
- b. Port Physics (or the physical characteristics of the port or the maritime logistics industry in the HE), including such characters as: a relatively shallow estuary, turbid water that is full of suspended particles (biotic and abiotic particles), silt levels that results in constant re-demarcation of navigation course, rate of coastal erosion, flood history, and rate of sand-muck formation. The region also experiences simultaneous effect of sinking coastline and isostatic rebound. The cumulative effect is that we have an apparently stable region, yet not all vessel types can call at the ports at all times.

It emerged from the interviews that the port affects the natural environment and the environment also affects the port to create hazards in the logistics chain. Hence, CS2 sums it all by stating that: *“The port is risk to the natural environment, and the environment is also a risk to the port”*. Knowing this interrelationship can enhance management’s preparedness for disruptions and subsequently the sustenance of the

logistics network even under difficult conditions. After the respondents have identified risks/hazards as listed in figure 12, the investigation then focused on some contemporary issues including the current levels of disaster preparedness at the ports on the HE.

i) Investigating “Who/What can be affected” by an event in the HE

Respondents narrate several incidents that have caused disruptions in port operations (in the HE) in the recent past. The incidents ranged from strikes (industrial actions), ICT failure, accidents and injuries on site, icing, dangerous/hazardous cargo leakages, emissions, tidal, and so on. Whatever the source of risk/hazard (as in figure 12) that led to a disruption in the logistics chain, all the respondents (overtly or covertly) agreed that the following can be affected in one way or the other if a disaster occurred in the facility:

- The **people** including: customers, employees, visitors on site (tourists), communities which share boundaries with the port, and other users of port facilities at the time of an incident.
- The **environment** including: port facility and its immediate surrounding such as the water ways, and organisms in the water, birds, worms, and plants that define the port’s ecosystem. These could encompass the biotic (living) and abiotic (non-living) elements that affect or can be affected by the port and its activities.
- **The assets** such as essential handling and communication equipment, vessels, roads, rails and other physical infrastructural resources

- The **reputation** and other intangible assets of the ports, and its functional enterprises which can result from the system's failure to meet standards and the customer's expectations.

The CROs know these by the acronym '**PEAR**'.

To further expatiate the ripple effects that some incidents can have on the entire port industry, CS5 painted the following picture:

“...If we have bad weather, vessels will be littered all over the place and cannot dock; if the lockgates fail, we cannot get vessels into or out of port; if there is strike, we will not be able to make or take our deliveries; heavy rains or other floods (e.g. from bad roof, burst sewage pipes, and gutters) can get some cargo washed away, drenched, or damaged....” (CS5).

There is suggestion (from the above scenario) that one incident can result in a series of other disruptions across the port/maritime logistics chain.

ii) The expected Duration of incident

Concerning the duration when an event will begin to show its full effects on the port/maritime logistics chain, the respondents unanimously agreed that duration is 'event dependent' as well as the criticality of the affected resource. For example most respondents cited the 2005/06 strike action, they stated that it took about four to five weeks for paper producing companies in England [whose supply comes from Finland] to start experiencing major disruptions in production of paper products. CS5 (agency) notes that, perhaps this was because the strike occurred during an off peak season. Otherwise the impact of the disruption would have been felt within the first two or three weeks' of the strike action. On the other hand, CS3 (a manufacturer) adds that the duration for which the effects of a disruption in the port/maritime logistics can

affect the operations of their company is ‘product market dependent’. For highly demanded products, particularly food products and industrial raw materials, CS3 says that the effects could be felt within a day (24 hours). For other products it will take a week, for others it could take up to a month or a couple of months for the effects of the disruptions to be felt. In the opinion of CS6 (a transporter), the duration can depend on the strategy used to combat an incident and the location where the event had taken place. However CS7 appears to differ slightly by suggesting that sometimes the duration also depends on the experience of the site manager at the time of event. On the average, the respondents estimate between twelve (12) hours and two months for effects of an incident to cause major disruption at the port/maritime logistics network. Therefore it emerged from the respondents that the duration for which the effects of disruption can affect major port/maritime logistics functions depend on many factors and not just one.

iii) Critical Infrastructure

The investigator wanted to know ‘what infrastructure is critical’ to the functioning of port/maritime logistics industry. The respondents listed some of the critical infrastructure/services including: ICT system, power supply system, lockgate, Jetties, pipelines [for fuel, water, and waste], vessels, essential equipment like cranes, and labour (*human*) resources. The list is actually non-exhaustive and is contingent on the core business of the functional enterprise whose CRO was involved in the data collection process. For example, freight forwarding agencies rated ICT system as very critical to their operations, whereas port operators think that the jetties and the essential

handling equipment (e.g. the cranes and trucks) are rather more critical. On the other hand, transporters labelled vessels as the infrastructure that must function at all cost for their business to keep running. Therefore it seems the critical infrastructure depends on the core business of the functional enterprise whose representative was interviewed.

Next, the investigator discussed the ‘recoverability of critical infrastructure’ in case a disaster/disruption emanates from one of the risks (hazards) prevalent in the HE. This portion was overlooked (or ignored) by majority of the respondents. In the opinion of CS6, the question was too difficult. However, according to CS3 (manufacturer), almost every critical plant and equipment in their establishment is recoverable. CS3 argues that:

“...We create reserves for all the essential parts [this seems to re-echo the concept of necessary redundancy]. It enables us to switch on to the reserve facility until maintenance work is complete on a substantive plant. Everything we use here that is critical to our operations has some reserve or spare (plant or equipment) part for which we can fall on for the running of our business. So if one fails, we switch on to the back-up until maintenance is done on the failed section and then we switch back to continue with our normal operations. Therefore for our part, we can say that everything is perhaps recoverable if anything happens today....”

iv) Cost of an incident

The investigator further asked about ‘Cost estimates’ if an incident should happen.

It seems that the cost of a disruption can also be event dependent. However for research purposes, we have categorised the cost of an event happening into: human cost, capital cost, environmental cost, and others (or the opportunity cost).

a) Human cost

For instance in CS7’s narration, the human cost is obviously the death or injuries that

may occur during an accident. Sometimes an incident can lead to loss of a very valuable skilled personality. Some human related costs may involve the psycho-emotional effects that an incident can have on the enterprise.

Perhaps in a kind of self-defence, CS3 believes that their company does not anticipate any human costs if an event happens in their facility today. Rather, CS3 argues that:

“...if there is disruption such that we cannot produce or export our products, we can lose several billion pounds worth of business. The cost to be incurred is mostly commercial in nature.... We have high safety standards and we observe them strictly. So I do not anticipate human cost. Nonetheless, there can be opportunity cost to be incurred in terms of reputation. BP’s 2010 platform disaster in the Gulf of Mexico (USA) has taught us all (companies) a lesson and has made us to remain alert at all times so that we can lift up and preserve our image/reputation....”

However, it seems that opinions might differ if all respondents had answered that question. [We expected that the respondent will talk about probable loss of life or costs associated with evacuation and relocation of employees and communities that live within certain radius off the site, where the impact of an accident can be felt, to safe place until things settle down. But the extract above is the opinion of that respondent].

b) Capital cost

Capital in business terms includes investment, physical infrastructure, or the equipment that can enhance business operations. These can be destroyed, damaged, or lost to a disaster and will have to be replaced after an event had occurred. This can have dire consequences on business operations, some of which may include suspension of some important port logistics functions till alternative solutions have been found.

c) Potential environmental cost

By implication, CS2 identified the cost of an event to be the stable and pollution-free environment that the region and its occupants have to sacrifice for a turbulent one. The Humber Estuary is an international designated site for large population of different species (including birds, worms, fishes, water, plants as well as a rising human population). Therefore any activity or an event that can affect anything which the area is designated for as well as human comfort can be a cost to the environment. Majority of the respondents seem to support this assertion. Therefore:

“...the EIA has worked out a proposition that something in the region of 1% - 3% of the cost of an activity must be set aside to go into the environmental assessment for that project. The ports may argue about it being too high, politicians may criticise the cost involved, but that is what they have to do if we think of environmental sustainability” (CS2).

Although there has not been an exact figure mentioned here, it seems the environmental cost can be calculated based on the value of the EIA set-aside cost as CS2 mentioned here.

d) What is the opportunity cost?

The opportunity costs varies, depending whether one looks at it from the point of business, or from the point of environmental activist. Whereas the environmental group may list the opportunity costs to include the sacrifice of current relatively stable (HE) environment to such phenomena as the extinction or endanger of certain species, global warming, destabilised ecosystem and upsurge in natural catastrophes, the business advocates may mention loss of customers due to persistent customer dissatisfaction, frequent cancellation of bookings, and possible relocation of business to other ports as the opportunities to be forgone if a catastrophe happens. Other

opportunity costs can be expressed in terms of major customer suspending, or boycotting business with the port facility.

v) Precautions taken against disruptions in the logistics chain

This section investigates the preparations that have been put in place against potential event happening. Evidence seem to suggest that all the CROs involved in the data collection believed in preparedness and indeed have put a number of precautions in place in anticipation of most commonly occurring disruptions in the logistics system. Some of these precautions include: the proper documentation of all events and port activities; the provision of necessary redundancy (e.g. standby equipment, spare parts for critical part/plant on site and personnel training); observance of high standards, and maintenance of organisational culture. Some of the companies have independent inspectorate team to advise them; others have established reliable ICT infrastructure, and good intra/extra communication network. Below are some of the extracts relative to the above sub-theme:

“...We are having IT infrastructure (authentic backup) that allows everything we do to be replicated and saved off site outside our premises. So if one site goes down we can work from other sites by just switching sites or retrieve the lost information. We can decamp and operate from various locations within the port facility at a very short notice. At worst, we can do manual processing of our day’s transactions. However we cannot operate manually for more than 24 hours, because of the large volume of work that is involved in port logistics operations....” (CS5)

“...We have put some additional safety measures in place; we speak to the men and crew on board the vessels, “men with tools” and those in stores; we have additional training and additional supervision in place; and we also have constant communication with the ship’s agents on land” (CS7).

“... all the senior management have laptops and they also have internet connections at home. And from home you can dial in to every aspect of company’s computer system. So everybody can work from home [in a worst case scenario]. Everybody has company

provided mobile network, so that we can contact one another if that happens. And hopefully it never happens ...and if it does, there shouldn't be any problem with us continuing with our business [from a ships' agent's point of view]. There is backup elsewhere in another path of the terminal some couple of miles away so that if anything happens here we have got access to our backup for business to continue....” (CS4)

CS2 however states that some of the precautions taken at the moment in the HE and elsewhere in the EU involve the various directives, laws, and sanctions that can be imposed on those who flout environmental policies/regulations. For example, we have MARPOL, UNCTAD, UN, EU laws on environment, and the IMO laws and requirements.

We have already learnt through our previous interactions with industry practitioners (at club meetings and seminars) that IT is key to traffic control and related logistics operations in the port system. Additionally, CS1 opines that the functioning of ICT system is a real big issue in shipping. CS1 explains that in today's shipping world, everything they do in the industry is driven by computer. Seeing the importance and the potential risks associated with the ICT system usage therefore, companies have resorted to acquisition of backups, and other assistance (storage) system that can help entities to retrieve information even if there is IT failure. For example:

“...There is an emergency system in Immingham where our VTS can operate from in case there is a breakdown or failure of the equipment at the Spurn point. Actually the port logistics operations can go on without the VTS. However businesses have tended to rely on VTS, GPS, EDI, RFID, and others. So we have this backup or standby system at Immingham from where we can operate in case there is system failure at the Spurn....” (CS1)

Elsewhere, literature shows that the shift towards ICT dominant logistics system has improved operational efficiency and effectiveness but not without its own risks. For instance, Bichou (2008) acknowledges the consequences of the super-sized Post-

Panamax container vessel and the risks that large cargo manifest have on the existing ICT capacity to contain and analyse the large data produced.

It is also worth noting that terrorism threats and terrorist attack have gained currency in port/maritime logistics industry's operations. Port operators in the Humber Estuary are currently managing this menace through collaborations with government agencies including the police, special intelligence agencies, special branch units, and all possible means [including the public]. CS1 intimates:

“...The issue of terrorism is currently a global phenomenon and it depends where you are in the world Here in the port of Hull for instance, a terrorist threat is possible especially if it involves one of those passenger ferries. So really our ports here could absolutely be a target. However we've got control measures in place to try and manage it. [In our own sense, and looking at the level of collaborations between the ports and the other stakeholders, we can say that we are prepared enough though we can't know what level will be adequate]....”

As part of their current preparedness, CS3 says that their company enforces high safety standards as well as always follow the organisation's disaster/crisis management plans. This document (disaster/crisis management plan) spells out the steps and procedures that one needs to follow when a particular disaster such as fire, explosion, leakage of dangerous/hazardous products, and many others occurs.

“...We have planned for every event that we think has high potential to occur [high frequency], or can affect our business operations [high impact]. And these plans are always strictly adhered to at any particular time of our operations....” (CS3).

CS7 adds:

“...We believe that we have done what we can possibly do for now. We do have all sorts of emergency drills, we do all sorts of tests on our plan, and those kinds of things.... But I think there is always some room for improvement on this kind of things. But given the kind of organisation we are, and what we have within our control, I don't think we are doing particularly bad job at that. One could argue that we might want to improve and that is what we aspire to....’

In conclusion, CS5 adds that:

“...By our work efforts and also by our standards we are probably fairly prepared, we are fairly well protected theoretically in our own system.... but we have not tested it in a real life scenario....”

The discourse above (particularly by CS5) supports the need to test whether the current level of preparedness is adequate such as we did in section 4.11. The results emerged in chapter four (4) that policy change (interventions) in terms of technology change (advancement), port activity, forecast accuracy, preventive compliance measures are among key variables which influenced the structural behaviour of disaster preparedness, state of environment stability, and the resilience of port logistics in the HE.

(#2) Investigating traffic congestion/management at the HPC

This question required the respondents to discuss the situation of traffic congestion at the docks (both inside and outside), and whether the phenomenon is associated with any hot-spots.

It appears that ports in the HE do not have much problem with the flow of traffic. For instance it became apparent on the facility of CS3 that traffic (both human and vehicular traffic) is efficiently managed to prevent congestion. The following excerpts are the opinions and perceptions from some of the respondents about the sub-theme ‘traffic congestions in the HPC’:

“...We do not experience traffic congestions in our facilities really....our vessels arrivethey notify the pilotage. ABP runs the conservancy of the four major ports on the Humber. They [the Humber pilotage] control all the vessel movements [from the VTS station at the Spurn].... Vessels have to book for time and they are allowed to come into the

docks at allotted time, (sometimes) according to their priority such as whether they are tidal vessel or non-tidal vessel. By this, congestion is highly controlled in the ports....” (CS4).

“...At the water side we don’t have much congestion here now, we have got two berths here [for our company] and the customer level is not really more than one ship at the berth per period. So there is no congestion as such at the water side at the moment. At the dockside we have a ‘one way system’ in place; congestions are usually a ‘two way-traffic’ [system phenomena]. However there are times when we need an extended berth because of the way our terminals are set out. As you can see, the berth goes all the way down the far end there [indicating with hand gestures to the investigator as they stood a few metres way from the terminal at a safe spot], and half of the quay lies on someone else’s terminal. So when we have two vessels at a particular time then there can be some sort of congestion here....” (CS7).

All these said however, CS5 implied that traffic congestion can be possible outside the terminals especially in a place like the Port of Hull which is a bit of one road in and one road out traffic flow. CS5 upholds that:

“...If there is any incident on A63, that can affect vehicles coming in and those leaving the ports along the east bound and the west bound highways....we cannot notice it immediately. The loading bays will keep loading trucks all day and then the trucks cannot get out of the docks. That can become a big issue. On site, traffic congestion may occur when there is slow loading, or when there are lots of ‘live loadings’. Live loading normally occurs at lunch time..... You might get about 6-10 live vehicles turning up at the same time and that brings temporal congestion at the loading bay....”

Concerning tidal variation and the effects it can have on traffic flow, CS1 says that big tidal variations (especially low neap tide) can actually be a risk to vessel navigation at certain parts of the Humber River. CS1 emphasised:

“...You need enough water to operate a port. To some extent, even dredging cannot be done if the ports do not have enough water. Even though we have the lockgates to keep water levels at near constant, if it is not deep enough, that will drive most vessels [the tidal vessels] away to other ports....”

Issues concerning space and congestion are very vital to port logistics operations. CS1 argues that ports thrive on space among other things.

“...If you have got no space to do business then you can't do the business; and if you can't do it safely, you either don't provide the service, or you injure people in the process. Ports need to provide facilities that the business demands and if they don't, then the business will go somewhere else because some other ports will pick it up and provide them..... So if you don't provide the facilities, you lose the business....it's as simple as that....” (CS1).

(#3) Illustrating common disruptive events in HPC

This item investigates the common (illustrative) sources of disruptions in maritime logistics chain. Furthermore the investigator intends to know whether events such as per the narration by the respondents still persist in the logistics chain and if so what is being done about it.

According to CS7, perhaps one of the biggest threats to port operations is “accident” happening in the course of execution of duty. This has the potential to halt company's operations. Accidents and incidents can lead to the imposition of tougher legislations and sanctions on the port (e.g. the health and safety legislation); which could also impact on logistics activities. For example, CS7 recalls a casualty at one of the terminals a couple of years ago, when a crew-man stepped off the ship incorrectly. Operations were interrupted and they remained frozen for above twelve hours because it involved the police and other interest groups. Such events can cause the company to change how it does things every time they occur. CS7 argues that accidents can be inevitable in a high risk industry such as the port. However remedies (such as raising health and safety standards) are being sought to try and eliminate their occurrences.

As an illustration, CS5 narrates a strike action at the source [such as in Finland], which occurred somewhere in the year 2005/06 that caused a big disruption in paper

production/supply. The strike action lasted for about five weeks. After the first week CS5 says that the company's ships call in at the ports with little bit of timber but they carried no paper.

“...Our stock [paper] shrunk from 60,000 tonnes to 30,000 tonnes at an average forwarding out rate of 5,000 tonnes – 6,000 tonnes paper per week. Our customers became troubled because of the delays. My customers' customers who use the paper were not getting the quantity they needed. So that had a big impact on us....The paper companies did what they could by sourcing from their alternative mills in Europe (France and Germany). They brought in paper by road to top up the stock level during the period of the strike at an extra cost....” (CS5).

Other strike incidents and the impact they made on port logistics system in HPC were narrated. For example CS4 alluded that:

“... if the Dockers go on a strike then it may be difficult for us to work with our vessels and they may run behind schedule as liner agencies.....strikes if they do happen (or there is lack of requisite human resources), that can delay the ship's departure which can cause a problem for our customers. Remember some of the customers have other alternative routes. So if the ship is late they [customers] can very often cancel booking and get on elsewhere.... So it does have an economic effect on the business in that point of view....”

“... Operational disruptions are clearly possible, particularly if staff do become embroiled in disagreement with the company.....that has the potential for industrial actions and strikes. There was a strike here in 2001 by the pilots. The pilots had a private company that provides pilotage services and there was disagreement between us (ABP and the pilotage) which led the latter to withdraw their services. The strike action did affect traffic on the river to some extent. However, since then, measures have been put in place and we do not experience or envisage strikes any longer....” (CS1 added).

CS3 confirmed the narration by CS1 and adds that that strike posed a big challenge to them at the time, as manufacturers. However, CS3 said they quickly rallied their own people (the few experienced hands available who have worked with ABP before) to take over and manage the facilities, activities, and services provided by ABP, which are vital and are directly linked to CS3's core business [temporarily]. That was after an agreement was reached between CS3 and ABP. CS3 says that they were able to

control the situation until the strike action ended and things normalised. This respondent also reiterate that they do not foresee anything of that sort happening again.

A large majority of the respondents (managers) believe that their employees are highly satisfied with their job package. Moreover some of the companies such as the one that CS3 represents do not encourage the formation/activities of any workers' unions. So it appears that strike related disruptions particularly those coming from the workers' side is a bit remote from occurring at the moment. But none of the respondents also ruled out the possibility of a cascaded industrial actions from another region onto ports on the HE.

Arguing from a different (academic/environmentalist) perspective, CS2 narrates the below which appears to persist perhaps due to the peculiarity of the source of the events:

“...As soon as Immingham built [or extends] its dock and terminal, it created a problem of siltation and accretion along that section of the Humber River. This increased the risk for boats going over or around the silt....[problem with vessel navigation]. On top of that you have got the effects of all those pollutants and the effects that the port has on the environment. For instance at a place like the Immingham, sediments come inside the docks every time they open the lockgates. When the locks are closed the particles settle down just around the lockgates..... Now you have got fine sediment that has got not only fine soil particles in them, but they also contain lots of organic matter in them. If you leave that there, eventually that fine sediment starts producing methane, and some hydrogen sulphide gases [toxic substances] which becomes health and safety hazard to the port workers. So things like that can generate natural problems. It is natural problem because of where the port is situated [location effect which can be positive or negative]. But it has now become a health and safety issue for the port, in the same way as the isostatic rebound. This is a typical geological hazard, showing one way that the port affects the environment and how the environment also affects the port in return. Such threats still exist partly due to the fact that ports in the HE have either been wrongly sited...or these may be natural risks that can be associated with the life of a super infrastructure such as the port. For instance floods in Hull and its environs can be attributable to coastal squeezing as settlements develop and the city's economic activities grow in size....phenomena which we can't do without.”(CS2).

Naturally, port activities (such as constructions, extensions, dredging, and so on) seem to be on the increase [on the Humber] perhaps due to natural river dynamics and also due to trade expansion and globalisation which calls for introduction of bigger and more sophisticated vessels. It appears that no end can be put to some of these activities especially those that relate to the port physics (external environmental issues). Hence management can only look for alternative interventions and become prepared to minimise the risks/hazards and disruptions that such events may cause to the logistics chain.

A detailed illustration of this aspect became one of the foci of this research. The influence of port activities on port stability (or port environment instability), disaster preparedness, and resilience, did emerge clearly under the respective sub-sections (4.11) of this document.

(#4) Investigating crisis management scheme in the HPC

Question four (4) seeks to learn about the crisis management systems (regimes) that ports in HE follow. As part of the investigation, we looked at who has the responsibility of managing crisis, and how disaster management plans [activities] are prioritised by the ports so as to ensure continuous improvement and sustainability of port/maritime logistics network.

To this theme, all the respondents demonstrated evidence of having disaster/emergency preparedness plans that seems to be in operation. Some

respondents also spoke about the functions, and what such plans really do. For example:

“...The emergency management plans serve as a guide to the management team in times of crisis. Generally disaster/emergency preparedness plans are documentary frameworks that give guidance to people in charge of crisis management. The framework only shows the command structure (such as who to contact, and the chain of activities to follow in case something happens) and the sequence of process which one needs to go through in order to overcome a crisis situation.... But it does not actually think for you. Perhaps most often people tend to forget some of the information when disaster strikes....instead they act on their own instinct....” (CS1).

According to CS3, the crisis management system that follow as a company (manufacturer) is the ‘Group Definition Practice (GDP)’. The GDP comprises of a team of management that is tasked with the responsibility to drawing up a company-wide crisis management plans. Being a multinational company, the same GDP system exists for CS3’s organisation at the local, national, and international levels. The GDP team sets standards and procedures for the entire system to follow in CS3.

On the case of prioritisation of disaster/emergency management, CS3 told the investigator that the sequence of priority follows: People → Environment → Assets →Reputation (PEAR) order of priority. There are groups within the GDP teams whose members are responsible for specific emergency plans. CS3 says further that the implementation of crisis management plan is done by the incident management team that is (i.e. a group) within the GDP of the company. Everything that the group does must be in line with the laid down plan by the headquarters. Every department, as well as every employee, is required to carry out the policies/rules/regulations as laid down by the mother multinational company. If there is any case of emergency, the group’s sequence of priority must follow the PEAR [see p.347 for note on PEAR]. According

to CS3, the guidelines require that everything that is done in the company is documented [whatever happens, whatever is done; every activity that is carried out, every event that takes place at any time, who was involved, whatever steps of mediation was followed should be well documented] and be made accessible to all stakeholders immediately. CS3 notes that the essence of proper documentation is that if an event of that nature occurs again [or a similar incident occurs elsewhere in a sister company], the management team will be able to trace the solution to the problem following the steps as documented. But most of the CS3's local activities here on the Humber are done in collaboration with the port owners [ABP]. The ABP owns and operates the jetties, VST control point, and other essential services. Therefore, CS3 needs their involvement in all its emergency plans as well as in all their preparedness measures that can affect the ports and its environment. CS3 appears to suggest that because they have outsourced key logistics functions to port owners, it follows that the solution is also handed over to those who perform the logistics functions. CS3 argues that:

“... The port owners are responsible for vessel control system, therefore they have to procure marine insurance policy that covers our logistics operations. We focus only on normal, non-predictable and inevitable risks that can be associated with complex operations such as ours....

Also the responsibility for the implementation of business continuity (or crisis management) plan (or policy) rests on the site director. S/he oversees that the system, or the plan, works according to the laid down rules” (CS3).

CS3 mentioned that they also follow the “Six Sigma⁵⁵”(Neuman and Cavanagh, 2000) method for their continuous improvement standards. They react to every situation as quickly as possible, no matter how small it might look, and they strive to continually improve upon what exist at any time.

Contrarily, CS5 (port operator) says that their company is ISO ⁵⁶ 9001: 2000 accredited. It appears that majority of the functional enterprises interviewed suggest the lack of [own] written down policy for continuous improvement. However, they indicate that they [company] comply with the ISO requirements. According to CS5, the ISO standards generally talk about ways that one can do things such that the entire organisation can improve and remain sustainable. CS5 explain that they [company] also observe trend of events, and when they are not satisfied with anything, they review the current system internally to continually aim at improving operations until they achieve better results than it used to be.

Majority of the respondents agreed that policy issues (especially environmental related policies) have the potential to be a major challenge to the ports operations whenever they think of any major developments or change on the Humber (such as building a jetty, extending terminal, building/fortifying flood defence walls [barriers], or undertaking any massive infrastructural change). On such massive infrastructural

⁵⁵ "...**Six Sigma** is a rigorous and disciplined methodology that uses data and statistical analysis to measure and improve a company's operational performance by identifying and eliminating 'defects' in manufacturing and service-related processes (www.businessballs.com/sixsigma.htm).

⁵⁶ **ISO International Standards** ensure that products and services are safe, reliable and of good quality. For business, they are strategic tools that reduce costs by minimizing waste and errors, and increasing productivity (www.iso.org/iso/home/standards.htm).

developments, the entity will have to comply with several policy directives [as mentioned on page 335 of this thesis] and also demonstrate extensively that it satisfies all requirements in order to get support and approval from stakeholders for the project.

“.... The company (port) has to put in place all the necessary mitigations against any negative impacts that a major development will have on the environment before you get the parliament (legislation) to approve that you have enough mitigation on the destruction of land, worms, birds, and everything else. So that is where the environment side of the Humber management system kicks into our business.... This is what we really need to look to when doing any project outside the closed docks [on the crown estate territory]. If we stay inside the docks, that one is not really a big issue....” (CS5)

From a transporter’s point of view, CS6 explains the crisis management regime that they have put in place, or what they are required to do. CS6 illustrates that if they have any problem, all crew members are informed first. Then depending on the vessel’s location, the local port authority will be contacted for emergency support. According to CS6 they (crew members) try to avoid incidents from happening in any activity that they carry out (precautions and standards are high on whatever is done). CS6 stressed that there are various marine emergency plans that transporters must follow. There are also several maritime policies, rules and regulations (at local, national, and international levels) that guide their activities irrespective of the port they sail to. In CS6’s opinion, those rules, laws, plans, regulations, and policy directives, rather help the transporter positively. For example they need plans (rules) to manage disasters like oil spillage, or pollution (air water and soil), and sewage discharged. When garbage is produced aboard any vessel, it has to be accounted for.

“...It is important to prepare for hazards or to prepare for those kinds of risk events at all times following a laid down plan....preparedness equip us to face challenges with some confidence....” (CS6)

CS6 further revealed that their company follows the ISM guidelines and procedures. This requires that they do certain minimum number of drills, training, exercises, and simulations periodically in order for them to reinforce what they should do when disaster strikes. They must comply with these requirements if only they wish for the renewal of their certificate of operation as seafarers.

“...These keep us ready and alert to be able to face and manage crisis situations that may come our way as we go along with our maritime transport duties...”(CS6).

CS6 argues that IT and communication systems are very important in the shipping industry in general, and particularly in logistics and transport operations. However the problems that are associated with IT and especially in relation to information storage, system failure, and so on, are not very common aboard a ship, or from the crew’s point of view.

CS7 says that they have got an environmental management system in place such that if something happens, or in the event of an accident they can initiate quick response. Thus depending on the event that happens, there is procedure in place for the most likely ones [suggestion of high frequency events]. Event prioritisation is based on what the company thinks has most likelihood to occur [after risk identification and risk assessment]. Management then develop strategies to tackle the most probable event(s) first, and the least probable event(s) last. This seem to be in line with the orthodox risk management approach which many companies follow. Concerning the ownership and control of IT system that serve CS7, the respondent explains that the company has a department for that. But the group-wide IT system is looked after by a third-party. So

if CS7 have a problem beyond their capability they contact the third party for the solution.

Just like CS5, CS7 says that they follow the ISO 9001 standards for quality and continuous improvement. CS7 readily affirms that in the short term, those policies/standards could be hindrance to the company's operations, but at the long run, they tend to improve organisational efficiencies at work. However, in CS7's view, such policies and standards make an entity to be more prepared.

“...You have to plans in advance so that the processes, procedures, and strategies would have already been mapped out just in case an incident occurs...”

In CS7's company, the general responsibility for the implementation of standards and policy guideline is led by the HR executive teams. And then it trickles down to site managers, and through to the work force.

(#5) Expected changes and potential risks in the logistics chain

Item #5 of the research, investigates the changes that are likely to occur in the port/maritime logistics industry and the potential risks that may follow changes. It emerged from the interviews that all the respondents expect one form of change or another in their respective functional enterprises. For instance, CS1 (port authority) is looking forward to a lot of renewable energy related businesses. The Humber's Economic and Sustainable Development (Grant, 2013) reports that Siemens will start manufacturing wind turbines in Hull for the world's largest offshore wind-farm in the

North Sea. There will also be an increase in biomass production from straws. Industrial, economic, plus demographic and infrastructural expansion is expected to reach 2 million homes, plus 5000 jobs in Hull by 2020. As a result, it seems policy risk issues are going to be high on the port stakeholders' agenda. Furthermore, environmental matters are becoming more and more challenging to ports and stakeholders. According to CS1, they (ABP) could do anything they liked and get on with it in some ten (10) or fifteen (15) years back. But now, the impact of whatever is being done (i.e. the EIA and AP) should consider the long term sustainability of the environment.

“...The environmental impact [EIA] of the business on many ports is quite massive these days in terms of costs. The Humber ports in particular, because the river Humber is that strict on environmental designations, it means that developing [port infrastructure] on the Humber requires a lot of hurdles to jump over and to deal with...” (CS1).

CS2 had explained the relationship between the port and the environment (pp. 346 – 347) which also connects with CS1's expression of environmental sustainability issues vis-à-vis port operations. CS2 alluded (though covertly or by implications) that:

“...There may be more directives, and the existing ones could be reviewed as we attempt to secure and prevent further degradation of the environment of the HE. There will be more stringent actions and sanctions on those who will not comply....in order to ensure a clean environment especially. Businesses which cannot cope with the demands for those compliance measures will have to 'bow out'.... It is a fact that political interferences in scientific facts and finding will increase though...” (CS2)

CS2 further predicts that environmental matters can affect logistics operational activities in the HE by causing necessary delays. There is also going to be increases in cost of logistics operations: an example being the 1% - 3% on EIA and AP.

Nonetheless, the good ending to all these chaos will be ‘a sustainable environment to operate in’.

From a manufacturer’s view point, CS3 revealed that the company foresees further growth in production of industrial raw materials which may translates into growth in logistics activities on the HE. CS3 anticipates major changes in the field of oil and gas sector [energy production].

“...There is possibility of more energy producing companies relocating to this vicinity [the Humber Estuary]. This includes wind turbine power stations (e.g. Siemens) as well as solar and nuclear power stations....” (CS3).

In the wake of these developments, CS3 expects that their company may have to review its production processes and its production plans so as to cater for the manufacture of products that may feed the new companies in the Humber region. Whiles the increase in port activities (due to inflow of new companies) is a positive change (socio-economically), it is predictable that the new companies may contribute significantly to the degradation of the apparently serene, clean, and stable environment through pollution and clogging of the flow in port logistics chains. This will subsequently result in the institution of environmental laws, directives, policy regulations, and imposition of sanctions on the use of environment, as a measure to controlling the risks/hazards that will be associated with the activities of the new neighbours. There will be the need for more collaboration with the statutory port authority and other stakeholders to control the excesses. But of course each stakeholder will be guided by its own local, national, and international policy guidelines (if there exist any such policies).

In CS4's view (ship agency), they expect to start new services out to Spain and the Mediterranean coast soon (i.e. business expansion or an increase in size of the logistics chain). The agency and its compatriots are also moving into a group-wide IT system in the next couple of years in order to bring in more transparency into the group. According to CS4, the expansion will bring in much more synergy into the logistics operation when all the fragmented companies (agencies) hook onto the group-wide computer system. The effect of this change will enhance service quality that they provide. Also, the globalised IT system may encourage gigantism and produce large data which (Bichou, 2008) asserts that computer networks have not yet adapted to and that it may lead to system failure or crash. Additionally, processing document may take longer and thus leading to operational disruptions, congestions at the central hub (port), plus the roads and rail network that connect to the hub. Respondents are sceptical about the consequences of elongated route (greater exposure to maritime environmental risks and disruptions). Internally, group-wide IT is already putting some dedicated and loyal staff to premature end of career (risk of staff redundancy and redeployment), especially those who cannot cope with the new challenges.

On the side of pollution control, the International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted at IMO in 1973/78 but came into effect in 1983 (www.imo.org). The aim for this regulations was to prevent and minimise pollution of marine environment by ships as a result of their routine operations and potential accidents. Currently there are six amendments call Annexes. Annex VI which came into force in 2005 sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances.

Designated emission control areas (the HE being one of such areas) set more stringent standards for SO_x, NO_x and particulate matter. A chapter adopted in 2011 covers mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships. Amendments to MARPOL Annexes I, II, IV, V and VI were proposed in March 2012 and were entered into force on 1st August 2013. This was to enable small Island Developing States to comply with requirements for ports to provide reception facilities for ship waste through regional arrangements. This regulation requires regional parties to develop a Regional Reception Facilities Plan and also provide particulars for the identification of Regional Ships Waste Reception Centres as well designated areas for ports that have limited facilities. Perhaps it is these regional arrangement which are taking effects in the regions mentioned by respondents during the interview. However, a reading from the website of Holman Fenwick Willan LLP (2015) seems to confirm the respondent's assertion and fear that 1st January 2015 marks the commencement date of new emissions regulations for vessels operating in Emissions Control Areas (ECAs). "Following regulation 14 of the IMO's MARPOL Annex VI, vessels will be obligated to burn bunkers with a maximum 0.1% sulphur content by mass within ECAs, which currently cover the North Sea, Baltic Sea, North American coastline and US Caribbean. Operators who fail to conform to this limit (and cannot demonstrate a defence or mitigating factor under the regulations) will face financial penalties and possible vessel detention by ECA states" (<http://www.hfw.com/Sulphur-Emissions-A-New-Years-Resolution-January-2015>). The fear by stakeholders is that this policy is going to add a lot of cost to the running of maritime transport/logistics business.

CS5 adds that there will be some changes in the mix of cargoes that they (the ports) do in the HPC/HE. The Humber as a region is developing fast to become the hub for energy and biomass production in the UK. CS5 anticipates that what used to be by-product to paper production (for instance), may become the main product, and the paper rather becomes a by-product to biomass production. Cargo shipment may change in the sense that it might be more economical to transport some cargo by road and rail trucks rather than by container shipment due to high fuel cost and the assortment of cargo that the container ship has to carry from different locations.

There is also a growing attention on the rule for the ballast system requirement. For example one cannot take lake water from one Swedish lake, or from one Finish Lake to another. Also water has to be changed and one cannot take ballast water from the Elbe River into any Finish lakes unless it is radiated to eliminate all bio-pollutants (or alien species). So also one cannot change ballast water from foreign seas in any USA ports.

In conclusion, the respondents expect many changes in the logistics networks; changes that have the potential to bring about positive or negative effects (temporal) on all stakeholders in the short-run, all which seem to gear towards port sustainability. However site of the possibilities of unintended consequences that follow the good intentions to produce social stability.

(#6) Investigating the need for disaster preparedness

The aim of this item was to find out whether it is important to prepare for uncertainties. The investigator also wanted the respondents' own view, about what can influence how one prepares for disruptions/disasters in the port/maritime logistics network.

In connection with this theme, CS1 says that the location of a port is very important relative to its customers, sea and deed water, major sea route, and also relative to the amount of steaming-time. Location determines port's level of economic success and viability. However location can also be a threat to port activity in terms of port security and stability. Some ports are more vulnerable to logistics hazards (risks) than others. The port's location can influence the type of preparedness to put in place against disruptions in the logistics chain. CS1 argues using an illustration that:

“.....In my business sense it doesn't need to have plans for everything that will go wrong. It is just good business sense if you think about it. For example if you are handling lots of cargo;maybe containers weighing 20 tonnes....and you are running only one crane that handles 20 tonne container, then you are going to have problems somewhere along the line because sooner or later you are going to have issue with one crane handling those things....”

The reader will recall that the essence of an emergency management plan has already been stated earlier under the theme 'crisis management scheme' (pp. 361 - 367). Continuing from there, CS1 adds that the responsibility of implementing the disaster preparedness plan (in their organisation) rests with a selected management team.

The subject of whether to be prepared or not seem to raise debate in many business circles. Depending on how business critical a resource is, majority of the respondents appear to uphold that “redundancy” is a waste of ‘precious capital’, yet it is indeed

necessary sometimes. They argue further that the “necessary redundancy” construct depends on a number of factors. However the main question to ask is: how business critical is the redundancy in relation to the position of your close competitors; and whether you can afford to take the risk not to prepare for incidents in your supply chain. To make the best out of the situation, you must make risk assessment on the business, taking into account the environment risks, safety risks, and the emergency response needs before you engage in creating ‘necessary redundancy’⁵⁷ (See Sheffi (2005) titled “The Resilient Enterprise”).

In connection with the risk assessment and disaster preparedness, CS2 implied that the location effects (especially port physics) should take precedence over anything else. According to CS2, port investors and risk managers need to ask: “*what is the site like?*” This question needs to be considered along two dimensions:

- a) The size of port’s operation, and
- b) The physics [or the physical characteristics] of the port’s environment.

For instance when one is considering investment in any major port infrastructure in the HE, it is highly probable that the investment may confront challenges such as: simultaneous relative rising and sinking coastlines; coastal erosions; flooding; variable depths of river course; water turbidity and associated siltation, sedimentation and accretion; as well as microbial and ecological activities (site restrictions) among other

⁵⁷ See Sheffi’s (2005) “The Resilient Enterprise” for details about the concept of redundancy in supply chain. Several authors including Bichou (2008) have identified or proposed a range of risk assessment formulas (techniques) in the maritime logistics environment. We wish to focus on establishing relationships between the environment, disaster preparedness and resilience of port logistics.

things. It appears that many investors end their assessment on the size of port operations and apparently exclude the assessment of port physics. Many are of the view that a thorough EIA is a function of the location effects; particularly the characteristics of port's physical environment should play a major role.

Probing the respondent further, concerning the cost of disaster management plan, CS2 intimates that the EIA requires that 1%-3% of the cost of an operation (or a project) must be set aside to go into the environmental assessment and disaster preparedness plan. CS2 argues that the ports, the investors (or its stakeholders) and politician may criticise the cost involved, nonetheless if that is what they have to do for environment sustainability then we have no options. In a very concerned mood, CS2 suggests that:

“...The law should be responsible for the implementation and oversight of disaster preparedness plan of ports and companies operating in the HE. If the law says you have got to do this.....and if you don't do it you can't operate, or we will take you to court.....there is usually no question about it than you to comply with the directive. Actually the minimum cost to pay is to comply with an order if only you want a license to operate.... Once they need the legal permission, businesses have got no options than to comply with the law....” (CS2)

CS2 further explained that this forms the basis why in most (developed) countries; you do need a license for everything you do. Anything you do that is going to have environmental impact, you need legal permit to do it.

“... if that is what the society decides to have then that is what the law says you must put in place for you to be given a license, and that is what prevails. In fact it is to the ultimate benefit of the entity to have a clean environment since that can translate into clean food, clean air, clean and healthy people (workers), and more profits....”(CS2).

Many large and complex organisations have the R&D department. It seems that as part of its job, the R & D department is to study events, finds out what can happen or what has happened, design ways which could prevent or minimise the effects of looming

disaster/disruption, and how changes in strategies can affect the logistics chain. For instance, the R&D may have to find out how new products can affect, or be affected by the system.

“...The R&D keep the company ‘fit on its feet’ at all times so that at any particular time we can confidently say we are safe. They initiate the trainings, drills, and simulation practices towards events occurring. These are very vital in preparation for future event occurrences....” (CS3)

In CS3’s organisation, the health and safety management team is responsible for implementation of company’s disaster management plan. The emergency management team meet regularly to review the crisis management plan. Contrary to the implementation team and the R&D theories, CS6 (transporter) says that they follow the ISM code⁵⁸ (www.imo.org/Publications/Documents). All these measures are attempts to making sure that the functional enterprises and the ports in general will continually be ready to counter disruptions in the logistics chain. In conclusion, CS7 reiterates that:

“...Preparedness is very important for any kind of crisis management. The more prepared you are, the more responsive you can become to tackling emergencies and thus become more resilient....”

Whatever form it assumed, disaster preparedness seem to be a key word in the success and sustenance of organisational growth. As narrated by various functional enterprises, different teams, and groups are responsible for disaster plan implementation under different improvement policies. However, the key assertion is that disaster preparedness is very important.

⁵⁸ The ISM is a Management Code for the Safe Operation of Ships. It provides an international standard for the safe management and operation of ships and for pollution prevention (see www.imo.org)

5. Section B: Discussion of #7 based on SD simulations

This section summarises the results produced from the simulation runs (i.e. the quantitative analysis). The data were derived from the transcribed interview results in #1 - #6 in section A, and the mental model (textual data) that was built from the hypothetical structure that we presented to the respondents. We have explained the choice of 100 day time horizon and also stated the source of the initial values for each state variable as well as those for the accompanying auxiliary variables in section 4.11.

For each individual sub-system (DP, PEI, and RPL), the trajectories of the curves show exponential increases in value (i.e. positive growth over the period). This appears to mirror what happens in the real world which we attempt to mimic based the respondents' mental database. For example an extract from the interview reads: “....*the more prepared you are, the more resilient you can be*”. Relationships so extracted from statements such as the one above (or their counter statements) were arranged to form a CLM and the feedback loops (figure 4) from which stock and flow diagrams were developed to enable the research to do quantitative analysis that graphically describes the structural behaviour of the key variables.

Since the models appear to be a close approximation to reality, it can provide stakeholders with a powerful insight into their problem at a glance and at no cost. By the use of modelling, we have been able to reveal the hidden structures that raise the question of understanding the interrelationships between the key variables of this research. We found how instability and preparedness interplay can influence resilience in port/maritime logistics chain.

One may observe that some of the research (auxiliary) variables such as: Technology Change, Port Activity (as dictated by location effects), as well as Risk Preventive Compliance Measures seem to influence the rates of flow significantly. For example, an increase in port/maritime logistics activities can lead to increase in the rate at which potential environmental risks/hazards (perceived or real) transform into actual incidents and thus throwing the port environment into a state of disequilibrium which may subsequently, increase the outflow rate (rate of disruption incidents in port logistics network). Increased instability in port logistics chain can stretch the resources that may be needed for emergency operations far beyond a predictable limit such that it may result in decreased disaster preparedness and also render the logistics system less resilient (i.e. unable to respond quickly, or bounce back quickly from disaster).

Many entities are susceptible to disasters of various kinds. These disasters have wide ranging consequences, some of which cannot be prevented. The consequences have dire implications that can influence how one prepares for current and future disruptions, and also one's recovery rate from catastrophic events. Paton (2005) observes that societies which have developed along places that are exposed to natural processes such as bushfires, storm surge, floods, icing, volcanicity, tsunamis, and seismic hazards can be exposed to such natural disasters. Paton postulates that even if the probability of risks from such hazards remains constant, the population, economic, plus the accompanying infrastructural dynamics continue to change over time. The consequence can be an increase in losses to disruptions that result thereof. Such risks/hazards as anticipated should help management to design adaptive measures (risk

management plans) that can enhance co-existence [by adaptation] with those natural environmental processes.

As a way to strategically cope with the difficult environment, ports have relied firstly, on physically managing risks/hazards via 'hard' engineering and robust policies which sometimes culminates in another disaster elsewhere. The second approach which is very important (but which appears to be ignored) involves understanding of the environment which the ports system operate in. Policies governing the use of the environment and its resources, the preparedness for hazards and incidents - how these elements interact to provide resilience in port/maritime logistics operations have to be understood.

Most often people interpret information they receive on the basis of their own expectations, experiences, beliefs, and misconceptions (Dow and Cutter, 2000; Lasker, 2004; Paton, 2004) which usually affect decision-making and their behaviour (Paton, 2005). For example during the interviews, some of the respondents seem to be concerned only about the rising costs of operations and potential hindrances posed by regulations as the most important risks in the port industry. They seem not to have any keen interest in the sustainability of the environment. Such beliefs can affect the approach to environmental risk management. Therefore the recognition of the interactions between environment, disaster preparedness and resilience can increase the CROs' capacity to adapt to adverse circumstances through improved anticipation and advanced planning for mitigations prior to incident occurring. For instance the simulation models in this research suggest that Technology Change can prevent disaster/disruption from happening (to some extent) in the logistics network. However,

beyond the limits of technological advancement, there can emerge disasters which have low probability of occurrence yet may have very intense destructive power (Lapp and Ossimitz, 2006; Mrotzek et al, 2007).

We have observed that the behaviour of the curves as derived in the ‘extreme condition tests’ seem to be a reflection of the *theories of structuration* (Giddens, 1979). Particularly, *rational actions* may result in *unacknowledged conditions and unanticipated consequences* (see chapter 2 subsection 2.3.6.). The curves seem to suggest that, strategic decision on risk interventions can rather amplify the frequency, nature, and magnitude of disruption in port/maritime logistics chains per time period. Issues of these kind necessitated the adoption of the SD methodology which seemed to have the capacity to help problem owners in framing, understanding, and discussing the complexities involved in the interactions between the state variables in this research.

To allow effective disaster management planning that is required for preparedness, the models in this research give the risk management team an opportunity to examine, test and evaluate the system [through the observable structural behaviour] whether it is adequately prepared (Adivar et al., 2010), and resilient enough in real-time. The detection can enhance policy changes towards disaster preparedness and maintenance of high level resilience in the logistics network. We also believe that the models will generate debate across the fields, policy-holes may be revealed through collaborative debates such that it can lead to solutions being found to mitigate the impact of disruptions on port/maritime logistics industry.

Analogous to Mrotzek et al's (2008) catastrophe archetype, the stocks in this research may not matter very much, but the flows are. For example being disaster prepared is not enough, but being able to anticipate and respond to emergencies in real-time, is what the research is concerned about. It does not matter how much resources one has stockpiled, if such resources cannot be readily available for use when they are needed. Besides there can even be overloads in a system. By that, it means a self-regulating system can become self-escalating system. One will agree with the research that technological advancement can help port/maritime logistics chains in solving problems including issues about disruptions. However, the graphs suggest that bad technology application such as "technology crowding", or "over technologisation", can also result in chaos, and rather create more systemic disruptions in the port/maritime logistics chain more than one can imagine.

Much the same is true about good or bad port activities and poor policy on environmental risk management. The interview results somehow suggest that there seem to be a creeping feel of invulnerability (by the management) to disruptions in the logistics network of the HPC. It has emerged from the interviews as well as from many literature that the HPC is perceived to be located in an environment that is relatively stable in terms of natural disasters. Majority of the respondents also seem to believe that the ports apply the most modern (sophisticated) equipment in their operations, and for that matter they can claim to be up-to-date in almost all the technology they need in carrying out their day-to-day functions. However we believe that such over exaggeration of operational and systemic security can make management to overlook potential risks (especially low frequency – high impact risks) and operational incidents

which may accumulate into catastrophic events that can set the tone for series of catastrophic disruptions in the logistics chain at the long run (see Lorenz, 1973 butterfly effect).

Need for disaster resilience

Disaster Resilience is the quality that enables an entity to cope with, adapt to, and recover from a disaster incidents (Rioli and Savicki, 2003; Pelling and Uitto, 2001; Buckle et al., 2000; Mallak, 1998; Hornes, 1997). Resilience also represents “situation awareness, management of keystone vulnerabilities and adaptive capacity; in a complex, dynamic and interconnected [*logistics*] supply chain environment” (McManus et al., 2007), or the ability of a system to return to its original, or a better, state after a disturbance from a stressor (Pettit et al., 2010). Elsewhere, literature suggests that to be able to bounce back from a stress, the system must have an increasing capacity to learn from the past, then build within itself some risk resistance or protection capabilities (preparedness), so that it can effectively reduce the potentials for disruption in the future. A logistics chain system’s capacity for risk resilience may include physical, institutional, social, economic, resources and other means (Ponomarov and Holcomb, 2009), not excluding leadership styles that could enhance the management of hazards and the implementation of systemic policy change. Resilience in a company is not just being concerned with flexibility⁵⁹, recovery, or crisis preparedness at one specific instance; it requires the entity to continually be

⁵⁹ Flexibility in a supply chain entails creating capacities in the logistics chain to respond by using existing capacity that can be redirected or relocated. It comes from investments in infrastructure and capability long before the flexibility is needed (Sheffi and Rice, 2003; 2005)

innovative and rigorously analyse its strengths, weaknesses, threats, and opportunities (Hamel and Valikangas, 2003). It is then that the company can map out the appropriate strategies as well as device alternative windows that can enhance its survival in times of adversities and beyond.

In a recent studies, Stewart, Kolluru and Smith (2009) note that researchers' interest on the concept "disaster resilience" has increased tremendously since the strike by hurricane Katrina in 2005. It seems that understanding 'resilience' can provide an insight into the ability, and how those impacted by a catastrophic event (stakeholders) and the systems they represent will respond to adversity. Hence several studies have been conducted that address issues of resilience from different perspectives including: national disaster planning (Arnold, 2008; Edmonson, 2008); sociology and urban planning (Sapountzaki, 2007; Thomas, 2007; Campanella, 2006); business continuity planning (Tompkins, 2007; Sheffi, 2005); and supply chain management (see Supply Chain Management Review, 2006; Sheffi, 2006, 2005; Sheffi and Rice, 2005; Woodham, 2008). It appears that in all the instances, the phenomenon (resilience) is consistently conceptualized as one's ability to recover from a disaster. We suggest that an increase in resilience of an entity is perhaps a half-way guarantee to the entity's sustainability in whatever business it is carrying out. Therefore port/maritime logistics networks need to aim at improving resilience at all levels (i.e. operational, tactical, and strategic levels).

Furthermore, it seems that resilience is a function of logistics chain security; where we consider security as the level (scale) of safeguarding against unwanted and/or unexpected effects. Apparently, security issues focus on the level of proactive

preparedness for sudden event (disruption or disaster), as opposed to being reactive to event occurrence. Security conscious logistics chains incorporate security (safety) in the design phase of the chain as built-in qualities to mitigate or to avoid disturbances (disruptions) as much as possible. We note that Sheffi (2001) categorised supply chain security in six distinct phases, include: the preparation to guard against disruptions; the actions required during occurrence of a disruptive event; the actions required immediate (or first response) to the disruptive event; the initial impact (rate of escalation – slow/rapid) of the disruption; the preparations for recovery; and finally the recovery process that leads to resumption of normal operations (bounce-back-ability). Sheffi concludes that it is essential that leadership sets the tone for its logistics chain's security awareness if success of preparedness is to be achieved. Senior management need to get involved in the development of security-related policies. However it seems this cannot happen if policy-makers cannot understand the antecedents that can lead to disruptions. Security requires that logistics chains identify the factors that trigger disruptions and the sources of vulnerabilities, using early warning approaches such as we attempted to mimic in this thesis. Craighead et al. (2007) and Hendricks and Singhal (2003) also belief that logistics chains that have adaptive and visibility capabilities are less likely to be impacted by disruptions, any efforts at making logistics chains resilient should target at adaptability and visibility improvement. This requires cooperation and network transparency through effective communication [through debates as espoused in our research models] that involves all stakeholders.

Need for disaster preparedness

It appears that all management decisions are made to influence or affect the future of the organisation (Sutherland and Woodroof, 2009). Organisations, governments, communities and societies at large have sometimes made decisions (strategic policies) that were not backed by the necessary preparedness. For instance, Sutherland and Woodroof (2009) cite the 2001 European Environmental Agency's commitment to promoting biofuel as a typical case that can arise when policies are instituted, but are not backed by necessary preparedness. In conclusion the co-authors recommend that policy makers should 'research and monitor for early warning' and also they should search out and address blind spots and gaps in scientific knowledge. Holmes and Clark (2008) also found out how lack of preparedness for the outbreak of the 2001 foot and disease in livestock cost the British government over ten (10) million sheep and cattle and an amount of over £8 billion revenue loss. In short it is better to prepare for the unexpected than to wait for it to happen.

However, resources (time, financial, infrastructural including technology and human resources) are necessary means to reducing entity's vulnerability to disaster. It appears that policies and management decisions often decide resource allocation at any time. Therefore poor judgement leading to bad decisions can create systemic vulnerability as opposed to accurate judgement and decisions. Because it is often difficult to get management and policy makers convinced about disaster preparedness. Models (such as the ones in this research) can help such stakeholders to understand better the consequences of policy interventions when tested on different scenarios before they are implemented. Covington and Simpson's (2006) recommendation, it seems the models adopted in our research (System Dynamics model) can assist problem owners

to improve their current understanding of causes and effects of disruptions in their logistics chain. We have not created any measurement (or metrics); our models only support management, policy makers, stakeholders, and other users to gain insight into policy interventions [through scientific debates] that may influence the structural behaviour of the key constructs of the research [environment instability, disaster preparedness, and resilience in the port/maritime logistics industry].

Chapter Six: Thesis Summary and conclusion

To refresh the reader's memory, this final chapter of the thesis restates the research problem, the research objectives, reviews some key aspects of the methodology, and finally provides a summary of the findings. We ended the chapter by providing a brief conclusion based on the research results and suggested a direction for future research in this area.

Research aim, objectives and questions

We aim at applying System Dynamics (SD) models to analyse the interdependencies between the environment, disaster preparedness, and resilience in maritime logistics industry as policy changes (or strategic risk management interventions) are tested on a port system prior to decision implementation. This move is geared towards improving current level of understanding the causes of disruptions in port/maritime logistics chain. To achieve this grand aim, we considered the following objectives:

Objective 1

To identify potential sources of risks/hazards in the logistics chain of ports on the Humber Estuary;

Objective 2

To analyse the structural behaviour of the interactions between environment instability, disaster preparedness, and resilience as a response to frequent policy change;

Objective 3

To employ SD models as aid to risk managers for:

- a. improving current levels of understanding the sources of disruptions in port/maritime logistics chain;
- b. testing the robustness and efficacy of strategic risk interventions prior to implementation; and
- c. communicating through debates, the potential outcomes of policy interventions prior to implementation

Literature reviewed (see section 1.4) suggest that the lack of preparedness may have direct impact on logistics system's resilience to disruptions. To understand how strategic interventions can influence port stability, disaster preparedness, and resilience we focused on answering the following questions:

1. What potential risk/hazard types prevail in the logistics chain of ports on the HE?
2. What impact can frequent policy change (strategic risk interventions) have on port/maritime logistics operations in the HE?
3. What is the relationship between environment instability, disaster preparedness, and resilience in port/maritime logistics industry?

Methodology

Society is a complex system whose component parts work together to promote stability (Parson, 1902-1979). Parson further states that social systems have four basic functional prerequisites: adaptation, goal attainment, integration, and pattern maintenance. Every system therefore strives to contribute to meeting these basic functional requisites by relating well with the environment. According to the social

functionalism theory (Parson, 1902 – 1979; Durkheim, 1858 – 1917), we act the way we act because we expect a certain outcome from our action that will produce social stability. It appears that the same goals of attaining and maintaining stability lead to the institution of policies and regulations that call for change. However, change management is often met with mixed reaction perhaps due to the fear of unacknowledged condition and unintended consequences (Giddens, 1979). Both those who effect the change and those who may be affected by a change seem not to understand why there is need for change. Change can be managed through preparedness for risks.

Preparedness for disasters (risk/hazard, or disruption) that can result in resilience (bounce-back-ability) in port/maritime logistics chain seems to be policy change (interventions) issue. While many scholars argue that preparing for risks is necessary, an equally good number (particularly in the business circles) counterclaim that redundancy is a waste and locks up resources. We applied SD simulation modelling to analyse the interactions between environment instability, disaster preparedness, and resilience of the port/maritime logistics chain in the HPC.

Basically, the SD is a methodology and mathematical modelling technique for framing, understanding, and discussing complex issues and problems. Several other scholars including Sterman (2000) say that the SD is an approach to understanding the behaviour of complex systems over time. It deals with internal feedback loops and time delays that can impact the behaviour of an entire system. It may lead to theory building.

The title of this research requires that we analyse what influences resilience in the context of port/maritime logistics network within the industrial cluster of the HPC. Due to the complex nature of the research problem, we adopted a design that followed the pragmatic (mixed methodological) approach. We employed the positivist (quantitative) epistemology (i.e. reality is objective) using Euler's numerical integration methods to computer simulate [analyse] the structural behaviour of the three state variables considered. At the data collection, we employed the interpretivist (qualitative) epistemology (i.e. reality is perceptual) using personal in-depth semi-structured face-to-face interviews with selected elites in the maritime industry. Thus quantitative methodology became the primary approach (Morgan, 1997); implying that we employed qualitative methods first in data collection, followed by a qualitative (thematic) data analysis, which we topped up with quantitative (simulation or sensitivity) analysis and interpretations.

Interviews were conducted between August 2012 and March 2013, with access duly obtained from the appropriate sources. The composition of participants include CROs representing the Port Authority, Port Operators, Liner Agencies, Transporters, manufacturers, and some Academia who are knowledgeable in marine biology, coastal and estuarine studies.

Research Findings

Our study revealed the below findings:

All three state variables seem to be sensitive to the six (6) auxiliary variables that we selected (on the basis of interviews and literature search) to test the structural

behaviour as according to the graphical representation (see section 4.11 of this thesis), though there were a few discrepancies.

Based on the responses from the respondents, it seems that the most common occurrences such as strikes and basic accidents (associated with port operations) have been kept under controlled at the moment in the HPC. Arguably, the control may be deemed temporal since issues relating to human thoughts, perceptions, and behaviour can be quite unpredictable. Thus there is still the chance to review company stance and approach to arriving at strategic interventions towards instances of operational accidents in particular, and the current levels of apparent precautionary measures that are in place.

Results have identified natural hazards (geological and climatic) as the potential major sources of disruptions in port logistics network in the HE. However, some dominant factors that can trigger off environmental instability are port activities such as constructions, extension of existing facilities, emissions, and sometimes human errors. Such alterations may be orchestrated by policy initiatives (interventions) some of which produce unintended outcomes (see Giddens', 1979 theory of structuration).

Concerning crisis management schemes and responsibility of disaster management plan, it appears that all respondents proved that they have disaster (crisis) management plan that can guide them. Nevertheless, it became apparent that though the companies have, and sometimes they conspicuously display disaster management charts, their usefulness seem to be limited to guidance purposes only. For instance, majority of the respondents argue that such documents serve only as guides to show the chain of command (the organogram) and order of events, "*they do not think for the individual*

or for the team". Those staff (management) that have many years of work experience, indicate that they may not rely entirely on disaster management plans when actual incident occurs. They suggest that training, drills, and simulation exercises be intensified, to enhance and update workers with skills for risk management. It seems that such activities can stick in the mind and rather become internalised behaviour so that problem owners can respond instinctively when crisis occurs.

We also found that the responsibility of crisis management plan rests in the bosom of ABP as the statutory port authority (SPA). All functional enterprises within the port industrial cluster work in collaboration with the SPA. They consult or involve the SPA in drawing up and implementing the disaster management plans. However, it seem that each functional enterprise has different plan based on what the mother company (the headquarters – national, or international) uses.

Furthermore, industry players anticipate the following changes based on port economic dynamics:

- i. Increases in energy production (wind, solar, and nuclear power generation) as the region is gradually becoming future energy hub for the UK
- ii. Biomass and industrial raw materials (BP) production to increase
- iii. Growth in food and edible oil production (AAK and Cargill)
- iv. Migration of many industries (relocation) into the industrial cluster (e.g. Siemens to manufacture wind turbines in Hull)
- v. Expansion of shipping routes to new regions, increase in concept of gigantism, and growth in call rates by large/specialised vessels

- vi. Physical expansion and reconstruction of port infrastructural facilities and many others.

Potential risks (hazards) that may accompany the above expected changes:

- a. Increased pollution and introduction of alien species to the ports and the environment
- b. Possible congestion at the water ways, ports, and roads which can adversely lead to further land squeezing and the potential consequent floods, waste management, and social vices
- c. Increased cost of environment sustainability including cost of waste management (recycling and disposal) and pollution-free fuel price soaring
- d. Review of production processes in the region
- e. Increase in innovations, technology change management, and technology related accidents
- f. Tightening policy and regulations leading to delays in logistics flows
- g. Expansion can produce geographical hazards and spatial dimensional effects on adjoining regions and may have possible global effects
- h. Increase in consequences of location effects and port activities.

To the above theme (regards anticipated changes), we suggest an increase in cost for EIA and AP plus high penalty for recalcitrant elements as a way to increase disaster awareness and preparedness, cause a reduction in port activities, and decrease instability, such that it may result in increased resilience of the logistics chain. There seems to be general consensus among the respondents that it is not enough to promulgate laws, regulations, or directives (risk preventive compliance measures),

there should be a minimal cost to be paid for the protection of the environment. Commitment to compliance must be demonstrated before licensing; and the license must be checked and reviewed periodically in order to ensure sustenance of compliance. This assertion seems to be supported by the graphical analysis under the SD models (section 4.11.3). However, the simulation tests suggest that when directives become too restrictive, that can also ruin the purpose for which they were promulgated. Therefore modelling can help stakeholders to ‘strike a mean point’ where policy decisions could be mutually beneficial to both the problem owners and the environment they operate in.

All our respondents agreed that disaster preparedness (or readiness, or risk alertness, or hazard anticipation) is very important if port/maritime logistics chain operations should become sustainable. Furthermore, all respondents assert that location effects significantly determine what to prepare for and the entity’s level of preparedness.

As part of preparedness, majority of the respondents recommended a viably strong R & D so that management can constantly be advised about port dynamics using models that involve problem owners (such as the one designed in this research) to brainstorm and raise levels of understanding the needs for policy change (interventions) that may lead to sustainable logistics network in the HE. Apparently, no level of preparedness may be adequate at any time. Perhaps this is because events often occur before they trigger off response [typical stimulus – response relationship].

Technological change management has also been identified as potential risk in the port/maritime logistics industry. It is also a fact that modern day disaster [especially technology related] sometimes overwhelm management. Some respondents also

believe that the level of management experience can play significant role in disaster management. However, we wish to emphasise the need to consider Giddens' (1979) 'unacknowledged conditions' and 'unintended consequences' as well when planning for interventions and change management in logistics networks. Consistent with the results, one will expect that an increase in technology advancement will proportionately lead to decrease in PEI, but increase in DP and RPL. However the graphs (P7 and P8) suggests that continuous increase in technology will only produce a relatively marginal gap between L_1 and L_2 . Therefore moves for such risk interventions need to be tested prior to policy implementation, so that both the effectors and the affecters may have fair knowledge when unintended results begin to unfold in real world situations.

We note that crisis regimes which can lead to continuous improvement of which the respondents seem to be familiar with include: ISO, Six Sigma, GDP, and ISM standards. All these schemes seem to be governed by directives from local, national and international levels. Though some initiatives may seem difficult to adopt and adapt to, it seems that if an entity becomes aware of the benefits and needs for the change, by being involved in designing the change process, the probability of acceptance and its successful implementation may be high. There is consensus by the respondents that the responsibility of change implementation should lie in the hands of a competent management team, and should be backed by an appropriate law.

Finally, the study reveals that there is strong interdependency between the dynamics of port physics (environmental stability), disaster preparedness, and resilience. A detailed analysis shows that 'Technology Change', 'Port Activities', and 'Forecast Accuracy',

significantly affect the structural behaviour of the three state variables (see figure G1 and G2). However 'Frequency of Rescue Mission' and 'Extent of Damage' do not influence the change in behaviour of level of preparedness significantly, they rather affect environment instability and resilience in logistics chain. Each trajectory of the three stock variables show individual positive growths (increased value) as the number of days increase according to the SD simulation runs. Nonetheless, the general model (figure G4 - G29) shows that the trajectory of disaster preparedness and resilient seems to decline whereas the trajectory for port environment instability seem to grow (worsening) contemporaneously within the test period. The graphs therefore suggest that the state of the port environment significantly influence the capacity to respond (preparedness) as well as the capacity to bounce back (resilience) from disruptions. Understanding these structural behaviours may help management to embrace more environmentally sustainable policies with less resistance from either the effectors or affecters (or both) in the port/maritime logistics industry. Policy makers will be able to anticipate the consequences of certain risk interventions prior to their implementation.

Conclusion

Opinions are divided among scholars whether preparing for uncertainties (disruptions) in logistics chain is necessary and whether redundancy (Sheffi, 2005) is a waste or a gain to the logistics parties. Thus whiles management think they are doing their best to fight hazards, risks, and disruptions in port/maritime logistics system of HPC, investors and other stakeholders on the other hand think management is not doing enough and have become impatient, or intolerant to risk mismanagement. Hence

resource requirement for emergency operations continue to dwindle per period. There is need to improve current levels of understanding the sources (causes) of disruptions in port logistics system beyond what is currently known. The level of understanding can deepen when all stakeholders can appreciate the interdependencies (influence relationships) between key variables that influence risk management leading to resilience (sustainability) of port logistics network.

Disaster preparedness and resilience in a logistics chain seems to be policy intervention issues. Change management can encounter mixed reactions from the logistics parties, some of which may produce serious unintended consequences (Giddens (1979)). As a means to depart from methodological polarisation (i.e. departing from purely quantitative or qualitative research dominance as pertains in the field of maritime logistics), researchers may adopt the system dynamics (SD) simulation modelling approach to analyse the interactions between environment instability, disaster preparedness, and resilience of logistics chain in the Port Complex of the Humber River Estuary. Through SD (graphical presentations) they may apply mathematical modelling technique (Euler's numerical approximation) to frame, understand, and discuss complex phenomena of a research. This approach (SD) can help to understand the behaviour of complex systems over time, since SD deals with internal feedback loops and time delays that can affect behaviour of the entire system.

We conducted face-to-face, semi structured interviews with selected CROs at the industrial ports complex on the HE. Data was analysed applying steps in Grounded Theory's (Glaser and Strauss, 1967) coding processes (see Corbin and Strauss, 2008; Straus and Corbin; 1990; 1998; Kim and Anderson, 2008; Kopainsky and Luna-Reyes;

2008). Simulation runs were performed for a 100 day time horizon. The simulation models were able to combine evidence from interviews to approximate how real-life systems may behave under 'extreme condition tests'. The results suggest that there is strong influence relationship (or interdependency) between environment instability, risk/disaster preparedness, and the adaptive capacity to bounce back from disruptions (resilience). As the trajectory of the curves of port instability increase, those for disaster preparedness and resilience decline exponentially, suggesting a bi-directional influence relationship (inverse) between environment instability on one hand, and the levels of disaster preparedness, and resilience on the other hand [see figure G29 of this thesis].

We found that the models can help researchers and problem owners (policy-makers) to translate evidence from stakeholder debates into forms that can be readily understood by all, then through experimentations, plausible possible outcomes of policy interventions can be anticipated. Such dynamic risk assessment process can be used to evaluate the situation (task, or entity at risk) when carrying out any form of activity routine, or rare.

Furthermore, our approach and findings can assist stakeholders to identify and assess policy-relevant holes in their strategic decisions such that possible mitigations can be designed prior to policy implantation. Fundamentally, the results (or conclusion drawn) from our interview data and the SD simulations models do not differ from theoretical literature. The assumption or the theoretical underpin of this research is based on the structuration theory (Giddon 1967) and stratification theory (Davis-Moore, 1948). These two theories can influence management decisions outcomes. The

structuration theory acknowledges that society [port/maritime logistics system] is a complex whole such that each part performs a role with the aim to bring about stability. The attempt to establish the requisite balance can produce unintended consequences. Based on this theory, we believe that researchers and problem owners can use the models designed in this research to anticipate and test (using scenarios) for outcomes of policy interventions in real-time, prior to decision implementation. On the other hand, the stratification theory should enable management to rank potential outcomes and risks associated with policy decisions such that it can enhance prioritisation of risk mitigations efforts. Consequently, our research findings and models can help to reduce the conflicts between management and stakeholders and thus reduce natural reactions and mixed feelings that usually come with change management in the maritime logistics industry.

Researchers in port/maritime logistics risk, security, and disaster management may adopt this methodological pluralisation technique to translate raw textual evidence into forms which decision-makers can readily understand and possibly experiment with, prior to decision implementation. We conclude our research by stating that potential sources of disruptions in maritime logistics system of ports on the HE can be “port physics” related. However the subtle triggering factors appear to be related to the “port size”. The research models can lead to improving the understanding of this relationships as well as aid strategic policy makers to communicate (demonstrate) the potential outcomes of decisions in real-time.

Future researchable areas

This research has opened avenues for further studies to investigating the interrelationship between environment, disaster preparedness and resilience of port/maritime logistics systems. In order to enhance result comparability and theory falsification (such that it can lead to generalizability), we suggest that the models be tested on other major port complexes and industrial clusters elsewhere, including: the industrial port complex of Rotterdam, the port complexes of New York and New Jersey, the Los Angeles port complex, the port complex of Guangzhou, the Busan Ports, or the Ports of Kembla using the same data collection and analytic tool as the ones engaged in this research.

We also suggest the use of a different design (e.g. survey method with a large N-sample) that may allow the employment of advanced statistical tests for correlations between the state variables in this thesis, using appropriate econometric analytic tools (models) such as the [General] Autoregressive Conditional Heteroskedasticity ([G]ARCH), the Survival Model, the Logistics Function, or the Multiple Regression Model; to falsify the result either in the maritime logistics industry or elsewhere in a complex organisation. In the immediate future, we would like to investigate whether disaster preparedness plans/charts (as displayed in many offices) actually have any effects on an organisation's capacity to respond to emergency/crisis at the point of incident and how often such plans are reviewed.

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Appendix A

Sample research questions

Qn#1:

- i. Please, how you will describe the port/maritime logistics network in the Humber Estuary (or the Humber Port Complex) [*will you say it is risk (challenge) prone, or it is a stable region*]?
- ii. Please can you mention any three (3) or four (4) major hazards/risks (natural, or human) that can interrupt port logistics activities in this region?
- iii. Assuming an event you identified in (ii) above caused a disruption in your logistics chain (e.g. closure of major terminal, or one of the major ports becomes inaccessible, or the VTS station fails, or the lockgate fails):
 - a. Who/what will be affected? *You may illustrate how the entity would be affected?*
 - b. What could be the duration of the crisis?
 - c. What infrastructures/services are critical [*must continue to function even under extreme conditions*]?
 - d. Which critical services/infrastructure can be recoverable if the events you identified occurred? How long can the logistics chain continue its operations/functions without the critical services/infrastructure?
 - e. Could you please estimate the cost involved if an event occurred [*human cost, capital cost, financial cost, and potential environmental*]?
 - f. What opportunities would your logistics chain lose to the crisis?
 - g. What precautionary measures have you put in place (or intend to put in place) in order to reduce, or to avoid risks of disruptions in your logistics network?
 - h. How will you describe the current level of preparedness in your logistics chain [*is it sufficiently (significantly) adequate for you to be able to respond to, and also to recover from (bounce back) from a major disruptions event*]?

Qn#2. Please tell me about traffic congestions in your logistics system in relation to:

- i. The waterside;
- ii. The dockside; and
- iii. Inland inside of the port.

What are the hotspots (i.e. *is it related to certain peak periods, or is it a facility/capacity constraints*)?

How are these issues being managed currently?

Qn#3. Could you illustrate how an event(s) which affected your business operations in the past 1, 5, 10, 15, 20, or 25 years? Do such events still pose risk/threats to the port's logistics chain?

Qn#4. Please let us talk about crisis management in your enterprise.

- i. What crisis management system(s) does your company have (in place) at the moment?
- ii. How do you prioritise crisis management plan [*could you illustrate some instances*]?
- iii. Who controls the information/communication infrastructure in your logistics system?
- iv. Do you have any continuous improvement system(s) (*policies*) for crisis management?
- v. What continuous improvement standards do you follow (e.g. ISO, Six Sigma etc.) and how is this standards affecting your continuous operation?
- vi. Are there any policy guidelines (on the environment or otherwise) for risk (disaster/disruption) management?

vii. How do the guidelines affect port logistics in HPC in their preparation towards disaster?

Qn#5. What significant change(s) do you anticipate in the operations/functions of your logistics chain within the next few years ahead (two to ten)?

What are the potential risks that can be associated with the expected changes?

[Illustrate please]

Qn#6. What role can risk/hazard preparedness play in your business with regards to crisis management?

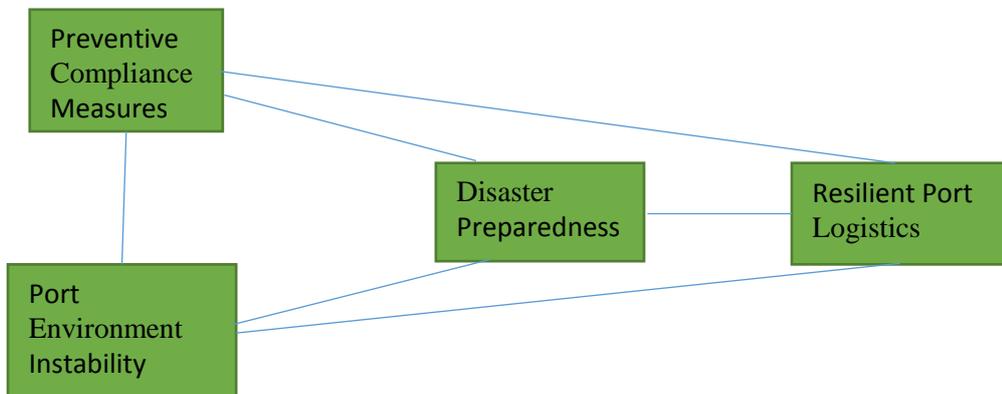
What factors can influence your company's (or port's) preparedness for disruptions (disasters)?

Who is responsible for implementing your disaster management plan?

Qn#7. In your opinion (with reference to the diagram below) could you indicate the cause and effect relationship (influence) between the matching pairs on the table? Indicate the strength, and briefly comment on whether one element has positive or negative influence on the other element please.

	Weak (low)				Strong (high)
Matching pair	1	2	3	4	5
Disaster preparedness vs. Disaster resilience					
Disaster preparedness vs. Managerial behaviour/policy including risk perception and risk appetite					

The environment vs. Disaster preparedness					
The environment vs. Management behaviour/risk policy and risk appetite					
The environment vs. Disaster resilience					
Managerial policy/behaviour vs. Disaster resilience					



Hypothetical relationship between key research

Relationships between risk preventive measures, physical environment, disaster preparedness, and logistics chain's resilience

DEFINITION OF TERMS

Terms defined: Disaster, Risk, Vulnerability, Disaster Preparedness, and Resilience

For the purpose of this research, we adopt the definitions for key terms as follows:

Disaster is ‘a potentially traumatic event that is collectively experienced, it has an acute onset, and is time delimited; it may be attributable to natural accidents (e.g. flood, storms, earthquake), technological accidents/failures (e.g. large industrial accidents/incidents), or human causes (e.g. episodes of mass violence)’ (McFarlane and Norris, 2006) such that it could lead to huge financial/economic/social consequences.

Risk is the multiplied result of hazard, exposure, vulnerability and capacity (Davidson, 1997) to contain an uncertainty. Or **Risk** = Hazard x vulnerability x preparedness for hazards x capacity to contain (Villagran de Leon et al., 2006)

Vulnerability is the relative degree of risk, susceptibility, resistance and resilience (McEntire, 2001)

Disaster preparedness is ‘a process of ensuring that an entity:

- a. has complied with preventive measures;
- b. is in a state of readiness to contain the effects of a forecasted disastrous event in order to minimise loss of life, injury and damage to property;
- c. can provide rescue, relief, rehabilitation and other services in the aftermath of the disaster; and
- d. has the capability and resources to continue to sustain its essential functions without being overwhelmed by demand placed on them (BusinessDictionary.com)

Disaster Resilience is the quality that enables an entity to cope with, adapt to, and recover from a disaster event (Riulli and Savicki, 2003; Pelling and Uitto, 2001; Buckle et al., 2000; Mallak, 1998; Hornes, 1997).

Resilience also represents “situation awareness, management of keystone vulnerabilities and adaptive capacity; in a complex, dynamic and interconnected [*logistics*] supply chain environment” (McManus et al., 2007);

or

The ability of a system to return to its original, or a better, state after a disturbance from a stressor (Pettit et al., 2010).

Appendix B

Analysing the simple influence diagram

Possible Feedback Loops According to the Diagram (figure 4)

1 Port Activity	2 Disaster Preparedness
<p>Loop Number 1 of length 2</p> <p>Port Activity</p> <p>Port Environment Instability</p> <p>Disaster Preparedness</p> <p>Loop Number 2 of length 3</p> <p>Port Activity</p> <p>Resilience in port logistics</p> <p>Preventive Compliance Measures</p> <p>Disaster Preparedness</p> <p>Loop Number 3 of length 3</p> <p>Port Activity</p> <p>Port Environment Instability</p> <p>Preventive Compliance Measures</p> <p>Disaster Preparedness</p> <p>Loop Number 4 of length 4</p> <p>Port Activity</p> <p>Port Environment Instability</p> <p>Resilience in port logistics</p> <p>Preventive Compliance Measures</p> <p>Disaster Preparedness</p>	<p>Loop Number 1 of length 1</p> <p>Disaster Preparedness</p> <p>Port Environment Instability</p> <p>Loop Number 2 of length 2</p> <p>Disaster Preparedness</p> <p>Resilience in port logistics</p> <p>Preventive Compliance Measures</p> <p>Loop Number 3 of length 2</p> <p>Disaster Preparedness</p> <p>Port Environment Instability</p> <p>Preventive Compliance Measures</p> <p>Loop Number 4 of length 2</p> <p>Disaster Preparedness</p> <p>Port Activity</p> <p>Port Environment Instability</p> <p>Loop Number 5 of length 3</p> <p>Disaster Preparedness</p> <p>Port Activity</p> <p>Resilience in port logistics</p> <p>Preventive Compliance Measures</p> <p>Loop Number 6 of length 3</p> <p>Disaster Preparedness</p> <p>Port Environment Instability</p> <p>Resilience in port logistics</p> <p>Preventive Compliance Measures</p> <p>Loop Number 7 of length 3</p> <p>Disaster Preparedness</p> <p>Port Activity</p> <p>Port Environment Instability</p> <p>Preventive Compliance Measures</p> <p>Loop Number 8 of length 4</p> <p>Disaster Preparedness</p>

	Port Activity Port Environment Instability Resilience in port logistics Preventive Compliance Measures
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Table 1: Examples of feedback loops extracted from figure 4

Continuation of Possible Feedback Loops According to the Diagram (figure 4)

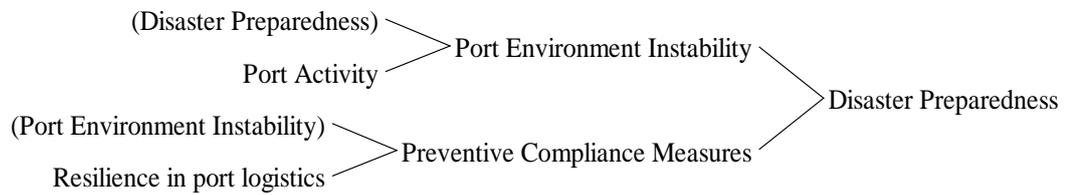
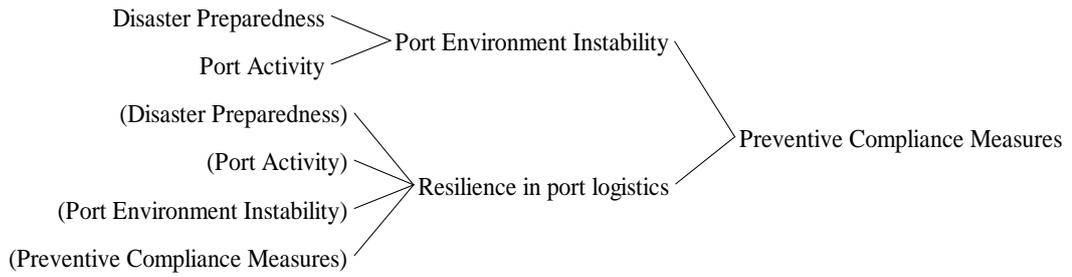
3 Preventive Compliance Measures	4 Port Environment Instability
Loop Number 1 of length 1 <p style="text-align: center;">Compliance Measures</p> Resilience in port logistics	Loop Number 1 of length 1 <p style="text-align: center;">Port Environment Instability</p> Disaster Preparedness
Loop Number 2 of length 2 Compliance Measures Disaster Preparedness Resilience in port logistics	Loop Number 2 of length 2 Port Environment Instability Preventive Compliance Measures Disaster Preparedness
Loop Number 3 of length 2 Compliance Measures Disaster Preparedness Environment Instability	Loop Number 3 of length 2 Port Environment Instability Disaster Preparedness Port Activity
Loop Number 4 of length 3 Compliance Measures Disaster Preparedness Environment Instability Resilience in port logistics	Loop Number 4 of length 3 Port Environment Instability Resilience in port logistics Preventive Compliance Measures Disaster Preparedness
Loop Number 5 of length 3 Compliance Measures Disaster Preparedness Port Activity Resilience in port logistics	Loop Number 5 of length 3 Port Environment Instability Preventive Compliance Measures Disaster Preparedness Port Activity
Loop Number 6 of length 3 Compliance Measures Disaster Preparedness Port Activity Environment Instability	Loop Number 6 of length 4 Port Environment Instability Resilience in port logistics Preventive Compliance Measures Disaster Preparedness Port Activity
Loop Number 7 of length 4 Compliance Measures Disaster Preparedness Port Activity Environment Instability	

Resilience in port logistics	
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Table 3: Examples of feedback loops extracted from figure 4

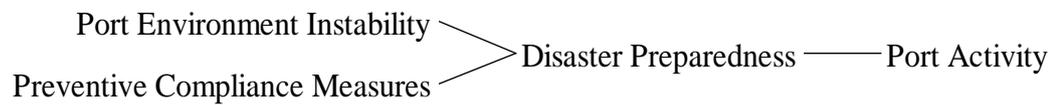
The extended causal tree diagram from figure 4

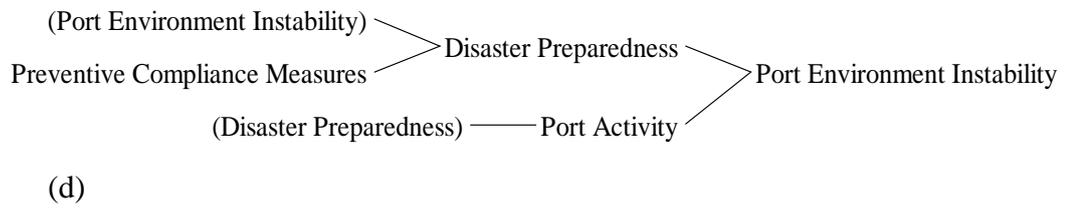
(a)



(b)

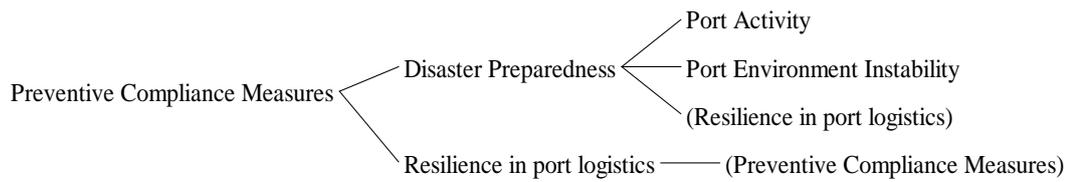
(c)



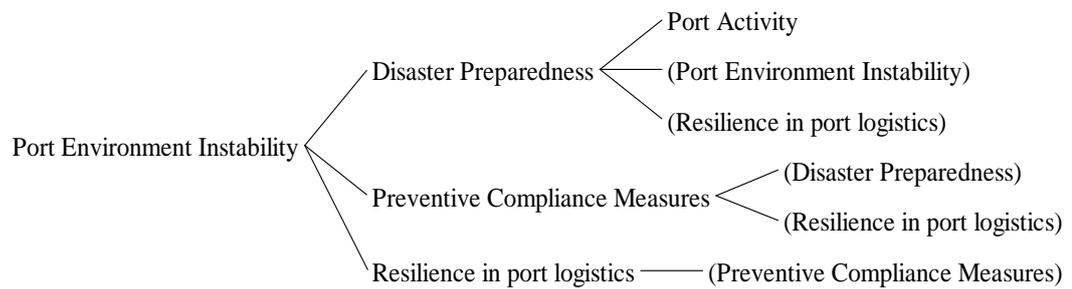


The use tree diagram representing what elements can be influenced by disaster preparedness

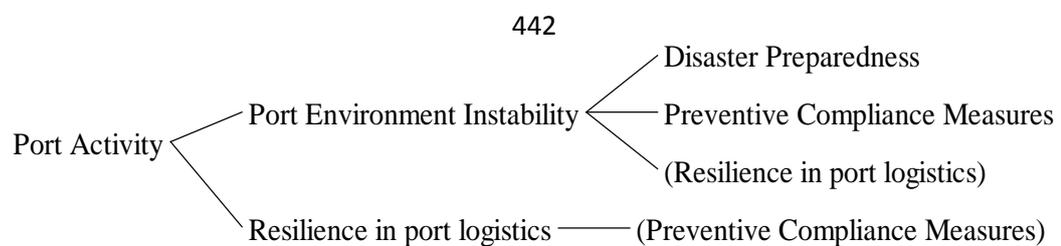
(a)



(b)



(c)



Appendix C

Samples evidence for documents regulating access and conduct

Ethical Issues

Prof David Menachof
Peter Thomson Chair in Port Logistics
Room 216 Nidd Building
Tel:
e-mail:

DD/MM/YYYY

Dear Sir,

ETHICAL APPROVAL FOR DOCTORAL RESEARCH

I am writing concerning Mr John Kwesi-Buor's doctoral research at the Humber Ports Complex in the East Yorkshire of the United Kingdom. I am John's doctoral research supervisor and I can confirm that John has my approval to carry out the interviews that are needed in order to gather empirical data for his research.

John has already completed the necessary ethical approval processes and procedures, including training on research ethics, within the University of Hull. This makes him qualify as researcher in the University's Business School. He therefore has the approval from the University to carry out this exercise.

I hope John is given the necessary help to enable him gather data for the purposes of his research. If there are any queries, do not hesitate to contact me, as John's research supervisor, through the above links.

Yours faithfully

David Menachof

The Logistics Institute
Room 104 Derwent Building
University of Hull
Hull
HU6 7RX
DD/MM/YYYY

The Harbour Master
Humber Ports Complex
East Yorkshire

Dear Sir,

**REQUEST FOR APPROVAL TO CARRY OUT RESEARCH IN THE
HUMBER PORTS COMPLEX**

My name is John Kwesi-Buor. I am a PhD research student in the Logistics Institute of the University of Hull. My research supervisor is Prof. David Menachof.

I wish to request for approval from your outfit to enable me carry out my fieldwork within the Humber Ports Complex (i.e. ports of Hull, Immingham, Grimsby and Goole). The fieldwork is expected to start on 1st December 2012 and we hope to end on 31st March 2013.

The title of the research is: *Applying System Dynamics Modelling to Building Resilient Logistics: A Case of the Humber Ports Complex*

The prime objective of this research is to study the interrelationships between environment stability, disaster preparedness and resilience in port logistics network. How policy interventions can influence disaster preparedness, and the potential impact on resilience of logistics activities in the Humber Ports

Complex (HPC). The research aims at improving the current understanding the sources/causes of disruptions in maritime logistics, and how disaster preparedness could improve port resilience (i.e. response to crisis and recovery from disaster/crisis situations)

The research will conduct interviews with the Chief Risk Officers at the ports of concern, an expert in maritime security/risk management, a seismic expert in the region, and other stakeholders such as the head of Stevedore companies in the HPC. The research will also request for statistical data from which it will design simulation models that could help CROs, risk management team, and policy makers to communicate easily and be able to test for robustness and efficacy of crisis management decisions so that optimal choice among possible decision outcomes towards disaster preparedness can be made prior to decision implementation.

I have sought for and have gained ethical approval from the University of Hull's ethical committee (find in attached document). All other necessary measures that will ensure high level confidentiality have been put in place and will be strictly observed throughout the life span of the data. For example I will seek the approval of the HPC and whoever is concerned before any publication that will involve information from this data is put out for public use. I have attached details of my research proposal, and a proforma for ethical approval from my University for your perusal.

I hope this request shall meet your kind consideration and approval.

Thank you.

Yours faithful,

John Kwesi-Buor
Tel: 0750 222 8211
e-mail: j.kwesi-buor@2010.hull.ac.uk

cc: CROs (or leader of Risk Management teams), Head of VTS at the Spurn,
Head (port geology department), Leader (Stevedore Companies in HPC),
marine security expert.

Invitation to Participate, Confidentiality, and Anonymity Procedures

Please for the purposes of not losing vital points that will be raised by you (respondent), for the sake of clarity/quality, and also to reduce time spent (in long handwriting, or others), I wish to seek your permission to record this interview.

Please as respondent(s), you may withdraw your participation from this research if you deem it fit to do so at any particular stage and time. I am happy to inform respondent(s) that they (each individual participant) will decide what can be done with interview material. Please you have the right to state when you want to be off records and to interject the interview recording proceedings. The participants are assured that under no circumstance will the research quote or paraphrase any participant without seeking your prior approval to do so, and if require, research will invite you to edit the portion in question.

For further information, queries, and concerns, please contact the researcher directly through the address below:

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Tel: 0750 222 8211
e-mail: j.kwesi-buor@2010.hull.ac.uk

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Director of Research (HUBS)
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