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**RISK MANAGEMENT IN LIQUEFIED NATURAL GAS  
PORTS AND MARINE TERMINALS SUPPLY CHAINS**

**By**

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*B.Sc., M.Sc.*

**A thesis submitted to Plymouth University  
in partial fulfilment of the degree of**

**DOCTOR OF PHILOSOPHY**

*International Shipping and Logistics Group  
Plymouth Graduate School of Management*

**2013**

## **Abstract**

### **RISK MANAGEMENT IN LIQUEFIED NATURAL GAS PORTS AND MARINE TERMINALS SUPPLY CHAINS**

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Due to its environmental attributes, Liquefied Natural Gas (LNG) as a clean fossil fuel source of energy has witnessed a steady increase in demand worldwide over the last decade. This increase is mainly attributed to higher demand from the power generation sector as well as from domestic and industrial usages. This growing role of LNG among competing energy sources has raised concerns over the safety and security of the LNG chain of production, transport and distribution and its related infrastructure. Within this context, LNG ports and marine terminals, being strategically located at the midstream of the LNG Supply Chain (SC), are further exposed to safety and security risks and represent credible targets for international terrorism. Ensuring uninterrupted, robust and resilient LNG SC requires first, adequate management of safety and security risks in LNG ports and marine terminals. While each discipline of risk, be it safety or security, has received significant attention both in theory and practice, less attention was given to the management of interfaces and shared impacts among LNG Ports safety and security risks which led to the existence of gaps in the risk management (RM) systems of LNG ports and may represent a major source of risk and disruption to LNG ports. This research addresses such gaps which are poorly addressed in the current literature and proposes a holistic and integrated approach to the issues of LNG ports safety and security risks assessment and management. It also aims to model safety and security RM from a SC perspective and examines the relationships and shared impacts among LNG ports safety and security risks in the present context of increased LNG demand worldwide in the post 9/11 terrorism era.

A unique combination of multiple methods within port and maritime SCs, including a Delphi survey, quantitative survey, Soft Systems Methodology (SSM) and a focus group expert consultation, is applied to reformulate the prevailing RM approach marked by dichotomy and a disciplinary silo and to propose a more enhanced and holistic approach to safety and security RM. The results of the study confirm that an integrated and holistic approach to the issue of RM in LNG ports and marine terminals is necessary to cost-effectively address safety and security risks and ensure reliable and resilient LNG SCs. Furthermore, a practical framework, in the form of a conceptual model, for LNG ports risks and emergencies management is proposed which integrates all facets of safety and security risks and emergencies management, including risk prevention, mitigation, emergency planning and response and port business continuity. The proposed conceptual model shows how the proposed RM approach can be practically applied in the context of LNG ports in the Middle East and North Africa (MENA) region, as well as in any LNG port worldwide which lacks an integrated approach to risks and emergencies management.

**Key Words**     *Safety, Security, Risk Management, Emergency Planning & Response, LNG Supply Chains, integrated approach, all-hazards approach, Port Business Continuity*

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## **Acknowledgments**

My first thanks should go to Allah, who I always trust and from whom I acquire wisdom, blessing and providence.

First and foremost I would like to thank Prof. John Dinwoodie and Prof. Jingjing Xu. Thank you both for your initial willingness to take me on and for all your guidance, wisdom, and unwavering support and encouragement over the past five years. Your advice, recommendations and comments were of great benefit and give me confidence throughout the research journey.

To my parents, my late father Chaibi and my mother Khaira, I want to say thank you for teaching me and guiding me throughout my life, your education and guidance has helped me to choose right from wrong and made me a more confident and secure person. I have got the best of you, and I want you to know that I could not have had better parents. I will always love you.

I would like to thank my wife Laila, whose support during the research period was unlimited; you have always been part of my success. To my son Yasser Briouig for appreciating my desire for mental punishment, and for his patience during the research period. My apologies for some of the fun that was sacrificed along the way; I shall make up for the trade-offs!

To my sisters and brothers and their families, you have always provided me with love and advice. I shall always treasure you.

Special words of thanks to Dr Feisal Al-Thani the Deputy Managing Director of Maersk Oil- Qatar and to Mr David Fernie, Port Security Director at DP World, UAE. Your guidance and technical feedback has been of great benefit to this study.

I wish to express my sincere gratitude and appreciation to all friends and colleagues in Qatar and in different parts of the world who provided me with precious advice and participated in my surveys and interviews. Special thank you to all colleagues at Qatar Petroleum, Ras-Laffan and Mesaieed Ports, Qatar-Gas Terminal Operations; Oman National Oil Company, Shell, Total, PFI-UK and Imperial College London. Without you this work would not have been possible.

To all persons and organisations which I may have missed, thanks to all of you, you have made this work so much easier than it may have been.

Mohamed Briouig- Doha, 6 December, 2013

## Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

This study was financed in full by the author.

A programme of rigorous research was undertaken, which included an introductory course in SPSS and attendance at appropriate graduate research support series workshops.

Relevant scientific seminars and conferences were regularly attended at which papers were presented.

Publications:

- 'LNG Ports Supply Chain Risk Management' presented at the University of Plymouth 2009 Postgraduate Symposium;
- 'LNG Supply Chain Risk Management, The Case of LNG Ports and Marine Terminals', Paper presented to the LNG Outlook Conference – Dubai- UAE on 24<sup>th</sup> July 2012. Conference proceedings 2012.

Presentations, Seminars, Forums and Conferences Attended:

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- Participated to the 20<sup>th</sup> World Petroleum Congress in Doha-State of Qatar, 4-8 December, 2011.
- Participated to the Offshore Arabia Conference and Exhibition, organised by RECSO- Dubai, 26-28 Feb. 2012.
- Participated to the LNG Outlook Conference-Dubai, May 22-23, 2012.

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- Qatar Petroleum, Qatar (numerous);
- Department of Maritime Affairs, Morocco (numerous);

Word count of main body of thesis from chapter 1 through 10 inclusive: 70542

Signed: Mohamed Briouig

Date: 6 December, 2013

## List of Abbreviations

|        |                                               |
|--------|-----------------------------------------------|
| AIS    | Automatic Identification system               |
| ALARP  | As Low As Reasonably Possible                 |
| Bcm    | Billion Cubic Meters                          |
| BP     | Business Process                              |
| BPR    | Business Process Re                           |
| CBA    | Cost Benefit Analysis                         |
| CCTV   | Close Circuit TV                              |
| CEA    | Cost Efficiency Analysis                      |
| CEE    | Centre for Energy Economics                   |
| COMAH  | Control of Major Accident Hazard Regulations  |
| CSR    | Construction Safety Report                    |
| DHS    | U.S. Department of Home Land Security         |
| DNV    | Det Norsk Veritas                             |
| EEZ    | Exclusive Economic Zones                      |
| EFA    | Exploratory Factor Analysis                   |
| EMP    | Emergency Management Plan                     |
| EPSA   | Exploration and Production Sharing Agreements |
| ERP    | Emergency Response Plan                       |
| ESD    | Emergency shutdown systems                    |
| EU     | European Union                                |
| FA     | Factor Analysis                               |
| FER    | Fuzzy Evidential Reasoning                    |
| FERC   | the US Federal Energy Regulatory Commission   |
| FOB    | Free on board                                 |
| FSA    | Formal Safety Assessment                      |
| GBS    | Goal Based Standard                           |
| GTL    | Gas To Liquids                                |
| HAZID  | Hazards Identification study                  |
| HazMat | Hazardous Material                            |
| HLAs   | Helicopter Landing Areas                      |
| HOA    | Heads of Agreement                            |
| HSE    | Health Safety and Environment                 |
| HST    | Hard systems thinking                         |

|        |                                                          |
|--------|----------------------------------------------------------|
| IACS   | International Association of Classification Societies    |
| IMO    | International Maritime Organisation                      |
| ISM    | International Safety Management Code                     |
| K      | Thousand                                                 |
| LNG    | Liquefied Natural Gas                                    |
| LOS    | Levels of Service                                        |
| LPG    | Liquid Petroleum Gas                                     |
| M      | Million                                                  |
| MARPOL | Maritime Pollution Regulation                            |
| MEPC   | IMO's Maritime Environment Protection Committee          |
| MHIDAS | Major Hazard Incidents Data Service                      |
| ML     | Maximum Likelihood                                       |
| MMBtu  | Million Metric British thermal units                     |
| MMtpa  | Million Metric tonnes per annum                          |
| MOA    | Memorandum of Agreement                                  |
| MOU    | Memorandum of Understanding                              |
| MSC    | IMO's Maritime Safety Committee                          |
| MTPA   | Million Tonnes Per Annum                                 |
| NAFM   | U.S. National Association of Fire Marshals               |
| NEMP   | National Emergency Management Plan                       |
| OECD   | Organisation for Economic Cooperation and Development    |
| PCSR   | Pre-construction Safety Report                           |
| PPE    | Personal Protective Equipment                            |
| QRA    | Quantitative Risk Assessment                             |
| RA     | Risk assessment                                          |
| RBDM   | Risk-Based Decision Making                               |
| RCO    | Risk Control Option                                      |
| RM     | Risk Management                                          |
| RPT    | Rapid Phase Transition                                   |
| SC     | Supply Chain                                             |
| SCRM   | Supply Chain Risk Management                             |
| SHI    | Samsung Heavy Industries                                 |
| SIGTTO | Society of International Gas Tanker & Terminal Operators |
| SMS    | Safety Management System                                 |
| SOLAS  | Safety Of Life At Sea                                    |
| SPAs   | Sales and Purchase Agreements                            |

|        |                                                       |
|--------|-------------------------------------------------------|
| SPSS   | Statistical Package for the Social Sciences           |
| SSM    | Soft Systems Methodology                              |
| STA    | Systems Thinking Approach                             |
| STCW   | Standard of Training, Certification and Watch keeping |
| T      | Trillion                                              |
| Tcf    | Trillion Cubic Feet                                   |
| TQM    | Total Quality Management                              |
| UK     | United Kingdom                                        |
| UNCLOS | UN Convention on the Law of the Sea                   |
| USA    | United States of America                              |
| USCG   | United States Coast Guard                             |
| VC     | Value Chain                                           |
| VTMIS  | Vessel Traffic Management and Information System      |

## CHAPTER 1 INTRODUCTION AND BACKGROUND

### 1.1 INTRODUCTION

Ports are complex hubs of multiple stakeholders, organisations and flows fulfilling complementary, competing and highly integrated functions and roles, making them active members within international maritime logistics and SC systems. Ports and marine terminals handling dangerous and highly flammable substances, such as liquified gases are exposed to further complexity and risks which require special diligence in their planning and operation. Furthermore, since the 9/11 terrorist attacks in the US., the possibility of security threats against LNG ports infrastructure, marine terminal facilities and LNG tankers has been considered a credible risk scenario which LNG ports and related LNG SC members have to consider seriously for due mitigation and response. During the last decade, LNG has become a high growth market commodity, due mainly to its limited environmental footprint. Demand for natural gas is expected to eclipse oil by 2030, while demand for LNG specifically will increase 10% per annum through 2015 (Theodoropoulos 2009, p. 144). Hence, the frequency of LNG shipments through ports has increased tremendously and raised concern over their safe and secure operations, especially with consequential scarcity in skilled technical manpower. Moreover, since the 9/11 terrorist events, the process of managing risks in ports and maritime SCs, has undergone a paradigm shift both in scope and scale due to the following reasons:

1. Ports are strategically located at the mid-stream of the LNG value chain (VC) and represent the only node within the maritime SC bringing together multiple logistics, port and maritime related organisations and stakeholders,



functions, roles, processes and flows. Therefore, LNG ports are attractive targets to terrorist groups and need diligent RM planning, mitigation and response as well as appropriate contingency planning.

2. The nature of security risks has shifted from local and limited impact acts of stowaways, drug smuggling, cargo theft etc. to more global and widespread impact attacks from global terrorism. Thus, low frequency high consequence events, such as large scale security incidents, can no longer be neglected and need to be integrated within the routine LNG SC risk portfolio.
3. In practical terms, taking into consideration the LNG SC process in addressing LNG SC security means necessarily integrating the safety procedures and practices as well, which constitute an important part of LNG operating systems of production, storage, transport and distribution. Therefore, LNG maritime and port security should be analysed and addressed in conjunction with and taking due account of safety measures and practices and from the broader SC perspective. In this respect, safety measures and safeguards are, and shall be considered the first line of defence for security incidents. As such, these technical safety safeguards shall be integrated within the overall security risk assessment (RA) and management system.
4. Despite LNG's 40+ years proven safety record of production and shipping with few accidents, LNG SCs still remain under both safety and security threats due first to the increased volumes of LNG being shipped worldwide, which increase the potential and likelihood of maritime and port accidents, and secondly due to the widespread threat of terrorism. Although the

industry is justifiably proud of its extraordinary safe history, Meyer *et al*, (2007) argue that

*'Only one serious LNG incident, however, could severely undermine this near-perfect record and likely redefine the RM calculus for most stakeholders'*

This further attests to the ultimate importance of approaching the issues of LNG ports SC safety and security risks from a holistic perspective and highlights the need for a comprehensive and coordinated RA and management framework to effectively address safety, security and related environmental threats in a cost effective manner.

## **1.2 WHY STUDY RM IN LNG PORTS?**

As asserted by Notteboom and Winkelmanns (2001), seaports are key constituents in international SCs and their pre-eminent role in international distribution is unlikely to be challenged. LNG ports are located at the mid-stream of the LNG VC, therefore playing a pivotal role in the storage and flow of LNG cargoes to world markets. Any safety or security incident within the port areas may have detrimental effects on the whole LNG SC with cascading impacts on LNG exporting and importing countries and their industrial and energy based sectors. It is generally agreed that constantly available and affordable energy supplies are vital to maintaining and enhancing quality of life and promoting economic growth.

Ensuring uninterrupted, robust and resilient LNG SC requires first, adequate management of safety and security risks in LNG ports and marine terminals. While each discipline of risk, be it safety or security, has actually received significant attention both in theory and practice, less attention was given to the

interfaces and shared impacts between safety and security risks in LNG ports SCs. This led to the existence of gaps in RM which does not promote a cost effective RM in LNG ports SCs and may constitute a source of disruption or delays in the LNG ports activities. This research intends to address such gaps which are poorly addressed in the current literature and proposes a holistic and integrated approach to the issues of safety and security risks assessment and management in LNG ports.

The authors' interest in the subject started earlier in his career as a logistics and port professional and continued throughout his professional career in various seaports. This practical interest turned into a practical subject of enquiry when the author was serving as on-scene commander for maritime search and rescue (SAR) services. Recent involvement of the author in the planning and management of industrial seaports along with the development of recent safety and security standards through the international maritime community, especially security frameworks, has increased his interest in the research subject. LNG ports have recently received high attention in terms of safety and security regulations; however the implementation of international and domestic safety and security standards is done in isolation and with less coordination which may create difficulties to the safety and security systems of LNG ports and may ultimately represent a risk of disruption to the international LNG SC. Moreover, uncoordinated management of safety and security risks may not allow cost effective RM and prevent efficient emergency planning and port business continuity.

### **1.3 RESEARCH AIM, SCOPE AND OBJECTIVES**

The interfaces and shared impacts among safety and security risks in LNG ports and marine terminals represent a vital area of research which has not been sufficiently investigated and which urgently requires in-depth research both at theoretical and practical levels. The discipline of HSE RM has received wide attention by researchers and practitioners, meanwhile, security in general and terrorism risks in particular, especially during the post 9/11 era have also generated a large literature and the promulgation of international regulations in a wide effort to address terrorism related risks. However, less attention has been given to the relationship, interfaces and shared impacts between port safety and security risks both at theoretical and practical levels.

Such areas of research offer exciting possibilities for the development of an integrated approach to the relationships, interfaces and shared impacts among safety and security risks assessment and management in LNG ports. The present research aims to model safety and security RM, from a SC perspective and within the framework of an integrated and holistic RM approach, addressing the interfaces between safety and security risks. Such an approach shall take advantage of the strategic leadership role played by the port authority, to coordinate and integrate the role that the LNG port community can play within a participative approach.

The scope of this research extends to the RM of port SCs handling LNG. The focus of the study is on the management of safety and security risks with a special emphasis on security risks stemming from global terrorism and organised crime due to their significant and widespread impact as well as to the lack of historical data and experiences of terrorism related incidents in the LNG

industry which can guide appropriate coordinated security RA and management. Moreover, recent experience shows that management of safety and security risks are conducted in relative isolation and with insufficient coordination, especially within LNG ports and marine terminals known to be complex and critical areas of interest for multiple LNG stakeholders. This requires further coordination and cooperation in the safe and secure storage, handling and transport of LNG to world markets. It should be noted, however, that although safety and security risks are different in terms of their respective risk factors and related RA methods, they are still interrelated, interfaced and have shared impacts. Therefore, their assessment and management should be best integrated and coordinated within the framework of an all-hazard approach. Process-wise, the study extends its scope to the LNG port SC from the LNG storage facility, often localised within the port premises, to the LNG tanker alongside the jetty and the surrounding maritime and shore-based port environments. Thus geographically the LNG port SC encompasses both the onshore and offshore port components.

Following the considerations set forth in the above section and based on a detailed descriptive analysis of the international LNG SC as well as the extensive literature review of safety and security risks assessment and management methods and approaches, the following research questions are generated:

1. What are the interfaces and shared impacts in the management of safety and security risks in LNG ports and marine terminals?

2. What impact does uncoordinated and isolated management of risks have on the efficiency of overall RM in LNG ports and marine terminals?
3. How are safety and security risks managed in LNG port SCs?
4. How can safety and security risks be best managed from an integrative and holistic perspective within the LNG port management system?

The following objectives are developed from the research questions set to direct and focus the research:

1. To analyse the LNG SC, its main components, flows and processes with particular emphasis on the strategic role of ports and marine terminals in the LNG SC including tangible and non-tangible flows and processes.
2. To evaluate current international maritime and port safety and security regulatory frameworks and characterise them from a logistics and SC perspective.
3. To analyse the relationship between port SC safety, security and quality; mainly in terms of assessment and management methodologies and approaches.
4. To identify relationships and interfaces among safety and security risks managements in LNG ports and discuss their possible mutual and shared impacts.
5. To propose and test a standard high level conceptual model ensuring integrated LNG port SC RM and enabling coordinated mitigation plans, contingency measures and port business continuity strategies.

## **1.4 RESEARCH METHODOLOGY AND APPROACH**

### **1.4.1 Structure of the thesis and research design**

After introducing the subject in chapter one and providing its scope and methodology, the research report continues with a presentation and analysis of the LNG VC in chapter two, its components and characteristics as well as the role of ports and marine terminal organisations as critical nodes within the global LNG SC. Chapter two provides detailed information on the port and shipping components of the LNG VC as well as the main characteristics of international LNG markets. Initial identification of risk factors is undertaken during this stage stemming from possible unintentional threats translated by recent high LNG market growth which testifies to the scarcity of skilled work force throughout the LNG value chain activities, especially in the maritime and shipping node. Meyer *et al.* (2007) and Griffin (2012) argue that noticeable increase in LNG production and export worldwide is not actually supported by a corresponding increase in skilled resources in the LNG VC activities, especially in shipping and maritime activities. Such a pressing need for skilled labour impacts on the expansion plans of LNG projects and forces the industry to use a less experienced workforce which in turn may constitute a source of risk. Other risk factors, related to LNG maritime and port infrastructure are also identified including intentional and unintentional sources.

An extensive literature review is undertaken to help generate and refine the research problem. Chapter three reviews literature pertaining to LNG ports and maritime safety and security risks assessment and management. The focus is mainly on literature addressing relationships, interfaces and shared impacts

between safety and security risks, risk factors and the RM approaches actually applied in LNG ports SCs worldwide. Detailed presentation and descriptive analysis of the entire LNG VC and the LNG port SC in chapter two, as well as the literature review in chapter three, refines the scope of the research problem and related research questions.

Such qualitative analyses reveal a research gap in the literature related mainly to the scarcity of studies addressing the relationship between safety and security in ports in general and in ports and marine terminals handling LNG, in particular. Very little literature has discussed theoretical and practical interfaces among safety and security risks and even less has addressed the management frameworks or methodologies for such interfaces. Moreover, even when they do, they address the issue from a port facility risk point of view and rarely analyse the issue from a SC perspective. The present study intends to bridge those gaps by studying safety and security interfaces and shared impacts from a SC perspective and proposes an integrated RA and management framework capable of providing robust and resilient LNG port SCs, to ensure uninterrupted LNG supplies to world markets.

To characterise the role of ports and marine terminals within the international LNG SC, a review of the main LNG SC characteristics as well as the most known RA and management theories and frameworks is undertaken. The empirical analysis draws on the experience of the world leading LNG ports in the Arabian Gulf region, due to their strategic importance, as major LNG exporting hubs, and their strategic role in the international LNG SC.



The legal and historical part of the enquiry is critically discussed in chapter four and includes an extensive review of:

- International maritime and port safety legal frameworks, including the international agreement for the Safety Of Life At Sea (SOLAS), the Collision Regulations (COLREG), the Standard for Training, Certification and Watch-keeping for seafarers (STCW),...etc. Other international standards, more specifically addressing LNG shipping and ports, are reviewed and evaluated such as the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, (IGC Code). Other less global safety standards with regional and national coverage are also reviewed; including the EU led standards, the UK HSE and the USA LNG Coast Guard safety regulations.
- International legal security frameworks developed by the international maritime community as a response to terrorism in the wake of the 9/11 terrorist attacks are also reviewed and discussed. In this respect, multilaterally endorsed regulatory measures include the International Ship and Port Security (ISPS) code, the IMO/ILO code of practice on security in ports and more recently the Framework of Standards to Secure and Facilitate Global Trade known as the WCO Framework. Other less global security packages yet of wider application may be considered and reviewed as deemed relevant to the LNG SC including industry led rules, regulations and practices governing the setting and operation of LNG facilities, both onshore and offshore; an analysis of the combination of technical and legal practices, and their ability to withstand the new risks and threats portfolio posed by global terrorism.

Chapter five appraises the main safety and security RA and management methods and approaches used across world LNG ports. The focus is on RA methodologies developed to cater for safety and security risks from a holistic and integrated perspective. Various approaches are presented and benchmarked against the '*all-hazards approach*' introduced recently by the U.S Coast guards.

Chapter six outlines and justifies the research methodology used to address the research problem and provides an answer to the research questions. It also discusses the philosophical foundation of the research.

In chapter seven, an empirical study undertaken to generate primary source data is reported. This includes detailed qualitative Delphi study which is run in two rounds, as well as a quantitative survey. The Delphi study results are tested and validated through a quantitative study using factor analysis and other statistical techniques. This quantitative enquiry is based on an online survey conducted among a relatively large sample of LNG risk professionals. The Delphi findings are used as hypotheses to be further cross checked and tested quantitatively through factor analysis and other statistical techniques. The outcome of the quantitative study forms the basis for the high level LNG RM conceptual model proposed in chapter eight.

Chapter eight begins with a summary of the main findings of the quantitative study and introduces the use of a Systems Thinking Approach (STA), more specifically the Soft Systems Methodology (SSM), to build the conceptual model for LNG ports SC RM. This model is developed on the basis of Checkland & Scholes (1990) and Checkland (1999) SSM process. The choice of SSM is

justified because it provides the most appropriate analytical framework to deal with complex management problems such as those posed by this research. The proposed conceptual model is further tested and validated through a focus group discussion with a panel of LNG port managers and RM specialists.

Chapter 9 discusses the main findings of the study and its implications on theoretical and practical levels.

Chapter 10 summarises and concludes the study by highlighting its contribution and limitations. It also provides recommendations for future research.

#### **1.4.2 Research methods**

Table 1.1 provides a summary of research methods deployed to collect primary and secondary data and to direct the provision of appropriate answers to the research questions.

**Table 1.1 Summary of Research Design and methods**

| <b>Chapters</b>   | <b>Mixed modes of Data collection</b>                                                                                                                                     | <b>Purpose of data collection source</b>                                                                                  | <b>Justification of adoption</b>                                                                                                                                                                                       |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Chapter 1</b>  | Introduction: Observation, research scope, research objectives and methodology. (Secondary data source)                                                                   | To Introduce the research problem and its scope, objectives and the methodology adopted                                   | Necessary to get a purposeful research                                                                                                                                                                                 |
| <b>Chapter 2</b>  | LNG SC Analysis through critical review of literature. (Secondary data source)                                                                                            | To understand the characteristics of the LNG SC, the LNG markets and to characterize the role of ports in the overall SC. | Necessary to understand the subject, generate its research questions and provide full explanation of its main components.                                                                                              |
| <b>Chapter 3</b>  | Extensive literature review (secondary data source)                                                                                                                       | Extensive review of literature to define and further scope the research problem and related research questions            | Necessary to know what has been published so far as literature about the subject and to detect research gaps.                                                                                                          |
| <b>Chapter 4</b>  | Secondary data source – Critical review of existing safety and security RM regulatory framework.                                                                          | To integrate this into the overall picture of the descriptive part of the enquiry.                                        | Necessary to understand the legal and methodological frameworks which govern the theoretical and practical sides of the enquiry.                                                                                       |
| <b>Chapter 5</b>  | Critical review of RM approaches and methodological practices in LNG ports                                                                                                | To integrate this into the overall picture of the descriptive part of the enquiry.                                        | Necessary to understand the practical side of the enquiry.                                                                                                                                                             |
| <b>Chapter 6</b>  | Methodology                                                                                                                                                               | To explain the philosophical stance, the approach and the relevant methods applied in the research                        | Necessary to Justify the methodology adopted and how it is followed up to provide response to the research problem.                                                                                                    |
| <b>Chapter 7</b>  | - Exploratory Delphi study through an online survey. (Primary source data)<br><br>- Quantitative study survey analysed quantitatively through SPSS. (Primary source data) | To get primary source practical data on the subject<br><br>To test and validate the findings of the Delphi study          | Appropriate and cost effective method of primary data collection within the context of a multi-disciplinary management topic.<br><br>Cost effective and accurate way of data testing for the confirmation of findings. |
| <b>Chapter 8</b>  | Soft Systems Method (SSM)                                                                                                                                                 | To build the conceptual model for LNG ports SC RM                                                                         | Systemic way of representing solutions to the problem situation from a holistic perspective                                                                                                                            |
| <b>Chapter 9</b>  | Discuss and Synthesize the findings in a logical way                                                                                                                      | To discuss the main findings of the research and benchmark alternatives.                                                  | Necessary to sum up the main findings and provide its sequence.                                                                                                                                                        |
| <b>Chapter 10</b> | Conclusion                                                                                                                                                                | To conclude the research                                                                                                  | Provide an end to the enquiry by reflecting on what has been achieved as objectives and state limitations of the study.                                                                                                |

## **1.5 MAIN CONTRIBUTION OF THE STUDY**

At the theoretical level, this study highlights a more holistic approach to the issue of RM in energy ports in general and LNG ports and marine terminals in particular. It differs from existing approaches and practices of RM which favour dichotomy and a disciplinary silo approach. It argues that safety and security professionals should leave behind existing traditional beliefs and a practice through which they assess and manage risks in isolation and without considering interplays and shared impacts between safety and security. They require a new understanding through which safety and security risks and their control options and strategies (RCOs) are looked at holistically from a systems perspective and then evaluated collaboratively to yield synergized and cost effective safety and security RM. Furthermore, the RM process in LNG ports will require re-engineering so that work flow, processes and procedures are organised around outcomes and not isolated tasks. As stated by Greswell (1998), the principles of re-engineering consist of organising around outcomes not tasks.

Therefore the study highlights the advantages of applying integrated, holistic and coordinated approach to RM in LNG ports, in contrast with the prevailing approach of isolated management of safety and security risks and emergency response. This study sheds light on the necessity of applying a unified and coordinated RM approach to risks in LNG ports which shall deliver efficient and cost effective safety and security risks management system as an integral part of the port management system.

At the practical level, this research investigates a vital real-world problem faced by ports managers and RM specialists in industrial ports in the Arabian Gulf and MENA region. A panel of managers from those ports was consulted during all stages of this research and their expert opinions were considered and integrated as primary source data in the analysis of the research subject. During all stages of the enquiry, both port managers and safety and security professionals consulted, either during formal interviews/ questionnaires or during informal discussions, have testified to the practical nature of the research problem and the usefulness of addressing it in a more pragmatic and practical way taking into consideration the complexity of the port system and its strategic importance within the international LNG SC.

This research succeeds in shedding light on the gaps of relevant RM theories and approaches. Further it contributes at a practical level to the debate among ports managers and RM specialists on the necessity of applying an-all hazards approach to all sources of risks. Furthermore, the study proposes an effective integration among the port RM system and the emergency response system within the overall port management system for optimal, cost effective and resilient port SC and port business continuity.

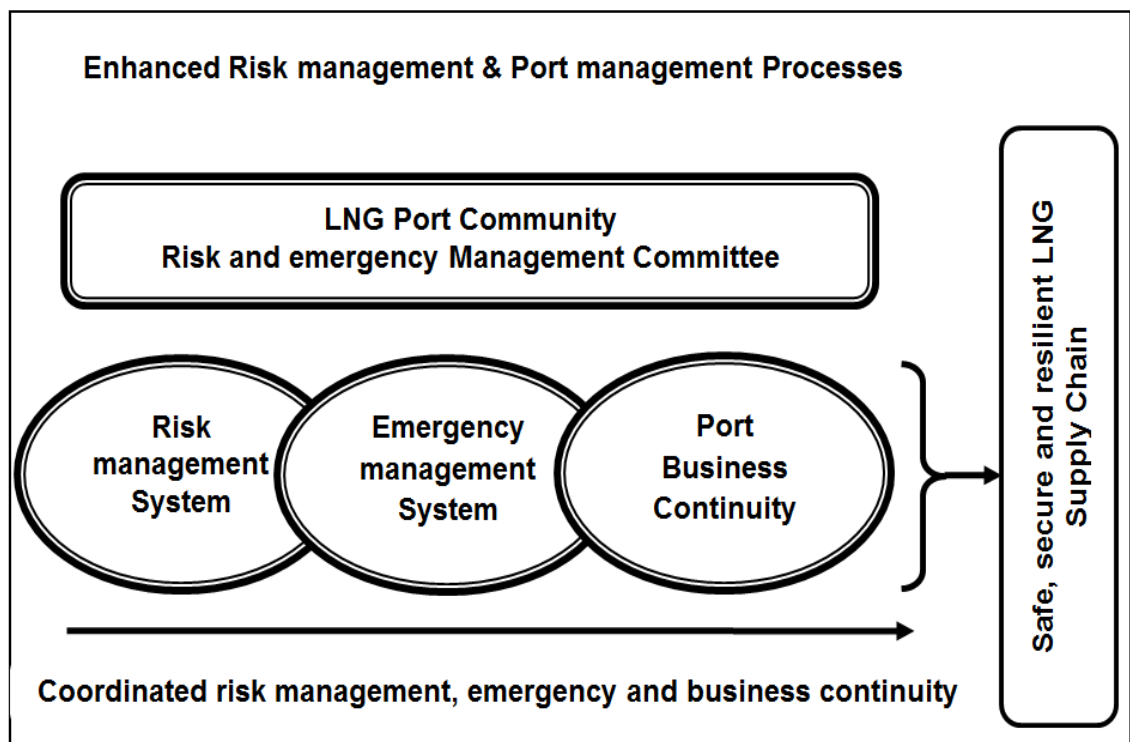
## **1.6 ORIGINALITY**

This research is original in its approach since it sets out to question the validity and usefulness of established theories on RM which tend to favour dichotomy and isolated management of safety and security in ports instead of an integrated and holistic approach to RM. It also claims an extended role of the port community in the management of risks within the port SC by proposing a

re-structuring of the LNG ports RM system, integrating safety, security and possibly environmental risks management and emergency planning and response. The research is an amalgamation of some established principles, viz. organisational theory and port safety and security RM, which sets out to form one conceptual model of the port RM system as an integral part of the overall port management system.

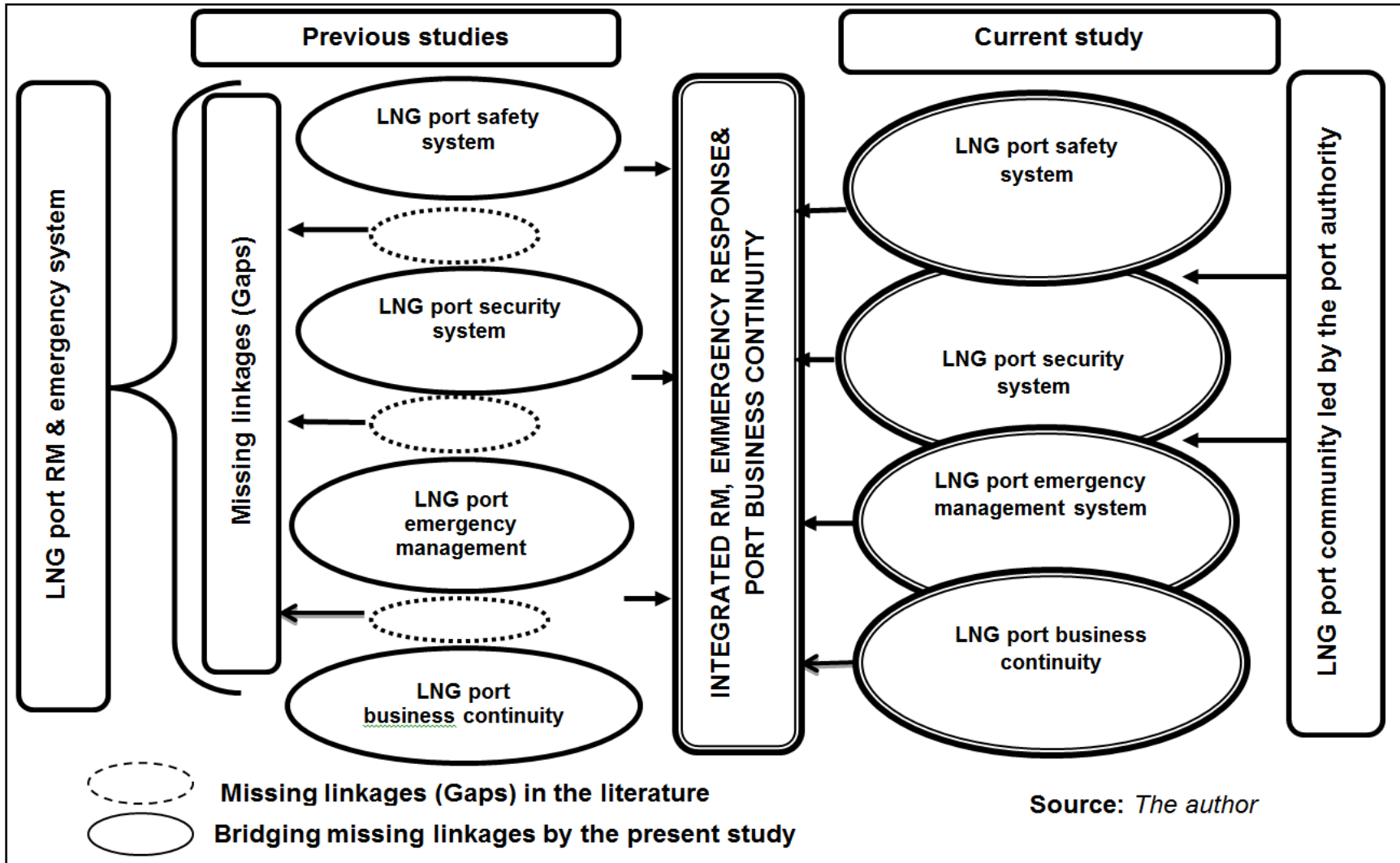
Such an integrative model has the merit of presenting a unified and focused management of LNG port risks in connection with emergency response and more importantly consolidating the bases for port business continuity.

**Figure 1.1 Port RM and emergency gaps bridged by current research**



Source: *The author*

Figure 1.2 Comparison between previous studies and current study





In doing so, the proposed approach testifies to the resilience of the whole LNG SC. This research can be considered as an investigation into established theories which resulted in the finding of research gaps with the aim of bridging such gaps and producing a conceptual model proposing how a holistic and unified approach to risk and emergency management in LNG ports can be achieved within the framework of a comprehensive and participative approach. The claim of originality is summarised in Figure 1.2.

The proposed model introduces a practical framework for integrated LNG ports risks and emergencies management. Such framework is applicable in the context of the LNG ports of the Middle East and North Africa (MENA) region, as well as to any LNG port worldwide which lacks integrated approach to risks and emergencies management.

## CHAPTER 2 THE LNG SUPPLY CHAIN

### 2.1. INTRODUCTION

As defined by Globe Business Publishing Ltd (2006), LNG SC is a process continuum, by which natural gas is produced, transformed into LNG, and transported from where it is produced to where it is needed and consumed.

LNG currently represents the most exciting aspect of the international gas landscape (Griffin, 2012). Though the overall percentage of gas transported as LNG is less than 10% of global gas trade, it is growing rapidly, involving an increasing number of buyers and sellers. The past two decades have seen phenomenal growth in the LNG trade, which is expected to continue unabated this decade. LNG is simply an alternative method to transport methane from the producer to the consumer. Methane ( $C_1H_4$ ) gas is cooled to  $-161.5^\circ C$  ( $-260^\circ F$ ), converting its gaseous state into an easily transportable liquid whose volume is approximately 600 times less than the equivalent volume of methane gas. Thus  $600 \text{ ft}^3$  of methane gas will shrink to a volume of around  $1 \text{ ft}^3$  of clear and odourless LNG. It is usually stored and moved at cold temperatures and at low pressure. Gas converted to LNG can be transported by ship over long distances where pipelines are neither economic nor feasible. At the receiving terminal, liquid methane is offloaded from the ship and heated, allowing its physical phase to return from liquid to gas. This gas is then distributed to gas consumers by pipeline in the same manner as natural gas produced from a local gas field.

The LNG process is more complex than pipeline transportation. The “LNG chain” shown below, consists of discrete sections: upstream, midstream liquefaction plant, shipping, regasification, and finally, gas distribution. LNG technology is not new; the first commercial LNG facility was built in 1941 in Cleveland-USA as a peak shaving facility. Unfortunately, this plant was closed in 1944 after a gas leak and explosion accident. According to Natgas.info (2011), the decision to commercialise a gas field by either LNG or direct pipeline is related to the distance to the market from the gas reservoir and to the availability of a port or marine terminal for the export of LNG by ships.

Natgas.info (2011) asserted that an industry commonly known rule states that LNG could be a viable option versus pipeline transport when the following characteristics are present:

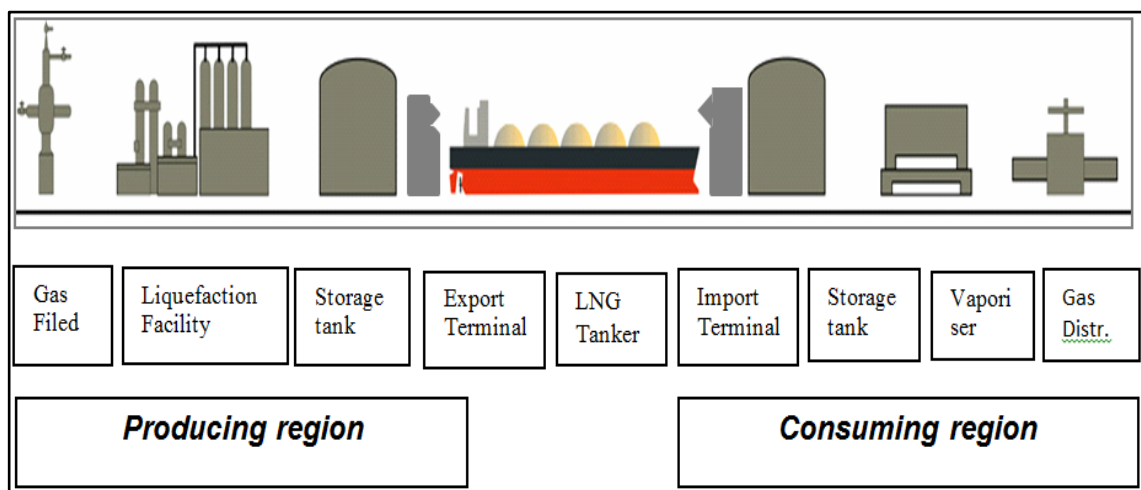
- The gas market is more than 2,000 km from the field.
- The gas field contains at least 3 tcf to 5 tcf of recoverable gas
- Gas production costs are less than \$1/ MMBtu, delivered to the liquefaction plant.
- The gas contains minimal other impurities, such as CO<sub>2</sub> or sulphur.
- A marine port where a liquefaction plant could be built is relatively close to the field.
- The political situation in the country supports large-scale, long-term investments.
- The market price in the importing country is sufficiently high to support the entire chain and provide a competitive return to the gas exporting company and host country.

- A pipeline alternative would require crossing uninformed third-party countries and the buyer is concerned about security of supply.

## 2.2. OVERVIEW OF THE LNG VALUE CHAIN (VC)

The LNG VC consists of a number of different operations which are highly integrated, interdependent upon one another and capital intensive.

**Figure 2.1 Steps of a typical LNG value chain**



**Source:** (CEE, 2012)

Major stages in the LNG VC, excluding pipeline operations, are:

### 2.2.1 Exploration and extraction

Exploration and extraction of natural gas from underneath the earth's crust called reservoirs. It is then produced and delivered to separation and gas treatment plants. Most, but not all, natural gas is extracted during oil production. Associated and non-associated gas is the terminology used to differentiate between the two types of gases depending on whether gas is found associated with oil or not.

### **2.2.2 Liquefaction and storage**

During this stage, natural gas is converted into a liquid state by cooling it to  $-161^{\circ}\text{C}$ . Liquefaction reduces the natural gas volume by approximately 600 times, making it economically viable to be shipped between continents. Liquefaction also provides the opportunity to store natural gas for use during high demand in cold seasons (LNG peak shaving storage).

### **2.2.3 Transportation**

LNG is shipped in special purpose vessels (LNG tankers) through ports and marine terminals which can be either shore based infrastructures or offshore structures (single point mooring or offshore platforms). LNG export/ receiving ports are central nodes in the LNG VC and play a crucial role in moving LNG to international markets. In fact, LNG shipping provided the main motivation for transforming natural gas from a local to a global commodity, traded internationally.

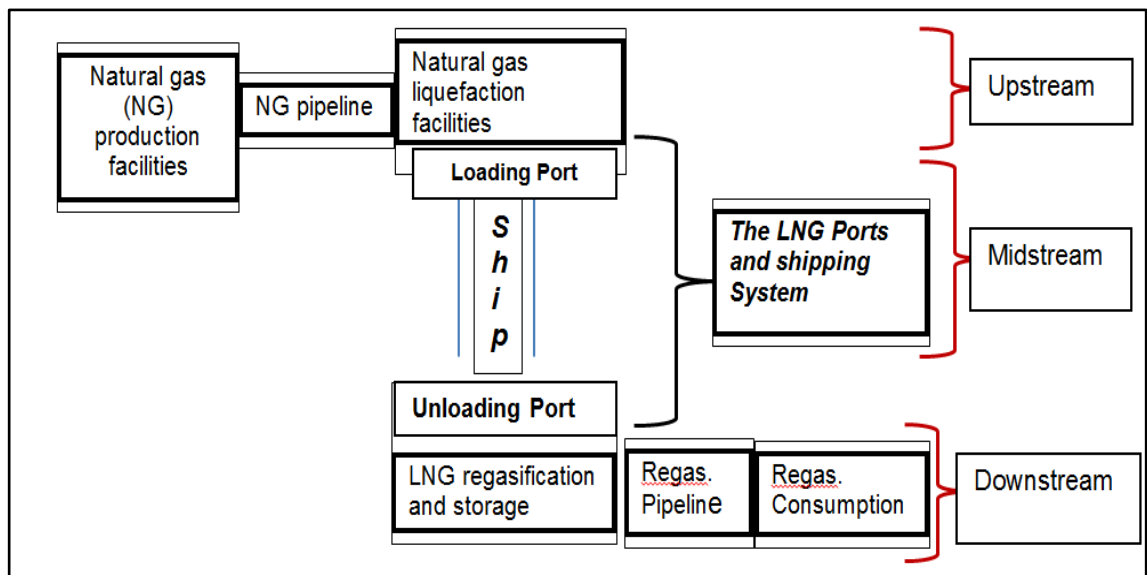
### **2.2.4 Storage and re-gasification**

This is an important step in the LNG VC through which LNG unloaded from tanker is re-directed, through pipelines, for storage and re-gasification.

Due to the interdependency of its components, the structure of the LNG process can be defined as a chain. This has upstream functions represented by natural gas production (Extraction, treatment, pipeline transport to liquefaction facilities and liquefaction to produce LNG). In

the centre of the VC are the midstream functions of LNG selling and shipping where LNG ports, marine terminals and tankers play a consistent role in the whole VC by enabling LNG to be an energy commodity traded internationally. Finally, at the bottom of the chain, the downstream functions are located and concern LNG regasification and storage, pipeline distribution to end user and consumer, either domestic or industrial. In the case of domestic usage, retail distribution is assured to end users.

**Figure 2.2 Composition of physical infrastructure of a typical LNG VC**

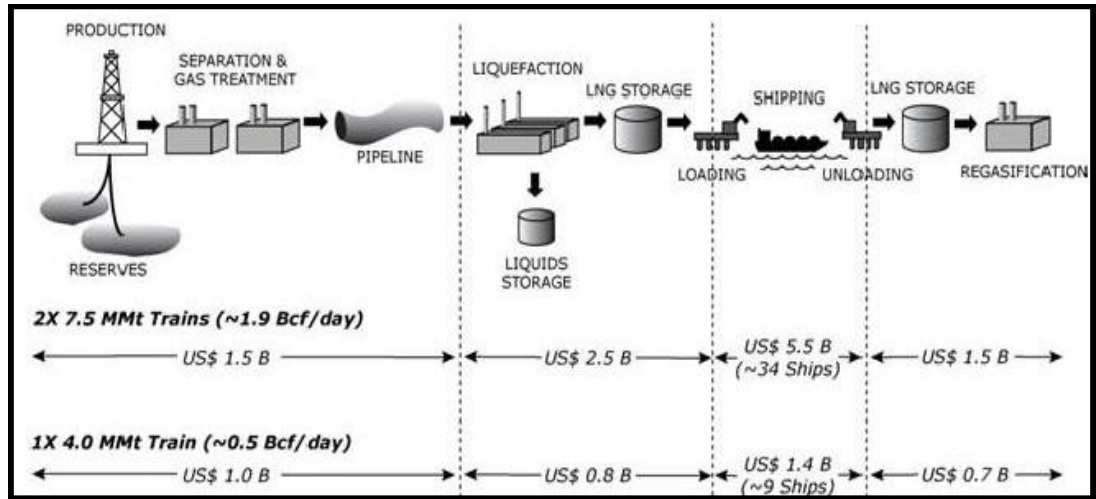


**Source:** Adapted from Globe Business Publishing Ltd (2006)

Building an entire LNG VC is expensive since it is compulsory to invest huge CAPEX cost all along the VC components. Nowadays, it is a general practice that major world gas producers invest in all LNG VC components, mainly to ensure control over the whole process.

Dubois-Denis (2004) estimated typical CAPEX requirement for two integrated LNG VCs as follow:

**Figure 2.3 CAPEX figures for typical integrated LNG VCs**



**Source:** Dubois-Denis (2004, p.2)

Gas is an energy source with a bright future. Just in the space of three decades, natural gas, previously reserved for most noble of industrial uses, has become popular for a number of different uses including, but not limited to, power generation and household energy. The gradual decline in natural gas reserves in the OECD countries combined with a constant growing demand for more environmentally friendly fuels when added to a wide range of key technological breakthroughs have opened up a huge number of transport and hence selling options for natural gas worldwide. At the end of 1990, industry observers predicted that demand for gas would grow at about 3% per year, and the most recent forecasts put growth at about 2% annually up to 2020, compared with 1.3% for oil. It is expected that gas will overtake oil by 2020 (Biol 2006). Furthermore, gas is expected to gain market share in the overall energy mix. Over the last ten years, power

generation has become the driving force behind global growth in gas demand. Gas is feeding 25% of the world power generation plants (Theodoropoulos 2009).

**Table 2.1 World LNG major consumers**

| <b>Country</b> | <b>% of world LNG Consumption</b> |
|----------------|-----------------------------------|
| <b>USA</b>     | 23%                               |
| <b>Russia</b>  | 15%                               |
| <b>UK</b>      | 3%                                |
| <b>Canada</b>  | 3%                                |
| <b>Germany</b> | 3%                                |
| <b>Iran</b>    | 3%                                |
| <b>Total</b>   | <b>50 %</b>                       |

*Adapted from Theodoropoulos (2009, p. 145)*

Major gas importers include most OECD countries and South Asia accounting for 50% of world consumption, the other 50% is shared by countries listed in the table above.

Actually, there is no truly global gas market as it is the case for oil, but three separate markets- North American, Western Europe and Asia, with different growth rates. The North American market leads the others. Market growth is mainly driven by two elements:

1. Environmental concerns, as many industrialised countries are trying to shift to natural gas to minimise the consequences of climate change.
2. Demand growth. This is encouraged by gas availability. Up to now demand has not kept pace with discoveries in recent years. Other factors also play a role in gas demand such as weather conditions, economic growth and fuel competition.

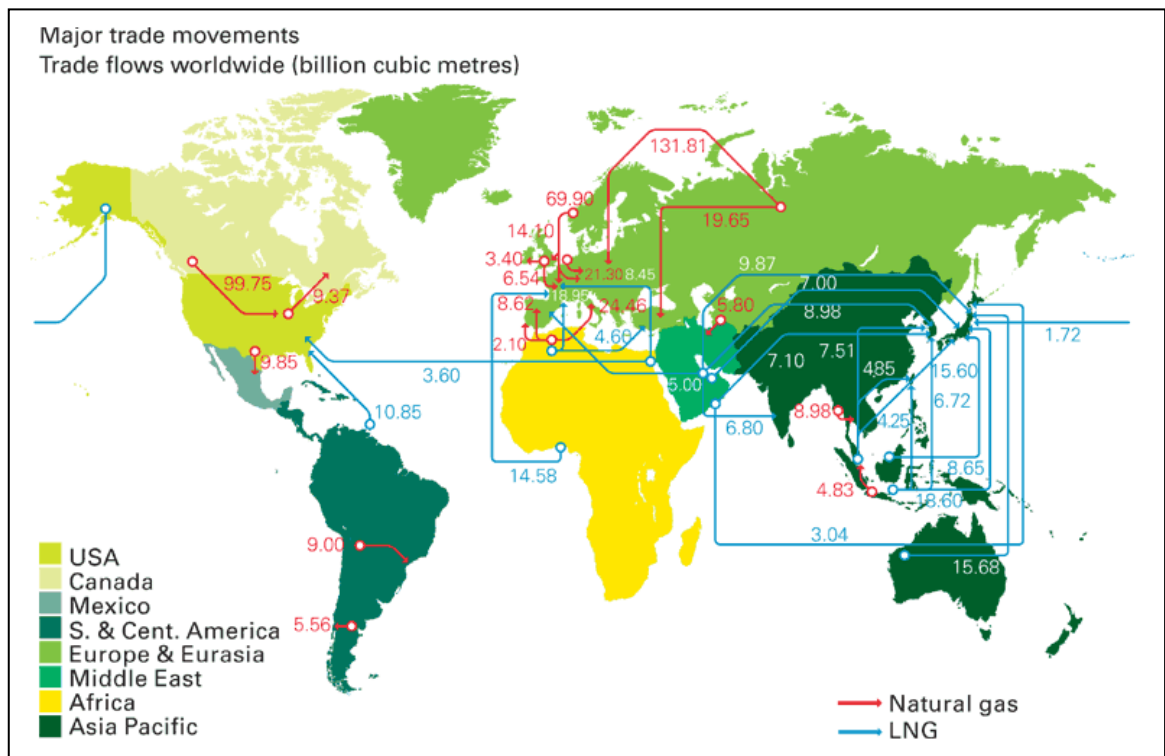


From the supply side, world gas reserves were estimated at 177.4Tm<sup>3</sup>, representing an average reserve life of about 65 years at the 2007-08 world consumption levels. Gas reserves are concentrated in three main countries, called the gas trio: Russia (27%), Iran (15%) and Qatar (13%), comprising more than 50% of the world's reserves. However, 20 countries make up 80% of the world's gas, while in oil only 10 countries control 80% of oil (Theodoropoulos 2009).

MENA region will lead supplies of natural gas for many decades to come. The region's production of natural gas is projected to grow even more rapidly than that of oil, trebling over the projection period to 1210 bcm in 2030. The biggest volume increases in the region occur in Qatar, Iran, Algeria and Saudi Arabia. The bulk of this increase will be exported as LNG. Demand for the regions' gas will be driven by strong global demand and decreasing output in many other gas producing regions (Birol 2006).

LNG exports are expected to grow at faster pace than other energy sources and many regions in the world will be more reliant on LNG imports including western and southern Europe and Asia. This has the potential to put further pressure on the LNG SC to provide safe and secure shipments and prevent supply disruptions due to catastrophic events.

**Figure 2.4 World natural gas and LNG trade movements in 2007**



**Source: BP (2007)**

### **2.3. LNG PORTS AND MARINE TERMINALS**

A port is commonly defined as a facility at the edge of an ocean, river or lake; purposely made and equipped to facilitate reception of ships and transfer of cargo and persons to and from them (Ronza 2007).

Critical to the functioning of a seaport is the existence of sufficient water depth at its channels and berths; to be sheltered enough to provide protection for ships from winds and waves; and to have direct access to inter-modal transportation.

**Figure 2.5 The Gate Terminal in the Netherlands**



**Source:** (Huisman, 2007)

In fact, a modern port system goes beyond being a geographical point where several modes of transport meet to fulfil logistical and economic purposes. Ports are complex hubs fulfilling various functions and activities within the intermodal transport SC. As such, ports are characterised by:

- Being the link between sea transport and land modes of transport, including road, rail, mechanized conveying systems and pipelines.
- Various stakeholders and authorities meet at the port and interact to perform various logistics and SC activities, related to the transport of goods and mobility of passengers.
- Ports are subject to many types of flows and processes including tangible flows of goods, passengers and money; and non tangible

flows such as information, wire transfers, and immaterial transfers of financial payments (Bichou *et al.* 2007)

- Ports are subject to various logistical and economic value adding activities: Transport, warehousing, stripping, packaging, storage, loading and unloading of goods. Sometimes manufacturing, transformation and storage of different types of goods are made within the port geographical limit or within the immediate port hinterland for logistical and/or transshipment convenience. Example: LNG liquefaction and regasification plants (Fig.2.5).

The maritime and port industry involved in the logistics and SC of LNG has a double risk undertaking: one represented by LNG as an intrinsically high risk commodity and the other stems from the nature of modern ports as complex and risky business environments, due to the existence of multiple stakeholders, logistics processes and multitude flow types, commodities handled, relationships and services.

Ports are strategic nodes within the LNG logistics and SC. This is the case of LNG export/import terminals and regasification facilities. They both serve a single chain of operations from the gas well and processing plant to the final consumer. It is not possible actually to conceive an LNG project without the maritime and port component. The port and maritime transportation make LNG projects economically viable, allowing safe and cost effective transport of large quantities of LNG from producing and exporting regions to distant importing countries worldwide.

In general, the party owning the liquefaction project has to plan and construct the LNG export terminal facilities including the export Jetty(ies), the loading arms and pipeline system and the necessary storage facilities at or near the port/ marine terminal. On the other hand, the LNG importing party has to construct and equip the LNG import complex, including the marine import terminal, as well as the storage, regasification plant and the gas distribution system.

Recently, most LNG projects are established through large public/private partnership, under exploration and production sharing agreements (EPSA), where critical SC infrastructure are owned variably by the partners along the SC. Therefore, an import and regasification terminal in an importing country is partly owned by the LNG exporting party. Examples include the South Hook terminal in UK and the Adriatic import terminal in Italy.

## **2.4 LNG SHIPPING**

The transportation of LNG is intrinsically linked to the sales and purchase agreement (SPA). Each LNG project is structured with contractual commitments which stipulate the way LNG will be shipped from the seller to the buyer and the party to have responsibility over the shipping function.

Generally, LNG is shipped either on an ex-ship basis or on a FOB basis. In the first case, the seller is responsible for shipping the product to the customer, whereas in case of FOB contract, the buyer assumes responsibility for the LNG transport. In either case, the LNG project

always contains contractual commitment regulating how the sale and purchase of LNG is structured and who takes responsibility over the shipping component of the overall chain (Theodoropoulos, 2009).

In practice, the shipping function is assumed either by the seller or the buyer, whichever owns the LNG ships. Alternatively, the party which has the responsibility for shipping LNG may contract out this function to an independent LNG ship owner under a separate charter party agreement. The case of several LNG projects in the MENA region reveals that the shipping function is established as a specialised entity serving the LNG project. Most LNG extraction and liquefaction projects in Algeria, Qatar and Yemen have their own shipping companies which own their tankers or alternatively charter them under long term charter party agreements.

LNG projects tend to establish their own shipping entities for a number of reasons: first, as stated earlier, LNG projects are capital intensive chains of infrastructure which cannot afford disruption or delay; therefore LNG project owners need to get full control of the transportation node to ensure its reliability in performing its function properly and timely. Second, LNG tankers are very expensive pieces of equipment and critical to the success of the LNG SC, therefore, full control over this node is preferred to ensure cost effective and efficient delivery of LNG to distant customers.

LNG ships operate a “virtual” pipeline in a sense that they continually transport LNG from producing countries to consumers without interruption. As a ship is

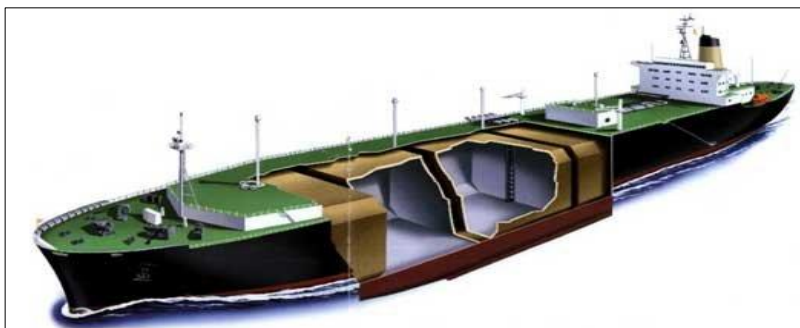
being loaded, a sister ship may be discharging its cargo, and the remaining members of the fleet are either en route to the buyer's regasification facility or on the way back to the LNG export terminal to pick up new cargo. The LNG tanker fleet is assimilated here to a pipeline which delivers LNG without interruption from producing to consuming regions. However, as the LNG spot market increases, ships are loading LNG from different terminals and discharging their cargoes wherever the prices are best at the time.

### **2.4.1 LNG tankers**

LNG is transported in large, specially designed ships. These are doubled hulled and have a capacity of 210k to 266k m<sup>3</sup>. LNG tankers are fitted with a special cargo containment system inside the inner hull to maintain LNG at atmospheric pressure and at required temperature of -160 C° (Theodoropoulos, 2009).

Three main technologies exist for the design and construction of LNG tankers, two of which are predominant in current LNG fleet: Spherical moss design (52% of the existing fleet) and membrane design (46%).

**Figure 2.6 Photo illustrating a membrane LNG tanker**



**Source:** (CH.IV International, 2006)

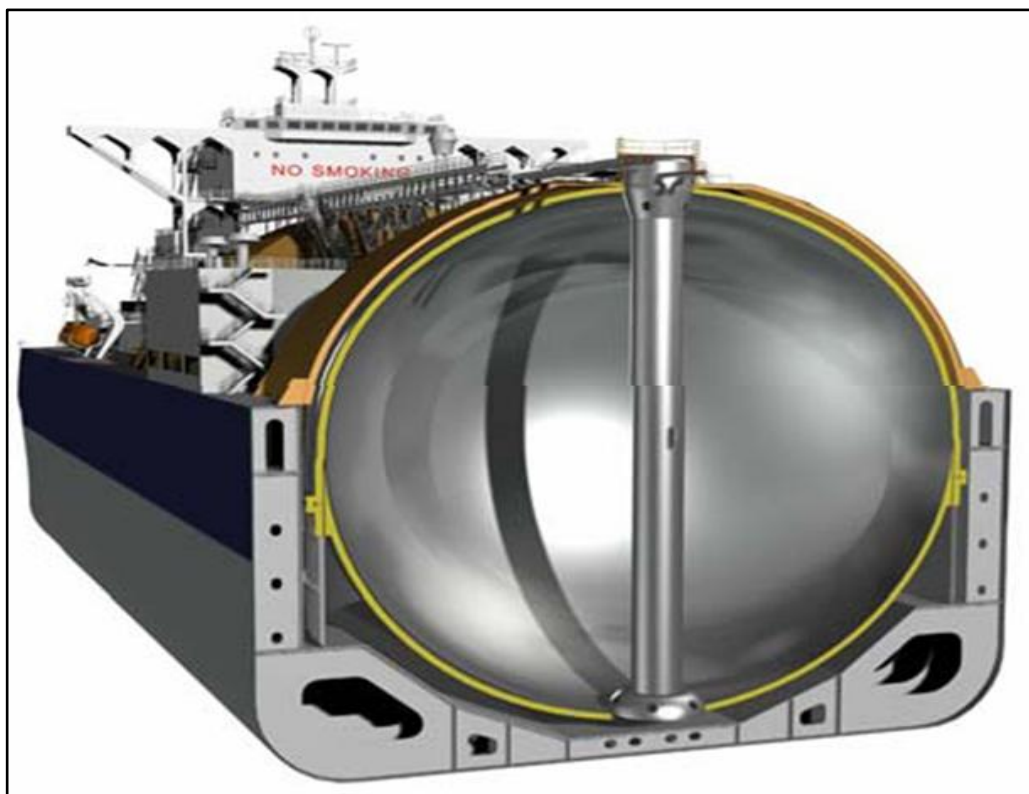
Membrane tanks are composed of a layer of metal (primary barrier) insulation, another liquid-proof layer, and an extra layer of insulation. Those several layers are then attached to the walls of the externally framed hold (Fig.2.6)

**Figure 2.7 Spherical moss tankers**



**Source:** (CH.IV International, 2006)

**Figure 2.8 Tank Section of a Spherical moss tanker**



**Source:** (CEE, 2012)



The alternative to a membrane tank is a self-supporting tank. The most well-known is the Moss-designed spherical tank that many people equate with the appearance of an LNG carrier (Figures 2.7 and 2.8). The covered insulation surrounding the sphere can channel any leakage to a drip tray located under the sphere's "south pole" (CH.IV International, 2006).

#### 2.4.2 Size and capacity of emerging LNG carrier designs

Many new LNG carriers are being designed to carry as much as 265,000 m<sup>3</sup> of LNG. The new 215,000 m<sup>3</sup> membrane carriers are often referred to as Q-flex designs, and the 265,000 m<sup>3</sup> membrane carriers are often referred to as Q-max designs.

**Table 2.2 Emerging LNG carrier size and capacity**

| Class     | MEMBRANE DESIGNS |          |          |          |
|-----------|------------------|----------|----------|----------|
|           | 145,000m         | 155,000m | 215,000m | 265,000m |
| Tanks     | 4                | 4        | 5        | 5        |
| Length(m) | 283              | 288      | 288      | 345      |
| Width(m)  | 44               | 44       | 50       | 55       |
| draft(m)  | 11.4             | 11.5     | 12       | 12       |
| Class     | MOSS DESIGNS     |          |          |          |
|           | 138,000m         | 145,000m | 200,000m | 255,000m |
| Tanks(m)  | 5                | 4        | 5        | 5        |
| Length(m) | 287              | 290      | 315      | 345      |
| Width(m)  | 46               | 49       | 50       | 55       |
| draft(m)  | 11               | 11.4     | 12       | 12.5     |

**Source:** (Poten and Partners, 2006)

Table 2.2 provides an overview of the general size and dimensions of current and emerging LNG carriers for both membrane and Moss-type cargo tank configurations.

**Figure 2.9 Q-Max and Q-Flex Tankers at their home port in Ras-Laffan**



**Source:** *(Qatar Gas Operating Company Ltd, 2009)*

From the data presented in the table above, a couple of key points should be noted. One is that the new larger LNG carrier designs are becoming longer and wider, not necessarily deeper. Because of channel depth limitations in many ports, the new ships (Fig.2.9) are designed to have similar drafts as current LNG carriers. Also, the volume of LNG per cargo tank is increasing from nominally 30,000 – 40,000 m<sup>3</sup> for the current fleet of carriers to as much as 53,000 m<sup>3</sup> for the larger LNG carriers. This means that spill rates and spill volumes from the new LNG carriers could be larger which increase the safety and security risks of such carriers.

LNG ships have been in service for 40 years and their size and designs were very much standardised. As stated earlier, until 2002, the size of plant production and shipment of LNG was based on geography and SPAs. Geography dictated the market in terms of source of supply and customers' demand.

In short, the symbiotic relationship between the SPA, the plant size, the proximity to the market and the conventionally accepted design and size of the ship, resulted in a very logical and tight set of drivers that was ripe for a catalyst to bring a new order.

In the early nineties, Qatar, with its vast reserves of non-associated natural gas, entered the market when Qatar-Gas signed SPAs with a total of eight Japanese power companies to supply six MTPA of LNG for 25 years. The gas was to be supplied from Qatar- Gas first three LNG trains that each had a design capacity of 2 MTPA.

These agreements were established in a similar way to that in which the industry had established itself elsewhere and so ship capacities in the order of 135,000 m<sup>3</sup> were built to match the plant capacities of 2-3 MTPA per liquefaction train and SPA requirements. A fleet of 10 LNG tankers were commissioned in the "conventional" size of 135,000 m<sup>3</sup> using five spherical aluminium tanks to contain the cargo.

For further details on this, a full history of LNG tankers is given in Appendix 1.

## 2.5 THE WORLD LNG MARKET

Traditionally, the LNG industry has been highly structured, tied to long term contracts. Due to the vast cost of building the facilities, finance was only available if banks could see long term guarantees of a project's viability in place. The SC was characterized by fixed contracts with destination clauses to prevent cargoes being diverted into markets other than those stipulated. In the early 1990s, the LNG world trade was firmly divided between the Atlantic Basin and Asia Pacific markets. There was minimal trade between these two regions, and consequently little or no market or price interaction (Thompson, 2009). Specific import terminals serviced specific contracts, with the shipping capacity contracted for specific routes, meaning that vessel supply and demand were normally very closely matched, with few vessels spare for short term or spot operations.

However, with debottlenecking and the expansion of liquefaction plants in exporting countries, more surplus volume was offered which either effectively rolled into long-term contracts and sold to the same buyers or flowed into the alternative markets. As a result of the latter a short-term market started to emerge and regionalisation of the industry began to break down. Other drivers favouring the short-term market include:

- Flexibility of supply: if long-term buyers cannot absorb the contracted volume, with more flexible contract terms (i.e. no destination restriction clause), the sellers can divert the cargo to alternative buyers in order to arbitrage prices between the markets;

- Quick response to gas demand: if natural events affect buyers such as a sudden increase in seasonal demand, they can search for gas from alternative supplies.

With the growth of the short-term trade, a new global and competitive gas market is in the making. But the long-term market is still important and working well since no supplier has yet undertaken to build a new facility on a speculative basis without a long-term agreement (Wang & Notteboom, 2011)

### **2.5.1 Drivers for demand of natural gas and LNG**

Both the consumption of natural gas and demand for LNG have been increasing in recent years due to a number of factors:

- Global economic growth and energy demand are increasing.
- Natural gas is a cleaner burning fuel than coal and oil, encouraging an increase in power plants that run on natural gas.
- Natural gas is widely applicable as a fuel source for power generation, industry and commerce.
- The consumer trend is to greater diversity of fuel sources.
- The natural gas market is undergoing deregulation in several key markets.
- LNG prices have dropped as the cost of liquefaction and regasification has declined. This is due to improved technology, efficiency gains and more competition.

- LNG vessel construction costs have declined, resulting in lower shipping costs.
- Domestic gas production in many areas is insufficient to meet rising energy demand.

### **2.5.2 A growing global market**

According to Teekay LNG Partners LP (2011), the LNG market is expected to develop as follows:

- Total demand for natural gas is projected to increase from 3,149 bcm in 2008 to 4,535 bcm in 2035. This is a 44% increase over the period at an average annual growth rate of 1.4%.
- 84% of the increase in global gas use in the period to 2035 is expected to come from non-OECD regions. Demand in China is expected to grow by 5.9% p.a., more than any other region, driven by booming demand in the power, residential and industrial sectors. Demand in the Middle East, non-OECD Asia (in particular India) and Latin America is also expected to grow rapidly over the forecast period.
- Despite much less rapid economic growth, North America and Europe still account for 12% of the expected growth in world gas consumption to 2035. In many cases, gas continues to be the favoured choice over coal and oil for environmental reasons, especially in power generation. In Europe, carbon penalties help gas to compete against more carbon-intensive coal in the power sector and heavy industry.
- Inter-regional natural gas trade is projected to increase from 670 bcm in 2008 to 1,187 bcm in 2035. This is a 77% increase over the period at an

annual average rate of 2.1%. Trade rises much faster than demand due to the pronounced geographical mismatch between regions of production and consumption.

- The volume of LNG trade is projected to increase from 210 bcm in 2008 to 500 bcm in 2035. The share of LNG in total natural gas trade versus pipelines is projected to grow steadily from 31% in 2008 to 42% in 2035.
- Japan, Korea and India are the biggest Asian importers. In 2009 these countries received about 55 per cent of total global LNG trade. Spain, France and the US are the Atlantic Basin's biggest importers closely followed by the UK. China is currently the world's ninth largest LNG importer and is expected to become a major buyer of LNG in the future.
- Qatar, Malaysia and Indonesia are the biggest producers accounting for 44% of all LNG exports in 2009. Other major producers include Nigeria, Algeria, Australia and Trinidad & Tobago.
- The pattern of global LNG trade is expected to change in the future. Up to now LNG trade has been concentrated in the Asia-Pacific region with gas sourced from Asia and the Middle East. Although this market will continue to expand, LNG demand from the Atlantic basin is also expected to increase.
- As of June 2010 global liquefaction capacity totalled 360 bcm per year. An additional 77 bcm per year is under construction while a further 500 bcm per year is currently in the planning stage. Australia, Nigeria, Iran and Russia account for 77% of the planned new production capacity, though not all of these projects are expected to come online due to political and economic barriers.

The global LNG fleet is growing rapidly to meet increasing demand. As of November 2013 there were 364 LNG vessels in service with a further 104 vessels on order (Lloyds List Intelligence, 2013).

## **2.6 RISK MANAGEMENT, EMERGENCY AND PORT BUSINESS CONTINUITY**

### **2.6.1 Risk management**

The concept of risk has always been comprehended as associated with loss. The traditional approach views risk as burden to avoid or transfer. Accidental loss of property, income, life, health and/or liability toward others covers all facets of everyday life. Risk varies depending on the outcome of these events, the more severe are the consequences of events, and the higher is the amount of risk. A hazard is a physical situation or condition with the potential to cause harm (Trbojevic and Carr 2000). Risk, on the other hand, is the likelihood of harm defined in terms of combination of the likelihood of hazard occurrence and the severity of the consequences should it occur. The relationship between hazard and risk must be treated very cautiously. Risk may be proportional to the hazard under certain conditions.

The discipline investigating ways and procedures to control and mitigate the consequences of threats and incidents is called RM. Effective RM is the one that succeeds in aborting, reducing the likelihood or exacerbating the severity of the outcomes of events.

Although modern RM recognises the possible negative consequences of risks, it takes a positive attitude towards them. First, it views risks as manageable events and takes all necessary measures to better respond to threats and turn



them into opportunities. In this respect, RM looks at risks as opportunities rather than threats. Seizing them to create higher value and strengthen one's own position in the market is a risk managers' target. This approach marks a significant shift from the traditional thinking of risk as something to be avoided and if possible transferred, to the proactive approach of RM.

#### **2.6.1.1. RM in the maritime and port industry**

The maritime and port industry has a long history of risk prevention and management. Since its inception, IMO as the UN specialised maritime agency, long has had as main agenda "Safe, Secure and Efficient Shipping on Clean Oceans". This reminds us of the strategic importance of RM in a rapidly changing maritime industry. However, it is noticeable that much of the maritime safety policy worldwide has been developed in the aftermath of serious accidents, such as *Exxon Valdez*, *Estonia*, *Erika* and *Prestige*. The majority of current international maritime standards have been enacted following a reactive approach, often as ad-hoc response to serious accidents.

Industry circles have questioned the wisdom of such a reactive approach and requested a new safety culture based on anticipation and prevention (Kontovas *et al.* 2007-2). Recently, the international shipping industry has begun to move towards a proactive approach through the Formal Safety Assessment (FSA) as a systematic methodological framework for assessing maritime safety risks (Kontovas *et al.* 2007-1). Attempts are made to generalise such an approach to port safety.

As stated earlier, the maritime and port industry involved in the logistics and SC of LNG is exposed to further risks stemming from LNG as an intrinsically high

risk HazMat as well as from the nature of modern ports as complex and risky business environments.

#### **2.6.1.2. LNG properties and potential hazards**

Within the natural gas industry, the LNG VC of extraction, production, transportation and distribution is subject to various types of hazards. Considering the vast array of risks associated with the LNG SC, this review will only consider operational and environmental risks and hazards related to LNG marine terminals and LNG carriers within port facilities. Operational risks are related to safety whereas security-type risks are considered environmental ones, as a result of external factors to port logistics and maritime SCs. Since LNG is increasingly becoming a strategic commodity to the world economy and due to its hazardous chemical attributes, LNG risks and hazards, mainly safety and security-types, have much potential impact on people, property and the environment. Although the LNG industry has enjoyed a good safety record during the past forty years, this has not been without incidents. Communities and the industry alike are still concerned about the safety and security of LNG transportation systems. In the US for example, since the trend has been to build more infrastructure to support LNG imports, Walker *et al.* (2003) pointed out that *“especially in the wake of the terrible events of September 11, 2001, government and citizens are apprehensive about the potential risks transporting large quantities of LNG by ship through our coastal waters and into our ports”*. Therefore, worldwide concerns do not only stem from LNG safety hazards as a consequence of deliberate human errors and natural disasters, but more importantly from intentionally caused spills and releases such as terrorism.

**Table 2.3 List of some major LNG port accidents**

| Year | Incident location                                    | LNG facility involved                     | Injuries/ fatalities    | Material damage         | Cause                                                                                                                                                                  |
|------|------------------------------------------------------|-------------------------------------------|-------------------------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1944 | Ohio/ Cleveland, USA                                 | Storage tanks at the port                 | 128 deaths              | Yes                     | Tank failure                                                                                                                                                           |
| 1965 | Canvey Island, UK                                    | LNG transfer from ship to terminal        | Yes, 1 seriously burned | Yes                     |                                                                                                                                                                        |
| 1965 | Tanker Methane Princess at Port                      | Methane Princess                          | No                      | Yes                     | Disconnecting after discharge                                                                                                                                          |
| 1974 | Tanker Massachusetts at Terminal                     | Ship loading at Terminal                  | No                      | Yes                     | Valve leakage, deck fracture                                                                                                                                           |
| 1977 | Arzew, Algeria                                       | LNG storage facility within the port area | Yes, 1 fatality         | Yes, estimated at 1 M\$ | LNG releases from storage facility causing fire and explosion.                                                                                                         |
| 1977 | Tanker Aquarius LNG at Terminal                      | Ship loading at Terminal                  | No                      | No                      | Tank overfilled                                                                                                                                                        |
| 1979 | Columbia Gas LNG Terminal- Cove Point- Maryland, USA | LNG receiving Terminal                    | Yes, 1 fatality         | Yes, estimated at 9M\$  | Explosion occurred within the Terminal electrical substation causing fire and explosion. One operator killed and another seriously injured plus major material damage. |
| 1979 | Mostefa Ben Boulaid Ship at Terminal, Algeria        | Ship unloading at Terminal                | No                      | Yes                     | Valve leakage, deck fracture                                                                                                                                           |
| 1979 | Tanker Pollenger at Terminal                         | Ship unloading at Terminal                | No                      | Yes                     | Valve leakage, Tank cover Plate fracture                                                                                                                               |

**Table 2.3 Continued**

|      |                                      |                                                   |                    |             |                                                                                                                                            |
|------|--------------------------------------|---------------------------------------------------|--------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 1980 | Tanker Taurus at Port                | Ship at the port area                             | No                 | Yes         | Ship Stranded. Ballast tanks all flooded and listing. Extensive bottom damage.                                                             |
| 1985 | Tanker Gradinia at Port              | Ship at the port area                             | No                 | Yes         | Disconnecting after discharge                                                                                                              |
| 1985 | Tanker Isabella at Port              | Ship unloading at Terminal                        | No                 | Yes         | Cargo valve failure. Cargo overflows. Deck fractures.                                                                                      |
| 1989 | Tanker Tellier at Port               | Ship unloading at Terminal                        | No                 | Yes         | Broke moorings, Hull and deck fractures.                                                                                                   |
| 2004 | Skikda, Algeria                      | Skikda LNG liquefaction plant and export Terminal | Yes, 27 fatalities | Yes, 54 M\$ | LNG Plant explosion which damaged also the LNG terminal, electrical substation and nearby community homes and buildings.                   |
| 2010 | Withnell Bay LNG facility, Australia | Ship loading at Terminal                          | No                 | Yes         | The ship suffered cryogenic burns due to leakage of 2000 to 4000 litres of LNG                                                             |
| 2010 | Montoir de Bretagne Terminal, France | Ship unloading at Terminal                        | No                 | Yes         | LNG passed into the gas take-off line during discharge. Damage to Ship manifold and its feed lines                                         |
| 2011 | Yung An LNG Terminal, Taiwan         | Ship unloading at Terminal                        | No                 | N/A         | Suspected leak. Unloading operations suspended and ship taken off the berth. Discharge operations resumed after rectification of problems. |
| 2011 | Pyeongtaek LNG Terminal, South-Korea | Ship unloading at Terminal                        | No                 | Yes         | The ship disconnected from the berth after a minor leak detected. Damage to Unloading arms was recorded.                                   |

**Source:** (CEE, 2012)

Table 2.3 provides a list of some past LNG Port accidents listed chronologically. Such list is not exhaustive and provides only some accidents that occurred within the port area, either within LNG storage tank farms or at terminals during ship to shore loading/unloading operations. This history, although showing relatively less consequences from such accidents, demonstrates that hazards and risks associated with the LNG VC are real and should be dealt with constantly in a comprehensive and systematic way.

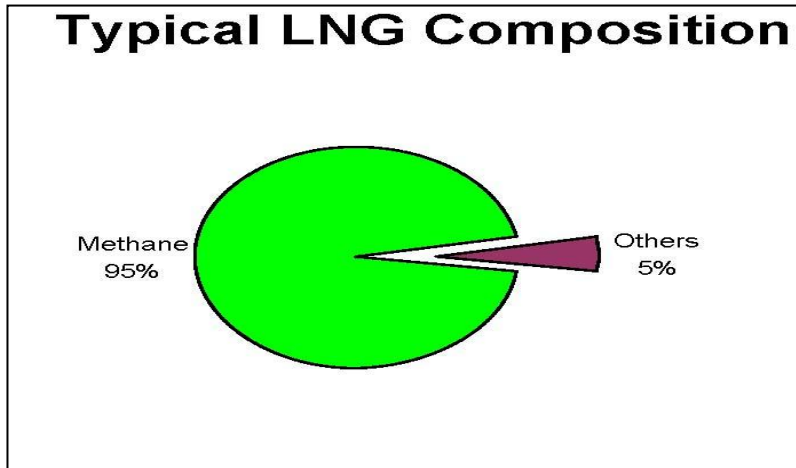
This is why the process of risk identification and management in LNG SC is critical to the industry, to people working and communities living, close to LNG facilities. To assess the extent and likelihood of LNG hazards, it is important to understand LNG properties and the conditions required for related hazards to happen.

### **LNG Properties**

LNG is the liquid form of natural gas, produced as a result of liquefaction process at normal atmospheric pressure. It is a clear, non-corrosive, non-toxic, cryogenic and odourless liquid.

Even though LNG is not a toxic substance, it may cause asphyxiation due to insufficient amount of oxygen when a concentration of gas is developed in a confined and closed area. LNG physical composition shows methane as the main component.

**Figure 2.10 Typical composition of LNG**



**Source:** CEE (2007, p.17)

Generally methane fuel constitutes between 92 to 99% of LNG, depending on its origin (CEE 2007). Other components of LNG are heavier hydrocarbon materials such as ethane, propane, butane and nitrogen. The liquefaction process of natural gas requires prior removal of the non-methane components, such as water, carbon dioxide, butane, pentane and heavier components from the initially extracted natural gas to prevent forming solids during the cooling process. LNG is less dense than water, thus if spilled on water, it floats on top and vaporises rapidly (CEE, 2007).

### **LNG hazards**

According to CEE (2012), LNG hazards originate from natural gas physical properties including:

Explosion: An explosion usually happens when a substance changes its chemical state, mainly when ignited or uncontrollably released from a pressurised state. For a release to happen, there must be a structural failure or puncture to the LNG tank or containment container. An explosion may happen

only in case of uncontrolled release, which comes into contact with a source of ignition. Moreover, since LNG is stored at normal atmospheric pressure (not pressurised), a structural failure of the storage tanks will not create immediate explosion (CEE, 2012).

Vapour Clouds: In case of uncontrolled release, LNG forms a fog or a vapour cloud above the released liquid, as LNG is heavier than air. When gas warms up to the atmospheric temperature, it mixes with the surrounding air and begins to disperse. The LNG fog will only ignite if it encounters a source of ignition while concentrated within its flammability range. The flammability range is the concentration of methane into the air which makes it ready to burn. Flammability range is between 5 and 15%. Above or below this concentration, LNG will not ignite even in the presence of an ignition source (CEE, 2012).

Freezing Liquid: In case of accidental release, LNG cryogenic liquid can come into direct contact with people and freeze the point of contact, damaging the skin tissue. Primary containment of LNG tanks mostly prevents such uncontrolled release. Also, facility personnel are required to wear gloves and protective masks when entering potentially hazardous area. Moreover, initial facility design takes into consideration safety distances, so as to make sure the spill risk is contained with the facility boundary (CEE, 2012).

Rapid Phase Transition (RPT): A large release of LNG makes methane liquid vaporise too quickly causing RPT. The RPT phenomenon consists of a rapid change of state from a liquid to a vapour with an associated release of energy of explosive proportions. A large RPT carries the risk of severe structural damage to port facilities and LNG vessels. LNG is not a water pollutant, it is

insoluble in water, has very low toxicity to marine organisms and it vaporises quickly in water. However an explosion in the marine environment caused by RPT could result in lethal effects to marine organisms in the immediate vicinity of the explosion (Walker *et al.* 2003).

Asphyxiation: In high concentration, LNG can act as an asphyxiant by diluting the oxygen concentration below that necessary level to sustain life. (CEE, 2012).

Other LNG hazards include rollover which is caused by loading multiple densities of LNG cargoes within a single tank at one time. These different cargo classes do not mix at first and may cause excess pressure on the tank systems and cause cracks and structural failure to the tank. Another LNG hazard is sloshing which is a violent motion of the fluid associated with ship tanks being partially filled with LNG, especially in harsh marine environment. This can mostly materialise in offshore LNG terminals, where LNG tankers are not sufficiently protected from waves and currents as is the case in onshore terminals (CEE, 2012).

## **LNG hazards in Ports and Marine Terminals**

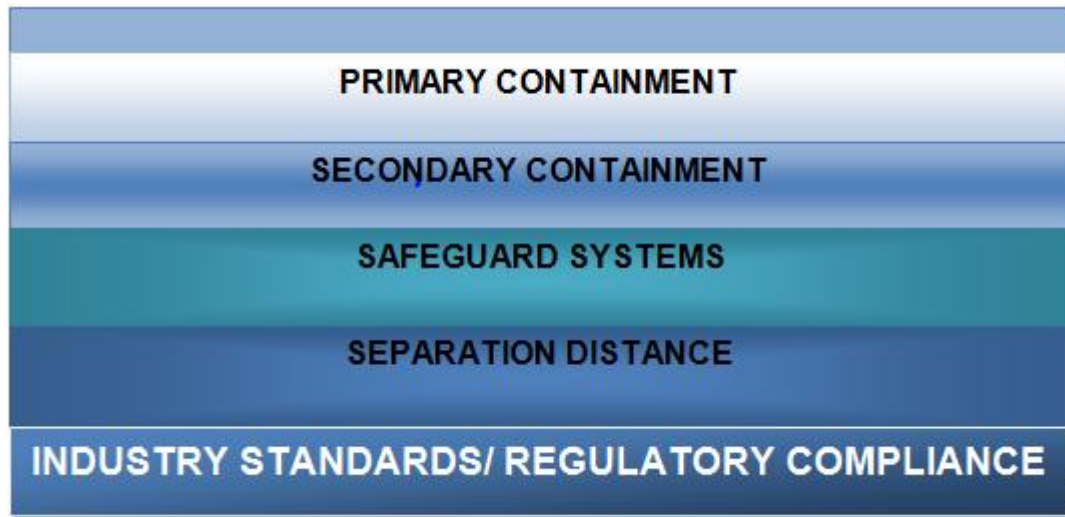
### **2.6.1.3. Safety considerations in LNG terminal operations**

LNG SC safety has been achieved mostly through implementation of sound technical and operational advancements and strict enforcement of international standards. Such standards have been developed by both the LNG industry and international specialised bodies. Multiple layers of protection are applied in LNG facilities, including LNG marine



terminals. These protection layers are coupled with the industry standard procedures which form a robust protection for employees and nearby communities, infrastructure facilities and the surrounding environment.

**Figure 2.11 LNG critical safety conditions**



**Source:** CEE (2012, p.9)

Four (4) safety requirements are observed in LNG infrastructure, including LNG Export/ Import Terminals (CEE, 2012). These are mainly:

- **Primary containment.**

This is the first and most important safety requirement for LNG by which safe storage and isolation of LNG is ensured through the use of appropriate material for the construction of LNG tank storage and facilities, both onshore and on board tankers.

Safe handling and use of LNG requires thorough knowledge of this substance and its physical properties and an understanding of its

behaviour at cryogenic temperature. Material used for storage tanks, piping and other equipment which come into contact with LNG is critical. Materials suitable for cryogenic service and providing protection against material failure are mainly high nickel content steel, stainless steel, aluminium and pre-stressed concrete.

Onshore storage tanks: They have several engineering design features but are generally constructed as double-walled structures (a tank within a tank with insulation in between the walls) which must withstand the hydrostatic load of the LNG.

LNG Vessel Tanks: Similar engineering design safety requirements apply to LNG ships. Existing LNG ship cargo containment systems are constructed according to one of the following three designs:

- ❖ *Spherical moss design*
- ❖ *Membrane design*
- ❖ *Structural prismatic design*
- **Secondary Containment** provides assurance of full containment in case of LNG spill. Every LNG storage system onshore or on board tankers includes a dam impoundment surrounding a single containment tank in order to contain any leakage in the event of tank failure. The advantage of such a system is to allow any uncontrolled LNG release to be isolated and controlled.
- **Safeguards systems:** This provides an additional level of safety whereby minimizing the frequency and size of LNG releases both

onshore and offshore. LNG industry uses extensive safety systems to detect LNG releases, such as:

- Gas detectors,
- Ultraviolet or infrared fire detectors,
- Smoke or combustion product detectors,
- LNG level, low temperature and vapour pressure detectors,
- Emergency shutdown systems (ESD)
- Close Circuit TVC (CCTV) systems to monitor all critical locations of LNG facilities.

Furthermore, LNG transfer lines are designed and constructed to prevent and mitigate LNG release. A leak from a transfer line of an LNG facility is unlikely to occur due to design requirements for equipment, such as the use of suitable material for construction and rigorous periodic testing of LNG piping systems. Also, Detectors for fire and vapour gas along with fire fighting systems are automatically activated to ensure rapid dispersion and containment of gas vapours and fire hazards. Emergency shutdown procedure is automatically activated in case of sensor alarm due to accidental leakage.

- Finally, LNG facilities designs are required by regulations to observe **Separation distances** from any surrounding urban or industrial facilities. Safety zones are also required around LNG tankers (CEE, 2012).

The multiple layers of protection described above create four critical safety conditions, all of which are integrated with a combination of industry standards and regulatory compliance (Fig.2.11).

## 2.6.2 Emergency management

With all efforts in preventing and mitigating incidents and accidents, it is not possible to detect and avoid every threat. Therefore emergency situations are and always have been part of today's reality and do occur.

Emergency management in ports is an important component of port daily business and should be integrated within the port management model. Its objective is to defend the port against incidents or accidents by providing timely response to a security attack or a safety accident and minimising the impact of such events on port operations and port critical infrastructure. Pinto & Talley (2006) provided a description of the incident cycle of a port. They explained that, for example, the security of a port consists of prevention, detection, response and recovery phases. They also noted that there have been significant improvements in the prevention and detection phases, but little investigation of the response and recovery phases of a port's security incident cycle (Pinto & Talley, 2006).

Emergency management and response includes the response and recovery phases of an incident (ex post incident). They are lengthy tasks which require mobilisation and cooperation of several public and private entities which should put together resources and expertise to mitigate and respond to emergencies when they strike. However, as asserted by Coppolla (2007), '*when disasters strike, there may be little or no time to make any additional arrangement, to learn any new skills, or to acquire needed supplies*'. That is why disaster preparedness is a paramount step which normally precedes response actions and should be given the necessary resources and time to be effective.

According to Coppola, (2007, p.209):

*'the goals of disaster preparedness are knowing what to do in a disasters' aftermath, knowing how to do it, and being equipped with the right tools to do it effectively'*

Emergency/ disaster preparedness is a lengthy process which may take years before attaining satisfactory levels and maintaining such levels normally require on-going efforts. Meanwhile, preparedness minimises the effects of disasters when they occur through effective precautions taken which ensure timely and efficient planning and delivery of response and relief actions. Emergency preparedness and response is delivered through a cooperative effort between public and private organisations and individuals. The public component includes administration, emergency management, public health, law enforcement authorities and other agencies. The role of these government entities is normally organised and conducted through the creation of specialised emergency committees, such as those dealing with maritime and port emergencies. Emergency committees carry out their functions through the creation and application of an emergency management plan (EMP) which is further re-enforced by training, exercises and drills. Government preparedness actions can be grouped into five categories: Planning, exercise, training, equipment, and statutory authority (Coppola, 2007).

#### **2.6.2.1. Planning**

Government entities are required to lead emergency planning and response. They need to know well in advance of a disaster or emergency what they have to do and how they should do it in case of a disaster. In the event of an

emergency, each government jurisdictional level will be expected to know its role, how to perform each task and function within the scope of that role and what equipment they need. Therefore, planning for disaster response is crucial in disaster preparedness and mostly done through the preparation and validation of a National Emergency Management Plan (NEMP). This plan is widely recognised as the most comprehensive methodology used for emergency planning and response. NEMP is a master document which can accommodate a wide variety of disasters response actions in a community or national infrastructure (Cities, regions, states, ports, airports...etc.) and define the roles and responsibilities of each government entity and how they should cooperate to deliver effective response and recovery tasks and actions. The following information is normally detailed in a NEMP:

- People and agencies to be involved in a response to hazardous events (Disasters);
- Responsibilities and actions of such people and agencies and where and when they will be called upon;
- Catalogue of equipment and facilities required and available inside and outside the jurisdiction.
- How citizens and infrastructure will be protected in the event of a disaster.

An effective emergency plan shall include the following components:

- Hazards and risks analysis;
- The basic plan;

- Functional annexes
- Hazard-specific annexes

Hazards and risks analysis is usually conducted prior to the creation of emergency management plans, since different risks have different consequences which require response mechanisms and actions specific to each consequence. Accommodating a wide variety of consequences should be considered in the context of limited available resources and normally refer to the community/ country risk acceptance level. This particular issue of risk acceptance constitutes an important link between RM and emergency management as functions that should be considered in continuum. This will be discussed later in the coming chapters.

The basic plan is the main body of the emergency management plan document that describes the emergency operations within a community or country. It generally includes an introduction of the main stakeholders and public agencies involved in emergency response and their responsibilities. It also introduces and explains various concepts and policies and delineates statutory authority.

The basic plan is often supplemented by functional annexes that provide much detail on the operational needs of specific response mechanisms. These annexes cover detailed information on who does what in fulfilling the different functions in an emergency response and for different disaster types.

Hazard-specific annexes cover detailed risk information for individual hazards including the population most likely to be affected; the geographic range of such hazards and, if possible, the season or time span the disaster can strike.

#### **2.6.2.2. Exercise**

A major part of emergency preparedness and response effort, as defined by emergency management plans, is a programme of exercises. Exercises allow those involved in emergency response to practice their roles and responsibilities prior to the actual occurrence of an event of emergency or disaster. The outcomes from such exercises are numerous: first, exercises prepare organisations, individuals and stakeholders to carry out their disaster response duties in a stress free environment. Second, it serves as a valuable preparedness tool allowing individuals and stakeholders to meet and know each other before actual disaster occur. Finally, exercises help find problems in emergency management plans, test their suitability and allow for adequate rectification actions to those plans prior to their effective implementation during emergency situations. Exercises are often tailored to the needs of the community, country or specific critical infrastructure (such as ports), and have four major components: Drills, table top exercise, functional exercise and full scale exercise.

A drill is a controlled method by which a single disaster function is practiced (exp. evacuation). A table top exercise is designed to allow emergency management to practice full activation of an emergency response plan; a functional exercise tests overall disaster management capability to respond to an event and finally, a full-scale exercise is *'a scenario-based exercise that seeks to create an atmosphere closely mimicking an actual disaster'* (Coppola, 2007).

In this exercise all players are required to act in real time and using the required equipment and procedures as in real life incident and as defined by the emergency management plan.



### **2.6.2.3. Training**

It represents the third component to government preparedness. Training is paramount in disaster preparedness since public authorities and disaster response teams are only effective when they are trained to perform their tasks. Furthermore, training is essential to the very safety of the response teams since without training, response officials may put themselves This may further strain response resources which will then divert part of responder's efforts to unnecessarily in dangerous situations, especially in particular specialized response, rescue their peers.

### **2.6.2.4. Equipment**

Tools and equipment for disaster response, rescue and recovery have tremendously assisted in the effectiveness of disaster response and recovery and in the protection of the lives of responders themselves. Number of equipment is available for disaster response which are developed and made available for different purposes:

- Fire suppression equipment
- Rescue equipment
- Personal Protective Equipment (PPE)
- Disaster medical care
- Communication systems
- Public warning and alert systems
- Other emergency and disaster response equipment.

The above is just a sample list of groups of equipment under which hundreds of specialized emergency response tools and equipment exist and which have made life saving and disaster response and recovery much easier and more efficient.

#### **2.6.2.5. Statutory authority**

Emergency preparedness cannot be complete without designation of a statutory authority which shall be invested with the responsibility of managing the whole emergency response actions and be able to take decisions during emergency time. This is an important requirement since government emergency response involves a diverse range of government officials and agencies as well as private volunteers. It also involves a large expenditure of funds and suspension of normal activities for private entities and public authorities. The designation of a statutory authority is crucial in order for appropriate crisis management to be carried out, including emergency response, rescue and relief actions in a disaster's aftermath.

Statutory authorities set up the lines of control and succession and provide the necessary power of authority to specific government authorities which are invested with the responsibility to take specific actions in case of emergency, as per the emergency management plan (EMP).

#### **2.6.3 Port recovery and port business continuity**

Both safety and security incidents may have the same consequences, especially when such incidents involve HazMat. However, most specialists tend

to consider that security incidents may usually yield larger consequences in terms of fatalities and economical damage. What actually matters for a port in an incident aftermath are the response actions which should be efficient enough to minimise the consequences of such incident. Most importantly, and due to its strategic importance, ports need to recover in a limited period of time and return back to operation, although it may be just partial in the early stage of recovery.

As asserted by Pinto & Talley (2006), port recovery phase begins when marine terminals and waterways that were shut down, as a result of an incident, are open again to operation, even on a limited basis. The recovery phase ends when such port facilities are back to normal operation.

In most post incident cases, emergency authorities are under pressure from port users and stakeholders once port facilities are declared safe from terrorist attacks, fire accidents or explosions. In this case, emergency authorities and law enforcement agencies are requested to finish their investigations ASAP and remove any obstructions from the port's channels and terminals to move forward and declare the port open for normal operations. In the U.S, since there has not been a recorded major security incident, the study of port accidents is used to provide useful information in the prevention of potential U.S. port security incidents (Pinto & Talley, 2006). This again attests to the relationship between port safety and security incidents which call for comprehensive RM which enables better information sharing and further cooperation along all phases of the port incident cycle: prevention, detection, response and recovery.

## 2.7 CONCLUSION

The global LNG industry is in a state of flux. Despite recent recession and abrupt competition from alternative sources like shale gas, the industry is poised to grow strongly in the long term. The clean fuel has transformed itself from a regionally traded fuel to a globally traded energy source. Low price, environmental friendliness and declining construction costs of LNG have resulted in a large number of countries and companies investing in LNG. This growth in demand is further fuelled by Asian and European countries, which have been converting their oil fuelled power plants to gas fired plants.

Discussing the strategic planning issues to be considered in the LNG business, Chen (1998) pointed out that the last five years have seen changes in the industry, and it seems there have been more changes in the past three or four years than in the entire previous history of LNG. Advances in technology have considerably reduced the cost of construction of an LNG plant, trading of LNG on the stock exchange has led to the development of a spot market, new ships are being built catering to no specific market and under no contractual obligations, the Japanese, Asian and European markets have been liberalised and there are more sellers and buyers on the market which is becoming increasingly competitive. These changes are revolutionising the way in which the LNG business is being conducted today.

From a RM perspective, as the LNG market further expands, the number and capacity of LNG tankers and terminals is subsequently increasing. Therefore the number and frequency of LNG tanker voyages between producing and consuming regions is expected to further increase, adding more risks to the

actual safety, security and environmental risks profile of LNG terminals and ships. This requires a comprehensive and integrated RM approach which can deal with these types of risks in a cost effective and efficient manner.

From the above, the following remarks can be made:

- ❖ LNG safety mitigation measures and safeguards constitute the first line of defence against security risks.
- ❖ Safety and security interfaces and mutual impacts exist and need to be adequately addressed at each level of the RM, emergency response and port business continuity processes.
- ❖ Integrated safety and security risks management shall ensure synergetic, efficient and coordinated safety and security risk control strategies.
- ❖ Coordination and information sharing shall be extended during emergency planning and response phases to ensure swift and efficient emergency response and quick port recovery to bring it back to normal operations, thereby minimising the consequences of port incidents, be they safety or security related.

This overview confirms the LNG maritime and port industry's need for a systematic RM framework based on a comprehensive, holistic and integrated approach to risks and vulnerabilities.

## CHAPTER 3

### SAFETY AND SECURITY RISK MANAGEMENT IN LNG PORTS

#### 3.1 INTRODUCTION

The objective of this chapter is to review recent literature on RM in ports and marine terminals handling LNG. The scope of the risk encompasses both safety and security risks, as related to LNG ports. Apart from commercial business related risks, safety and security types of risk are of paramount importance to the LNG industry and to its critical VC infrastructure. As asserted by *Walker et al. (2003, p.1)*, LNG maritime security is now added to the years of dialogue related to the safe transport of LNG, “*We are now in an environment where intentionally caused spills and releases must be factored into existing prevention, preparedness and consequence management planning.*”

The World Economic Forum (WEF) annual reports from 2008 to 2011 have emphasized energy security (LNG included) and its critical global infrastructure as one of top global risks (WEF 2008, 2009, 2010, 2011).

Therefore, since LNG is considered a hazardous material (HazMat), LNG maritime and port security should be analysed and addressed in connection with safety measures and practices.

Literature on port safety risks will be presented in section two, followed by a review and discussion of literature pertaining to port security risks in section three. Lessons to be learnt from the quality movement, especially the Total Quality Management (TQM) framework will be discussed in section four, and

finally, the chapter concludes with an account of the interfaces and shared impacts among LNG ports safety and security risks in section 5.

### **3.2 LNG PORT SAFETY RISKS**

Literature on LNG ports and terminals safety risks, for instance ( Walker *et al.* (2003), Sandia (2004), Ditali & Fiore (2008), CEE (2006), CEE (2012), Nwaoha *et al.* (2011, 2013)) have stated the excellent safety record of LNG vessels, with few accidents, during its entire history.

The few specific studies on LNG port safety such as Walker *et al.* (2003) have attempted to provide a comprehensive review of LNG/ LPG maritime and port networks safety in terms of built-in safeguards contained in LNG regulations, standards and industry practices. They provided a clear approach to LNG RM. For them, *“the risks associated with LNG and LPG are the possibility and probability that an uncontrolled release of either product will result in injury, market disadvantage, or destruction, such as loss of life, property destruction, and adverse impact on the viability of the market should an accident occur.... Since 9/11, the possibility of terrorist action against these facilities and vessels could result in a high number of fatalities and an interruption to the energy SC, is also a significant concern.”* Walker *et al.* (2003, p.1)

Throughout the analysis, Walker *et al.* (2003) demonstrated an intergated RM approach, combining both LNG safety and security threats. For them, LNG safety and security can be addressed effectively through various regulatory and non-regulatory techniques including:

- *“Risk communication messages to define clearly liquefied gas properties and hazards, safety, and environmental issues and the industry safety track record;*
- *Risk mitigation for vessels construction, human factors and training;*
- *Risk mitigation for terminals and jetties-siting and design, weather, traffic control, safe monitoring, transfer contingencies, safe distances, training, review of operating practices and procedures; and*
- *Port security and response plans for vessels of high concern.”*

Walker *et al.* (2003) noted, also, that while the LNG industry has a strong safety record coupled with stringent construction codes for vessels and terminals, it is very difficult to predict exactly what would happen if there was a major uncontrolled release of LNG on water. Tests with LNG have shown that the rapid phase transition (RPT) would be a serious concern if there was such a release. That is why the authors recommend the use of effective contingency planning which aims at maintaining a state of readiness and timely appropriate procedures to mitigate emergency situations. For Walker *et al.* (2003, p.2) *“sound contingency planning, in addition to RM programs, stakeholder outreach and port security plan, must incorporate the interests, expertise, and experience of the industry in LNG projects.”*

Since loss of containment and subsequent LNG spills are the most feared hazard scenarios in LNG operations, two pioneering works in LNG spill modelling include Fay (1969) and Fannelop and Waldman (1972) which were summarized and reported by Brebbia (2001). Fay (2003-1) presented a complete model for predicting the dynamics of spills from LNG and oil product



tankers. The model uses fluid mechanics principles and physical properties of LNG and oil spills on water. Both physical models and software programmes are used as RA tools to explain, evaluate, compute and assess the extent and impact of hydrocarbon spills on ocean environment as well as on people and infrastructure.

The UH IELE (2003) and CEE (2003, 2006, 2012) reports focused mainly on the U.S LNG sector. They discussed safety and security aspects of LNG through an overview of its main physical properties, the safety record of LNG facilities and ships, the impact of LNG operations on the environment as well as regulations and agencies concerned with LNG safety and environmental protection. The reports concluded that LNG has been and can continue to be used safely as long as industry standards, regulations, design and technology are maintained to the highest level and continuously improved, taking advantage of the long accumulated industry experience and the advances in science and technology.

The UH IELE report referred to a 1998 study carried out by the New York State Energy Planning Board. Major finding of this referenced study was: *“LNG is as safe as other available conventional fuels and over the past two decades it has had an excellent safety record. Since 1980, there have been seven plant or ocean tanker accidents worldwide and four vehicle-related accidents in the U. S. with no fatalities, which compares favourably with the safety record of facilities for competing fuels”* (New York Energy Planning Board (1998, 9-1).

In view of the above conclusions, the UH IELE concluded that *“risks and hazards associated with LNG and LNG industrial facilities are manageable.*

*These conclusions also show that LNG industry safety practices contribute toward reduced potential for catastrophic events such as might be associated with acts of terrorism” The UH IELE (2003, p.43).*

This UH IELE (2003) conclusion is conform to Walker *et al.* (2003) and demonstrates the relationships between LNG safety measures and practice and security mitigation measures in LNG facilities.

One of the studies which focused on LNG shipping hazards and risks but included LNG port facilities as related to ship location is Pitblado *et al.* (2004). This study tried to develop a range of well conceived failure cases from accident or terrorism causes in order to predict hazard zones for LNG import terminals. He stated that the LNG marine transport component appears to have more vulnerability to threats than the LNG terminal itself which has robust LNG tanks and secure boundaries. Pitblado *et al.* (2004) carried out a formal HAZID with the participation of a group of experts from classification societies, industry and risk specialists to identify precursor events that could lead to credible loss of containment events. These were converted into maximum credible hole sizes.

For Pitblado *et al.* (2004), consequence assessment is valuable for decision making, particularly for locations beyond the hazard ranges predicted. For critical locations within hazard ranges, a more detailed risk analysis, that takes account not only of the consequence but also of the safeguards and explicitly assesses the likelihood of events, would be most appropriate. The scope of the shipping activity covers port entry, port transit, manoeuvring and jetty activities. Maximum credible accidental release case for 750mm hole as well as for non

accidental release case of 1500mm hole are presented in Tables 1 and 2 (Appendix3).

ABS Consulting (2004) performed a study for the account of the US. Federal Energy Regulatory Commission (FERC). The goal is to identify appropriate consequence analysis methods for estimating flammable vapor and thermal radiation hazard distances for potential LNG vessel cargo releases during transit and while at berth. While the objective of the study might be similar to that of Pitblado *et al.* (2004), the scope of the FERC study is limited to accidental releases and to consequence assessment methodologies modelling the consequences pertaining to LNG spills on water. Regarding the methodologies used, Pitblado *et al.* (2004) deployed a combination of qualitative and quantitative techniques while ABS Consulting (2004) relied solely on quantitative techniques.

Both ABS Consulting (2004) and Pitblado *et al.* (2004) concluded that the recommended consequence assessment methods can provide only rough estimates of the magnitude of effects for incidents involving large LNG releases on water, due to the variability in actual incident circumstances as well as uncertainty inherent in the methods used.

The SANDIA (2004) report discussed both safety and security threat implications stemming from extensive LNG spill over water. The report considers three types of reference accidents at sea: accidental collision with a small vessel, accidental collision with a large vessel and grounding. For the three cases, the report expected a breach of 5-10 m<sup>2</sup> limited to one container for the second case, with an actual spill area of 0.5-1 m<sup>2</sup>. In most cases, the spilled

LNG will burn in a pool fire about 150 m in diameter (1 m<sup>2</sup> breach): thermal hazards will extend to approximately 250 m and 750 m. In some cases, LNG will evaporate from the pool and disperse as a vapour cloud, extending beyond 1600 m in about 20 min., under stable atmospheric condition and 2 m/s wind velocity. SANDIA (2004) also investigates several intentional LNG cargo tank damage scenarios, including sabotage, insider threats, and external attacks. The same conclusion was confirmed by the report prepared by the U.S. National Association of State Fire Marshals (NASFM, 2005). The security part of this study-report will be discussed later as part of the section on LNG port security.

Based on the findings of the SANDIA Report, Bubbico *et al.* (2009) made a preliminary risk analysis for LNG tankers approaching a marine terminal. The study was based on the case of LNG ships approaching Panigaglia LNG terminal in Italy. Considering the information reported by the SANDIA study which indicated that the required velocity to cause a breach of LNG cargo tank during 90° collision with a large vessel is 6 to 7 knots, Bubbico *et al.* (2009) concluded that accidental collision of an LNG tanker with a small or large vessel, cannot be excluded due to the congestion of the harbour. Nevertheless, due to the low ship velocity when approaching the terminal, it is unrealistic that a collision will occur at the speed of 6-7 knots required to open a breach in the cargo. Grounding cannot be excluded as well but generally does not result in LNG cargo breaches, especially at low speed.

For Bubbico *et al.* (2009), the only plausible scenario for an accidental breach of an LNG vessel tanks is an intentional action against the tanker; such a case

was investigated further using the consequence analysis technique. This will be discussed in the next section dealing with security risks.

CH-IV International (2006) provided a comprehensive chronological summary followed by a historical analysis of LNG accidents. The study, which is a comprehensive report on the safety history of international LNG operations, demonstrated the outstanding safety record of LNG production and transportation chain. Almost the totality of accidents occurring in LNG exports, regasification plants and LNG tankers worldwide are reported and analysed.

Among other findings, the study reported that most of the accidents which happened on land did not involve LNG directly, but are rather attributed to the formation of explosive atmospheres in enclosed spaces as a result of bad maintenance or to problems unrelated to the dangerous properties of LNG.

Generally, the study reported five major incidents in onshore facilities (including export/receiving marine terminals) directly attributable to the LNG process which resulted in one or more fatalities: Skikda, Algeria-2004; P.T. Badak-Bontang, Indonesia, 1983; Cove Point Maryland, 1979; Arzew, Algeria, 1977; and Cleveland, Ohio, 1944. There was two other LNG incidents, Portland 1968 and Staten Island 1973, involving death, but these are considered by the report as "Construction accidents" since no LNG was present. CH-IV International (2006) noted also that in all LNG tanker voyages and associated cargo loading/unloading operations at terminals, no fatality has ever been recorded for any crew member of LNG ships or member of the general public as a result of LNG incident. Among LNG import and export terminal personnel, only one death can be reported. A worker in the LNG export facility at Arzew-Algeria was

killed during a ship loading operation due to a failure of a large-diameter valve. This caused the worker to be sprayed with LNG, coming into contact with the extremely cold LNG liquid.

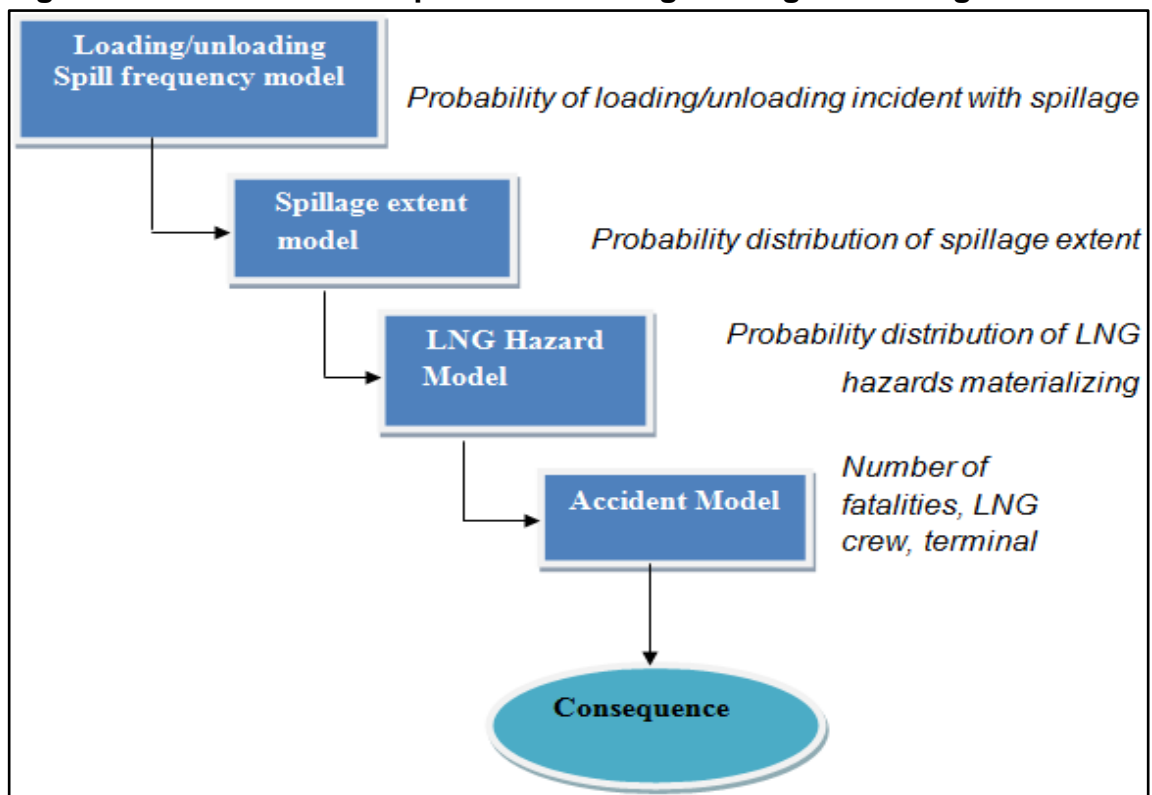
The above studies (CEE, UH IELE, SANDIA, CH-IV International and NASFM) were published in an effort to inform and guide the public debate around the advantages and disadvantages of LNG imports to the USA, in light of the public opposition to permitting new LNG plants and receiving terminals due to their high risk profile. All of them reported the excellent safety record of the industry and warned about the threat represented by intentional acts of terrorism.

Another interesting study undertaken under the SAFEDOR Project and co-funded by the EU is Vanem *et al* (2008). The study carried out a high-level risk assessment of LNG carrier operations, including operations at LNG terminal-berths. One of the aims was to encourage innovative ship design for cleaner and safer maritime transport under the IMO's FSA methodology. To that end, concepts for risk-based regulatory framework are developed to assist in the development of novel design concepts based on risk analyses. This study, which concerns LNG Carrier Operations, is step 2 of the SAFEDOR project which undertook generic FSA studies on various vessel types.

As a results of this study, Collision was found to be the highest source of risk. This result concides with the conclusions of Darbra and Casal (2004) which analysed historical accidents in seaports. For Vanem *et al.* (2008), both individual and societal risk levels associated with LNG shipping operations lie within the ALARP region. This means that further risk reduction can be required only if cost effective RCOs are identified.

Due to their particularities (congestion, confined waterways, existence of diverse fleet and cargo movements..etc), ports and marine terminals are perfect areas where such accident types can happen including collision and grounding in the port channel or while at berth, fire and explosion at the terminal as well as all types of incidents due to loading and unloading operations (valve failure, hose failure or loading arms failure). However, the study stated that “spillage events during loading or unloading of cargo while in port are generally assumed to be of small scale, where only a limited number of crew are exposed to risks of injuries or death. Fatal accidents are only deemed likely for crew members directly exposed to the cryogenic LNG” (Vanem *et al.* 2008).The resulting risk model is illustrated in the figure below, which is an example of event trees used.

**Figure 3.1 Risk Model for spill events during loading/ unloading**



**Source:** Vanem *et al.* (2008, p. 1336)

Vanem *et al.* (2008) concluded that despite the uncertainties associated with this model, the overall LNG carriers risk is found to be in the ALARP area.

Three generic accident scenarios are together responsible for about 90% of the total risk related to LNG carriers, i.e. collision, grounding and contact. All three scenarios describe a situation where an LNG vessel is damaged due to an external impact from an external floating object (another vessel, the sea floor, submerged object, the jetty or any other structure). Upon closer investigation of the risk models associated with these scenarios, four sub-models are found to be in need of further risk reduction: the accident frequency model, the cargo leakage frequency model, the survivability model and the evacuation model. As a result, the study recommends that further effort should focus on measures related to the following areas:

- Navigational safety
- Manoeuvrability
- Collision avoidance
- Cargo protection
- Damage stability
- Evacuation arrangements

Despite its uncertainties and broad results, this high-level risk analysis remains an interesting example of the application of FSA to LNG shipping and port safety. Another interesting study which applied Formal Safety Assessment (FSA) framework to LNG carrier systems' safety is Nwaoha, *et al.* (2011) which investigated the safety/ risk level of an LNG carrier system through the application of fuzzy evidential reasoning (FER) method to uncertainty treatment



of its failure modes, given the high level of uncertainties in the historical failure data of LNG carriers (Nwaoha *et al.* , 2011).

The study provided risk level estimations for LNG tanker containment system and developed risk control options (RCOs) to mitigate such risks. Prioritization of the best RCO is used to improve the safety level of the system (Nwaoha *et al.* , 2011).

Although the study did not include the possible failure modes of LNG carrier at the port (navigation in port channels, loading/ unloading at terminal...etc), some of the generic risks obtained could also apply to LNG ship at port or while along side the jetty . Based on the above study, Nwaoha *et al.* (2013) developed a new risk analysis framework combining fuzzy evidential reasoning (FER), risk matrix and fault tree analysis (FTA) techniques to investigate risks and provide a new risk ranking methodology for hazards of LNG carrier operations and their fundamental causes. The approach taken in this study is considered proactive since it does not rely solely on historical data and go further in identifying new hazards that have not yet materialised. One important contribution of the study is the prioritization of LNG carrier operations risks which identified the top risk event for due mitigation. The risk matrix under this study identified twenty six hazards of LNG carrier operations from which two are found to be in the 'very high risk' area. Other hazards associated with LNG ship operations are in the 'high risk', 'moderate risk' and 'low risk' areas in the same risk matrix table (Nwaoha *et al.*, 2013).

The study result indicates that an LNG spill from the transfer arms has a higher risk level than failure of the ships' containment system (Nwaoha *et al.*, 2013).

This result is obtained using the FER method to further prioritise the hazards of the same score which are, in this case, the two hazards under the 'very high risk' category. This result is interesting not only for ranking hazards but also for the prioritisation of the RCOs in the risk management phase.

It is noticed that research on LNG risks in general has been more active in the last decade due mainly to the increasing demand for LNG as an alternative clean energy source and to the subsequent drastic increase in the frequency of LNG shipments per year which raised concerns over the safety and reliability of LNG tankers and terminals alike.

Another remark is that more and more research started very recently to consider safety and security risks assessment and management from a holistic and integrative approach (Walker *et al.* (2003), Sandia (2004), Pitblado *et al.* (2004), Ditali & Fiore (2008), CEE (2012), Nwaoha *et al.* (2011, 2013), Vanem *et al.* (2008), Bubbico *et al.* (2009)).

Pitblado *et al.* (2004), Sandia (2004), CH-IV International (2006), Bubbico *et al.* (2009) and CEE (2006, 2012) concluded that LNG safety is assured through a combination of safety standards, regulations, technological advances and high level industry practice and experience. For them, the only plausible threat to the LNG VC is the intentional hazard represented by global terrorism. Also, the few available literature on LNG safety has focused on LNG shipping with partial analysis of related LNG port safety. Therefore, further research effort is needed in connection with LNG ports and marine terminals safety. However, other studies such as Walker *et al.*, (2003), Vanem *et al.* (2008) and Nwaoha *et al.* (2011, 2013) demonstrated a more integrated safety and security RM approach.

### 3.3 LNG PORT SECURITY RISKS

Most safety studies that addressed LNG hazards and risks tried to demonstrate how those hazards, even if they have happened before and may still happen in the future, have little chance of occurring and if they do occur, will have less widespread effects due to industry safeguards contained in LNG infrastructure siting, regulations, standards, technological advances and industry operational safety practice.

The majority of those studies have shown that for such hazards to occur, there must be severe conditions, producing huge intensity of energy in order to penetrate the multiple layers of containment and exclusion zones to produce high consequence incidents, which would probably correspond to acts of terrorism.

As asserted by Walker *et al.* (2003, p.1), LNG maritime security is now added to the years of dialogue related to safe transport of LNG, *“We are now in an environment where intentionally caused spills and releases must be factored into existing prevention, preparedness and consequence management planning.”*

Since LNG is considered a HazMat, LNG maritime and port security should be analysed and addressed in due consideration of safety measures and practice. For Walker *et al.* (2003), security risk is defined as a function of consequence, vulnerability, and threat. Consequence is a measure of the severity of results after a targeted system or infrastructure is attacked. Vulnerability is a measure of how well a site is physically protected and the threat is a measure of the probability of a site or infrastructure being targeted by a person or a group.

Walker, *et al.* (2003) recommend that security RA in the LNG maritime and port industries be based on a careful analysis of the process where LNG or LPG is produced, shipped and then transferred to downstream users. Also, such analysis needs to consider those parts of the process that will yield most casualties and provide the best photo opportunity for terrorists.

It is clear that this approach provides a wider dimension to RA and management by adopting a logistics and SC perspective to the issues of LNG safety and security, with an emphasis on security based threats and vulnerabilities due to their far reaching consequences on the whole LNG VC. Furthermore, contrary to LNG accidental releases and since LNG is perceived as high consequence material, risk scenarios pertaining to intentional terrorist acts would most likely include the ignition source necessary to cause fire and explosion in case of massive LNG release, which is the most feared breach scenario.

For the above reasons, risk mitigation should focus mostly on reducing consequence and vulnerability rather than reducing threat because security threat is a measure of the unknown and law enforcement entities have limited control over them (Walker *et al.* 2003). Pushing further, control over security threats means making fundamental changes to the way the industry conducts business at existing facilities or vessels, which could adversely impact the economics and profitability of the entire VC (Walker *et al.* 2003).

In this respect, security risk mitigation strategies usually target system vulnerabilities and plan to reduce them as much as it is practically possible, through an increase in physical security hardware, people and processes.

Security improvements should be site-specific because effective security RA should be based on facility location, characteristics, and related internal and external environment. Furthermore, an indepth security defence planning and strategy should be flexible and continuously reviewed and updated to cope with the change in threat profile in the surrounding environment.

Practically, taking into consideration the LNG SC process means necessarily integrating the safety procedures and practice which are an important part of the LNG production, storage, transport and distribution processes. By adopting such an approach, safety and security RAs should not be dissociated and have to be performed in connection with each other, with the safety safeguards being in place at first instance.

Walker *et al.* (2003) provided a comprehensive RM approach combining a thorough analysis of both safety and security risks, however this study has not discussed the methodology(ies) for security RA and management as well as no indication of the role to be played by each member of the maritime and port SC in this collaborative effort.

The CEE (2003) in its report on LNG security noted the industry's excellent safety record over the past 40 years. The safe and environmentally sound operation of these facilities and their protection from terrorist activities or other incidents are a concern and responsibility shared by operators as well as federal, state and local authorities across the U.S. Onshore LNG facilities are industrial sites and, as such, are subject to all rules, regulations and environmental standards imposed by the various jurisdictions. The CEE approached security RM of LNG terminal facilities as a right combination of

regulations, standards and technologies which have to be implemented adequately to yield the optimum possible security protection to these strategic facilities.

Although this study provided valuable insight regarding LNG safety and security hazards management and acknowledged the link between safety and security, it did not provide any methodology for RM. Also, its approach was confined to the facility-security perspective..

Fay (2003) investigated a possible scenario of a boat bomb attack on a tanker's combustible liquid cargo, which would certainly escape from cargo holds punctured by the force of a resulting explosion. He stated that the fire that would ensue from a boat bomb attack on a tanker would be of unprecedented size and intensity. However, no one can tell exactly the magnitude of this phenomenon since no relevant industrial experience exists with fire of this scale, from which to project measures for securing public safety. To overcome the lack of such experience, scientific understanding gained from laboratory and physical experiments of much smaller scale is used to predict the characteristics of real world hydrocarbon fires.

The author developed a mathematical model for the spills and fires from liquid fuel marine tankers which is based upon scientific papers published in peer-reviewed journals. He then applied such a model to the case of tankers delivering liquid fuel cargoes (LNG and Oil products) to Boston harbour.

The results of this research in terms of spill volume, fire duration, pool area and thermal radiation zone are presented in table 3.1.

**Table 3.1 Physical parameters of tanker spills**

| <b>Tanker spill parameters</b>                            | <b>LNG</b> | <b>Gasoline</b> |
|-----------------------------------------------------------|------------|-----------------|
| Spill Volume (m <sup>3</sup> )                            | 14,300     | 1140            |
| Fire duration (Min.)                                      | 3.3        | 5.1             |
| Maximum pool area (10 <sup>4</sup> m <sup>2</sup> )       | 18         | 8.0             |
| Maximum pool radius (m)                                   | 340        | 230             |
| Average heat release rate (TW)                            | 1.5        | 0.12            |
| Distance to average heat flux of 5 KW/m <sup>2</sup> (Km) | 1.1        | 0.9             |

**Source:** *Fay (2003)*

The main conclusions of this research are:

- The resulting liquid cargo pool fires from both LNG and oil tankers, due to a boat bomb attack, are unprecedented in scale. There is no possibility of lessening the fires effects, much less extinguishing them during the short time of burnout.
- At any point along the inner harbour route of the tanker to the berth, severe pool fire thermal radiation, capable of killing people and burning building, can be experienced along the waterfront and well inland.

However, such results cannot be verified through experimental data and therefore, it is very difficult to confirm them on a scientific basis since, initially, the model inputs are based on assumptions made by literature.

Fay used a methodology classified as consequence method. This particular method was investigated further by ABS Consulting which asserted that such methods can provide only rough estimates of the magnitude of effects for incidents involving large LNG releases on water. This is typically the case with

consequence assessments which cannot provide precise estimates of effects due to uncertainty in the method itself.

ABS Consulting (2004) identified three issues regarding consequence assessment methods:

- No release models are available that take into account the true structure of an LNG carrier, in particular the multiple barriers existing in modern LNG tankers represented by the tanker's double hulls and the cargo tanks.
- No pool spreads are available to account for wave action or currents.
- The scarcity of experimental data necessary to validate models involving large LNG spills on water. (ABS Consulting 2004)

Another consequence assessment study was performed by Pitblado *et al.* (2004) for the account of DNV. The objective was to review the range of potential LNG marine spillage events from collision, grounding, operational error, and terrorism. Therefore the scope of the study covered both safety and security risks.

The methodology employed involved a review of published literature and operational experience with LNG carriers and LNG experimental trials. A hazard identification study (HAZID) was carried out using a group of industry and risk specialists to identify precursor events that could lead to credible loss of containment. These were converted into credible hole sizes. At a refinement stage, Sandia Laboratories were consulted to refine hole sizes due to terrorist events. Finally, the PHAST software model was used to predict maximum hazard distances from maximum credible Hole sizes.



Hazard zones that were presented in the study are well below many values predicted by most LNG spill studies. Hazard zones include benefits associated with the current vessel designs and safe operations procedures adopted by operators, port authorities and the Coast Guard.

However, similar to Fay and ABS Consulting, Pitblado *et al.* (2004) acknowledged the existence of uncertainties associated with any consequence study. It should be noted that these modelling issues concern both accidental and intentional LNG releases.

Parfomak and Flynn (2005) in their report to the US Congress on LNG terminals security, stated that LNG infrastructure attractiveness to terrorists has been the subject of debate since Sept.11, 2001. Many experts believe that, like LNG safety, concerns about security threats to LNG facilities may be overstated and should not impede LNG imports into the U.S. However, the U.S. Department of Homeland Security, DHS (2009) believes that risks associated with LNG shipments are real, and they can never be entirely eliminated. The same conclusion has been asserted by the Sandia report which concluded that a range of potential terrorist attacks on LNG tankers could be considered “credible and possible” and that the consequences from such attacks could be “severe” (SANDIA 2004).

Most hazard analyses for LNG terminals and shipping actually depend on computer models to approximate the effects of hypothetical accidents and incidents. U.S. Federal siting standards specifically require computer modelling of thermal radiation and flammable vapor cloud exclusion zones (49 C.F.R. §§ 193.2057, 2059). Such models are necessary because there have been no

major LNG incident of the type envisioned in LNG safety and security research and because historical LNG experiments have been limited in scale and scope. However, LNG hazard models simulate complex physical phenomena and are inherently uncertain, relying on calculations made on assumptions.

Similarly, SANDIA (2004) reported such limitations in existing data and models for analysing LNG spills over water. However, it concluded that such analytical tools can be used to identify and mitigate hazards.

In the U.S., the FERC also remarked that unlike LNG safety, historical experience provides little guidance in estimating the probability of a terrorist attack on an LNG tanker or shore-based facilities (GAO 2007). A former Director of Central Intelligence believes that a terrorist attack on LNG facilities is unlikely because it may not produce a great impact compared to other targets. However, he could not tell how this would not yield big impact and which targets he is referring to as comparison (GAO 2007).

The U.S. Coast Guard has also expressed concern about the increase in the security costs from growing U.S. LNG imports and subsequently requested additional resources to secure future LNG deliveries. Addressing this funding issue, the Energy Policy Act of 2005 requires private and public sector cost-sharing for LNG tanker security. Accordingly, FERC requires new LNG terminal operators to pay the cost of any additional security or safety measures needed for their facilities. The FERC also recommended that LNG operators provide additional staff to supplement the coast guard and local government security forces. Additionally, FERC will not approve any facility security plan unless the LNG operator has a security arrangement with the local government and the

Coast Guard pertaining to the provision of adequate security resources supporting the facility security plan (Parfomak and Flynn 2005).

Bajpai and Gupta (2007) recognised the threats to oil and gas infrastructure represented by international terrorism. they noted that the biggest difference in performing RA following the 9/11 terrorist attacks is that high consequence-low frequency events cannot be neglected, and therefore the risk from intentional acts are considered both real and credible.

The approach of this study tries to reduce both frequency and consequences from terrorist attack. Although it highlighted the lack of exhaustive database on historical terrorist attacks on oil and gas facilities on the international arena, Bajpai and Gupta (2007) used a record of 90 incidents worldwide from Karmon (2002) concerning pipelines, oil and gas facilities and on personnel involved in the discovery, construction and exploitation of these resources for the period 1980-2000.

For Bajpai and Gupta (2007), security RA can be carried out qualitatively through the following methods:

- *Threat analysis (TA)*
- *Vulnerability analysis (VA)*
- *Security risk table*

TA is a study of all sources and types of threats and their likelihood (history of security incidents in and around the facility, intentions and motivations of adversaries, their capabilities, etc). To illustrate the TA, the authors provided a list of potential threats to oil and gas facilities and their transportation systems

(oil tankers, pipelines, etc), as well as a historical table showing the number of security incidents per region and per country, occurred during 1980-2002, which was extracted from (Karmon 2002).

VA involves identifying weaknesses in a system which can be exploited by adversaries. It identifies ways in which the credible threats selected in the TA could be realised. Since terrorists employ novel ways of attack, it is essential to be creative and imaginative in VA. The team that conducts VA should comprise of people from maintenance, production, management, safety, security, intelligence and law enforcement.

Bubbico *et al.* (2009) conducted a preliminary risk analysis of LNG carrier approaching the Italian terminal of Panigaglia. As stated earlier in section 3.1, since the required velocity to cause a breach of LNG cargo tank during 90° collision with a large vessel is 6 to 7 knots, Bubbico *et al.* (2009) concluded that accidental collision of an LNG tanker with a small or large vessel cannot be excluded due to port congestion. Nevertheless, the low ship velocity when approaching the terminal makes such a collision unrealistic at 6-7 knots speed to open a breach in the cargo. Grounding cannot be excluded as well but generally does not result in LNG cargo breaches, especially at low speed. Therefore for Bubbico *et al.* (2009), the only plausible scenario for a severe breach of an LNG tanker's tanks is an intentional action against the tanker; such a case was investigated further using the consequence analysis technique.

It should be noted that the possible final events and the impact zones calculated for the study case with a "basic" consequence software, such as ALOHA,

appear in substantial agreement with previous results from SANDIA (2004) and Fay (2003) based on more refined models, and well within the spread of experimental and calculated data available in the literature.

The consequence analysis showed that no, or very marginal, involvement of the resident population has to be expected due mainly to the location of the LNG terminal which is relatively far away from the population's residence areas. On the other hand, material as well as economic losses may occur, if the outer breakwater is damaged and/or the west passage is partially obstructed.

Noting the scarcity of studies on port security risk assessment (RA) which can provide solutions to enhance the quality of security assessments, Yang *et al.* (2014) proposes a quantitative security risk analysis using fuzzy evidential reasoning (FER) approach. This approach is applied to quantify port facility security risks and to conduct the cost benefit analysis for the evaluation of RCOs. The study's aim is to ensure that the Ports facility security Plans (PFSPs) under the ISPS security regime 'are rational to the risks faced by ports and can be cost-effectively implemented by operators' Yang *et al.* (2014).

Given that rational risk analysis is difficult to achieve with often uncertain and incomplete qualitative data, the authors suggest standardizing the way expert opinion is used to complement the lack of objective security failure data. The FER approach is introduced in this perspective and provides a novel approach in quantitative Port Facility Security Risk Assessment (PFSA) which has the prospect of proactively enhancing the security of ports and maritime terminals. Due to its generic nature, this methodology can be applied to ports and marine terminals handling LNG. On a larger scale, Berle *et al.* (2013) analysed

vulnerability in the LNG maritime transportation systems using a formal vulnerability assessment approach (FVA). The study is an attempt to adapt FSA to maritime SC security. It can be considered both as a continuation and innovation in the global supply chain RM research domain initiated by the work of Manuj and Mentzer (2008), and the earlier contribution of Cranfield university to the field of supply chain RM (Cranfield, 2003).

### **3.4 LNG PORT RISK MANAGEMENT AND QUALITY**

As stated earlier, freight transportation shifted its security focus from controlling theft and reducing contraband and stowaways before the 9/11 to fighting global terrorism. Lee and Wolfe (2003) asserted that terrorism has definitely transformed perceptions of security accross the SC. After Sept. 1, 2001, the highest-order definition of freight security changed from theft-proof to tamperproof. In this context, both government and the public at large are concerned with the potential of a terrorist attack against the maritime and port segment of SC. the private sector as well is concerned about the costs of assuring security, and the possible disruptions associated with potential terrorist acts. Government and industry have both responded with proposals to create more confidence in the SC. However, some proposed measures, such as increased information sharing among SC partners, heightened inspection and scrutiny of goods, can add cost, delays, and uncertainties in the SC. Furthermore, SC distruption from security breaches can be disastrous. It is very difficult to quantify the full direct, indirect cost, casualties, congestion and disruption to business from a temporary port closure following a terrorist attack (Lee and Whang 2005).

The private sector, especially SC professionals, are faced with a dilemma of how to improve security without jeopardising SC effectiveness. Lee and Wolfe (2003) explained that the answer may lie in the principles of the quality movement. For them, the quality movement of the 1970s and 1980s provides an instructive model for public and private business leaders as they develop a response to SC security challenge. The total quality principle teachings assert that decreasing production defects is possible without increasing costs. Therefore, strategies that both prevent and mitigate security breaches can be implemented while still delivering cost effective SC. The quality movement started with the recognition that defects can be very costly to a company. This provided a strong motivation for industry to become engaged in Total Quality Management (TQM), a process whereby the entire organisation, its suppliers and in some cases, costumers have to work closely together in order to improve quality. Similarly, companies need to recognise the importance and significant cost of security issues and to engage all stakeholders in driving out security breaches.

The first lesson from the quality movement is that quality should not rely on final product inspection since inspection does not improve quality, furthermore, inspection and screening is expensive and subject to errors. Therefore, in-process control to ensure that the process is functioning and under control is much better than final product inspection. According to Lee and Whang (2005), a process that is out-of-control will produce many more non conforming items. Identifying the causes of non-conformities in the system and restoring it to its in-control state and in a timely fashion will always improve quality. Secondly, quality assurance requires total organisational focus. Quality is not just the

responsibility of the quality control department or quality inspectors, but everyone's responsibility. The third message is that prevention is always the preferred strategy. Hence, the goal should be to find the way that once something has gone wrong, it could be immediately identified and corrected so that it could never turn into a defect. Finally, quality should be designed in. Products are designed in a way so they are less likely to be built with defects.

In recent decades, the quality movement has shifted from a focus on inspection to a focus on prevention. Prevention emphasises education, organisational collaboration, design improvement, process variation reduction and accountability of the total company (Lee and Whang 2005). In reality, many companies implemented the above principles and found out that it is possible to increase quality without increasing costs and jeopardizing productivity.

**Figure 3.2 SC Security and Quality**

| Quality Movement                               | Security Initiatives                                             |
|------------------------------------------------|------------------------------------------------------------------|
| Defects are very costly                        | Security gaps create big risks                                   |
| Total Quality Management                       | Involvement of all stakeholders                                  |
| Emphasis on prevention                         | C-TPAT, CSI, sealing and anti-tamper Technologies                |
| Source Inspection                              | CSI and source inspection                                        |
| Process Control                                | Automated chain of custody                                       |
| Identify, track, and improve (Six Sigma Cycle) | Container tracking and total Quality visibility                  |
| Root cause analysis                            | Profiling system for shipments, shippers, carriers, trade routes |
| "Quality is free"                              | Higher productivity with SC security and confidence              |

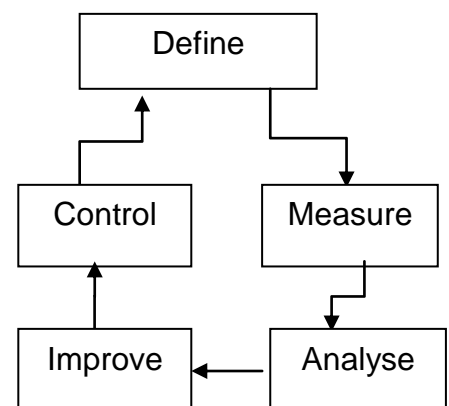
**Source:** Lee and Wolfe (2003, p.14)



Although acknowledging that the added costs of security are far from trivial, Lee and Wolfe (2003) still believe that it is possible to implement important security improvements in ways that enhance SC productivity and effectiveness. The quality movement in particular offers models that can be effectively applied to SC security. Lee and Wolfe (2003) see in the security initiatives actually implemented, especially in the USA, such as inspecting products and containers at point of origin, using technology to automate the chain of custody, monitoring the process closely during transport and creating transparency and visibility across the SC and information rather than physical inspection, all these measures are in conformity with the principles of TQM. Lee and Whang (2005) confirmed this by stating that the key to success in SC security is to apply prevention, process control and the Six Sigma approach, initially developed for quality control.

**Figure 3.3 The Six Sigma cycle**

**Define**: define what is to be measured, what the quality problems are, and how they could be identified.  
**Measure**: put in place a measurement system that would track and monitor the appropriate quality performance measures and provide visibility and access to key stakeholders.  
**Analyse**: perform analysis of possible out-of-control conditions and conduct a root cause diagnosis.  
**Improve**: respond to identified problems by restoring the process to an in-control condition, and communicate decisions to stakeholders.  
**Control**: Eliminate the root cause if possible, reduce process variations, and make structural changes to the process so that chance for the out-of-control condition to occur again is minimised.



**Source:** Lee and Whang

It should be noted that the Six Sigma steps: identify, assess and evaluate, mitigate, monitor and re-assess, are in fact similar to the general risk analysis paradigm followed by most known RA and management methods such as QRA and FSA. The same methodology is adopted by the recently released ISO 28000-2007 series which provide specifications for security management systems for the SC.

In the same way, Doak (2003) supported the new security approach and asserted that this is, in fact, not totally new: “Pre-inspections and key shipping/documentation information have always been sent well ahead for customs clearances and customer contract requirements. It made good business sense and is comparable to the emphasis on quality measures taken in the late seventies and eighties, with the focus on making it right first time” (Doak 2003). Commenting on industry complaints regarding the cost of compliance for security programs, Doak (2003) stated that executives did not argue with the costs for quality initiatives in the seventies and the eighties or with the recent Six Sigma programs. This is due to the fact that executives are realising that the long term benefits of quality far exceed the costs. He argues that a similar issue is happening to SC security.

Similarly, safety risk management in the maritime and port industry has been moving towards the application of the principles of the TQM, although this has been slow and conservative. Such move was accelerated by the multiple maritime disasters which repeatedly called for the adoption of a proactive approach to risks while much of the maritime safety policy worldwide has been developed reactively in the aftermath of serious accidents such as *theExxon*

*Valdez, the Estonia, the Erika and the Prestige*. The IMO's recent adoption of the Formal Safety Assessment (FSA) and the Goal- Based Standard (GBS) frameworks is considered a confirmation of the move of the maritime industry towards a proactive approach to risks and vulnerabilities.

Also, recent studies such as Nwaoha *et al.* (2011, 2013), Vanem *et al.* (2008) and Bubbico *et al.* (2009) have applied proactive approach by adopting robust quantitative and qualitative technics to proactively and integartively assess risks and vulnerabilities in the LNG maritime and port systems.

### **3.5 CONCLUSION**

Finally, it appears from the above review of literature that the subject of marine and port SCRM, as related to LNG transport and logistics has not yet been investigated thoroughly. The sparse existing literature on the subject is mostly published by professional bodies and rarely analyses the issue from a logistics and SC perspective. On one hand, most literature approaches the safety and security RM in isolation and on the other hand, the facility-security perspective prevails in most LNG port security studies instead of the SC perspective. However, recent papers have clearly indicated that LNG safety mitigation measures and safeguards are effective barriers to minimise the consequences of security risks in the event of intentional attacks on LNG facilities.

It is believed that while risk assessment of LNG safety and security risks and hazards is moving in the right direction, little is done in the area of LNG ports risk management, especially the lack of a practical standard framework capable of applying integrated and holistic approach to risks and optimally managing the interfaces and shared impacts among safety and security risks in LNG ports.

It is noticed that LNG ports safety and security interfaces are still to be investigated. A thorough analysis and understanding of those interfaces will have a decisive impact on the optimal RM approach which can enable effective protection of LNG ports SCs. The following table summarises the interfaces among safety and security RMs in LNG ports as discussed in the literature reviewed so far.

**Table 3.2 Safety and security interfaces in LNG ports**

| <b>Interfaces</b>                            | <b>Safety</b>                                                                                                                                                                                                                                                     | <b>Security</b>                                                                                                                                                                                                                                  |
|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>RA</b>                                    | <ul style="list-style-type: none"> <li>- Consider security requirements;</li> <li>- Integrate security regulations and procedures</li> </ul>                                                                                                                      | <ul style="list-style-type: none"> <li>- Consider safety requirements</li> <li>- LNG properties and hazards</li> <li>- LNG industrial processes</li> <li>- Integrate safety regulations and procedures</li> </ul>                                |
| <b>RM</b>                                    | <ul style="list-style-type: none"> <li>- Review of security RCOs</li> <li>- Impact of those RCOs on the safety system;</li> <li>- Notify any malicious acts in the port;</li> <li>- Awareness of security operations in the port</li> </ul>                       | <ul style="list-style-type: none"> <li>- Review of safety RCOs</li> <li>- Impact of those RCOs on the port security system</li> <li>- Notify any unsafe behaviour in the port</li> <li>- Awareness of safety operations and practices</li> </ul> |
| <b>Emergency response</b>                    | <ul style="list-style-type: none"> <li>- Communicate the safety ALARP level to be considered in the ERP</li> </ul>                                                                                                                                                | Communicate the maritime security (MARSEC) levels to be considered in the ERP.                                                                                                                                                                   |
| <b>Port recovery and business continuity</b> | <ul style="list-style-type: none"> <li>- Build redundancy in each critical infrastructure of the LNG port system</li> <li>- Coordinate between emergency response and port management to bring the port back to operation in the minimum possible time</li> </ul> | Declare the port safe and secure for normal/ partial operation in an incident aftermath, in full coordination with safety department and the port authority.                                                                                     |

**Source:** *The author*

## **CHAPTER 4 INTERNATIONAL SAFETY AND SECURITY REGULATORY FRAMEWORKS**

### **4.1 INTRODUCTION**

Since its inception, the focus of the international community, including the LNG industry has been on ensuring safety along the LNG VC which means ensuring safer liquefaction and regasification plants, LNG storage tanks and pipelines, LNG export/import terminals and vessels and making sure that these are designed, constructed and operated to the highest standards. This is necessary to minimise risks to persons and damage to property and to the environment (Griffin, 2012). Also, since the terrorist attacks of September 2001, terrorism has been a potential source of concern to the LNG SC, including LNG ports and LNG ships.

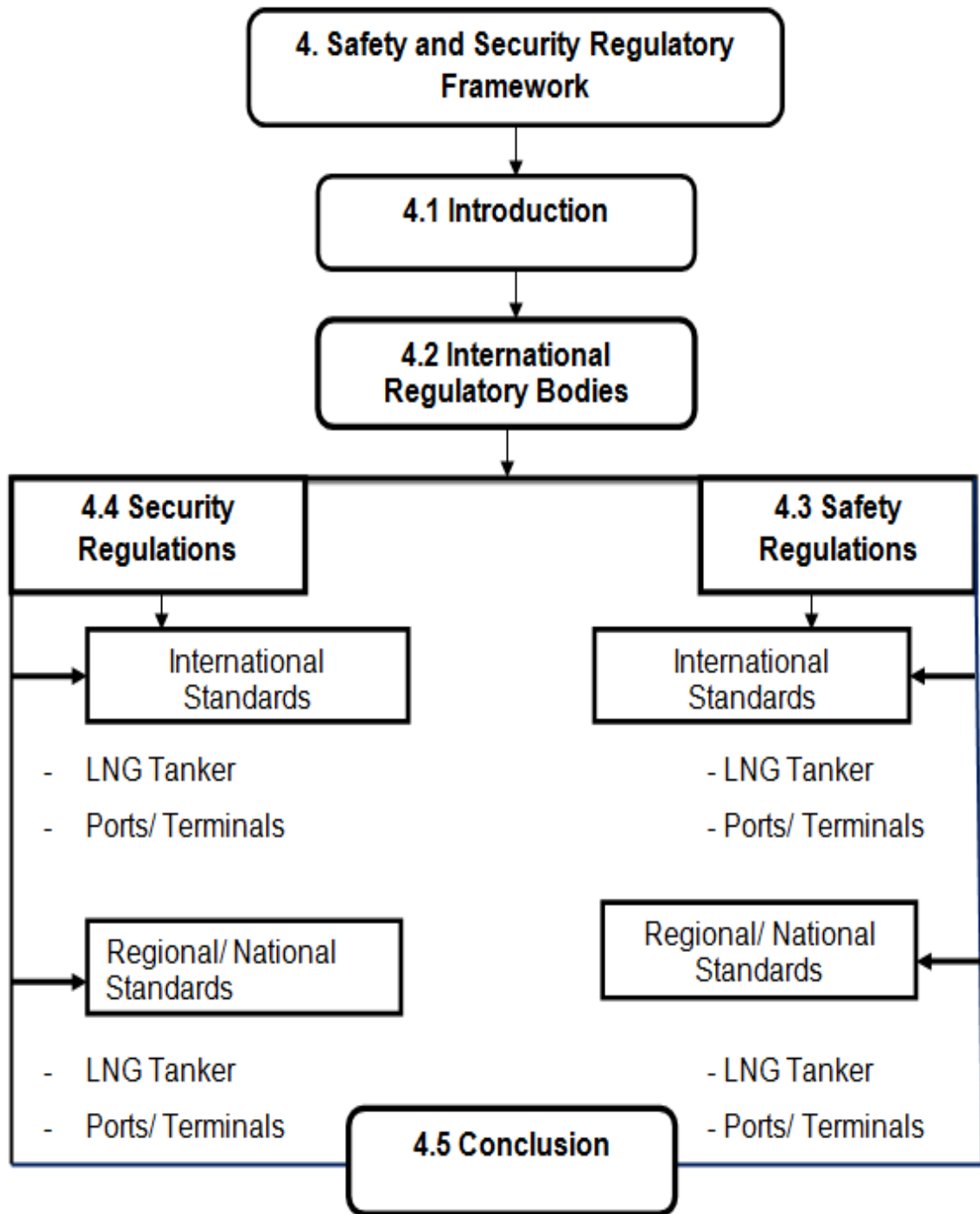
Although such risks are credible, the LNG industry has been successful, to a certain extent, in avoiding such risks and hazards and it still enjoys an enviable safety and security records with few incidents. Part of this success is attributable to the large armada of laws, regulations, standards, guidelines and industry best practices in place which have been developed, updated and implemented during the whole history of the LNG industry with a wide coverage of the whole LNG VC.

This chapter reviews the international safety and security regulatory frameworks applicable to the design and operation of LNG vessels and onshore marine terminals as well as the international organisations and industry bodies which

have played an active role in the set up and development of such a rich safety and security legislative framework.

LNG marine terminal facilities and tanker safety and security are subject to various international and national rules and regulations. These have been developed by both the LNG industry and international specialised bodies, such as the IMO. In today's LNG business environment, some specialists believe that the more prominent role of the LNG spot market could potentially open up the LNG business to a greater safety risks as operators become more risk averse in order to meet schedules. Also there are increasing concerns that rapid expansion of the LNG fleet could lead to a shortage in skilled personnel (Griffin, 2012).

Figure 4.1 Diagram showing the organisation and flow of the chapter



Source: The Author

## **4.2 INTERNATIONAL SAFETY AND SECURITY REGULATORY BODIES**

With the UN system, the IMO is the UN specialised agency most active in promoting maritime conventions at an international level. The Maritime Safety Committee is the IMO's technical committee addressing safety at sea, including construction and equipment of ships, aids to navigation, prevention of collisions, safety procedures and requirements, the handling of dangerous cargoes and the safe manning of ships.

IMO also adopts non-binding recommendations and codes of practices not suitable for regulation by formal treaty instrument (Griffin, 2012).

Other non-governmental bodies have also a crucial role in the safe design, construction and operation of LNG vessels and marine terminals. These include:

- The Society for International Gas Tankers and Terminal operators (SIGTTO);
- The Oil Companies International Maritime Forum (OCIMF);
- The International Association of Classification Societies (IACS)
- The National Fire Protection Association (NFPA)
- The World Shipping Council (WSC)
- The International Navigation Association (INA)

Among the above non-governmental organisations, SIGTTO is the industry leader in providing guidelines, recommendations and best practices to its members on matters related to safe handling and transportation of liquefied gases. Also, NFPA, although being a national American association, plays an



important international role in the development of codes and standards related to fire risks (Griffin, 2012).

Ship classification societies, represented by IACS, have long influenced the safe design, construction, and maintenance of ship hull structures and essential shipboard engineering systems by setting industry standards through inspection and rating of ships for marine insurance and other purposes. Their work complements the IMO's international treaties and conventions. The IACS and individual classification societies, such as Lloyd's Register (Lloyd's), have been proactive in enhancing LNG carrier safety, emphasising the need for incorporating risk analyses in shipping processes. Furthermore, IACS design guidelines for offshore LNG facilities fill a void created by the absence of specific governmental regulations (Garry, Weems, & King, 2012).

Public concerns about LNG safety and security make RA and communication a critical part of the facility siting process. LNG organisations routinely identify new risks and update their technical design standards and operating procedures to mitigate them. These recommended improvements are disseminated initially through organisations such as SIGTTO and IACS, but they eventually become requirements through international standards and government regulations.

Regarding enforcement, international maritime laws and regulations are enforced and policed at the national level by the flag state and the coastal state (Flag State/ PSCs). Under the UNCLOS 1982, coastal states are allowed to legislate and enforce regulations to ensure safety of navigation within their respective territorial seas and EEZ. Classification societies have also a crucial

role in this through policing the international law related to ships' and maritime safety regulations (Garry, Weems, & King, 2012). The responsibilities to ensure that vessels comply with the provisions of the relevant regulations rest upon the owners, masters, the Flag States and the Classification societies. Unfortunately, some Flag States, for various reasons, fail to fulfill their internationally-agreed commitments and, consequently, some vessels are sailing the world' seas in unsafe condition, threatening the lives of all those on board as well as the marine environment. Port State Control (PSC) is a system of harmonized inspection-procedures designed to target sub-standard vessels with the main objective being their eventual elimination.

PSC process was quickly accelerated by a number of successive shipping accidents, especially the Amoco Cadiz disaster which triggered the promulgation of more stringent regulations on shipping safety; and gave birth to the Paris Memorandum of Understanding (Paris MOU) on PSC in Europe. This covered safety of life at sea, prevention of pollution from ships and the living and working conditions onboard.

PSC is carried out by a PSC Officer (PSCO). The PSCO is a properly qualified person, authorised to carry out Port State Control inspections in accordance with MOU regulations by the maritime authority of the Port State and acts under its responsibility. A PSC Inspector will board a vessel without announcement and check primarily the ship's documents for completeness and validity. If there are any grounds to believe that the ship is substantially not in compliance with the international conventions, the inspectors will carry out an "*expanded inspection*" of the ship's condition and the required equipment. The ship master will receive an official inspection report consisting of Form A and B. Form A lists

the vessel's details and the validity of the relevant certificates. Form B shows the list of “*deficiencies*” found, together with the action code which describes a time frame for rectification for each deficiency. If there is evidence that the vessel represents a hazard to safety and/or to environment, the PSCO has the right to detain the ship in port until the respective deficiencies are rectified. The PSC authority will either re-survey by its own inspectors or ask for a survey report from the classification surveyor to verify the rectification. It should be noted that all vessels made for international voyage are subject to PSC, including LNG tankers. At present, there are around 9 regional agreements on PSC representing the PSC regions around the world. In the Arabian Gulf, *The Arabian Gulf Region* includes Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

In the following sections, international, regional and some domestic regulations related respectively to safety and security of LNG facilities design, construction and operation, will be presented and discussed. However, this overview will be limited only to regulations involving LNG ports and maritime terminals and tankers, including those general rules and regulations which are also applicable to LNG ports and vessels.

### **4.3 SAFETY REGULATIONS**

As discussed earlier, the LNG industry is subject to the same hazard and safety requirements as any industrial activity. Risk mitigation systems must be in place and maintained at all time to mitigate and reduce risk to employees, communities, infrastructure and facilities, and to the surrounding environment.

In this respect, LNG industry must conform to relevant international, national and local regulations, standards and codes as is the case for any process industry.

Beyond routine industrial safety considerations, LNG presents specific safety requirements related to the nature of LNG and its intrinsic properties as a hazardous material. Generally, LNG facilities are subject to multiple layers of protection which create four (4) essential safety requirements, all of which are integrated within an effective combination of industry standards and regulations.

*According to CEE (2006), 'industry standards are written to guide industry and also to enable public officials to more efficiently evaluate safety, security and environmental impacts of LNG facilities and industry activities. Regulatory compliance should ensure transparency and accountability in the public domain'*

The four essential safety requirements discussed earlier in chapter 2 for instance primary containment, secondary containment, safeguards systems and separation distance, apply to all LNG fixed and movable assets and facilities across the LNG VC such as LNG production, liquefaction, loading/ unloading terminal facilities, LNG tanker, storage and re-gasification plants.

Industry standards are the appropriate operating and maintenance procedures of any industrial system which should be put in place with an assurance that these are adhered to and that relevant personnel are appropriately trained to implement and apply them on a regular basis. LNG safety regulations concern also onshore industrial processes as well as technical maritime activities pertaining to tanker design and equipment, tanker manning and operation, tanker navigation safety and the ship/ port interface. All such regulations and

standards are jointly and cooperatively developed by the LNG industry (SIGTTO, OCIMF...etc.) and the IMO, ILO...etc.

#### **4.3.1 INTERNATIONAL STANDARDS**

LNG transportation by sea is internationally regulated through international maritime conventions and treaties developed and enacted by IMO in collaboration with the industry.

Safety related risks have been addressed cooperatively by both the IMO and the LNG industry since inception of the latter, mostly as a response to early incidents involving gas carriers and LNG terminals.

Earlier in chapter 2, the types of LNG tanker designs as well as their safety features were presented and discussed in detail. The ships' safety systems are divided into ship handling and cargo handling systems. The ship handling safety features, similar to any other international seagoing ship, include sophisticated navigation radars and GPS systems that alert the crew to other traffic and hazards in the ships' surroundings. Also, distress systems and beacons automatically send signals in case the ship is in difficulty. Such distress systems are also common to all ships engaged in international voyage.

The cargo safety system features include an extensive instrumentation package that safely shuts down the LNG handling system (ESD systems) if it starts to operate outside the normal working parameters. Moreover, LNG tankers are equipped with gas and fire detectors capable of detecting any abnormal gas leak and resulting fire.

LNG tankers are subject to a number of safety standards and codes, some are applicable to all international seagoing ships and others are specific to LNG vessels. LNG tankers are subject to the following IMO safety standards:

❖ **The International Convention for the Safety of Life at Sea, (SOLAS Convention) and its amendments.**

The first version of SOLAS was adopted in 1914 in response to the Titanic disaster, the second in 1929, the third in 1948, and the fourth in 1960. The 1960 Convention, which was adopted on 17 June 1960 and entered into force on 26 May 1965, was the first major task for IMO after the Organisation's creation and represented a considerable step forward in modernising regulations and in keeping pace with technical developments in the shipping industry. The objective was to keep the Convention updated by periodic amendments but in practice the amendments procedure proved to be very slow, to the extent that it appeared practically impossible to secure the entry into force of the convention amendments within a reasonable period of time.

As a result, a new Convention was adopted in 1974 which included not only the amendments agreed upon until that date but a new amendment procedure - the tacit acceptance procedure - designed to ensure that changes could be made within a specified (and acceptably short) period of time. The 1974 convention entered into force on 25th May 1980. The SOLAS Convention and its amendments are generally regarded as the most important of all international treaties concerning the safety of merchant ships. It provides, among others, that the ship should be designed, constructed, maintained and operated in full

compliance with the structural, mechanical and electrical requirements of a recognised classification society (Griffin, 2012).

The SOLAS Convention covered all essential measures to be taken on board during emergency situations. These measures, applicable to all seagoing ships, concern the necessity to carry on board a sufficient number of lifeboats and the necessary communication means for distress alert, procedures and training for emergency evacuation and the necessity for the ship to continuously monitor radio frequencies dedicated to distress calls. SOLAS also stipulated certain requirements related to the stability of passenger ships in both normal and damaged conditions (known as intact stability and damage stability). These requirements were extended to LNG ships. Other areas covered by SOLAS include fire protection, detection and extinction; design of life saving appliances; and conditions associated with the carriage of dangerous goods.

Of particular significance to LNG ships is Chapter V, regulation 22 (Navigation Bridge Visibility) which sets requirements for achieving good visibility from a bridge of a ship, including specifications for the field of vision from various positions. The elevated level of LNG cargo tanks and associated accessories poses a challenge to naval architects in complying with the visibility regulations. This issue is accentuated with the existence in certain ports of low bridges crossing port channels. As a result, LNG tankers designed to comply with navigation safety regulations cannot access certain ports where access channels are crossed by low bridges. It is worth mentioning that the provisions of SOLAS constitute an important part of the international maritime law controlled and policed under the PSC inspections.

### ❖ **The Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972**

The 1972 COLREG Convention was designed to update and replace the Collision Regulations of 1960 which were adopted at the same time as the 1960 SOLAS Convention. One of the most important innovations in the 1972 COLREGs was the recognition given to traffic separation schemes - Rule 10 which gives guidance in determining safe speed, the risk of collision and the conduct of vessels operating in or near traffic separation schemes (IMO, 2012).

The first such traffic separation scheme was established in the Dover Strait in 1967. It was operated on a voluntary basis at first, but in 1971 the IMO Assembly adopted a resolution stating that observance of all traffic separation schemes is made mandatory - and the COLREGs make this obligation clear.

The COLREGs include 38 rules divided into five sections: Part A - General; Part B - Steering and Sailing; Part C - Lights and Shapes; Part D - Sound and Light signals; and Part E - Exemptions. There are also four Annexes containing technical requirements concerning lights and shapes and their positioning; sound signalling appliances; additional signals for fishing vessels when operating in close proximity, and international distress signals (IMO, 2012).

### ❖ **The International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW), 1978**



The 1978 STCW Convention was the first to establish basic requirements on training, certification and watch keeping for seafarers on an international level. Previously the standards of training, certification and watch keeping of officers and ratings were established differently by individual governments, usually without international reference. As a result standards and procedures varied widely in shipping, an industry known to be the most international of all industries. The Convention, which entered into force on 28 April 1984, prescribes minimum standards relating to training, certification and watch keeping for seafarers which countries are obliged to meet or exceed (IMO, 2012).

The Convention did not deal with manning levels: IMO provisions in this area are covered by a regulation in Chapter V of SOLAS, whose requirements are backed up by resolution A.890 (21) Principles of safe manning, adopted by IMO in 1999.

The Articles of the Convention include requirements relating to issues surrounding certification and PSC. One especially important feature of the Convention is that it applies to ships of non-party States when visiting ports of States which are Parties to the Convention. Article X requires Parties to apply the control measures to ships of all flags to the extent necessary to ensure that no more favourable treatment is given to ships entitled to fly the flag of a State which is not a Party than is given to ships entitled to fly the flag of a State that is a Party.

The difficulties which could arise for ships of States which are not Parties to the Convention are one reason why the Convention has received such wide

acceptance. By December 2000, the STCW Convention had 135 Parties, representing 97.53% of world shipping (IMO, 2012).

According to (IMO, 2012), The STCW convention and its code were amended several times since their promulgation in 1974. A summary of these amendments can be found in Appendix 2.

#### ❖ **The International Maritime Dangerous Goods (IMDG) Code.**

The IMDG Code is accepted as an international guideline to the safe transportation or shipment of dangerous goods or hazardous materials by ships including LNG. It is intended to protect crew members and to prevent marine pollution in the safe marine transportation of hazardous materials. It is recommended to governments for adoption or for use as the basis for national regulations. Class 2 of the code concern the handling of gases transported in bulk, including LNG.

The implementation of the Code is mandatory in conjunction with the obligations of the members of United Nation governments under the SOLAS and MARPOL Conventions. It is intended for use not only by the mariner but also by all those involved in industries and services connected with shipping, including, for example, dockers and port workers involved in the handling of dangerous materials. It contains advice on terminology, packaging, labelling, placarding, markings, stowage, segregation, handling, and emergency response (IMO, 2012). The code is updated and maintained by the MSC Sub-Committee of the IMO every 2 years.

#### ❖ **The International Safety Management (ISM) Code:**

The ISM code concerns the safety of ships and the prevention of marine pollution by means of adequate ship management requirements which have to be met by ships and shipping companies on a yearly basis. It provides an International standard for the safe management and operation of ships and for pollution prevention. The purpose of the ISM Code is:

- To ensure Safety at Sea
- To prevent human injury or loss of life
- To avoid damage to the environment and to the ship.

SOLAS adopted the ISM Code in 1994 and incorporated it into chapter IX. By 2002 almost all of the international shipping community was required to comply with the ISM Code. In order to comply with the ISM Code, each ship class must have an adequate Safety Management System (SMS). Another requirement of the ISM Code is for the ship to be maintained in conformity with the provisions of relevant rules and regulations and with any additional requirements which may be established by the Company.

Each ISM compliant ship is audited, first by the Company (internal audit) and then each 3 years by the Flag State's Maritime Administration (MARAD) to verify the fulfilment and effectiveness of their Safety Management System. Once SMS is verified to be effectively implemented, the ship is issued with The Safety Management Certificate.

❖ **The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, (IGC Code).**

It is the most significant IMO regulation specifically related to LNG ships. The IGC Code was developed by IMO to provide an international standard for the safe carriage by sea of liquefied gases and other substances, by prescribing the design and construction standards of ships involved in such carriage and the equipment they should be fitted with so as to minimize the risk to the ship, to its crew and to the environment. LNG vessels are also required to apply specific provisions regulating their construction and equipment contained in the IGC code. The code applies to gas carriers constructed on or after July 1<sup>st</sup>, 1986.

Classification societies have incorporated the code into their rules pertaining to the design and construction of gas tankers (Griffin, 2012).

In addition to the above code, there are two additional gas codes, namely:

- **The Code for existing ships Carrying Liquefied Gases in Bulk (Existing Ship Code-IMO)**
- **The Code of Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (The GC Code-IMO).**

The regulations for the design and construction of gas carriers stem from practical ship designs codified by the IMO. All new ships (from June 1986) are built to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (the IGC Code). This code also defines cargo properties and documentation provided to the ship (the Certificate of Fitness for the Carriage of Liquefied Gases in Bulk), shows the cargo grades the ship can carry. In particular this takes into account temperature limitations imposed by the metallurgical properties of the materials from which the containment and piping systems are made. It also takes into account the reactions between

various gases and the elements of construction not only on tanks but also related to pipeline and valve fittings.

When the IGC Code was produced, an intermediate code was also developed by the IMO - the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (the GC Code). This covers ships built between 1977 and 1986. (UK-P&I Club, 2002)

It should be noted that gas carriers were in existence before IMO codification and ships built before 1977 are defined as 'existing ships' within the meaning of the rules. To cover these ships, a voluntary code was produced by the IMO – the Code for Existing Ships Carrying Liquefied Gases in Bulk (the Existing Ship Code). Despite its voluntary status, almost all ships remaining in the fleet of this age have certification in accordance with the Existing Ship Code. This mainly to safeguard international chartering opportunities which otherwise would be severely compromised (UK-P&I Club, 2002).

The above three codes are applied by the gas industry in addition to regulations and a survey cycle of operational fitness applied to other sectors of the shipping industry and which provide a solid base for safety of LNG shipping (Walker *et al*, 2003).

Also, LNG industry organisations such as SIGTTO, OCIMF and the classification societies have been active in setting up standards and industry best practice related to LNG tanker safety, design, construction and operation.

A sample of such standards and industry best practices include:

- ✓ SIGTTO Tanker Safety Training for Liquefied Gas, 2007: This is a completely new guide for Liquefied Gas Carriers., covering the IMO

specialised level course (Model 1.06) for ships' officers serving on both LNG and LPG carriers.

- ✓ SIGTTO Passage Planning Guide. Malacca & Singapore Straits, (3rd Edition) 2011.
- ✓ SIGTTO Liquefied Gases Marine Transportation and Storage, Edition 2000.
- ✓ Manifold Recommendations for Liquefied Gas Carriers, 2d Edition: These recommendations have been developed in conjunction with OCIMF to present a unified document on manifold arrangements and strainer guidelines for LPG and LNG carriers. The aim is to promote improved safety and efficiency in operations and assists in planning the position of loading and discharging facilities in new jetties (Wetherby Seamanship, 2011).

Modern LNG marine terminals incorporate numerous safeguards in the design, construction and operation of the facility and employ state-of-the-art technology. For instance, most projects use a full containment engineering design for onshore and offshore tanks. Full containment means that the LNG storage tanks are double-walled, which is basically a tank inside a tank (CEE, 2006).

The outer tank is made of pre-stressed concrete. The inner tank is specially designed to hold the cryogenic liquid and will consist of high-alloy steels with nine percent nickel. The space between the tank shells is filled with insulation material. Full containment tanks are designed so that if the inner tank fails, the outer tank is capable of safely containing the existing amount of LNG.

As discussed earlier, LNG carriers also use a double-hull design for enhanced safety. LNG tanks are constructed of either stainless steel or aluminium. They

are heavily insulated to protect the steel hull from cold and to maintain the LNG cargo at its low temperature. The area between the inner hull and the LNG tanks is filled with a nitrogen gas blanket that is permanently monitored for gas leakage through gas detectors.

LNG facilities also include high-tech gas detection systems to rapidly identify even the slightest break in containment, as well as shut-off valves to immediately prevent leaks and spills in the improbable case of tank failure. Safety of LNG import/ export terminals is ensured through an adequate mix of industry standard procedures, regulations and advanced technology. Such safety measures are incorporated from inception of the terminal project at the design stage and during construction and commissioning. Other operating standards are applied during the operation stage of the terminal to safeguard the onshore terminal facilities and employees as well as the tankers alongside and the surrounding environment.

There are non-port specific regulations and standards, most of them marine standards regulating ships, ships' safe manning, safe navigation and safe carriage of goods by sea. Most of the aforementioned international standards deal also with ships while at transit at ports. All aforementioned regulations mention indirectly the port, berths and their navigable waters in connection with the navigation and safety of ships.

Since LNG ports and marine terminals are located in territorial waters, they are not subject to international conventions in the same way as the case of vessels. Generally LNG port facilities are regulated by country specific national laws and

regulations pertaining to the transportation and handling of hydrocarbon and Hazmat products (Griffin, 2012).

In this respect, each country has got its own standards for the design and construction of LNG marine terminal facilities. Also, LNG industry organisations such as SIGTTO, OCIMF and the International Group of LNG Importers (GIIGN) have been active in setting up standards and industry best practice related to LNG terminal safety, design, construction and operation. A sample of such standards and industry best practices includes:

***Oil Companies International Marine Forum (OCIMF):*** Safety Guide for Terminals Handling Ships Carrying Liquefied Gases in Bulk

***International Chamber of Shipping (ICS):*** Ship/Shore Check List and Guidelines London, 1982.

***Society of International Gas Tanker and Terminal Operators (SIGTTO)***

- A Guide to Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk, SIGTTO. 2d edition 2001.
- A Guide to Contingency Planning for the Gas Carrier alongside and Within Port Limits, SIGTTO. 3<sup>rd</sup> edition, 1999
- A Contingency Planning and Crew Response Guide for Gas Carriers Damage at Sea and in Port Approaches.
- Liquefied Gas Handling Principles on Ships and in Terminals 3rd Ed. 1999

***World Bank Group:*** Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals, 2007

***World Bank Group:*** Environmental, Health and Safety Guidelines for LNG Facilities, 2007



It is also important to note that due to lack of international harmonized standards, the International Standard Organisation (ISO) formed an international working group in 2006 called **TC 67 Work Group 10: 'Standardisation for Installations and Equipment for LNG, Excluding product or Testing'**. The group's objective and scope of work include compatibility and harmonisation of LNG codes, adopted by individual countries, to bring them to an international standard level. This shall allow a significant reduction of the large number of various companies, industry, national, and regional standards in use today with significant cost savings to the industry (GIIGNL, 2009).

Standards development bodies (SDBs) such as API have offered to ISO/TC 67 a number of Specifications, Standards and Recommended Practices as basis for new international standards. Individual work group experts have contributed with specifications, technical reports etc. The new international standards are therefore based on a wide range of relevant documents.

SDBs seek to influence the new international standards so they are suitable for use locally and in businesses around the world. The standards are built by the consensus process which is vital for the success of any international standard. At the end of the process, the standards are voted to become ISO standards according to the rules of ISO. This process will yield international standards which are further developed than its base documents (Griffin, 2012).

Only one set of international materials and equipment standards are required for the oil and gas industry. Regional standards may continue to be in effect due to regulatory issues. Naturally each standard could include various performance

and quality levels, regional variations etc. to meet the wide ranging needs of the industry. National standard organisations may import the international standards into their own national documents to make these international standards available on a national basis.

The key to success of this worldwide oil and gas standardisation effort is one set of good and usable international standards, that have been developed through consensus building, and which meet the worldwide needs of the industry.

Another working group has been formed under the ISO Technical Committee 67 working Group 11 (ISO TC 67 WG 11). ISO Technical Committee (TC) 67 covers materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries, while Working Group (WG) 11 focuses on the coating and lining of structures and equipment. Qatar is the chair and hosts the secretariat of ISO TC 67 WG 11. The first meeting of WG11 was held recently in Doha under Qatar Petroleum's HSE Regulations and Enforcement Directorate. The first project of the working group is the development of a new standard on 'Coating and Lining of Internal Surfaces of Above-Ground Storage Tanks'. This international standard will establish the international requirements for corrosion mitigation of internal surfaces of the steel storage tanks used in the petroleum industry. The meeting was attended by coating experts from member countries of the International Organisation for Standardisation (Wetherby Seamanship, 2011).

#### 4.3.2 REGIONAL AND NATIONAL SAFETY REGULATIONS

- **European standards**

In Europe, project applicant for import terminal is required to conduct a safety RA according to the European standard for Quantitative RA (QRA), and submit the results of these QRA studies to the permitting agency for review and approval. The most important European legislation in this regards is the European directive 96/82/EC (SEVESO II) which aims at preventing major accidents involving dangerous substances, including LNG, and the limitation of their consequences. The provisions of this directive were developed on the basis of a fundamental review of the directive 82/501/EEC (SEVESO I). One of the main areas revised is the management policies and systems which were found to be responsible for 85% of the accidents reported. SEVESO II sets basic principles and requirements for policies and management systems enhancing the prevention, control and mitigation of major accidents (GIIGNL, 2009).

- EN 1473 - The European Norm standard EN 1473 *Installation and equipment for LNG - Design of onshore installations* evolved out of the British Standard, BS 77743 in 1996. It is a standard for the design of onshore LNG terminals. This standard is not prescriptive but promotes a risk-based approach for the design of onshore LNG facilities. A risk-based approach starts with the assessment of the likelihood of risk occurrence or failure and how such risk probability can be best reduced by mitigating factors; consequences are then measured relative to the level of mitigated risk (CEE, 2012).

- EN 1160 – *Installation and equipment for LNG – General Characteristics of LNG* contains guidance on properties of materials commonly found in LNG facility that may come into contact with LNG.
  - EEMUA 14744 - *Recommendations for the design and construction of refrigerated liquefied gas storage tanks*. This contains basic recommendations for the design and construction of single, double and full containment tanks for the bulk storage of refrigerated liquefied gases covering the use of both metal and concrete materials (CEE, 2006).
  - EN 13565 - *Fixed firefighting systems – foam systems*
  - Part 1: Requirements and test methods for components
  - Part 2: Design, construction and maintenance.
- **U.K HSE regulations**

According to Griffin ( 2012), no specific government permit is required to construct and operate LNG facilities in the UK. However, owners and operators of such facilities shall comply with relevant planning and HSE regulations. The primary responsibility for safety lies with the operator of the LNG terminal, who has to ensure that the terminal is designed and constructed, then operated safely (UK-HSE, 2013).

In this regards, planning permissions are required pursuant to the Planning Act 2008. The hazardous substances consent for the storage of LNG exceeding a threshold quantity of 15 tonnes must be acquired from the relevant local planning authority dealing with hazardous substances consents as per the Planning Regulations of 1992 (Garry, Weems, & King, 2012).

All companies wishing to construct and hold stocks of hazardous substances including LNG must apply to the Hazardous Substances Authority (HSA) which is usually the local planning authority. HSA has to consult eleven organisations, including HSE, about the advisability of locating a hazardous substance establishment in the location chosen by the investor. The HSE role is to assess the risks based on the plant particulars and features which have impact on the risk to people and which may need to become conditions of consent. HSE advises on health and safety under the Health and Safety at Work Act; while the scope of planning legislation is the responsibility of the hazardous substance authority (HSA) (UK-HSE, 2013).

Therefore, among other governmental organisations, HSE provides advice on health and safety related issues to the HAS and may advise that consent be granted subject to certain health and safety conditions. In most cases, HSE sets a consultation zone around the site so that for any future proposed development within that zone, HSE must be consulted to provide its technical opinion about the adequacy of locating particular developments in that zone. The planning permissions described above are separate from the hazardous substance consent. All of them relates to the land use planning process (pre-operation stage of the project) however, effective plant operations safety is achieved primarily through the Control of Major Accident Hazard Regulations 1999 (COMAH) (Garry, Weems, & King, 2012).

#### **a) Control of Major Accident Hazard Regulations 1999 (COMAH)**

COMAH are the principal legislation covering LNG establishments. Their aim is to prevent major accidents involving dangerous substances and to limit their

consequences to people and the environment. COMAH regulations cover the unloading equipment at the jetty, the site itself, and the LNG facilities behind the jetty up to the national gas transmission system, including the storage tanks, the re-gasification plant and the transmission pipeline. Dangerous substances on the ship are not covered by COMAH but are subject to the Dangerous Substances in Harbour Areas Regulations 1987. The COMAH regulations are enforced jointly in England and Wales by a Competent Authority (CA) comprising the Health & Safety Executive (HSE) and the Environment Agency (EA), while in Scotland; CA is composed of the HSE and the Scottish Environmental Protection Agency. In the case of LNG establishments HSE is the lead authority (UK-HSE, 2013).

Any LNG facilities developer is required to submit to CA a pre-construction safety report (PCSR) which should demonstrate and ensure that safety is considered fully at the design stage. The CA shall examine the PCSR to make sure sufficient and adequate safety precautions have been incorporated into the design which shall ensure the risk to be reduced to the ALARP level. Construction cannot proceed until CA has concluded its review. Regular inspections are made during construction to ensure compliance with the PCSR (Garry, Weems, & King, 2012).

The developer is then required to submit a pre-operations safety report (POSR) prior to the commissioning of LNG facilities. This report must prove that all safety measures are provided for to prevent major accidents and that risk from the operations of the plant is kept to the ALARP level. Operations cannot start until the POSR report is approved.

Prior to plant commissioning, the operator is also required, under the COMAH regulations, to submit an emergency plan related to incidents control minimising risk effects to persons and the environment (UK-HSE, 2013).

Since the Department of Transport (DoT) is the responsible party for the carriage of dangerous substances by sea, the Health and Safety Executive (HSE) is delegated to support DoT in ensuring enforcement and compliance with statutory maritime safety regulations. In this respect, the Marine Safety Code along with the Guide to Good Practice on Port Marine Operations, published by DoT, defines the duties of the port authorities and how they can best fulfil such duties. Compliance with such regulations at the port level is monitored by the Maritime Coast Guard (Garry, Weems, & King, 2012).

Regarding LNG operations such as carriage, loading, unloading and storage of LNG in harbour areas, these are controlled under the Dangerous Substances in Harbour Areas Regulations 1987. Such regulations confer to the HSE the responsibility for their enforcement according to the Health and Safety at Work Act; while statutory harbour authorities are still responsible for maritime navigation safety and the fitness and seaworthiness of vessels, including LNG tankers.

#### **b) The Pipeline Safety Regulations 1996**

Under the above regulations, pipeline operators are entitled to notify the HSE of any new pipeline planned to be constructed to connect to the national gas transmission grid. HSE shall assess and inspect the pipeline's design, construction and operations.

- **The U.S regulations**

The following are the main U.S standards regulating LNG facilities design, siting and operations, including LNG import/ export terminals:

- 49CFR Part 193 *LNG Facilities: Federal Safety Standards*- This section covers siting requirements, design, construction, equipment, operations, maintenance, personnel qualifications and training, fire protection, and security.
- 33CFR Part 127 *Waterfront Facilities Handling LNG and Liquefied Hazardous Gas* - This federal regulation governs import and export LNG facilities or other waterfront facilities handling LNG. Its jurisdiction runs from the unloading arms to the first valve outside the LNG tank which covers the LNG piers from the berth all the way to the LNG storage tanks at the tank farm.
- NFPA 59A *Standard for the Production, Storage, and Handling of LNG (LNG)* – This is an industry standard issued by the National Fire Protection Association (NFPA). NFPA 59A which covers general LNG facility considerations, process systems, stationary LNG storage containers, vaporization facilities, piping systems and components, instrumentation and electrical services, transfers of natural gas and refrigerants, fire protection, safety and security. It also mandates alternative requirements for vehicle fueling for industrial and commercial facilities using American Society of Mechanical Engineers (ASME) pressure vessel containers. This standard includes requirements for LNG facilities to withstand substantial earthquakes. The NFPA standard for level of design means that the LNG



facilities are strongly fortified for other events such as wind, flood, earthquakes and blasts. The latest update of NFPA 59A was published in 2001.

- NFPA 11 Standard for low, medium and high expansion foam.
- NFPA 17 Standard for dry chemical extinguishing systems.

Regulations applicable to LNG ships include:

- 33 CFR 160.101 *Ports and Waterways Safety: Control of Vessel and Facility Operations*. This U.S. federal government regulation describes the authority exercised by District Commanders and Captains of the Ports to ensure the safety of vessels and waterfront facilities, and the protection of the navigable waters and the resources therein. The controls described in this subpart are directed to specific situations and hazards.
- 33 CFR 165.20 *Regulated Navigation Areas and Limited Access Areas: Safety zones*. A safety zone is a water area, shore area, or water and shore area to which, for safety or environmental purposes, access is limited to authorized persons, vehicles, or vessels. It may be stationary and described by fixed limits, or described as a zone around a vessel in motion. It is commonly used for ships carrying flammable or toxic cargoes, fireworks barges, and long tows by tugs, or events like high speed races.
- 33 CFR 165.30 *Regulated Navigation Areas and Limited Access Area: Security Zones*. This section defines a security zone as an area of land, water, or land and water that is so designated by the Captain of the Port or District Commander for such time as is necessary to prevent damage or injury to any vessel or waterfront facility, to safeguard ports, harbors,

territories, or waters of the United States. It also determines the purpose of a security zone to safeguard vessels, harbors, ports, and waterfront facilities from destruction, loss, or injury from sabotage or other subversive acts, accidents, or other causes of a similar nature in the United States. Generally, it covers ships with flammable or toxic cargoes, cruise ships, naval ships, and nuclear power facilities and airports (CEE, 2006).

As can be noticed from the above, U.S. regulations generally cover the prevention and mitigation of events derived from both safety accidents and security acts of sabotage or terrorism in an integrated regulatory framework.

#### **4.4 SECURITY REGULATIONS**

##### **4.4.1 International Standards**

Since September 2001, the threat to the international transport systems has changed due to the widespread and impact of international terrorism. The international maritime community, represented by the IMO, has responded to such threat by developing the Ship and Port Facility Security Code (ISPS Code), along with the introduction of other amendments to the SOLAS convention. The IMO conference adopted the ISPS Code and the SOLAS amendments in December 2002 and they entered into force on July 1, 2004 (McNicholas, 2008). Chapter XI-2 of SOLAS 74 and the ISPS Code apply to ships and port facilities. The extension of SOLAS 74 to cover port facilities was agreed to be the speediest means of ensuring the necessary security measures entered into force and given effect quickly (IMO, 2003). It should be noted that the provisions related to port facilities under the SOLAS extension should relate only to the ship/port interface. The wider scope of the security of port areas was

agreed to be covered under another instrument which shall be enacted jointly by IMO and the International Labour Organisation (ILO). That's what was multilaterally endorsed in 2003 as the IMO/ILO code of practice (COP) on security in ports.

This COP is intended to be compatible with the provisions of SOLAS, the ISPS Code and resolutions adopted by the 2002 SOLAS Conference. The COP is not intended to replace the ISPS Code; it extends the consideration of port security beyond the area of the port facility into the whole port. Also, measures proposed within the COP will apply to the entire port, including port facilities, as defined in the ISPS Code; however, they should not replace the security measures in place within the port facility.

#### **a) The ISPS Code**

This code does not deal specifically with LNG terminals and tankers but has got a wider scope relating to all ports serving ships of 500 GRT and above, and to passenger and cargo vessels at ports engaged in international trade. As stated in IMO (2003), *'the objectives of this Code is to establish an international framework involving co-operation between Contracting Governments, Government agencies, local administrations and the shipping and port industries to:*

- *detect/ assess security threats and take preventive measures against security incidents affecting ships or port facilities used in international trade;*
- *to establish the respective roles and responsibilities of all these parties concerned at the national and international level, for ensuring maritime*

*security, to ensure the early and efficient collation and exchange of security related information;*

- *to provide a methodology for security assessments so as to have in place plans and procedures to react to changing security levels;*
- *and to ensure confidence that adequate and proportionate maritime security measures are in place' (IMO, 2003).*

It should be noted that the security threats addressed under the present code are not just terrorism related, but include also stowaways, piracy, drug and contraband smuggling, sabotage, hijacking, cargo tempering, hostage-taking, vandalism, the use of the vessel to carry perpetrators and their equipment, and the use of a vessel as weapon (McNicholas, 2008).

Under the ISPS Code, each vessel/ port facility must possess and carry on-board a ship security plan (SSP), approved by the relevant authority, specifying access control measures, security measures for cargo handling and ships' stores, surveillance and monitoring, security communication, incident procedures and training and drills requirements (Garry, Weems, & King, 2012).

Furthermore, each ship-owner company must appoint a ship security officer (SSO) responsible for the implementation, periodic review and updating of the SSP, as well as a company security officer who should be part of the company's shore side management. His role is to monitor and arrange for audits related to the implementation of the SSP.

The ISPS Code contains detailed security requirements for governments, port authorities and shipping companies under a mandatory section (Part A), together with a series of guidelines and recommendations on how to meet Part

A requirements and those of SOLAS Chapter XI-2 in a voluntary section (Part B). The code sets three maritime security (MARSEC) levels ranging from low/normal (1) to high (3) proportional to the nature and scope of the incident or perceived security threat.

### **b) Amendments to SOLAS**

IMO recognised the need for the 1974 SOLAS convention to be amended to provide for fast-track enactment and implementation median as well as technical and policy guidance for the ISPS code. The main amendments concerned changes in some existing regulations (regulation 19 of chapter V, regulations 3 and 5 of chapter XI-1) and the creation of a new chapter XI-2, titled '*Special Measures to Enhance Maritime Security*'. This chapter provides definitions related to maritime security and incorporate within the convention key policies and requirements of Part A of the ISPS Code (McNicholas, 2008).

### **c) The WCO Framework of Standards to Secure and Facilitates Global Trade**

The World Customs Organisation (WCO) framework of standards sets forth the principles and minimum standards to be adopted by customs agencies of the WCO member states in order to provide increased security to the global SC. Such initiative demonstrates the WCO belief that international trade is an essential driver of economic prosperity and that world customs agencies have a role to play in ensuring secured global trading system as an essential part of the global SC (McNicholas, 2008).

According to McNicholas (2008), the main objectives of the WCO framework are:

- *'Establish standards and provide SC security and facilitation at the global level to ascertain predictability and certainty;*
- *Enable integrated SC management for all modes of transport;*
- *Enhance the role, functions and capabilities of customs agencies to meet the challenges of the 21<sup>st</sup> century;*
- *Strengthen cooperation among customs and businesses and between custom administrations to improve capabilities to detect high risk consignments;*
- *Promote seamless movement of goods and secure international SC.'*

WCO Framework has two pillars; each one defines technical policy-related procedures and standards:

*'Pillar 1: Integrated SC management; cargo inspection authority; modern technology and inspection equipment; RM systems; high risk cargo or containers; advanced electronic information; targeting and communications; performance measures; security assessments; employee integrity; and outbound security inspections.*

*Pillar 2: Partnership; security; authorisation; technology; communications; and facilitation'* (McNicholas, 2008).

The WCO has been cooperating with the ISO organisation to establish standards to secure the global SC and provide step by step certification standard. The ISO has got many types of certifications and its cooperation work with WCO will go a long way towards progressively forcing SC security policies

and procedures through the whole cargo SC. The following section reviews and discusses some ISO SC security standards pertaining to the maritime SC.

**d) ISO Standards:**

- **ISO/PAS 28000 Security Management Systems for SCs**

ISO 28000 is a security management standard for SCs. It was first published in 2005 as a Publically Available Specification (PAS). This 2007 version, published on 15 September 2007, replaces the 2005 edition and has a main purpose to help improve the security of SCs by helping organisations to protect people, products and property. ISO 28000 applies to all organisations as parts of SCs regardless of their size. It applies to airports, seaports, and terminals as well as to organisations that move products by air, sea, rail, or road. This standard concerns logistics, storage, transportation, and service companies as well as manufacturers, shippers, wholesalers, and distributors (Praxiom, 2012).

ISO 28000 defines a set of security requirements and expects SC organisations to establish a security management system (SMS) that complies with these requirements. Such SMS is used to protect people, products, and property. By helping to establish and maintain a SMS, ISO 28000 will help to improve the organisations' overall security of SC and inspire the trust of its customers.

According to Praxiom (2012), *'Not only can ISO 28000 help you to preserve the integrity of your shipments and safeguard your customers' valuable property, it can also help you to protect personnel. When properly*

*implemented, an ISO 28000 SMS will not only decrease disruptions and shorten transit times; it can also help you to reduce theft and combat smuggling, piracy, and terrorism.'*

Since it is a generic security management standard, ISO 28000 helps organisations comply with national, regional and international security programs such as SOLAS requirements, the ISPS Code and the WCO frameworks.

- **ISO PAS 20858** provides recommendations regarding ISPS implementation on port facilities.
- **ISO 31000** is the latest ISO standard providing principles and generic guidelines on RM and released in October 2009.

#### **4.4.2 Regional and National Regulations**

##### **The EU security regulations**

Prior to the IMO security framework being adopted, the majority of security actions and response measures put in place throughout the European Union were as a result of individual actions by EU Member States. These include measures to protect against terrorism in the maritime sector which vary significantly across the EU. Following adoption of the new IMO security regime, the EU Member States agreed the need for measures at Community level to achieve the community's harmonised action. The adoption of Regulation (EC) No 725/2004 by the European Parliament and the Council on 31 March 2004 was an important step towards this goal.



The followings are the main EU regulations related to maritime and port security:

**Regulation (EC) No725/2004** on enhancing ship and port facility security. The main objective of this Regulation is to implement Community measures for enhancing the security of ships through preventive measures to combat the threats of intentional unlawful acts, including terrorism, piracy and armed robbery at sea. The Regulation provides a basis for the harmonised interpretation and implementation and community monitoring of the IMO regulations which amended the 1974 SOLAS Convention and established the ISPS Code. The Regulation went further than the IMO regime (ISPS Code) by making compulsory a number of recommendations introduced into Part B of the ISPS Code (Butcher, 2011-p.8).

**Directive 2005/65/E:** This Directive complements the security measures introduced by Regulation (EC) No 725/2004 by making an entire port subject to a security regime. In order to obtain maximum protection for maritime and port activities, measures should be taken that cover all ports within a perimeter defined by the Member State in question, thereby ensuring that security measures taken in accordance with the Regulation benefit from enhanced security within the areas of port activity. These measures should apply to all ports in which one or more port facilities covered under the Regulation are situated. The Directive also provides mechanisms for implementing these measures and checking their conformity. The Member States should have transposed this Directive by 15 June 2007 (Hellenic Shipping News, 2012).

The Directive adopted the same security levels stipulated by the ISPS Code, as per the perceived risk, namely:

- **Security level 1:** minimum protective security measures must be maintained at all times;
- **Security level 2:** appropriate additional protective security measures must be maintained for a period of time as a result of heightened risk of security incident; and
- **Security level 3:** further specific protective security measures must be maintained for a limited period of time when a security incident is probable, although it may not be possible to identify the specific target (Butcher, 2011-p.10).

**European Commission Regulation (EC) No 324/2008 on procedures for conducting Commission inspections in the field of maritime security**

In order to monitor the application by Member States of EU legislation on maritime security, the Commission conducts inspections to verify the effectiveness of national quality control systems and maritime security measures, procedures and structures at each level of each Member State and of individual port facilities and relevant companies. The European Maritime Safety Agency (EMSA) participates in these inspections led by the Commission's services and provides the Commission with technical assistance in the performance of the inspection tasks in respect of ships, relevant companies and recognised security organisations. In accordance with Directive on port security, the Commission should monitor the implementation by Member States of the Directive jointly with the inspections provided for ships and port

facilities. The regulation adopted on 9 April 2008 lays down procedures for the monitoring by the Commission of the implementation of Directive 2005/65/EC jointly with the inspections at the level of Member States and port facilities (Hellenic Shipping News, 2012).

### **Maritime Security Committee (MARSEC)**

The MARSEC is a regulatory committee established by virtue of Article 11 of Regulation (EC) No 725/2004. It assists the Commission with regard to its activities under Directive 2005/65/EC. The Regulatory Committee is chaired by the Commission and consists of experts representing all Member States. Periodical exchange of information between Member States and Norway and Iceland has taken place, as well as best practices and indications on national instructions. Most importantly, it was recently agreed to create a mechanism for securing mutual information where each Member State could insert sensitive information i.e. security levels adopted, threat evaluations and others topics relevant to the security of European shipping (Europa, 2013).

### **The UK security regulations**

According to Garry, Weems and King (2012), the transportation of dangerous goods in UK, including LNG, is the responsibility of the UK Department of Transport (DoT). For the case of sea transportation of dangerous goods, DoT has delegated such responsibility to the Maritime Coastguard Agency. The Coastguard's power is derived from the Coastguard Act of 1925, the Merchant Shipping Act of 1995, and the Merchant Shipping and Maritime security Act of 1997.

Following the promulgation of the ISPS Code at the European level, the maritime security regulation EC 725/2004 was adopted to enhance ship and port facility security and provide effect to the implementation of the ISPS code in EU member states. This regulation comes into force on May 19, 2004. (Garry, Weems, & King, 2012).

Although the ISPS Code was legally put into effect in the UK the same date, amendment to the relevant UK legislation was required to make some provisions of the ISPS code fully effective. This was done through the ship and port facility security regulations 2004. These regulations designated the UK maritime competent authority for maritime and port security and the maritime security focal point for the IMO regime; established a monitoring regime for compliance with security regulations and the IMO security requirements; imposed criminal sanctions for unlawful presence in a security restricted area of a ship or port facility; and introduced requirements for ship detention and revocation notices following any failure to comply with security regulations (Garry, Weems, & King, 2012).

The Department for Transport's Transport Security Directorate (Transec) has the authority to oversee and ensure compliance with the ISPS Code requirements by UK port facilities and UK flagged ships by the deadline of the 1 July 2004. Transec has set a policy framework through which Transec is responsible for UK ports and passenger shipping, and the Maritime and Coastguard Agency (MCA) has been delegated responsibility for non-passenger shipping (Butcher, 2011).

### **The U.S. security regulations**

According to CRS (2009), the Department of Transportation (DOT) and the Federal Energy Regulatory Commission (FERC) are the U.S. federal agencies primarily responsible for the regulation of onshore LNG facilities.

Also, several federal agencies oversee LNG infrastructure security. Under the Maritime Transportation Security Act of 2002, the Coast Guard has lead responsibility for LNG shipping and marine terminal security and the security and accountability for Every Port Act of 2006. On October 13, 2006, the Security and Accountability for Every Port Act of 2006 (P.L. 109-347) was enacted. While not addressing LNG security specifically, the act includes general maritime security provisions which could apply to LNG vessels and facilities.

The DOT's Office of Pipeline Safety (OPS) and the Transportation Security Administration (TSA) of the Department of Homeland security both have security authority for LNG storage plants within gas utilities. The Coast Guard, OPS and FERC cooperate in the siting approval of new LNG facilities, inspection and operational review of existing facilities, informal communication, and dispute resolution (CRS, 2009).

CEE, (2006) identified the following legal safety standards governing LNG terminal design and operation, as well as marine fleet construction and operation in the U.S.:

- a) 49 CFR Part 193- Federal Safety Standard which set requirements covering all LNG facilities from design to construction, equipment, operations, maintenance, personnel qualifications and training, fire protection and security. As it stands, this standard is comprehensive and regulates both fire

safety and security of LNG facilities from design all the way to construction and operation.

- b) 33CFR Part 127 - Waterfront Facilities handling LNG and Liquefied Hazardous Gas. This federal regulation covers all marine terminal import/export facilities from loading and /unloading arms to the valve outside the LNG tank.
- c) NFPA 59A - Standard for the production, storage and handling of LNG. This is a National Fire Protection Agency standard which covers the whole processes of general LNG facilities from production to liquefaction, storage, piping, instrumentation and electrical services, transfer of natural gas, fire protection, safety and security.
- d) NFPA 57 Standard for LNG vehicular Fuel Systems- Although this standard regulates mostly vehicle fuel system, its scope covers storage facilities of 70.000 gallons of LNG and less.

As asserted by Garry, Weems, & King, (2012), LNG ships are now subject to stringent security measures applicable under the Magnuson Act and the Ports and Waterways Safety Act. These measures include the following:

- Special traffic control measures for the LNG vessels while in transit or approaching a US port.
- Enforcement of security zones around the vessel to prevent other vessels from approach it;
- Escort by US Coast Guard patrol craft; and

- Coordination with other federal and state law enforcement and /or emergency management agencies to reduce the risks to other port areas or infrastructure.

After the 9/11 terrorist attacks, additional security measures were implemented, including the 96 hours advance notice of arrival for all ships calling U.S. ports, which was previously limited to 24 hours only. The U.S. Coast Guard shall conduct at sea boarding to ensure the vessel is under control while in transit at the U.S. port.

Furthermore, the Maritime Transportation Security Act 2002 aligns the U.S security legislation with the ISPS Code. This act applies to vessels, marine facilities and maritime personnel and extends the U.S. Coast Guard jurisdiction to 12 nautical miles from shore (Garry, Weems, & King, 2012).

#### **4.5 CONCLUSION**

From the above, LNG ports and maritime SC seems to be well regulated, either in the area of HSE or in security. LNG safety legislation is not new and has contributed in maintaining the extraordinary safety record of the LNG industry while legislation related to security is pretty much recent and still in the period of evaluation. Meanwhile, the international maritime and port community has achieved an important step forward in achieving safer and secured international SCs by establishing and implementing the ISPS Code and similar international standards.

However, the RM approach and the way maritime and port regulation is implemented may have a critical impact on the overall efficiency of safety and

security RM. Intra and inter port cooperation and information sharing among safety and security managements should be further developed to ensure effective integration in the implementation of safety and security legislation. The efficiency of this arsenal of regulations depends, to a large extent, on the way it is approached and implemented. Recent development in RM has privileged holistic and integrated approach (i.e. All-hazard approach in the U.S.). Such an approach will be discussed further in the next chapter.



## **CHAPTER 5**

### **RISK MANAGEMENT METHODS AND APPROACHES**

#### **5.1 INTRODUCTION**

This chapter discusses the RA and management methodologies and approaches related to safety and security risks in LNG Ports SCs. It intends first to present and analyse these approaches and methods; and secondly to investigate ways in which RM for both safety and security could be improved through integration of their assessment and management as well as disaster preparedness coordination and response from the stand point of a holistic approach.

Generally, risk can be assessed and managed in three ways: through (1) prevention, (2) mitigation or (3) through both prevention and mitigation.

Prevention seeks to avoid an accident or an attack; mitigation aims to reduce the consequences and effects of an accident or attack. Combination of the two types of strategies can improve both safety and security involving LNG Ports SCs and can enhance the protection system from a surety perspective.

First, existing safety approaches are discussed followed by an overview and discussion of internationally recognised security methods.

#### **5.2 CONVENTIONAL RISK ASSESSMENT IN SHIPPING AND PORTS**

The conventional approach to risk defines it as being the chance of occurrence of an accident or unwanted event. It combines a probabilistic measure of occurrence of an event with the consequence of such event in quantifiable

terms. Generally, the process of RA follows three main set of sequenced and inter-related activities:

- ❖ The assessment of what can go wrong, its probability of occurrence and the possible consequences/ impact should that event occur.
- ❖ The management of risk in terms of available measures/ RCOs and their trade-offs in terms of cost and benefits (Cost efficiency/effectiveness).
- ❖ The impact of RM decisions and strategies on future options and undertakings.

The system safety approach regards accidents as hazardous events for which causes and consequences are well known and which frequency is influenced by certain factors.

The total consequences of an event form the size of the accident, whereas the frequency of such event may range from high frequency low impact events to low frequency high consequence events. Events that tend to be repetitive and routine in nature are mostly low impact (car accidents, machine failure...etc.). However, low frequency events, such as natural disasters and terrorist attacks, tend to be more complex with long lasting and severe consequences.

In terms of risk analysis, several hazard analysis tools have been developed. Two main categories of tools can be distinguished depending on whether the causes or consequences of events are analysed and whether the sequence of causes or consequences is considered:

**Table 5.1 Major hazard analysis tools**

|                             | <b>Consequence Analysis</b>     | <b>Cause analysis</b>      |
|-----------------------------|---------------------------------|----------------------------|
| <b>Sequence dependent</b>   | <i>Event tree Analysis</i>      | <i>Markov Process</i>      |
| <b>Sequence independent</b> | <i>Failure mode and effects</i> | <i>Fault tree Analysis</i> |

**Source:** (Bichou, 2008, p: 5)

Generally, most RA methods and approaches are either cause related or consequence based methods. This does not mean that once methods focus on one variable of the equation, the other variable is completely neglected from the analysis. It is analysed according to the likelihood of occurrence of events (Bichou, 2008).

### **5.3 SAFETY RISK ASSESSMENT APPROACHES**

Different regions apply distinctively different safety regimes for avoidance of unintentional events, with the greatest divide being between consequence-based management and risk-based management.

*A consequence-based approach* for accidents as per NFPA 59A is applied in the U.S. and is common in Asia. The NFPA approach has the benefit of requiring less analysis than the risk-based approach, and may be easier to communicate to the public. By focusing on worst-case consequence scenarios for accidents while disregarding the probability of occurrence, however, this approach limits the ability to assess the effectiveness of project-specific measures aimed at reducing the likelihood of events. Meanwhile, by focusing on

worst –case scenario, proposed RCOs may be less cost effective since, generally, mitigation measures for worst-case scenario is costly to implement.

A risk-based approach begins with assessing the probability that the subject risk, or failure, will occur and how such probability can be best reduced by mitigating factors; consequences are not ignored, but are measured relative to the level of mitigated risk. Such an approach is embodied in EN1473, which is widely applied in the EU for safety. The processes differ slightly from country to country, but they all apply a risk-based approach. Russia has begun developing LNG legislation that will be risk-based as well. Qatar Gas used RAs to document that Q-flex-size carriers can dock at the terminal without increasing the risk to public. In fact, the risk may be reduced when comparing equal import levels.

Canada has a risk-based approach defined in her legislation, but it lacks formal acceptance criteria, and Canadians also look towards NFPA for plant layout. The risk-based approach requires competence and tools for performing state-of-the-art risk analysis. African countries generally lack defined legislation for LNG. Instead, the engineering contractor typically uses whichever international approach it has the most experience in applying.

Beyond the risk-based and consequence management approaches, safety RA techniques are numerous and it is not always possible to clearly differentiate among them. They can be organized into two parts: comprehensive RA approaches and partial RA techniques.

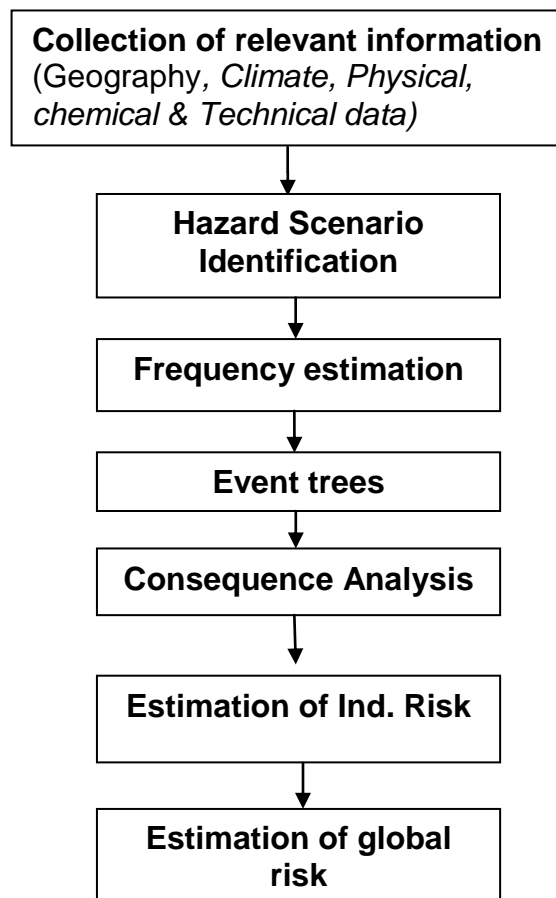
### 5.3.1 Comprehensive risk assessment approaches

These are methods accounting for hazard identification, frequency and probability of hazardous events and the consequence of accident scenarios. This means that these methods deal with risk in its entirety, defined as *the arithmetic product of probability and consequence of accidents*. Four (4) techniques are identified as part of this category: QRA, FSA, the Goal Based Standard (GBS) and the USCG Risk Based Decision Making Guidelines (Ronza 2007).

#### ➤ **QUANTITATIVE RISK ASSESSMENT (QRA)**

QRA aims at estimating the risk entailed by a system, in terms of human loss or, on some occasions, economic loss. QRA results are presented in two forms, (1)  $f$ - $N$  curves which represent the frequency ( $f$ ) and the number of victims ( $N$ ) caused by a number of determined accident scenarios. The acceptable risk level is also represented by a straight decreasing line. (2) Risk contours or iso-risk curves representing individual risk around the installation is analysed. Nowadays, there are a number of computer programs available which help performing QRAs.

**Figure 5.1 QRA Steps**



*Adapted from Ronza (2007, p.73)*

➤ **FORMAL SAFETY ASSESSMENT (FSA)**

FSA is a proactive safety approach adopted by IMO to ensure that actions are taken before a disaster occurs. It is a systematic process for assessing the risks associated with shipping activities and for evaluating the costs and benefits of IMO's options for reducing these risks. Furthermore, FSA is now used as a tool to assist in IMO decision-making process regarding the evaluation of new standards or for updating old ones (Ronza 2007).

FSA was first developed by the UK Marine Safety Agency in 1993 and proposed to IMO in 1996 to serve in the guidelines for safety assessment, with the aim to ensure oversight of safety and pollution prevention and facilitate the IMO decision making process regarding development of new regulations and standards (Trbojevic *et al*, 2000).

**Table 5.2 FSA main steps and activities**

| <b>FSA Steps</b>             | <b>Activities</b>                                                      |
|------------------------------|------------------------------------------------------------------------|
| <b>Risk identification</b>   | Brainstorming of all possible risks and risk factors                   |
| <b>RA</b>                    | Identification of credible threats, their likelihood and their ranking |
| <b>RM</b>                    | Identification of safeguard options                                    |
| <b>Cost-Benefit analysis</b> | Evaluation of safeguard options                                        |
| <b>Decision-making</b>       | Decision on the final risk mitigation strategy                         |

**Source:** (Ronza 2007)

Three analytical tools are used along with the FSA process:

- Brainstorming technique for risk identification (To identify all possible and plausible threats)
- The Cost-Benefit and Cost-efficiency (CBA, CEA) techniques for the evaluation of the cost effectiveness of safeguard options and risk mitigation strategies.
- The Delphi method for requesting and treating expert opinions, as an aid in the decision making.

The method has been considered as probably the most systematic and comprehensive framework for RM in the maritime safety and environmental

protection. It represents a significant evolution in the way IMO has been dealing with maritime safety.

The reason behind this methodological shift is the noticeable historical fact that while safety standards and techniques were improved and implemented, more and more accidents continue to occur. An analysis of the causes of failure for maritime accidents revealed that the origin of accidents lies not in the technical and human control systems but in the safety management practices (Trbojevic *et al*, 2000).

➤ **THE GOAL BASED STANDARD (GBS)**

Kontovas, *et al*. (2007-1) defined IMO's GBS as:

- “1. *Broad over-arching safety, environmental and/or security standards that ships are required to meet during their lifecycle;*
2. *the required level to be achieved by the requirements applied by class societies and other recognized organizations, Administrations and IMO;*
3. *clear, demonstrable, verifiable, long standing, implementable and achievable, irrespective of ship design and technology; and*
4. *specific enough in order not to be open to differing interpretations.”*

Following a proposal from Greece, Bahamas and IACS, the IMO's MSC78 adopted a five-tier system for the GBS. The first three (3) tiers constitute the goal-based standard to be developed by IMO, whereas tiers IV and V are detailed provisions and rules to be developed by classification societies and other industry organizations.



It is apparent from the above GBS system that IMO wants to play a larger role in the determination of standards to which the ships are built, which was traditionally the responsibility of class societies and shipyards.

**Table 5.3 GBS tier system**

| Tiers                                                                                                                                                                                          | Meaning                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Tier I:</b> <i>Goals</i>                                                                                                                                                                    | <i>A set of goals to be met in order to build and operate safe and environmentally friendly ships</i>                                                                                                                                                                                                 |
| <b>Tier II:</b> <i>Functional requirements</i>                                                                                                                                                 | <i>A set of requirements relevant to the functions of the ship structures to be complied with in order to meet the above-mentioned goals</i>                                                                                                                                                          |
| <b>Tier III:</b> <i>Verification of Compliance Criteria</i>                                                                                                                                    | <i>Provides the instruments necessary for demonstrating that the detailed requirements in Tier IV (Rules) comply with the Tier I and Tier II</i>                                                                                                                                                      |
| <b>Tier IV:</b> <i>The detailed rules which apply the functional requirements to satisfy the goals</i>                                                                                         | <i>The detailed mandatory requirements developed by IMO, National Administrations and/or classification societies and applied by National Administrations and or/ Class societies acting as recognised organisations to the design and construction of a ship in order to meet Tier I and Tier II</i> |
| <b>Tier V:</b> <i>Industry standards, guidelines, recommendations, codes of practice and safety and quality systems for shipbuilding, ship operation, maintenance, training, manning, etc.</i> | <i>Industry standards and shipbuilding design and building practices that are applied during the design and construction of a ship.</i>                                                                                                                                                               |

**Adapted from Kontovas, et al. (2007-1, p.4)**

IMO has developed the basic principles of the GBS to be applicable beyond the goal-based design and construction of ships to encompass goal based standards for other areas. Also, the high importance of GBS is further demonstrated through its recent inclusion in the IMO strategic plan.

Kontovas, *et al.* (2007-1) critically reviewed FSA and recent GBS approaches, in light of the recent on-going discussions at IMO to link the two approaches. They further cautioned against attempts from some rule makers and designers to cut corners and adopt risk based formulations borrowed from other industries, which may not be adequate for ships. The FSA approach needs to be improved prior to any attempt to use it as part of the GBS in modern maritime rule-making and design. The authors identified the following issues:

- Risk tolerance level for maritime transport is still lacking, and more effort is needed to define risk acceptance criteria for maritime transport. The recommended RCOs should be both effective in reducing the risk to the “desired level” and cost effective. IMO guidelines provide no official risk acceptance criteria and decisions are actually based on those published by the UK HSE (HSE, 1999).

**Table 5.4 HSE criteria for individual risk**

|                                                 |                                 |
|-------------------------------------------------|---------------------------------|
| <b>Maximum tolerable risk for crew members</b>  | <b>10<sup>-3</sup> annually</b> |
| <b>Maximum tolerable risk for passengers</b>    | <b>10<sup>-4</sup> annually</b> |
| <b>Maximum tolerable risk for public ashore</b> | <b>10<sup>-4</sup> annually</b> |
| <b>Negligible risk</b>                          | <b>10<sup>-6</sup> annually</b> |

**Source:** (HSE, 1999)

Risks below the tolerable level but above the negligible risk should be made As Low As Reasonably Possible (ALARP) by adopting a cost-effective RCOs. In

recent amendments to FSA guidelines (Annex 1 of document MSC 81/WP.8), it is made clear that the above numbers are only indicative. Therefore, the crucial issue of what are acceptable risk criteria for maritime transport is still not defined.

Moreover, the authors noted that the expression of these risk limits should be on a per trip basis (or per voyage as compared to 'per flight' basis accounted for in air transport) and not on an annual basis, since the later does not account for the number of trips per year undertaken by a person, which would influence the risk exposure of a passenger vis-à-vis the risk level of a crew member. In fact, the crew takes the risk of their job willingly, so it is assumed that they are willing to tolerate risk more than others.

Furthermore, risks formulated this way do not seem to compare adequately to air transport, in which the most recently estimated probability of being involved in a fatal air crash is  $10^{-8}$  per flight (Barnett 2006). This ironically means that a maritime transport passenger incurs annually 100 times more risk than the airline passenger who takes an average of 8 flights per year.

- HAZID Deficiencies:

Risk matrices translate the risk as the product of two variables (probability and consequence) into a single number. Doing so may lead to misleading results since much of the relevant information provided by the two dimensions of risk may be lost. Examples of risk matrices demonstrated that some frequent low consequence events are ranked on top of and prioritized over extremely rare but rather catastrophic events. This particular case may lead to problems in risk

prioritisation and may result into wrong conclusions. Therefore, there is a need to define an appropriate risk matrix for each FSA.

- Environmental Criteria Deficiencies:

Kontovas *et al.* (2007-1) noted that in all FSA studies, cost effectiveness is limited to covering only fatalities and injuries from maritime accidents. So far, no FSA study has tried to assess environmental risk. Furthermore, the initial FSA risk matrix does not provide for environmental risks within its severity risk index component.

- Deficiencies in CBA:

Kontovas *et al.* (2007-2) explained also how step 4 in FSA, which is CBA, is rather vulnerable because *“it involves numerous assumptions on a great number of variables, and as a result runs the risk of wrong conclusions”*

The recent formation by IMO of an MEPC correspondence group to review FSA steps is seen as an interesting action responding to Kontovas *et al.* (2007-1, 2) concerns regarding the above FSA vulnerabilities.

➤ ***The USCG RISK BASED DECISION MAKING (RBDM) GUIDELINES***

The U.S. Coast Guard has developed several RA and management tools dealing with maritime accidents in general, with some focus on port accidents. Some of these tools and methodologies allow for HazMat transportation, including LNG.

All USCG's work in this field is compiled in a comprehensive RM handbook forming the *Risk-based Decision-making (RBDM) Guidelines*. These guidelines are made up of 3 volumes:

- *Vol.1* (Risk-Based Decision-making Navigator) is an introduction to the next two volumes and presents methodologies followed.
- *Vol.2* (Introduction to Risk-based Decision Making) describes the principles of RBDM and risk evaluation, management and communication.
- *Vol.3* (Procedures for Assessing Risks) describes the following RA tools: *a)* Pareto Analysis; *b)* Checklists; *c)* Risk Ranking and Risk Indexing; *d)* Preliminary Risk Analysis; *e)* Change Analysis; *f)* What-if Analysis; *g)* FMEA; *h)* HazOp; *i)* Fault trees (FTA); *j)* Event trees (ETA); *k)* Event and causal factor charting; *l)* Preliminary Hazard Analysis (PrHA).

According to the USCG, the RBDM guidelines is a set of systematic methods which equip the marine safety offices (MSOs) with a complete, reliable and easy-to-use toolbox on which he can rely to carry out RA and evaluation. The notion of risk to which the guidelines refer is relatively wide and involves not only hazardous cargo, but also unexpected events causing harm to people, installations and the environment. Therefore, the USCG RBDM guidelines approach can be defined as more generic and able to assess risks beyond the safety systems.

The comprehensive approaches presented above tend to consider both probabilities/frequencies as well as consequences of risks and hazards. As such, most of them address simultaneously prevention as well as mitigation of risk in a relatively systematic way.

### 5.3.2 Partial risk assessment techniques

These are methods which focus only on one element of risk, either probability/frequency or severity of consequences according to the standard definition of risk as the product of probability of event times severity of consequences should that event occur.

#### ➤ *Historical analysis, databases and statistics*

Historical analysis is often used as a means to estimate frequency and /or the probability of accidents, and thus to design events or fault trees. Referring to past accidents is always an interesting way of forecasting possible undesired events in the future. It is mainly a qualitative exercise which allows drawing quantitative conclusions if sufficient records of accidents are available. Many aspects of accidents and their trends can be inferred from the data set: cause of accidents; substances involved; amount of HazMat spilled; accident type (Fire, explosion, gas cloud, and dust explosion....etc.); consequences of the accident (casualties, injuries, economic loss, environmental damage...etc.).

Moreover, past accidents represent “experimental data” which is, in fact, achieved at high cost but allow for lessons to be learned for the future. This is true in fields where experimental activities are practically impossible or can be performed at prohibitive cost. They are an important means of validating physical models for thermal radiation, blast propagation and gas dispersion. That is why nowadays, there are several institutions which maintain records of past accidents (databases): HSE in the UK, Chemical Safety and Hazard Investigation Board (CSB) and the National Transportation Safety Board (NTSB) are examples of such institutions. Some of these databases take also

records of incidents and near-misses because they provide as valuable information and lessons as those deriving from accidents.

➤ ***Frequencies, probabilities and event trees.***

In the area of quantitative RA, it is often necessary to assign a probability that certain events may happen instead of others. For example: the probability of a gas cloud being ignited or the probability of an LNG tanker running aground in the waterway. The frequency of a certain event happening over time, for example: the frequency of a tank failure. Frequency is expressed in terms of event/duration-time units. Alternatively, frequency can be expressed on a per operation basis, especially if the failure is expected to occur only when the device or machine is in operation. Example: a ship-ship collision in a port may be expected to occur, on average, once every ten thousand port calls. Probability and frequency data are used in QRA analysis. More often, probability and frequency calculations are made on the basis of expert opinion, but sometimes they are derived from historical analysis.

➤ ***Risk indices and ranking***

Risk indexing expresses the level of risk associated with a plant or an installation. It appeared first as a RA technique in the chemical industry. The first index to be used in the chemical industry was the Dow Chemical Company's Fire and Explosion Index, originally published in 1964 and its most recent update is the 1994 edition (Ronza 2007).

It can be argued that risk indexing is the same as QRA in a way that both approaches are intended to describe the level of risk. Whereas QRA expresses

risk in proper quantitative units (*Exp.* Expected casualties per year), a risk index provides only a generic ranking of risk based on expert judgment, which can be compared to actual figures calculated for a specific plant or system. In this case, a risk index is expressed in terms of verbal assessment (unacceptable, tolerable, negligible...etc.). The U.S. Coast Guard use risk indexing as a form of prioritisation to assist in prioritising and ranking risks in maritime and port safety. Risk indices are conceived based on expert judgment. An index is normally devised by a group of experts and follows a process of brainstorming, interviews, bibliography and on-site inspections.

Two main conclusions can be drawn from the above presentation of safety RA approaches:

- ❖ Both comprehensive and partial RA methodologies are exclusively used for the assessment of safety risks in the oil and gas as well as in the process industries, with the exception of the FSA and the US Coast Guard RBDM which are mainly used as systematic approaches for maritime safety, especially in the field of maritime navigation. The latter's scope includes both safety and security RA and management in the maritime and port networks.
- ❖ All above RA approaches share similar RA elements, processes and steps



## **5.4 SECURITY RISK ASSESSMENT METHODS**

### **5.4.1 The U.S. Department of Homeland Security's (DHS) RA methodology**

The DHS' scope of responsibilities is large, spanning over most, if not all, aspects of homeland security and supporting all government and private entities that contribute to homeland security. For some functions DHS is responsible for all risk analysis elements, while for others for which the responsibility is shared, effective coordination is required with owners and operators of private or public entities/ facilities as well as with state, territorial and local departments of homeland security and emergency management; as well as with other federal agencies. While DHS is responsible for mitigating a range of threats to homeland security, including terrorism, natural disasters, and pandemics, its risk analysis effort is weighted heavily towards terrorism (CRS, 2007).

Since it is widely accepted that every community faces a certain level of risk from terrorism, DHS officials acknowledge that it is impossible to protect and harden every target in US territories. Therefore, it is important to identify sites and critical infrastructure deemed to be at most risk and put efforts into their protection.

Following the 9/11 terrorist attacks, the US federal government created the Department of Homeland Security (DHS) as the specialised government arm to mitigate and protect the country against the threat of terrorism. It also created the State Homeland Security Grant Programme (SHGP) as assistance to states in their efforts to prepare for and respond to the threat of terrorism.

Since the beginning of the DHS security grant programme, a debate raised among states across America on the rationale for the grant monies allocation. At its inception, the allocation of security grants among states was made according to the size of population in the absence of sound risk assessment methods. This finds its origin in the fact that one of the main goals of terrorist attacks is to make the highest possible number of casualties among the civilian population.

However, this prioritisation method at the local, state and national levels was problematic to justify DHS security activities since it favours states of smaller population and low risk and disadvantages others such as the states of New York and California, with larger population and facing much higher terrorist risks.

Therefore, the rationale behind the distribution of the SHGP funding seemed counter intuitive. As a result, it was clear that a sound security RA methodology was required to enable rational and systematic identification and evaluation of homeland security risks as well as a transparent disbursement of SHGP funding among states.

#### **a) Evolution of the DHS risk assessment methodology**

DHS RA approach has evolved in line with the government approach to distributing DHS funding. *'The evolution of the grant programme and the risk methodologies it employs has occurred against the backdrop of the transformation of the nation's understanding of homeland security itself'* (CRS, 2007, p.3).

At its inception, DHS focus was solely on terrorism but with time and due to other catastrophic incidents, the DHS scope was enlarged to include a range of non-terrorism threats, such as natural disasters. Part of the DHS funds was also allocated to the mitigation of natural disasters.

Over the years, DHS faced numerous criticisms from various groups, including state and local leaders expressing their frustration with DHS's RA process and the related distribution of grant. The main source of frustration was on the perceived lack of transparency regarding the RA process, *“especially with regards to the source of information used and the weighting of the formula's variables and underlying data sub-elements”* (CRS, 2007, p.4).

In 2004, the National Commission of Terrorist Attacks upon the USA commonly called the 9/11 commission, recommended in its final report that homeland security assistance should be strictly based on assessment of risks and vulnerabilities. Furthermore, the commission questioned if useful criteria to measure risk and vulnerability be developed which can assess all variables and further suggested a number of factors that should be considered in the risks and vulnerabilities assessment, including population, population density, vulnerability and the presence of critical infrastructure within each state.

There have been at least three stages in the evolution of the DHS RA methodology:

**Table 5.5 DHS RA stages of development**

| Stages         | Period         | Risk assessment methodology                                                                                                                                                                                                                                                    |
|----------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Stage 1</b> | Pre-9/11 -2003 | <p>This stage is related to the period preceding the creation of the DHS. The Department of justice (DoJ) had primary responsibility for assessing risk.</p> <p><b>Risk was assessed and measured according to population numbers.</b></p> <p><b>R=P (Population)</b></p>      |
| <b>Stage 2</b> | 2004-2005      | <p>During this stage, critical infrastructure (CI), population density and other variables have been included in risk assessment.</p> <p>Risk was assessed as the sum of Threat (T), Critical Infrastructure (CI) and Population Density (PD).</p> <p><b>R= T+CI+PD</b></p>    |
| <b>Stage 3</b> | 2006-today     | <p>At this stage, the probability of particular events was systematically introduced into the risk estimation formula. Also for the first time, DHS introduced assessment of both risk to assets and geographical areas.</p> <p><b>R=T*V*C</b></p> <p><b>=T* (V&amp;C)</b></p> |

**Source:** Adapted from (CRS, 2007)

According to (CRS, 2007), Stage one in the development of the DHS RA methodology concerns the era prior to the 9/11 attacks and before the creation of the DHS and corresponds to the time when DoJ was in charge of security RA. Population (P) was the main risk factor considered in the calculation of risk (As per the Defence against Weapons of Mass Destructions Act of 1996). The states funding proportions after 9/11 was 40% statutorily mandated and 60% as per the state's risk level (**R=P**) (CRS, 2007).

In 2004, the 60% allocated according to risk was calculated as per the following formula:  **$R=T+CI+PD$** . Where, *T* refers to threat; *CI* relates to Critical Infrastructure; and *PD* refers to Population Density.

It was the first year DHS considered incorporating several sub-categories of data such as current threat level (T), critical infrastructure assets within an urban area (CI), and population density (PD).

In 2005, the risk calculation formula was changed and DHS considered other categories of data which were represented in the formula by  **$R=T+V$** . DHS did not move to a probabilistic risk formula until 2006.

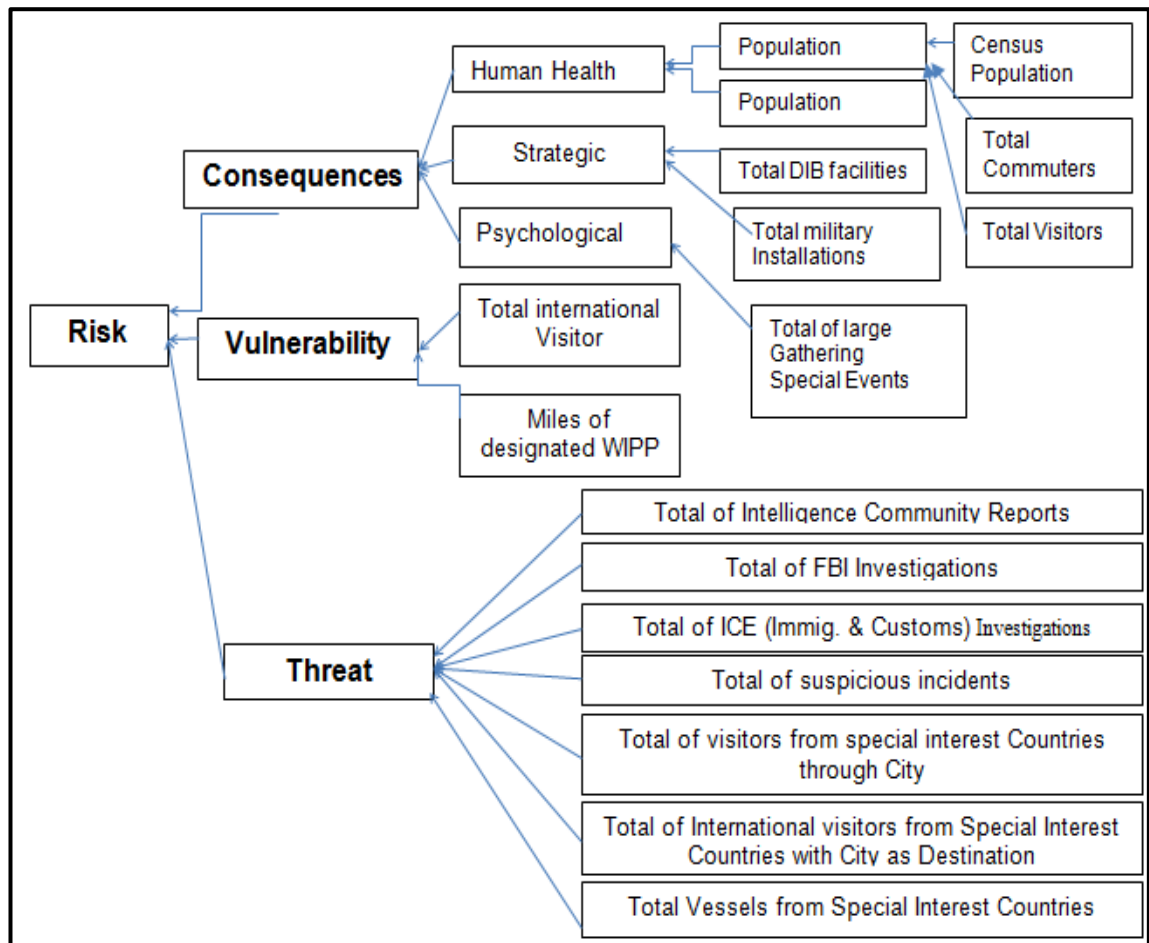
Since 2006, DHS has moved to a more developed formula which is still under use now.

The 40% statutorily mandated funding is still applied, however the remaining 60% depending on the states' risk level is calculated according to the following risk formula:

$$R = T * V * C$$

As per this formula, risk is calculated for both geographic areas and assets according to the following sub-categories:

**Figure 5.2 State geographic risk analysis attributes**

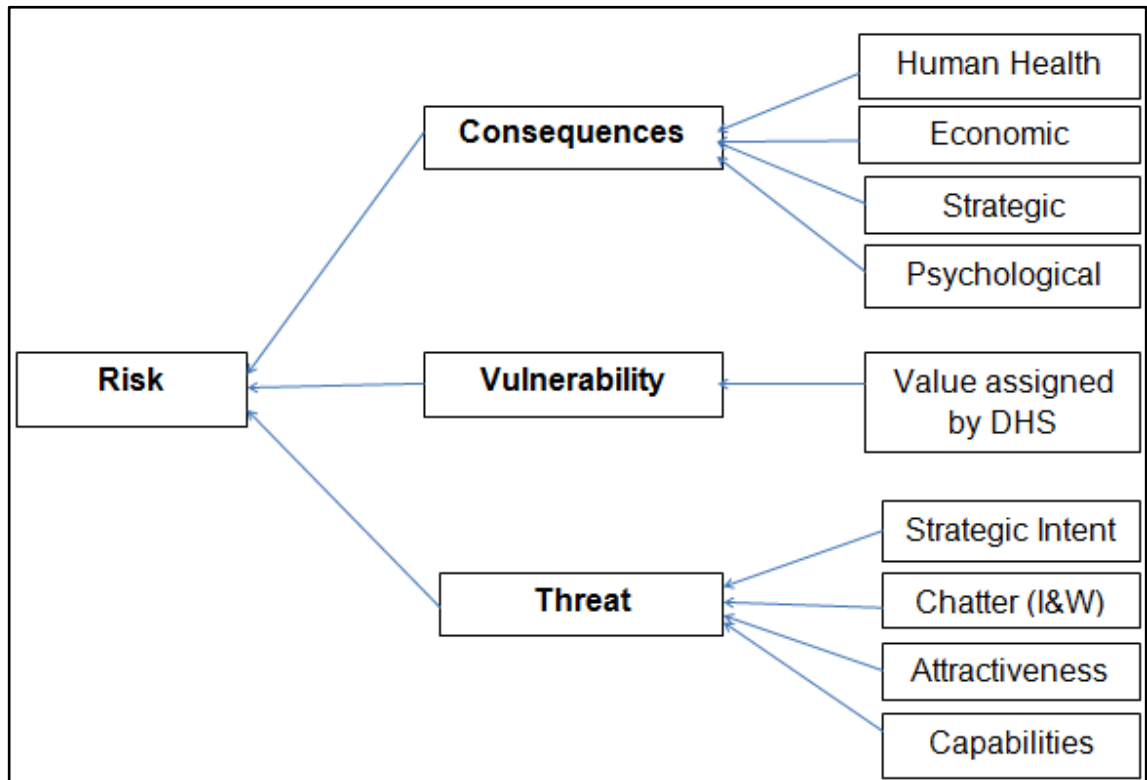


**Source:** (CRS, 2007)

Geographic: (Figure 5.2)

- *Threat (T)* is calculated according to intelligence reports and updated information.
- *Vulnerability (V)* is estimated according to total number of international visitors to any given state as well as the number of miles of international border...etc.
- *Consequence (C)*: human health, economic, strategic mission, psychological and other sub-sets of these categories.

**Figure 5.3 Asset-based risk analysis attributes**



**Source:** (CRS, 2007)

Assets: (Figure 5.3)

- *Threat (T):* strategic intent, attractiveness of target, capabilities.
- *Vulnerability (V):* Value assigned by DHS
- *Consequence (C):* human health, economic, strategic mission, psychological and other sub-sets of these categories.

In summary, the DHS formula for risk calculation remains the same whether it is asset-based or geography-based: **R= T\*V\*C**

This formula is strategic not only for DHS grant allocation but to all Homeland security Departments' activities as well. The scope of the DHS RA and management approach goes beyond terrorism threat to encompass risks of natural disasters as well as safety risks in the maritime and port domains.

While the RM process may be similar whether the source of risk is a hurricane or a terrorist attack, however the inputs provided into the RA model will be far different. DHS guidance shows that both the Urban Areas Security Initiative (UASI) and the Law Enforcement Terrorism Prevention (LETPP) programmes are largely designed to provide state and local governments with funds to prepare and protect against as well as respond to and recover from acts of terrorism. While this purpose also exists in the State Homeland Security Program (SHSP), it has the additional purpose of supporting the implementation of the National Preparedness Goal. The other two grants currently under the Homeland Security Grant Program umbrella, the Metropolitan Medical Response System (MMRS) and the Citizen Corps Program (CCP), are almost completely focused on preparedness for post-event response (crisis management).

In short, while DHS's RA methodology is largely geared toward countering terrorism, the results of the assessment, along with other factors, such as effectiveness, are used for purposes which go beyond terrorism (CRS, 2007).

Within DHS, there are other agencies and centres responsible for RA and management, including the U.S. Coast Guard – Office for Domestic Preparedness (U.S.C.G) and the Homeland Infrastructure Threat and Risk Analysis Centre (HITRAC). The latter is tasked with combining intelligence threat data, as assessed by the DHS Office of Intelligence, and analysis with infrastructure vulnerabilities. DHS detailed its RA approach in its *National Infrastructure Protection Plan* (NIPP), which was issued in June 2006 and updated in 2009.



## **b) The DHS National Infrastructure Protection Plan (NIPP)**

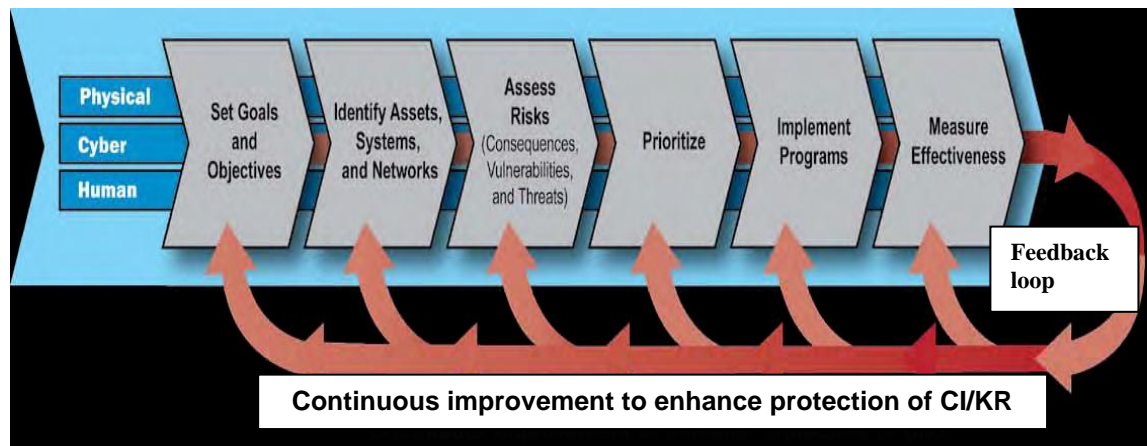
The National Infrastructure Protection Plan (NIPP) provides the coordinated approach needed to establish national priorities, goals, and requirements for critical infrastructure and key resources (CI/KR) protection so that Federal funding and resources are applied in the most effective manner to reduce vulnerability, deter threats, and minimise the consequences of attacks and other incidents. CI/ KR includes systems and assets, whether physical or virtual, so vital to the US. that their incapacitation or destruction would have a devastating impact on national security, national economic security, public health or safety, or any combination of those matters.

NIPP addresses the physical, cyber, and human considerations required for effective implementation of comprehensive programmes. The plan specifies the key initiatives, milestones, and metrics required to achieve the CI/KR protection mission. It sets forth a comprehensive RM framework and clearly defined roles and responsibilities for the DHS, Federal Sector-Specific Agencies (SSAs), and other Federal, state, local, tribal, and private sector security partners (DHS, 2009).

The cornerstone of the NIPP is its RM framework that establishes the processes for combining consequence, vulnerability, and threat information to produce a comprehensive, systematic, and rational assessment of national or sector risk. The RM framework is structured to promote continuous improvement to enhance CI/KR protection by focusing activities on efforts to: set goals and objectives; identify assets, systems, and networks; assess risk based on consequences, vulnerabilities, and threats; establish priorities based

on RAs and, increasingly, on return-on-investment for mitigating risk; implement protective programs and resiliency strategies; and measure effectiveness. The results of these processes drive CI/KR risk-reduction and management activities (DHS, 2009).

**Figure 5.4 NIPP RM Framework**



**Source:** (DHS, 2009)

DHS, SSAs, and other security partners share responsibilities for implementing the RM framework.

The RM framework is tailored and applied on an asset, system, network, or function basis, depending on the fundamental characteristics of the individual CI/KR sectors. This approach is appropriate for critical infrastructure of national or state importance, including ports handling Hazmat and their SCs, such as LNG export/ import marine terminals as well as activities/ organisations involved in the storage, handling, transportation and distribution of LNG and hydrocarbon based products across the maritime and ports SC.

**Table 5.6 NIPP core criteria for RA**

| <b>Criterion</b>    | <b>Description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Complete</b>     | The methodology should assess <i>consequence</i> , <i>vulnerability</i> , and <i>threat</i> for every defined risk scenario and follow the more specific guidance given in NIPP, such as documenting the scenarios assessed, estimating the number of fatalities, describing all protective measures in place, and identifying attack methods that may be employed.                                                                                                                           |
| <b>Reproducible</b> | The methodology must produce comparable, repeatable results, even though assessments of different critical infrastructure and key resources may be performed by different analysts or teams of analysts. It must minimise the number and impact of subjective judgments, leaving policy and value judgments to be applied by decision makers.                                                                                                                                                 |
| <b>Documented</b>   | The methodology and the assessment must clearly document what information is used and how it is synthesized to generate a risk estimate. Any assumptions, weighting factors, and subjective judgments need to be transparent to the user of the methodology, its audience, and others who are expected to use the results. The types of decisions that the RA is designed to support and the timeframe of the assessment (e.g., current conditions versus future operations) should be given. |
| <b>Defensible</b>   | The risk methodology must logically integrate its components, making appropriate use of the professional disciplines relevant to the analysis, and be free from significant errors or omissions. Uncertainty associated with consequence estimates and confidence in the vulnerability and threat estimates should be communicated.                                                                                                                                                           |

**Source:** *adapted from (DHS, 2009)*

In this respect, the case of the U.S. Coast Guard is interesting to be reviewed as a RM approach for the maritime and port sector.

#### **5.4.2 The US. Coast Guard's Maritime Security RA Model (MSRAM)**

Since the terrorist attacks of September 11, 2001, U.S ports have been considered critical infrastructure and potential terrorism targets for several reasons. According to GAO (2011), *'Ports, waterways, and vessels are part of an economic SC handling more than \$700 billion in merchandise annually and an attack on this system could have a widespread impact on global shipping, international trade, and the U.S. economy.'*

The U.S. Coast Guard, a component of DHS, is the lead federal agency for maritime security, which includes the protection of U.S. ports, coasts, and inland waterways as part of its Ports, Waterways, and Coastal Security (PWCS) mission. This mission involves protecting the maritime domain and marine transportation system, including preventing terrorist attacks, and responding to and recovering from attacks that do occur. In addition, the Coast Guard has other statutory missions such as enforcement and control of maritime safety rules and regulations.

The Coast Guard's primary approach to assessing and managing security risks has been embodied in its Maritime Security Risk Analysis Model (MSRAM). Since its development and implementation in 2005, MSRAM has provided the Coast Guard with a standardised way of assessing risk to maritime infrastructure, referred to in MSRAM as targets, which can include chemical facilities, LNG import/ export terminal facilities, oil refineries, hazardous cargo vessels, passenger ferries, and cruise ship terminals, to name a few. MSRAM is designed to allow comparison between different targets at the local, regional,

and national levels with the goal of reducing risk by prioritising security activities and resources.

From 2001 to 2006, the Coast Guard assessed maritime security risk using the Port Security RA Tool (PSRAT). PSRAT served as a rudimentary risk calculator that ranked maritime CI/KR with respect to the consequences of a terrorist attack. Among other limitations, PSRAT could not compare and prioritise relative risks of various infrastructures across port.

DHS's National Strategy for Transportation Security includes the development of risk-based priorities across all transportation modes. With regard to the Coast Guard, the Maritime Transportation Security Act of 2002 (MTSA) calls for the Coast Guard and other port security stakeholders, through implementing regulations, to carry out certain risk-based tasks, including assessing risks and developing security plans for ports, facilities, and vessels. In addition, the Coast Guard Authorisation Act of 2010 requires the Coast Guard to (1) develop and utilise a national standard and formula for prioritising and addressing assessed security risks at U.S. ports, such as MSRAM; (2) require Area Maritime Security Committees (AMSC) to use this standard to regularly evaluate each port's assessed risk and prioritise mitigation of the most significant risks (GAO, 2011).

Unlike PSRAT, MSRAM is designed to capture the security risks facing different types of targets, allowing comparison between different targets and geographic areas at the local, regional, and national levels. MSRAM's approach is intended to ensure that threat information is consistently applied across ports.

MSRAM vulnerability assessment includes three factors: achievability which is a factor designed to capture the innate degree of difficulty of an attack on a target; security system, a measure of the probability that the system in place will successfully interdict the attack and target hardness.

Consequence represents the projected overall impact of a successful attack on a given target or asset. Factors considered in this category include death/injury, economic, environmental, symbolic impacts and impact on national security (GAO, 2011).

The U.S. Congress requested the Government Accountability Office (GAO) to examine (1) the extent to which the Coast Guard's RA approach aligns with DHS RA criteria, (2) the extent to which the Coast Guard has used MSRAM to inform maritime security risk decisions, and (3) how the Coast Guard has measured the impact of its maritime security programs on risk in U.S. ports and waterways.

GAO reported that MSRAM generally aligns with DHS RA criteria, but additional documentation on key aspects of the model could benefit users of the results. MSRAM generally meets DHS criteria for being complete, reproducible, documented, and defensible.

However, DHS recently determined that the Coast Guard's risk reduction measure was not appropriate for inclusion as a DHS strategic performance measure and has considered it as a management measure. According to DHS, a strategic measure is designed to communicate achievement of strategic goals and objectives and be readily understandable to the public, and a management

measure is designed to gauge programme results and tie to resource requests and be used to support achievement of strategic goals (GAO, 2011).

#### **5.4.3 The Security Vulnerability Assessment (SVA) Methodology**

API & NPRA (2004) define the SVA as the process that includes determining the likelihood of an adversary successfully exploiting vulnerability and estimating the resulting degree of damage. Based on this assessment, judgments can be made on the degree of risk and the need for additional countermeasures.

SVA is a systematic process which evaluates the likelihood that a threat against a facility will be successful. It actually goes beyond the facility to encompass the potential severity of consequences to the surrounding community and to the wide energy SC. The SVA process rely on the skills and knowledge of various participants from related disciplines, such as process safety, physical and cyber security, emergency response, operations management and other disciplines as deemed necessary (API & NPRA, 2004).

The objective for conducting SVA is to identify security hazards, threats and vulnerabilities facing a facility or a SC, as well as their protection countermeasures.

The foundation of the SVA's security management approach is the need to identify and analyse security threats and vulnerabilities and to evaluate the adequacy of the RCOs provided to mitigate the threats. As such, the SVA is a management tool that can be used to assist in accomplishing this task.

SVA is not necessarily quantitative; but usually performed qualitatively using the best judgment of the SVA team. The goal is to get a qualitative determination of risk to provide a sound basis for rank ordering of security related risks and thus making priorities in the application of countermeasures.

According to (API & NPRA, 2004), it is essential to bear in mind that all security risks cannot be completely prevented. Security objectives are to employ four basis strategies to help minimize risk: **Deter, Detect, Delay, and Respond**

#### 5.4.3.1 SVA risk definition

**Table 5.7 SVA risk definition**

|                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Security Risk</b> is a function of:</p> <ul style="list-style-type: none"><li>• <b>Likelihood of</b> a successful attack against an asset and</li><li>• <b>Consequences</b> of a successful attack against an asset</li></ul>                                                  |
| <p><b>Likelihood</b> is a function of:</p> <ul style="list-style-type: none"><li>• The <b>Attractiveness</b> of the asset to the adversary</li><li>• The degree of the <b>Threat</b> posed by the adversary, and</li><li>• The degree of <b>Vulnerability</b> of the asset</li></ul> |

**Source:** (API & NPRA, 2004)



**Table 5.8 SVA risk variables**

|                       |                                                                                                                                                                                                                                                                    |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Consequences</b>   | <i>Consequences</i> are the potential of adverse impacts to a facility, the local community and/or the nation as a result of a successful attack                                                                                                                   |
| <b>Likelihood</b>     | <i>Likelihood</i> is a function of the chance of being targeted for attack, and the conditional chance of mounting a successful attack. This is a function of Threat, Vulnerability and Target Attractiveness.                                                     |
| <b>Attractiveness</b> | <i>Attractiveness</i> is a surrogate measure for likelihood of attack. This factor is a composite estimate of the perceived value of a target to a specific adversary                                                                                              |
| <b>Threat</b>         | <i>Threat</i> is a function of an adversary's intent, motivation, capabilities, and known patterns of operation. Different adversaries may pose different threats to various assets within a given facility or different facilities                                |
| <b>Vulnerability</b>  | <i>Vulnerability</i> is any weakness that can be exploited by an adversary to gain access and damage or steal an asset or disrupt a critical function. This is a variable that indicates the likelihood of a successful attack given the intent to attack an asset |

**Source:** (API & NPRA, 2004)

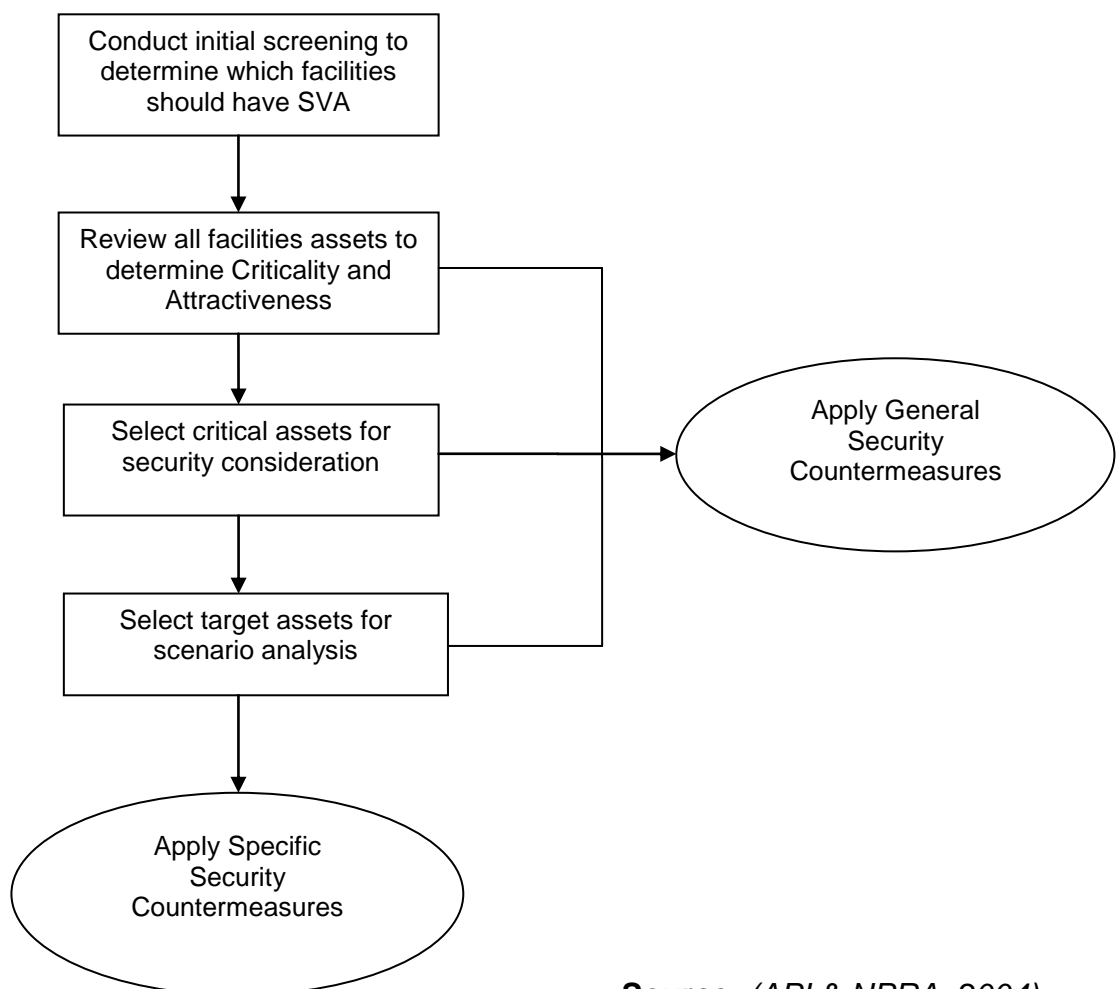
#### **5.4.3.2 SVA approach**

The SVA general approach is to apply RA resources and ultimately special security resources where justified based on the SVA results. The process involves consideration of each asset both at the general level and from specific asset viewpoint.

Consideration of the asset at the general level is useful in determining the overall impacts and loss, the outer perimeter security, access control and general physical security; whereas the specific asset level looks at the criticality

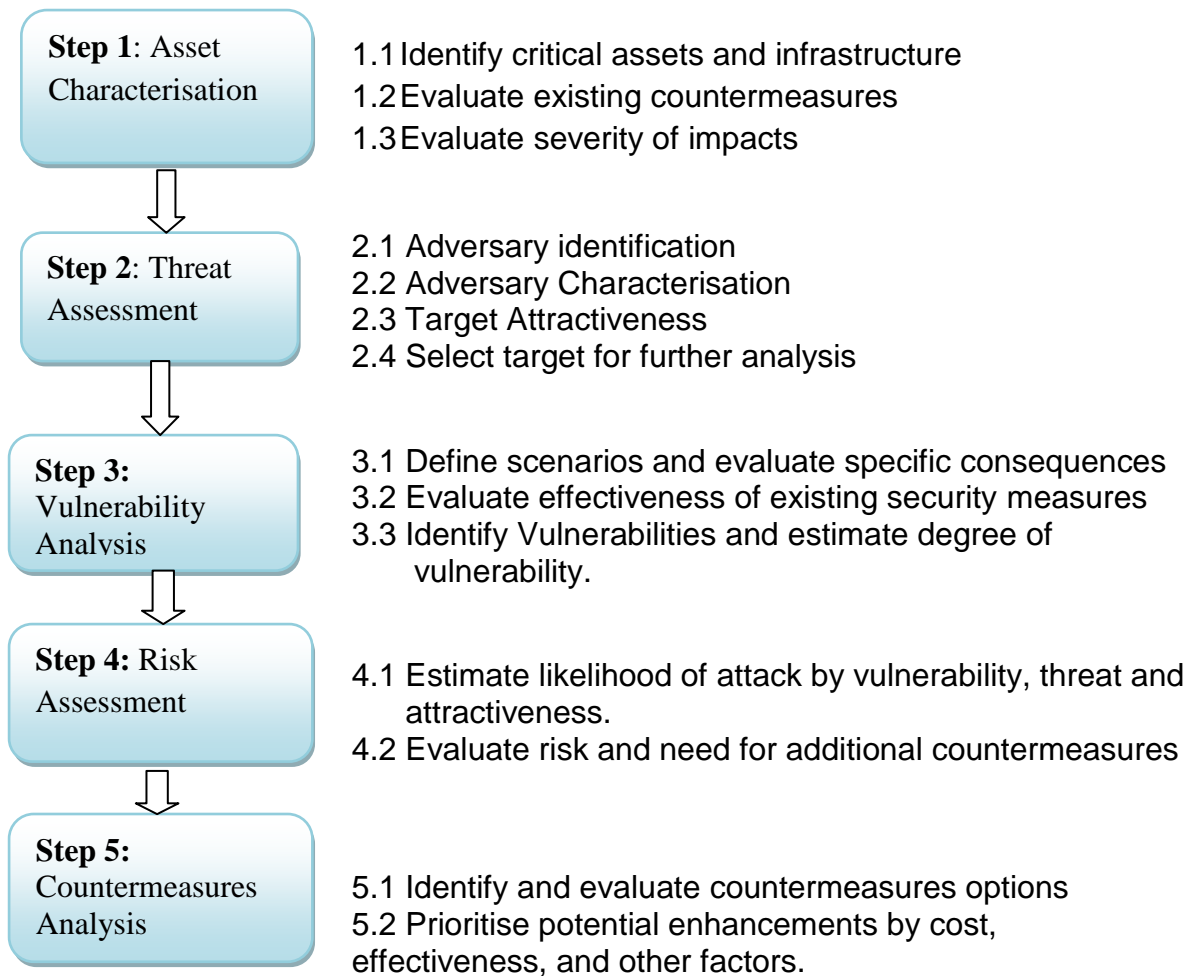
of the facility, its strategic value both in terms of economic and homeland security impacts as well as its value to the adversaries. Generally all facilities will maintain a minimum level of security with general countermeasures such as administrative and access control. Certain assets will justify a more specific level of security such as additional surveillance or barriers based on the strict consideration at the specific asset level.

**Figure 5.5 Overall asset screening approach**



**Source:** (API & NPRA, 2004)

**Figure 5.6 SVA methodology steps**



**Source:** (API & NPRA, 2004)

It should be noted that each step in the SVA process has got its own predefined methodology and process. Prior to conducting the SVA, there are a number of preparatory activities that must be done to ensure an efficient and accurate analysis. The following are factors which enable successful completion of an SVA:

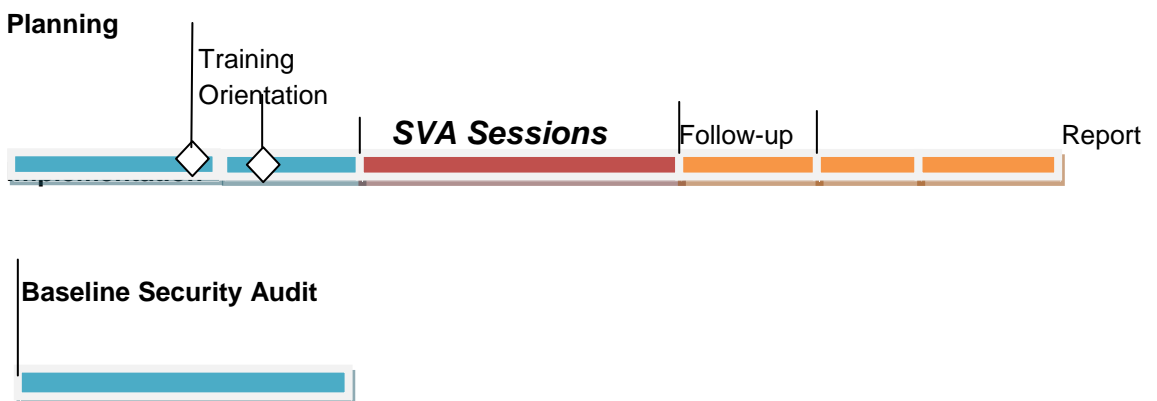
- The activity should be planned well in advance;
- Have the full support and clearance from the management;

- The data should be verified and complete;
- The objectives and scope should be concise;
- The SVA team should be knowledgeable and experienced at the process;
- The team leader should be experienced at the SVA process methodology.

Most important of the pre-SVA activities is the determination of the SVA specific objectives and scope, and the selection and preparation of the SVA team.




Pre-requisites to conducting the SVA includes gathering necessary study information, threat information, forming and training the SVA team on the method to be used, as well as conducting baseline security survey and planning the means of documenting the process (API & NPRA, 2004).

**Figure 5.7 Typical timeline for conducting SVA**



**Source:** Adapted from (API & NPRA,

2004)

-  SVA Planning Stage
-  SVA Sessions Conducted
-  Post- SVA Sessions (Follow up and reporting)

#### **5.4.3.3 SVA team**

The SVA approach relies on the use of a representative group of company experts as well as outside experts as deemed necessary to identify potential security related events or conditions.

The internal company group of experts typically consists of representatives from fields of security, RM, operations engineering, safety, environmental, regulatory compliance, logistics/distribution, IT and other team members as required.

This group of experts should focus on vulnerabilities that would enhance the effectiveness of the facility security plan. As stated by (API & NPRA, 2004), the primary goal of this group is to capture and incorporate information that may not be available in a typical operator database.

As part of the SVA approach, the terrorism RA for a process dealing with flammable or toxic substances should be handled by a team of experts from both security and process safety areas. This is because the team should evaluate and integrate traditional security protection with process safety countermeasures to enable a combined security and process safety strategy.

SVA is conducted primarily by a full time 'Core' team led by a team leader, complemented as needed by other part-time team members. Core competencies for the SVA full time and part-time teams are shown in the table below:

**Table 5.9 SVA team members**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>The SVA Core Team</b> members should have the following skills and experience:</p> <ul style="list-style-type: none"><li>• Team leader: knowledge of and experience with the SVA methodology;</li><li>• Security representative: knowledge of facility security procedures, methods and systems;</li><li>• Safety representative: knowledge of potential process hazards, process safety procedures, methods and systems of the facility;</li><li>• Facility representative: knowledge of the design of the facility under study including asset value, function, criticality, and facility procedures;</li><li>• Operations representative: knowledge of the facility process and equipment operations;</li><li>• Information systems/ automation representative (for cyber security assessment) - knowledge of information systems technologies and cyber security provisions; knowledge of process control systems.</li></ul> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Source:** *Adapted from (API & NPRA, 2004)*

The core team may be supplemented by part time competencies as required. Part time skills may include specialists in security, cyber security, process industries or operations.

**Table 5.10 Sample Statement of Objectives**

|                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>To conduct an analysis to identify security hazards, threats, and vulnerabilities facing a fixed facility handling hazardous materials, and to evaluate the countermeasures to provide for the protection of the public, workers, national interests, the environment, and the company.</p> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Source:** *(API & NPRA, 2004. p: 16)*

Such an approach has the merit of integrating safety and security RA and management which provides a stronger approach and better protection by addressing both safety and security vulnerabilities and the impact that may

arise from one risk aspect on the other within the framework of a global approach.

As stated in (*API & NPRA, 2004. p: 1*), the main characteristics of the SVA process is that it is 'a team- based approach that combines the multiple skills and knowledge of the various participants' including process safety professionals. Also, although SVA focus is on security threats and vulnerabilities facing an energy facility, it goes beyond the facility itself to encompass assessing potential consequences to the surrounding environment as well as to the energy SC.

Therefore, the SVA approach can be considered as a comprehensive methodology since its scope includes security and safety threats and vulnerabilities within the wider energy SC.

## **5.5 COMPARATIVE ANALYSIS OF SAFETY AND SECURITY RISK APPROACHES**

The system safety approach regards accidents as hazardous events for which causes and consequences are well known and frequency is influenced by certain factors.

The total consequences of an event form the size of the accident, whereas the frequency of such events may range from high frequency low impact events to low frequency high consequence events. As stated earlier in this chapter, events that tend to be repetitive and routine in nature are mostly low impact (car accidents, machine failure). However, low frequency events, such as natural disasters and terrorist attacks, tend to be more complex with long lasting and severe consequences.

**Table 5.11 Main characteristics of safety and security events**

| Safety event                                                                                                                                                                                                                                                                                         | Security event                                                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Predictable through statistical means and system failure analysis (near misses)</li> <li>• Managed through engineered mitigation measures and good practice.</li> <li>• Often triggered by an unsafe practice within the system (unintentional).</li> </ul> | <ul style="list-style-type: none"> <li>• Low frequency and high impact</li> <li>• Difficult to predict as they do not follow statistical reasoning;</li> <li>• Their management is more intelligence based;</li> <li>• Triggered by intentional act</li> <li>• May yield higher impact since the perpetrator is an intelligent agent who tends to maximise the outcome of attack.</li> </ul> |

**Source:** *the author*

Table 5.11 summarises the main characteristics of un-intentional events (safety risks) and intentional acts (security events). Although the input and focus of the RA in both safety and security are different, RA and management approaches in both disciplines generally follow the same process.

### **5.5.1 Main characteristics of the above safety and security approaches**

From our earlier discussion on popular RA and management approaches, the following remarks can be made:

- FSA is considered an advanced and proactive RA and management tool but needs to be extended to port safety to address the ship/port interface; this matter is still under consideration by IMO.
- The multi-layer International Security Regulatory Framework is complex and challenging but it offers the opportunity for efficient and secure trade, port logistics and SC operations.



- Most safety and security frameworks and approaches pose a dichotomy and provide less integration between the two disciplines in terms of RA and management, except for SVA, MSRAM and USCG.RBDM Guidelines.
- Some safety and security frameworks, for instance MSRAM, SVA and the USCG.RBDM Guidelines, although each one focuses more on a single type of risk they still consider both safety and security types of risks in their analysis. This is in line with recent developments within the risk community in USA which tend to apply a holistic approach to risk and believe that such comprehensive approach (Safety, security and natural disasters RM) would benefit the overall protection system.

### **5.5.2 RM strategies in LNG ports**

The outcome of the U.S based approach to risk has a direct impact on the LNG Port RM strategies implemented in the U.S as well as in other parts of the world. One of the factors that facilitated both conception and implementation of such all-hazards approach is the fact that maritime and port safety, security and natural disasters planning and response missions are all made under the U.S Coast Guard mandate.

In practice, every LNG port applies a customised RM approach depending on the site specific conditions and features. In the U.S, performance-based strategies are developed to provide the necessary flexibility to deal with combined and evolving safety and security threats. These 'performance-based strategies are often used in instances where there is a lack of good information on operational consequences or hazards (*SANDIA, 2004-p.55*).

The aim of such strategies is mainly prevention and mitigation of both safety and security risks in an integrative and cost effective manner. Prevention seeks to avoid an accident or attack; mitigation reduces the effects of an accident or attack. Combination of both types of strategies can improve both safety and security involving either accidental or intentional incidents.

**Table 5.12 Prevention and mitigation strategies in LNG ports**

| Prevention                                                                                                                                                                                                                 | Mitigation                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ISOLATION <ul style="list-style-type: none"> <li>Physical separation(distance)</li> <li>Physical barriers</li> <li>Keep-out exclusion zones(buffers)</li> <li>Interrupted operations (aircraft, bridge traffic)</li> </ul> | RECOVERY OPERATIONS <ul style="list-style-type: none"> <li>Plans in place and current</li> <li>Equipment &amp; people in place and ready</li> <li>Drills</li> <li>Evacuation plans</li> </ul>                                     |
| OF VOID SPACES WITH INERT GAS                                                                                                                                                                                              | MAINTAIN MOBILITY (Tanker + towing)                                                                                                                                                                                               |
| INERTING OF VOID SPACES                                                                                                                                                                                                    | LIMIT SPILL AMOUNTS & RATES                                                                                                                                                                                                       |
| VARIED TIMES OF OPERATIONS                                                                                                                                                                                                 | SECURITY EMERGENCY RESPONSE FORCES                                                                                                                                                                                                |
| INTELLIGENCE <ul style="list-style-type: none"> <li>Communication links in place and ready</li> <li>Timely updates</li> <li>Interagency communication links</li> </ul>                                                     | FIRE FIGHTING CAPABILITIES <ul style="list-style-type: none"> <li>Leak detectors</li> <li>Deluge systems</li> <li>Radiant barriers (high-pressure high density foam system)</li> <li>Backup fire fighting capabilities</li> </ul> |
| INCREASED MOBILITY (Tugs)                                                                                                                                                                                                  | REDUNDANT MOORING & OFFLOADING CAPABILITIES                                                                                                                                                                                       |
| ARMED SECURITY ESCORT(Boat, aircraft or on-board)                                                                                                                                                                          | OFFSHORE MOORING & OFFLOADING CAPABILITIES                                                                                                                                                                                        |
| SWEEPS (Divers, sonar, U.S.CG boarding)                                                                                                                                                                                    | SPEED LIMITS                                                                                                                                                                                                                      |
| SURVEILLANCE (On-ship, on-land, underwater and aerial)                                                                                                                                                                     | CRYOGENICALLY-HARDENED VESSEL                                                                                                                                                                                                     |
| EMPLOYEES BACKGROUND CHECKS                                                                                                                                                                                                | SHIP ARMOR, ENERGY-ABSORBING BLANKETS                                                                                                                                                                                             |
| TANKER ACCESS CONTROL PROGRAMME                                                                                                                                                                                            | MISSILE DEFENSE SYSTEM                                                                                                                                                                                                            |
| STORM PREDICTION & AVOIDANCE PLANS                                                                                                                                                                                         | REDUNDANT CONTROL SYSTEMS                                                                                                                                                                                                         |
| SAFETY INTERLOCKS                                                                                                                                                                                                          | BACKUP FUEL SOURCE (Oil)                                                                                                                                                                                                          |

**Source:** (SANDIA, 2004, p: 58)

For a complete picture on the potential consequences in a particular breach scenario, a target-mechanism-consequence model (TMC) is used. The target is the vulnerable element of the LNG infrastructure system on which some mechanisms act to produce un-desired consequences.

**Targets:** These can be floating targets, fixed targets in water or targets ashore.

**Mechanism** : Physical, cyber or interpersonal

**Consequences:** Can be local, cascading or delayed.

**Table 5.13 Example of the TMC model**

| Targets             | Targets afloat               | Fixed targets in water               | Targets ashore                       |
|---------------------|------------------------------|--------------------------------------|--------------------------------------|
| <i>Example</i>      | LNG Tanker                   | Bridge                               | LNG Terminal                         |
| <b>Mechanism</b>    | <b>Physical</b>              | <b>Cyber</b>                         | <b>Interpersonal</b>                 |
| <i>Example</i>      | Collisions                   | On-ship communications               | Sabotage                             |
| <b>Consequences</b> | <b>Local</b>                 | <b>Cascading</b>                     | <b>Delayed</b>                       |
| <i>Example</i>      | Death/ injury to tanker crew | Death/ injury to escort vessel crews | Death/ injury to rescue vessel crews |

**Source:** Adapted from (SANDIA, 2004, p: 55 &56)

**Mechanism** : Failure mechanism can either be accidental or intentional.

**Consequence:** Intentional mechanisms, such as deliberate acts of sabotage and terrorism, can often produce greater consequences than accidental mechanisms since the perpetrator can maximize the effects of an attack by

choosing the time and place which would yield the maximum effect. He may also plan several simultaneous attacks to compound the consequences. All these effects must be considered while developing the risk reduction and RM approach.

## **5.6 CONCLUSION**

From the above presentation of the RA approaches and methods, it is clear that such approaches and their level of integration and scope are strategic in designing efficient and cost effective RA and management strategies, especially those related to critical infrastructure such as ports handling hazardous materials.

It is also apparent that U.S. made methods are more advanced in this regards, since they evolved from conventional methods dealing separately with each type of hazard towards all-hazard approach integrating safety, security and natural disasters prevention and mitigation.

This approach, although adopted recently, has the prospect of being cost effective, since it unifies and rationalises the use of RA and response resources and provide better communication and coordination among the maritime and port SC RM stakeholders. However, this approach needs to be studied further to evaluate its efficiency as it continues to be applied by the U.S and in other parts of the world.

## CHAPTER 6 METHODOLOGY

### 6.1 INTRODUCTION

In their discussion of research purpose and the importance of research methodology Clough & Nutbrown (2002) claim that the task of methodology is to explain and justify the particularity of the methods used for a given study. They also emphasized that '*methodology provides reasons for using particular research recipe*' and further summarised the importance of methodology by asserting that '*research is methodology*' (Clough & Nutbrown, 2002, p.22, 3).

The aim of this chapter is to identify and support the rationale for the choice of methods selected to help achieve and fulfil the research aims and objectives. The chapter commences with a discussion of the theory of research methodology and paradigms and identifies that trade-offs exist in the various methodologies. It continues by identifying the research questions and objectives and puts forward justification for the use of mixed method approach to address the research problem and related research questions within the scope of the present topic of LNG ports RM. If the research selected the use of both qualitative and quantitative methods, it used a variety of methods and techniques even within each particular paradigm of research method, be it qualitative or quantitative.

### 6.2 RESEARCH PHILOSOPHY

Research philosophy and paradigm is an important part of research methodology which enables research orientation and data collection in a

systematic and effective way. Saunders *et al.*(2009. p. 107-108) state that research philosophy relates to the development of knowledge and its nature. It contains important assumptions about the ways the researcher views the world. Such assumptions underpin the research strategy and the methods chosen as part of that strategy. Holden and Lynch (2004) argue that those assumptions are consequential to each other. For them, ontological views affect epistemological persuasions and the choice of methodology logically follows the researchers' philosophical assumptions. Burrell and Morgan (1979) in Holden and Lynch(2004) state that developing a philosophical perspective requires the researcher to make assumptions about two dimensions: the nature of society and the nature of science. According to Burrell and Morgan (1979), the societal dimension involves two distinct views of society: regulatory or radical change. The first one views social evolution in a rational and cohesive way, while the radical change perspective looks at social development as contradictory and conflicting. Those two opposing perspectives are the basis of two different schools of thoughts: the rational view of society representing modernism, whereas the radical change perspective is the expression of post-modernism (Holden & Lynch, 2004).

Science may be considered subjective or objective. According to Holden and Lynch (2004) these philosophical approaches are delineated by core assumptions related to ontology (reality) and epistemology (knowledge). Ontology and epistemology are described by Clough and Nutbrown(2002, p. 30) as the twin terms of methodology for philosophers. Saunders *et al.*(2009) further explain that objectivism and subjectivism are the two aspects of ontology as concerned with the nature of reality.

### **6.2.1 Objectivism versus subjectivism**

According to Saunders *et al.*(2009), objectivism proposes that social entities exist in reality independent of social actors. Therefore, the objectivist stance dissociates social reality and the social actors. The subjectivist view, in contrast, looks at the social phenomena as creations from the perceptions and consequent actions of social actors. This subjectivist perspective is often associated with social constructivism which views the reality as socially constructed (Saunders *et al.* 2009).

Holden and Lynch (2004) argue that the objectivist approach to social research was developed from natural sciences. Social science researchers decided to use the highly efficient methods borrowed from the natural sciences to investigate social phenomena. However, subjectivism arose as critics to the objectivist approach which argues that social and natural sciences are disparate.

### **6.2.2 Positivism versus interpretivism**

Saunders *et al.*(2009) state that a study that reflects the philosophy of positivism is one that adopts the stance of natural science with regards to the formulation of hypotheses from an observable social reality and the production of a generalisable knowledge similar to the '*law-like generalisations*' produced by physical and natural scientists. In this respect, only phenomena that can be observed will lead to the production of credible data. Positivism assumes that the research objectives have inherent qualities that exist independently of the researcher Ibid (2009, p.113). For positivists, the outcomes of a study are evaluated in light of a theory of truth; in a way that the truth or

falsity of a statement is determined only by how it relates to the world, and whether it accurately describes it (Zulu, 2007).

The Interpretive approach argues that the social reality of business and management is far too complex to be reduced to definite laws similar to those generated by the physical sciences (Ibid, 2009). It assumes that social knowledge of the world is generally built through lived experiences or social construction of the world. The notion of 'social actors' is quite significant here which the researcher has to give due consideration. Conducting research among social actors such as humans shall be considered differently to objects (Ibid, 2009). Positivism assumes that the researcher and reality are separate, while interpretivism assumes that the researcher and reality are inseparable (Zulu, 2007).

There is an important consideration in this research philosophy and approach in the identification of an appropriate theoretical paradigm that can be used as the underlying basis for conducting scientific investigation. A theoretical paradigm is essentially a "loose collection of logically held together assumptions, concepts, and propositions that orientates thinking and research" Similarly; a paradigm has been defined as the "basic belief system or world view that guides the investigation" (Zulu, 2007).

Considering its interdisciplinary scope and nature, this research adopts a subjectivist interpretive stance throughout the exploratory part of the research. Also a positivist approach is adopted during the testing and confirmatory stage of the enquiry. This is believed to stand as an appropriate approach to explore and explain the far too complex, multi-faceted and socially constructed reality of LNG ports safety and security risks assessment and management. In this

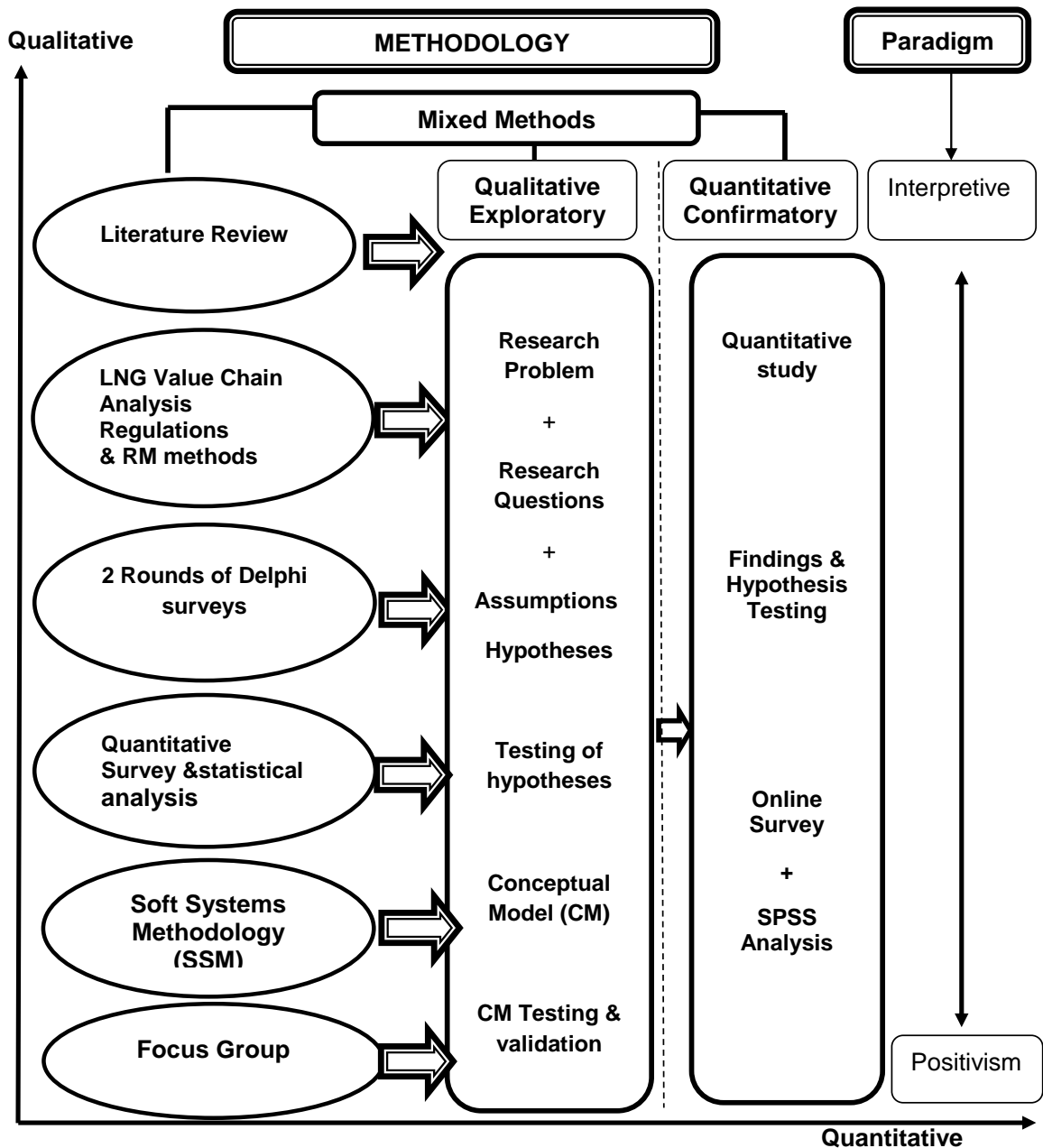


respect, Saunders *et al.*(2009) explain that it is the role of the researcher to seek to understand the subjective reality of their study customers in order to be able to make sense of their motives, actions and intentions in a meaningful way. Therefore, consideration of the social element, represented by safety and security professionals, is decisive in explaining the reasons for the various theoretical and practical gaps in the management of interfaces among the two disciplines of RM in the ports and maritime settings. The study then follows a multi-paradigm approach in addressing its research objectives; it follows a pragmatic stance described by Barbour(2008, p.161) as a philosophical framework where '*multiple assumptions and diverse methods can comfortably co-exist*'. Green *et al.* (2004, p. 277) argue that

*“Flexibility, creativity and resourcefulness- rather than a prior methodological elegance- are the hallmark of good mixed method design.”*

The present study deploys a combined approach that includes qualitative and quantitative research. Qualitative methods are used as exploratory tools to acquire primary and secondary data, whereas quantitative techniques are deployed to test and confirm primary and secondary data, as well as their assumptions and findings. Indeed, the nature of this study's research questions is such that it combines "what" and "how" types of questions, hence rendering a mixed methods approach necessary (Li-Anne, 2003). Such an approach can provide key insights into the broader theme of RM in LNG ports and focuses heavily on the central idea that RM in LNG ports and marine terminals has to be looked at and dealt with holistically from a SC perspective, integrating the pivotal role of the port authority assisted by the LNG port community.

Figure 6.1 Philosophical stance of the present research



Source: The author; adapted from Li-Anne (2003) pp. 135-139.

### 6.3 METHODOLOGICAL APPROACH

It is generally accepted that any research project will involve the use of theory. Saunders *et al.* (2009) state that the way the researcher will deal with theory has an impact on the research design. Glaser and Strauss (1967, 6) argue that the

generation of a theory involves a research process in which hypotheses and concepts not only come from the data but are systematically worked out in relation to the data. Also, theory can be developed at different junctures of the research according to the nature of the research and how it is approached (Dinwoodie and Xu, 2008). Generally, two methodological approaches are used in this regards, either induction or deduction.

According to Saunders *et al.*(2009, p. 124), deduction is the dominant research approach in natural sciences which involves the development of a theory that is subject to rigorous testing. A deductive approach favours first the development of a theory followed by the formulation of hypotheses which are subsequently tested using a well-designed research strategy. According to Robson (2002), there are five successive steps in the deductive research process: (1) deducing a hypothesis or preposition from a theory; (2) expressing hypotheses in operational terms to tell how it is measured; (3) testing of hypothesis; (4) evaluating the outcome of hypothesis testing to confirm, reject or modify the theory and; (5) confirm or modify the theory according to the findings.

Ibid (2009) states that as far as the research approaches are related to the research philosophies, deduction is more linked with positivism while induction, which is the alternative approach, owes more to interpretivism. Inductive research is more likely to be concerned with the context in which events take place. Researchers, using this particular approach, tend to work more with qualitative data and use various data collection techniques in an effort to construct different views of the phenomena under study (Ibid, 2009, p.126). Within this tradition, the researcher observes phenomena and collects data so

as to subsequently arrive at conclusions, or develop theory based on data analysis. Although this discussion may give the impression that there are rigid divisions between deduction and induction, this is not actually the case since it is possible and often advantageous to utilise both deductive and inductive approaches to the same piece of research (Saunders *et al.* 2009, p. 127).

As stated earlier in chapter one, abundant literature exists for port safety and security risks which discusses in details port safety and security risks management separately as two independent subjects. However, very little has been written on the relationships, interfaces and shared impacts among safety and security risks in the LNG port and maritime industry. Due to this scarcity of literature around the topic, the use of an inductive approach is chosen in an attempt to generate data from the industry and analyse such data to arrive at meaningful conclusions. Saunders *et al.* (2009) testifies that such an approach is appropriate in case the topic under study is new, generates much debate and on which there is little existing literature (Ibid 2009, p. 127). Therefore, an inductive approach is adopted throughout the exploratory and conceptual part of the research while deduction is employed during the testing and confirmatory phase.

This research has focused on theory generation in order to:

- Develop an integrated and holistic approach to the issue of safety and security risks assessment and management in LNG ports SC.
- Construct a high level conceptual model materialising such approach by identifying the main RM actors and stakeholders of the LNG port system, their roles and relationships within a coordinated and participative

approach. Such model shall also integrate the safety and security systems as an integrated part of the overall port RM system.

- Provide an enabler for a practical integration of the three main components of the port management system: port safety and security RM system, port emergency management system and port business continuity.

#### **6.4 RESEARCH STRATEGY**

The research has evolved from a number of data sources and observations. First of all, the researcher's own observation of the reality of RM, as a port professional, within the LNG ports in the Arabian Gulf has been the basis for the researcher's curiosity to further investigate and analyse the subject on practical grounds. It was clear from the observation and the various interactions with risk professionals at LNG ports that the overall RM system is fragmented and lacks a coordinated approach. An initial review of available literature on safety and security risks management approaches and methodologies revealed the existence of further distortions as well as theoretical and practical gaps. This assisted in the formulation of the research problem and helped to frame and refine the research questions. This stage, described by Filippini (1997) as the '*preliminary descriptive research*' enabled the researcher to build up a picture of the phenomenon being studied. During this stage, called also, conceptualisation phase, an attempt is made to make sense of conceptual frames, concepts and relationships in an effort to explain and scope the phenomenon under study. After clarifying and scoping the research problem, the next phase is to formulate an appropriate strategy to address the research problem and answer the research questions.

Considering the interdisciplinary nature of this research, a multi-method approach has been selected, composed of an in-depth literature review, the Delphi technique and quantitative statistical techniques. Such a multi-method approach is selected and deployed to make use of the triangulation technique. Triangulation, '*interpreted as a mean of mutual confirmation of measures and validation of findings*' (Berg, 2001 p. 5) is employed to test and validate the findings of the theoretical and empirical studies performed as part of this research; for instance the data collected from the literature review and the one derived from the two rounds of the empirical Delphi study.

#### **6.4.1 Qualitative versus Quantitative**

Over the years the terms multi-methods, triangulation and mixed methods appeared in literature as approaches to facilitating a combining qualitative and quantitative research that is intended to end the pragmatic war (Cicic and Patterson 1999; Zulu 2007; Collins and Dressier 2008). According to Barbour (2008) mixing methods is often employed to compensate for the perceived shortcomings of stand-alone methods with the aim of providing a more complete picture or a wider coverage.

Despite the views supported by the proponents of both qualitative and quantitative methods, both methods tend to have their strengths and weaknesses and both methods have long been used as research tools for social sciences. According to Sarantakos (2005), there is no absolutely 'right' methodology. A research methodology is chosen in the given research conditions, the research questions to be answered, the available resources,

and, above all, the types of data required. Thus, the use of both methods is acceptable, as they are not mutually exclusive and can be mixed and matched (Van Maanen, 1979). Berg (2001) asserted that qualitative and quantitative are not distinct approaches. Also combining both methods is not new; Strauss and Corbin (1998) suggest intermediate positions. They think that '*combining methods may be done for supplementary, complementary, informational, developmental, and other reasons*' (p. 28).

#### **6.4.2 Mixed Method**

According to Bazeley and Kemp (2011), there are multiple rationales for mixing methods and component parts of studies are integrated depending on the rationale or purpose. Three main rationales are put forward by Bazeley and Kemp in this regards:

- Integration of methods assists in building stronger conclusions, as the strengths of one method tend to compensate for the weaknesses of the other.
- Mixing methods is considered as a means to initiate a new understanding of the study subject since the dialectical approach, created as a result of mixing methods and approaches, promotes further exploration and understanding.
- Finally, mixed methods are seen as an alternative way to providing a more complete picture by understanding causal effects and processes.

Bazeley and Kemp (2011, p.56) asserted that in order to achieve one or the other of the above purposes, mixing methods should involve the following:

- *'having a common purpose or goal to unite these;*
- *Interdependence of these different elements in reaching the goal;*
- *Having a sum greater than the parts (Bazeley, 2010)'*

### **6.4.3 Triangulation**

Bazeley (2010.p 7) further states that the term

*'Triangulation is the most used and perhaps the most misused metaphor in the mixed methods'*

Bazeley (2010) argues that the concept of triangulation derives from Webb *et al.*, (1966) who suggested that triangulation is used to confirm a proposition as the most persuasive evidence of measurement, once such proposition has been confirmed by two or more measurements processes. Moreover, triangulation is a term commonly used in other professions as well such as surveying activities, map making, navigation and military. Many researchers adopt triangulation by using multiple data-gathering techniques to investigate the same phenomena (Berg, 2001; Seale, 1999).

For this research, an in-depth literature review, the Delphi technique and quantitative statistical techniques are deployed to make use of the triangulation technique. Triangulation is *'interpreted as a means of mutual confirmation of measures and validation of findings'* (Berg, 2001 p. 5). Apart from the misuse of the term triangulation by some researchers as detailed by Bazeley (2010), our understanding and use of the concept of triangulation, in the context of the present research, conforms to Webb *et al.*, (1966) and Olsen(2004) and has a purpose to test and validate the findings of the theoretical and empirical studies performed earlier; for instance the secondary data collected from the literature



review and the primary source data derived from the two rounds of the empirical Delphi study.

#### **6.4.4 Research methods**

Chapters 1 to 6 represented the theoretical descriptive part of the research. They address the 'who', 'what' and 'why' question types to find out what is occurring (descriptive) and why it is occurring the way it is (explanatory).

The exploratory part of the research begins in chapter 7 with an empirical analysis through two rounds of Delphi surveys undertaken among a panel of international experts, including industry professionals from world leading LNG ports of the Arabian Gulf. A Delphi study based on an online survey is selected to act as a scoping exercise which follows a sequential, mixed-method, and predominately qualitative approach. According to Barbour (2008, p.153), one common rationale for mixing methods is '*the development of research tools and usually involves using qualitative methods for the initial exploratory phase*' of the research. Mason (2006) argues that one main rationale for using mixed methods is to access multiple perspectives and dimensions since lived realities are multi-dimensional. Tapio *et al* (2011) look at the use of policy Delphi for scenario formation, and pose more fundamental questions about the combining of qualitative and quantitative information. Also, Meyrick(2003) argues that with respect to qualitative or quantitative approaches, the Delphi method can incorporate elements of both types of techniques. It is with this perspective that the empirical Delphi survey has been selected as an appropriate research tool in the initial phase of this research to explore the multi-faceted and multi-disciplinary dimensions of the present research problem. Unlike what the

literature review was thoroughly unable to do, the Delphi exercise will hear first-hand from experts and stakeholders on matters related to the research aim and objectives. In this respect, the Delphi study is used to build consensus among a panel of LNG ports and RM experts on a number of observations, hypotheses and prepositions raised from the earlier descriptive and explanatory stage of the study. In conformity with Rowe and Wright's earlier idea, the results of the Delphi exercise are considered just as a first step in the enquiry process which will be further interrogated and evaluated in phase II of the research through a quantitative empirical study. This is believed to further enhance and strengthen the outcome of the Delphi exercise.

With respect to the Delphi survey, a sample of LNG terminal operations and risk experts are consulted as part of this empirical study in an attempt to explore how safety and security disciplines of the LNG port SC organisations interface to solve common risk issues and what kind of work relationship prevails among them. Furthermore, the aim from the Delphi exercise is to explore the RA and management methods and practices in LNG Port SCs and to characterise the role of ports within the LNG SC. Particular focus is made on the relationships and interfaces between safety and security risks and the issues posed by such interfaces, as well as the role of port authorities and port stakeholders in the management of such interfaces to enable a coordinated and cost effective management of safety and security risks. Subsequently, the Delphi consensus among the panel of experts was reached after two rounds of questionnaires and its commonly agreed results (statements) were brought forward and used as hypotheses to be further tested through an online quantitative study using

online survey among a larger panel of international experts from the LNG ports and RM community.

As stated by Rowe and Wright (2011, p.1488) '*Using Delphi as only part of a wider process (with qualitative and quantitative components) may well prove a means to enhance its utility*'. This integration of qualitative and quantitative approaches and their sequences is believed to be useful since the first method enabled exploration of a wide range of issues in connection with the research problem which could not be seen during the initial explanatory and conceptual phase, and assisted in providing first confirmation of the observations made during the initial stage. Meanwhile, the quantitative methods were deployed to test and validate the Delphi findings.

Therefore, the Delphi survey research was triangulated with a quantitative survey study using factor analysis and other statistical techniques of the SPSS 20 package. Triangulation and mixed methods are used here in line with Bazeley and Kemp's (2011) rationale for providing a more complete picture by understanding causal effects and processes as well as a means to initiate a new understanding of the study subject, since the dialectical approach, created as a result of mixing methods and approaches, promotes further exploration and understanding. Also, Robson (2002) sees triangulation as the use of multiple sources to enhance the rigour of the research and to help counter all of the threats to validity.

This exercise will assist in reviewing and confirming the role of ports and maritime networks as focal points within the LNG SC and in assessing their capacity to lead integrated collaborative mitigation strategies and anti-terrorist

measures. The outcome of the quantitative study forms the basis for the high level LNG RM conceptual model to be proposed. For more details, the reader is referred to chapter 7.

In preparing for the conceptual model, chapter eight starts with a summary of the main findings of the quantitative study and introduces the use of Systems Thinking Approach (STA), more specifically the Soft Systems Method (SSM), as an appropriate method for this research to build the conceptual model for LNG ports SC RM. The choice of SSM is justified by the fact that this methodology provides an interesting analytical framework to deal with complex management problems such as the case of our research problem. According to Greswell (1998, p.112), Soft Systems Thinking (SST) in contrast to Hard Systems Thinking (HST), views the world as problematic and an ill-defined situation which can be tackled using certain systemic constructs to aid learning and understanding. SST was developed as an alternative solution to the problem of using HST's reductionist approach to tackle messy and ill structured problems which are predominant noticed in organisations and described as a process of enquiry and learning (Checkland, 1990). The SST approach has been developed by several authors notably Checkland (1981), Wilson (1984) and Ackoff (1981).

The proposed conceptual model has been developed according to the above soft systems approach. This approach has the merit to look at '*real-world problem*' as part of an overall system. Our earlier analysis demonstrated that due to their interfaces and shared impacts, safety and security risks management needs to be approached as part of a unified RM system which is

actually an integral part of the overall port management system. That is why the Soft Systems Approach has been selected as an appropriate analytical tool to assist in building the conceptual model for the real-world problem of LNG ports SC RM, to depict its components, its main actors and their relationships. The model has been constructed using Checkland's seven interconnected stages which form a learning loop (Checkland, 1999). The proposed conceptual model allows an optimal restructuring and re-organisation of LNG ports and marine terminals in the area of safety and security RM, leading to an integrated, holistic and coordinated management of safety, security, environment and quality risks and threats.

The research outcomes will need to prove its relevance to the situations being observed and explored and any proposal to be put forward will need to be justifiable and attainable (Dinwoodie and Xu, 2008). For these reasons, the proposed model has been put under the rigour of both the theoretical and practical scrutiny and tested through a focus group discussion with professionals and experts representing the main LNG port SC organisations led by the port authority. One of the main aims of this study was to tackle a real-world problem and arrive at a practical and applicable solution. Therefore, the process of enquiry started with the observation of the problem of RM from the actual reality of LNG ports and ended by contrasting the findings with the practical real-world to evaluate and justify its applicability.

The focus group consultation is performed with the participation of professionals from two major industrial ports in Qatar: the LNG hub port of Ras-Laffan which is the largest and busiest LNG exporting facility in the world and the multi-purpose hydrocarbon-based port of Mesaieed. A sample of six experts

representing the safety, security and ports logistics operations and management departments from those ports was consulted during all stages of the research, from inception of the enquiry until the testing stage of the conceptual model. This testing and evaluation step provided valuable feedback from the industry and enabled further refinement of the model.

## **6.5 CONCLUSION**

As discussed above, a mixed method approach has been applied to the research problem of RM in LNG ports SC with triangulation as a means to enhance the rigour of the research and provide a complete picture of the issues under study. Although the research approach used both qualitative and quantitative methods, it has adopted an overall predominately qualitative methodology which incorporated both inductive and deductive analyses. On top of the quantitative method used, one characteristic of the methodology adopted is its use of a variety of qualitative methods and techniques such as a survey in the form of a Delphi study, Soft System Methodology (SSM) and a focus group consultation.

The next chapter will explore the views and ideas of stakeholders and experts, on existing practices and future prospects of integrated safety and security risks management in LNG ports through the empirical study starting with the Delphi survey exercise.

## CHAPTER 7

### QUALITATIVE AND QUANTITATIVE STUDIES DATA COLLECTION AND DATA ANALYSIS

#### 7.1 THE EMPIRICAL STUDY- DELPHI STUDY ROUND ONE

##### 7.1.1 Introduction

As explained in the research design, it has been decided to use the Delphi technique for qualitative data collection with a web based questionnaire as a survey tool.

As stated by Linstone and Turoff (2002), the Delphi technique may be characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. For Sullivan and Claycombe (1977), Delphi is a systematic procedure for soliciting and organising expert opinion about the future.

Some studies (Ariel, 1989; Fadda, 1997; Yong *et al.*, 1989) have employed the Delphi technique to predict likely events in the future; others (Hwang, 2004; Cottam *et al.*, 2003; Anderson, Rungtusanathan, & Schroeder, 1994; Meier *et al.*, 1998) used the technique to investigate or explore a current situation. Linstone and Turoff (2002) as well as Okoli and Pawlowski (2004) suggest that the Delphi technique is suitable as long as it has the basic characteristics of expert panel members, anonymity of response, use of a series of questionnaires (iteration), and feedback.

For the purpose of this research, this technique has been selected due to its suitability and practicality to such a complex interdisciplinary subject of SCRM as applied to ports and marine terminals handling LNG commodity.

The following describes the Delphi approach applied and the results of the first round of the Delphi survey undertaken to collect and analyse qualitative data from a Delphi panel in LNG Ports SCs.

It is attempted here to look at the best way to have LNG port SC member organisations looking at the issues of safety and security in a more integrative and holistic way when it comes to the assessment and management of risks. Therefore, it is important to investigate available options to have a cohesive and unified RM approach in LNG port SCs. This will require a certain consensus among LNG port SC members on the importance and benefits of such an approach both on theoretical as well as on practical levels. The following section discusses the design, administration and panel respondents of the Delphi survey questionnaire.

### **7.1.2 Delphi questionnaire design and administration**

As there is no fixed guideline or rule pertaining to the number of statements which should be deployed in the first-round questionnaire, the first round questionnaire of this Delphi study was drawn deliberately from an in-depth literature review performed previously.

Since the research subject attempts to investigate the relationships, the opportunities for standardized and coordinated management options for safety and security risks in LNG ports SC and how the two disciplines of risk could



benefit from the tremendous advancement achieved in quality management discipline, it was decided to frame the questionnaire into four parts:

- Part one deals with questions related to security RA and management.
- Part two relates to safety types of risk.
- Part three investigates the relationships between safety and security, and;
- Part four questions how safety and security risk management could benefit from the principle and approach of Quality management, more specifically the Total Quality Management (TQM) approach which indeed is considered effective in addressing quality risks.

There are 26 statements in the first round of this research. Each statement has options of 'agree', 'disagree' and unable to comment'. In the case of disagreement, the respondent is asked to explain the foundation of its disagreement. An example (statement number twenty three of this first round Delphi survey) is given below:

1. Safety and security RA and management need to take advantage of the quality revolution, especially the *Total Quality Management (TQM) Principle*.

Agree?

Disagree?

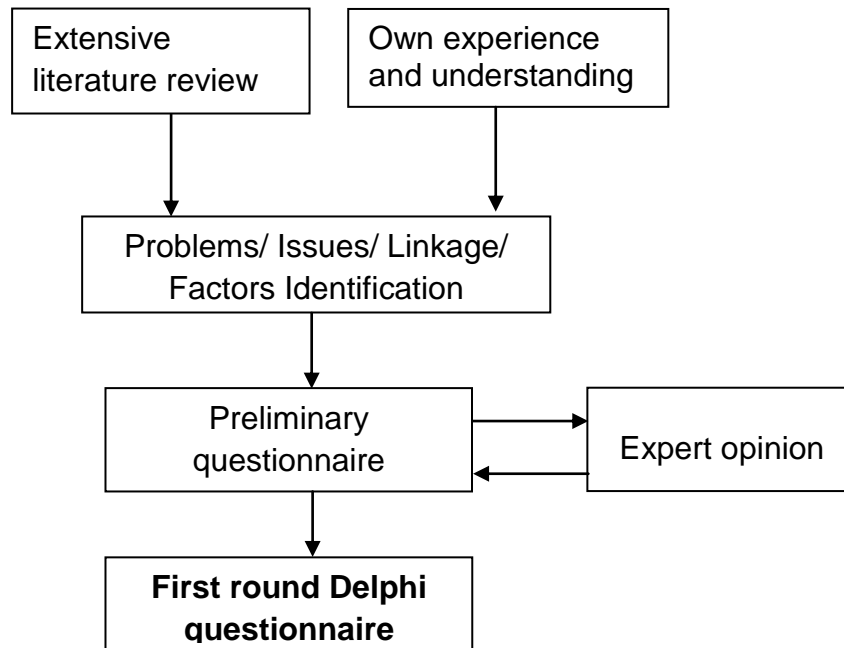
Unable to comment?

If your disagree, please comment as to why

.....  
.....

## Formulation of questionnaire for the Delphi First Round

Figure 7.1 Formulation of questionnaire for first round Delphi



Source: *The Author*

Figure 7.1 shows the formulation of the first round Delphi questionnaire. An in-depth literature review resulted in a preliminary questionnaire, which was pre-tested in collaboration with prominent LNG port experts during a professional forum held in 2010 in Doha- State of Qatar. The author accepted the opportunity during a SIGTTO (The Society for International Gas Tanker and Terminal Operators) regional meeting held in the State of Qatar to discuss research assumptions and observations with LNG experts from the Middle East. Those experts are managers and leaders of LNG Terminals, LNG shipping companies, LNG port authorities and LNG RM specialists.

In light of expert discussions and subsequent comments, the first round Delphi questionnaire was finalised.

Based on the comments from experts, the number of statements for the first round Delphi survey questionnaire is set to 26. Since the internet provides easy and efficient administration of surveys, it was decided to use a web-based survey by loading the questionnaire already finalised on the Survey Monkey website. Invitation to participants to take part to the online survey was done by email messages sent individually to respondents. The email message reproduced the invitation letter with a deadline for responses and included the web link to the survey posted on Survey Monkey website.

The questionnaire for the first round survey with the forwarding letter is attached in Appendix 4.

### **Panel and Process of the Delphi Study**

The selection of an appropriate panel is very important for a successful Delphi study. The panel members are chosen so that they have a deep interest in the issue under study, and can share their experience and expertise.

Since the topic's main objective is to investigate safety and security risks assessment and management in the context of LNG port SC, it was necessary to involve RM experts as much as possible from all LNG port SC organisations. In this context, the following types of professional organisations have been consulted in this survey:

- LNG Port logistics managers
- LNG Shipping lines
- LNG Security departments
- LNG HSE departments

- LNG terminal managers
- LNG port authorities-Harbour Master
- LNG Port Development sections
- Natural Gas upstream organizations
- Quality management specialists
- Academia, specialist in RM

A list of 40 potential participants was prepared with detailed contact numbers and email addresses. The author used his knowledge of the LNG port sector to recruit potential experts in the LNG SC to obtain their permission to participate in the online survey.

Before sending email invitations, most respondents were contacted by phone to request their approval and explain to them the subject under study and the importance of their expert opinion for the study, as well as to convince them to allocate part of their valuable time to complete the survey.

Potential respondents were canvassed in initial phone conversation and if they requested, the questionnaire was sent by email. They were asked to reply within two weeks and then were reminded again (up to 3 email reminders and at least one telephone call per participant). These efforts yielded 50% response rate and a panel size of 20 respondents. This response rate is encouraging because many Delphi surveys experienced much lower participation rate.

**Table 7.1 Structure of the Delphi panel in Round One**

| <b>Category of panel members</b>   | <b>Number consulted</b> | <b>Number responded</b> |
|------------------------------------|-------------------------|-------------------------|
| LNG Port logistics and SC managers | 4                       | 4                       |
| LNG Shipping lines                 | 2                       | 1                       |
| LNG Port Security departments      | 4                       | 1                       |
| LNG HSE Department                 | 6                       | 4                       |
| LNG terminal managers              | 2                       | 1                       |
| LNG port authority                 | 6                       | 4                       |
| Natural Gas upstream organizations | 3                       | 1                       |
| Quality management specialists     | 4                       | 1                       |
| Academia, specialists in RM        | 8                       | 3                       |
| <b>Totals</b>                      | <b>40 (100%)</b>        | <b>20 (50%)</b>         |

**Source:** *The author*

The panel broadly represented the three levels of management: five (5) from top management (responsible for strategic management), nine (9) from middle management (responsible for management of a functional unit or department) and six (6) from junior management (responsible for operational or supervisory works).

### **7.1.3 Results of the first round Delphi survey**

There are 26 statements in the First Round Delphi Survey; all participants responded to all questions, except for two questions (Q19 and Q21), which

were responded to by nineteen panel members. Two panel members each one skipped one question.

Detailed results of the first round can be found in Appendix 4.

The following formula for Average Per cent of Majority Opinions (APMO) is then applied.

**APMO** = (Aggregate of Majority Agreements + Aggregate of Majority Disagreements)/

Total Opinion expressed including UCs X 100

Thus, **APMO = 265/ 516\* 100**

**= 51.36 %**

According to the APMO calculated, the 'cut-off' point for achieving consensus is 51 %, any statement having 51 % or more opinion is said to have supported the hypothesis (or assumption). Statements having less than 51 % opinion are included in the second round questionnaire to determine the importance of not having consensus among the panel members. A higher level of consensus on any statement means more certainty, reliability and acceptability on the issue.

❖ **Statements having 51% + consensus: 16 (61.5%)**

❖ **Statements having less than 51%% consensus: 10 (38.5%)**

As indicated above, 16 statements out of 26 achieved consensus in this first round survey, whereas 10 did not get consensus which will form the basis for the second round Delphi survey. Each second round Delphi question will be

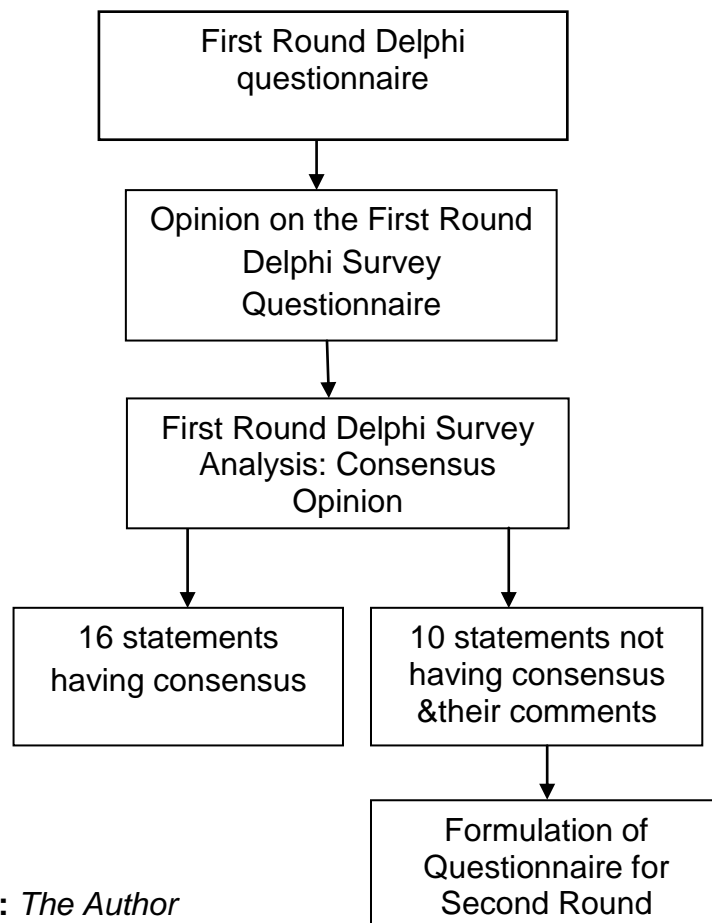
formulated on the basis of comments made by respondents during the first round survey.

Appendices F and G show all comments made by respondents to questions having achieved less than 51% consensus. Comments are reproduced as expressed by respondents without rewording.

## **7.2 DELPHI STUDY SECOND ROUND**

As stated earlier, the second round questionnaire of the Delphi study was generated from the comments of the respondent's panel on the original ten statements which did not achieve consensus. These comments were made into 34 statements which formed the second round Delphi survey (Appendix 5)

**Figure 7.2 Formulation of questionnaire for second round Delphi**



**Source:** *The Author*

It was mentioned already that 20 panel members, who participated to the first round survey, were sent the questionnaire for the second round, fourteen (14) of whom have responded (*70% participation*). A comparison of participants for the first and second round survey is provided in table 7.2.



**Table 7.2 Structure of the Delphi panel in the two rounds of Delphi**

| <b>Category of panel member</b>    | <b>Participants (%) in 1<sup>st</sup> round</b> | <b>Participants (%) in 2<sup>nd</sup> round</b> |
|------------------------------------|-------------------------------------------------|-------------------------------------------------|
| LNG Port logistics and SC managers | 4                                               | 3                                               |
| LNG Shipping lines                 | 1                                               | 1                                               |
| LNG Port Security departments      | 1                                               | 1                                               |
| LNG HSE Department                 | 4                                               | 3                                               |
| LNG terminal managers              | 1                                               | 1                                               |
| LNG port authority                 | 4                                               | 2                                               |
| Natural Gas upstream organizations | 1                                               | 1                                               |
| Quality management specialists     | 1                                               | 0                                               |
| Academia, specialists in RM        | 3                                               | 2                                               |
| <b>Total respondents</b>           | <b>20(100%)</b>                                 | <b>14(70%)</b>                                  |

*Source: The author*

### **7.2.1 Result of the Second Round Delphi Survey**

There are 34 statements (against the ten original statements in the first round which did not receive consensus) in the second round Delphi survey; and fourteen panel members have provided opinions/ comments on every statement, out of the 20 respondents consulted.

It is worth mentioning that among the six participants who dropped out in the second round have changed their respective positions and

companies and therefore were unapproachable by email since the only communication medium with them was through company email. The other four participants seem to be extremely busy during the duration of the survey. Three of them informed me by email that they are away from their countries and they will come back to me afterward to respond to the survey, however after chasing them for more than two weeks, they had not responded.

Finally, 14 out of 20 participants responded, which is a 70% participation rate.

The same APMO formula was applied. Thus **APMO =  $\frac{273+0}{446} \times 100 = 61.2\% \approx 61\%$** .

Considering the 61% Average Per cent of Majority Opinions (APMO), 23 statements achieved strong consensus with a score of 61% and above; and 11 statements got a score less than 61%.

**Table 7.3 Second round consensus achieved**

| <b>Consensus level</b>  | <b>Consensus (score %) achieved</b> |
|-------------------------|-------------------------------------|
| Strong Consensus >61%   | <b>23</b>                           |
| No Consensus < 61%      | <b>11</b>                           |
| <b>Total statements</b> | <b>34</b>                           |

**Source:** *the author*

As per the second round survey results, every original statement has got at least one second round statement/ comment having achieved consensus.

Therefore, consensus among respondents is achieved. Detailed results of the 34 statements of the second round Delphi survey are shown in Appendix 5.

## **7.2.2 Results of the Two Rounds of Delphi**

The findings of the survey will be discussed under the following conceptual dimensions or categories:

- LNG port SC security
- LNG port SC safety
- LNG port SC safety and security
- LNG port SC RM and quality

Under the above categories, combined results from the two rounds of the Delphi study are presented here.

### **7.2.2.1 LNG port SC security**

The panellists strongly agreed that security risks are becoming as important as safety risks and need to be integrated in the overall risk portfolio faced by LNG ports SCs (Statement 1). This is in conformity with most security literature which highlighted the increased security threats since 2001 and their widespread impact on international SCs. Many security specialists stressed the need to seriously consider security risks and address them in an appropriate manner to avoid SC disruptions.

Also, these results confirmed the strategic role of LNG ports as central nodes within the overall LNG SC (Statement 2), since they bring together multiple

logistics, port and maritime related organisations and stakeholders, functions, roles, processes and flows.

Responding to the statement 'LNG Ports are sufficiently protected against security threats' most participants agreed that LNG ports, due to their sheer size and accessibility both onshore and offshore, cannot be considered sufficiently protected against terrorist risks.

Also, this statement cannot be generalized to all LNG ports and terminals, since these facilities differ in the degree of protection worldwide. In this respect, respondents stipulated that much work and international cooperation is required to improve security controls.

Respondents also agreed that current international security legal framework is an advantage; however, ISPS and similar codes such as CT-PAT only require minimum level of protection. In certain environments these may not be sufficient to ensure adequate protection against security threats. Two issues of concern were identified in this regards:

The implementation of security frameworks may need to be integrated from a holistic approach to avoid discrepancies and redundancy in the security system.

Current frameworks are still treating individual facilities in relative isolation; therefore a coordinated approach needs to be applied to ensure resilience within the whole SC.

Finally, it was agreed that RM across various disciplines such as security and safety takes place in isolation and little to no coordination exists between security and safety managements in the LNG Port SC. Furthermore, there is no

official structure within the LNG Port SCs which enables such coordination between security and safety RM.

#### **7.2.2.2 LNG port SC safety**

Responding to statements around the LNG Port SC safety system, the panellists confirmed the importance for each individual port SC member to ensure safety of its own operations (Statement 10.4); however, it was also argued that the safety of the whole LNG Port SC is a joint responsibility which should be coordinated and ensured by the port authority (Statement 10.3). Therefore, the Port authority is ultimately responsible for the overall safety of LNG facilities and must ensure that LNG facilities within the port perimeter are properly risk managed. Regarding the safety framework, most respondents agreed to the need for a standard safety framework to address both LNG shipping and port networks (Statement 13) and this will assist in better addressing the ship/ port interface (Statement 14). In this regards, respondents believe that the IMO's FSA, as a safety framework initially devised for shipping, should be extended to address port safety as well (Statement 12).

#### **7.2.2.3 LNG port SC safety and security**

In this category, respondents agreed on the benefits of having a coordinated RM integrating both safety and security risks in LNG port SC, since they believe that safety and security are closely related issues and may yield better outcome if managed under a single entity and using a standard framework (Statements 15, 16 and 17). Meanwhile, they argued that safety and security are two different disciplines which have different requirements in terms of RA, therefore

their risk assessment methodologies need to be different to cope with their specificities and requirements (Statements 18.1, 18.2 and 18.3).

From the above, respondents concluded that although safety and security risks in LNG port SCs are two disciplines that may have different requirements, their management should be coordinated within the framework of a holistic RM approach to the benefit of a resilient and cost effective RM (statement 21).

#### **7.2.2.4 LNG port SC RM and quality**

It is important to note that respondents anonymously agreed on all five statements of this category. Participants accepted that there is a similitude between Port SC safety, security and quality management, mainly in terms of assessment and management approaches. (Statement 22). Since the quality discipline, especially the TQM principle, has introduced a revolution in terms of quality control and quality assurance methods and practices, respondents agreed that safety and security managements need to take advantage and learn from the quality approach in addressing risks and vulnerabilities.

Finally, it was unanimously accepted that LNG Port SCs need to adopt an integrated risk assessment and management approach based on the principles of TQM and capable of dealing more efficiently with the three types of risks, safety, security and quality (Statement 26).

### **7.3 QUANTITATIVE STUDY- SURVEY ANALYSIS USING SPSS**

#### **7.3.1 Introduction**

Considering the strengths and weaknesses of the qualitative and quantitative methods, a triangulation technique, which includes in-depth literature review,

two rounds of Delphi surveys and quantitative techniques such as factor analysis, was adopted for this research. Having first completed an extensive literature review as well as two rounds online Delphi, the next step is to undertake a quantitative survey which is then factor analysed.

On the other hand, an online survey, supported by email messages, is chosen for data collection, primarily to achieve higher speed and reliability as well as lower cost.

The adoption of a quantitative study through an online survey method is selected in the absence of reliable historical data on safety and security events and near misses from world LNG ports and marine terminals. While data on safety accidents is available and may be obtained from recognized HSE databases, sufficient and reliable statistics on security incidents is difficult to obtain from LNG port terminals since it is generally considered sensitive and highly restricted.

Therefore, an online survey carried out among a sample of representative panel experts was chosen to achieve cost effective research in terms of time and budget as well as higher data reliability. This data is then quantitatively analysed using factor analysis as well as reliability and validity tests such as Likert chi-square. The objective is to test and validate the hypothesis and results obtained so far from the two rounds of Delphi and to a lesser extent the insights and assumptions derived from the extensive literature review (Chapter 3).

### 7.3.2 Sample size and sample selection strategy

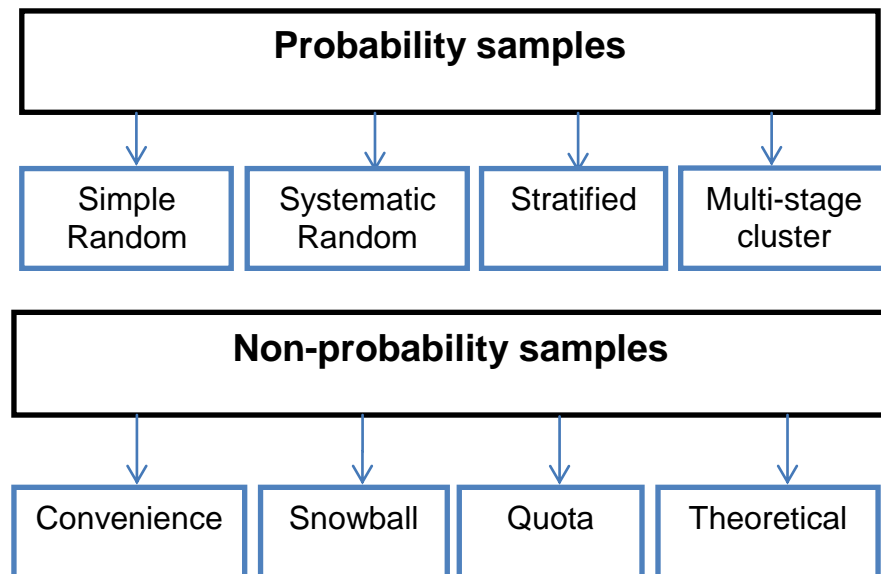
Usually, collecting data from a large and infinite population is a difficult task which requires both long lead time and high cost. Marques de Sa, (2007) asserted that 'population data is usually not available for study, since most often it is either infinite or finite but very costly to collect'. Similarly, Corbetta (2003) stated that research cannot be carried out on a social reality in its entirety. Therefore, the researcher has to draw a subset or sample from the population to have a look at and extract data from. This population subset or sample shall be representative of the studied population- '*that it represents a small image of it*' (Marques de Sa, 2007). In a survey, a sample consists of those members of the population who are actually consulted.

As pointed out by Marques de Sa, (2007), a representative sample should not mean having a composition similar to the composition of the population, rather this sample should be drawn randomly.

Barreiro and Albandoz, (2011) distinguish between probability sample and non-probability (haphazard) sample. For them '*a random choice is by no means a choice without rules*'. Therefore, a random sampling is inherently a probability sampling which follows certain criteria and procedure that enable the results obtained to be generalized to the whole population. According to Ladner (2008), probability methods include random sampling, systematic sampling, stratified and multi-stage cluster sampling. In non-probability sampling, subjects are picked up from the population in a non-random manner. These include convenience sampling, theoretical sampling, quota sampling, and snowball sampling.



**Figure 7.3 Type of samples**



**Source:** (Ladner, 2008)

Sampling a representative panel of respondents from the international population of managers and experts in the area of safety and security RM in the LNG ports SCs is a crucial exercise to the validity and generalisability of the research results. For this study, a stratified sampling technique has been selected to recruit experts for the online survey (Attached as Appendix 4). The first step was to decide about the groups or strata of the panel experts. The following criteria were used to define the panel groups:

- The groups must cover all disciplines and specialties with direct and indirect impact on RM in the LNG ports SC.
- Members of each group shall be homogenous and belonging to a relevant LNG port discipline.

The criteria for selecting respondents for all groups are:

- ❖ Individual respondents must have sufficient expertise in their respective areas; not less than 10 years of experience for managers of LNG ports and terminal operators, as well as for consultants, HSE and security executives.
- ❖ Individual respondents shall have experience in LNG ports and terminal operations.

Furthermore, individual expert respondents were chosen from different parts of the world with experiences spanning the Middle East, Europe, south East Asia and the Americas.

For this research, most of the panel respondents were randomly selected from experts satisfying the above criteria who participated, with the author, to the international LNG Outlook seminar held in Dubai in May 2012.

**Table 7.4 Structure of the panel respondents**

| <b>No</b> | <b>Category of panel members</b>                    | <b>Number consulted</b> | <b>Number Responded</b> |
|-----------|-----------------------------------------------------|-------------------------|-------------------------|
| <b>1</b>  | <i>LNG port logistics and LNG terminal managers</i> | 20                      | 13                      |
| <b>2</b>  | <i>LNG Shipping Managers</i>                        | 20                      | 8                       |
| <b>3</b>  | <i>LNG port security specialists</i>                | 20                      | 5                       |
| <b>4</b>  | <i>LNG HSE specialists</i>                          | 20                      | 6                       |
| <b>5</b>  | <i>LNG quality specialists</i>                      | 20                      | 4                       |
| <b>6</b>  | <i>Academia and consultants with LNG knowledge</i>  | 50                      | 26                      |
|           | <b>Total</b>                                        | <b>150 (100%)</b>       | <b>62 (41%)</b>         |

**Source:** the author

Table 7.4 shows the structure of the panel respondents comprising the six professional categories deemed of international expertise covering the research subject. Six professional groups were selected to provide expert opinion on the

safety and security risks of LNG ports SCs. These groups believed to cover all disciplines and specialties having direct or indirect involvement in the management of safety and security risks in LNG ports. Thus stratified sampling is the technique selected for the purpose of this survey.

As asserted by Marshal & Rossam (1999), the persons surveyed are managers and leaders in their respective organisations and therefore, they are highly influential, well informed and can provide expert opinion about the survey research subject. This is thus an elite interviewing method proven to be highly beneficial as it strengthens the reliability and validity of the data.

From table 7.4 above, a total of 150 questionnaires were emailed and 62 responses were received; a response rate of 41.33% is achieved. Such response rate remains acceptable by the study requirements and can be explained by the following factors:

First, it is noticed that the consultation period coincided with the summer holidays (July and August). Since most participants were invited through their business emails, many did not respond back, most probably because they were busy or they usually don't check their business emails during that period.

Second, out of 20 port security professionals initially consulted, only 5 have responded. It is noticed that ports and terminal security managers are reluctant to provide opinion on surveys addressing security issues, probably because, from their perspective, such information is considered security sensitive. The consultation period ended on 2nd September 2012 and late replies were not accepted.

### **7.3.3 Data analysis**

The objective of the present analysis is to quantitatively test and validate the Delphi results according to the data collected as a result of the survey. Such data should be consistent with the idea that the retained variables measure four different constructs or factors.

First, a Principal Axis Factoring Analysis is conducted. This analysis attempted to create factors, which are linear combinations of the variables (the 27 items on the questionnaire) that estimate the “latent variables” or constructs that the instrument is measuring. The Principal Axis Factoring analysis method of creating factors attempts to create them in such a way that alpha (reliability) is maximized. Factors can be created as much as there are variables, but that is not the intention. Since it is claimed earlier that this instrument measures four constructs, SPSS is asked to create only four factors. More details on SPSS results can be found in Appendix 6.

### **7.3.4 Methodology**

All data in the returned questionnaires (responses) was manually input into SPSS.

Report queries were then written to enable the data to be extracted and analysed. All responses included multiple choices. This consultation exercise was not a referendum or a vote, its purpose was to seek the opinion of a panel of experts in the LNG Ports SCs, mainly on safety and security risk assessment and management methods, approaches and practices. The main objective of such exercise is to test and validate the findings of the Delphi surveys.

### 7.3.5 Results

**Table 7.5 Frequency results**

| Statements | % Agree & strongly Agree (A) | % Disagree & strongly disagree (D) | % Neutral (N) | Final result |
|------------|------------------------------|------------------------------------|---------------|--------------|
| Q2         | 82.5                         | -                                  | -             | Agree        |
| Q3         | 87.1                         | -                                  | -             | Agree        |
| Q4         | 56.5                         | 8.1                                | 35.5          | Agree        |
| Q5         | 72.6                         | -                                  | -             | Agree        |
| Q6         | 71.0                         | -                                  | -             | Agree        |
| Q7         | 54.9                         | 25.8                               | 19.4          | Agree        |
| Q8         | 61.3                         | -                                  | 29.0          | Agree        |
| Q9         | 61.3                         | -                                  | 32.3          | Agree        |
| Q10        | 80.6                         | -                                  | -             | Agree        |
| Q11        | 66.1                         | -                                  | -             | Agree        |
| Q12        | 67.8                         | -                                  | 29.0          | Agree        |
| Q13        | 92.0                         | -                                  | 6.5           | Agree        |
| Q14        | 35.5                         | 22.6                               | 29.00         | Agree        |
| Q15        | 27.4                         | 19.3                               | 53.2          | Neutral      |
| Q16        | 48.4                         | 22.6                               | 29            | Agree        |
| Q17        | 77.4                         | -                                  | 22.6          | Agree        |
| Q18        | 35.6                         | 8.1                                | 56.5          | Neutral      |
| Q19        | 77.4                         | -                                  | 19.4          | Agree        |
| Q20        | 85.5                         | -                                  | 14.5          | Agree        |
| Q21        | 58.0                         | -                                  | 32.2          | Agree        |
| Q22        | 61.3                         | -                                  | 21.0          | Agree        |
| Q23        | 75.8                         | -                                  | 21.0          | Agree        |
| Q24        | 82.3                         | -                                  | 16.1          | Agree        |
| Q25        | 79.0                         | -                                  | 17.7          | Agree        |
| Q26        | 67.7                         | -                                  | 25.8          | Agree        |
| Q27        | 82.3                         | -                                  | 14.5          | Agree        |
| Q28        | 80.7                         | -                                  | 16.1          | Agree        |

**Source:** the author

The final result for each question should be either 'Agree', 'Disagree' or 'Neutral' , following the highest percentage score of responses achieved.

### **a) Factor Analysis**

A factor analysis is defined as a method for simplifying complex sets of data (Kline, 1994). A factor analysis addresses the structure of the inter-relationship or correlation of a factor among a large number of variables by defining a set of common underlying dimensions (Hair et al., 1995). A factor analysis technique helps achieving a number of objectives:

1. It can be used to assess or to identify the structure and degree of relationships among a set of variables, which are tapping one concept (correlation between variables).
2. A factor analysis may be applied to a correlation matrix of an individual respondent based on their characteristics.
3. A study may have a large number of variables and issues and a factor analysis can be applied to reduce a large set of variables to a much smaller set of variables.
4. The use of factor analysis is to condense a large number of variables into a more limited number of factors.
5. A factor analysis also tests the reliability of data.
6. A factor analysis can be employed to create an entirely new set of variables, smaller in number, to replace the original set of variables for inclusion in a subsequent technique.

Earlier in this chapter, four (4) dimensions or conceptual categories of RM are found in the LNG Ports SC, but more than fifty issues or variables are obtained

as a result of the two rounds of Delphi study undertaken. Thus, the research applies factor analysis to examine whether the issues could be condensed to a smaller number of dimensions.

According to Cronbach (1951), the two most widely used forms of factor analysis are principal- component analysis and principal- factor analysis (in SPSS named as principal-axis factoring). A factor analysis is mainly concerned with describing the variation (or variance), which is shared by the scores of respondents on the variables. This is called common variance. A variable may have specific variance, which is unique and not shared with other variables and thus obviously is distinguished from the common variance. There may be another type of variance, error variance, which is the variation due to fluctuation or error in measuring something. But a factor analysis cannot distinguish error and specific variance. Thus these two variations combine to form unique variance. So, total variance = common variance + unique variance. In a principal-component analysis all (both common and unique) variances of a score or variable are analysed whereas in a principal-axis analysis only a common variance is analysed. Therefore, a principal component analysis is considered perfect, reliable and without error. For the sake of the present study, the following steps will be followed for conducting survey analysis:

- Extraction of factors
- Calculate a correlation matrix of all variables
- Rotation of factors to create a more understandable factor structure
- Conduct a reliability and validity test

- Testing of hypotheses
- Interpretation of results

### **Extraction of factors**

The prime objective of factor extraction is to make an initial decision about the number of factors underlying a set of measured variables. The first stage involves extracting factors from a correlation matrix to get the number of factors.

Principal component analysis is used to facilitate these decisions (Green *et al.*, 1997). The first step of factor analysis through SPSS is to select the combinations of variables whose shared correlation explains the greatest amount of total variance. The first extracted factor of a principal components analysis (unrotated solution) is termed factor 1. Then factor 2 that is the combination of variables that explains the greatest amount of the variance remaining (after factor 1 extraction). This process continues until as many factors have been extracted as there are variables. There are mainly two criteria to decide which factor to include and which to exclude. The first criterion, known as Kaiser's criterion, is to select those factors having eigenvalue, the variability of a factor, greater than one. The underlying reason of setting this criterion is that the total variance of any variable has been set (standardised) at one. In other words the factors having eigenvalue less than one (which explains less variance) are excluded. But in large matrices this greatly overestimates the number of factors. The relative magnitude of eigenvalue has to be considered and the researcher should have an initial decision about the number of factors based on the a priori conceptual beliefs (hypotheses) about the number of underlying dimensions. In this study, four conceptual dimensions are retained



which are used throughout the previous Delphi analysis. The same set of categories will continue to be considered and their correlations with the 27 variables forming the survey will be further checked.

Therefore, we requested SPSS to create only four factors. The communalities in the extracted column tell us how much variance each variable has in common with the four factors. Items 2, 5, 7, 11, 14, 15, 16, 22 and 28 were found to have disturbingly low values. If a variable does not share much variance with the other variables or with the retained factors, it is unlikely to be useful in defining a factor. By checking the above nine (9) variables, it was found that they have no impact on the validity of the factors; therefore, they were simply excluded from the analysis. Consequently, 18 variables are left which are to form the four factors or conceptual categories.

The factor matrix gives us the loadings that are the correlations between each variable and each factor. Note that items 3, 4 and 6 are positively correlated with Factor 1(part1) and items 8 through 10 are positively correlated with Factor 2 (part2) and items 12, 13, and items 17 through 21 are positively correlated with Factor 3 (part3), and items 23 through 27 are positively correlated with Factor 4 (part4).

### Rotated Factor Matrix

|     | Factors     |             |             |             |
|-----|-------------|-------------|-------------|-------------|
|     | 1           | 2           | 3           | 4           |
| Q6  | <b>.681</b> | .396        | .298        | .333        |
| Q3  | <b>.471</b> | .121        | .065        | .116        |
| Q4  | <b>.422</b> | .008        | -.013-      | .043        |
| Q25 | .551        | <b>.575</b> | .312        | .191        |
| Q27 | .118        | <b>.572</b> | -.124-      | .270        |
| Q26 | .546        | <b>.549</b> | .121        | .355        |
| Q24 | .538        | <b>.546</b> | .154        | -.033-      |
| Q23 | .442        | <b>.487</b> | .172        | .102        |
| Q20 | -.097-      | .537        | <b>.622</b> | -.073-      |
| Q17 | .200        | .150        | <b>.590</b> | .178        |
| Q12 | .501        | .019        | <b>.526</b> | .349        |
| Q19 | .004        | .375        | <b>.467</b> | .064        |
| Q18 | -.087-      | -.091-      | <b>.445</b> | -.106-      |
| Q21 | .241        | .180        | <b>.437</b> | .058        |
| Q13 | .225        | -.043-      | <b>.435</b> | .085        |
| Q10 | -.050-      | .181        | .329        | <b>.706</b> |
| Q9  | .213        | .097        | -.007-      | <b>.585</b> |
| Q8  | .111        | .041        | -.035-      | <b>.454</b> |

Extraction Method: Unweighted Least Squares.

Rotation Method: Varimax with Kaiser

Normalization.

Rotation converged in 9 iterations.

### b) Reliability Analysis

Cronbach's alpha (Cronbach, 1951) is a measure of reliability. More specifically, alpha is a lower bound for the true reliability of the survey.

Mathematically, reliability is defined as the proportion of the variability in the responses to the survey that is the result of differences in respondents' opinions. That is, answers to a reliable survey will differ because respondents have different opinions, not because the survey is confusing or has multiple interpretations. The computation of Cronbach's alpha is based on the number of items on the survey ( $k$ ) and the ratio of the average inter-item covariance to the average item variance (Cronbach, 1951).

$$\alpha = k \frac{\text{cov/var}}{k-1} \frac{1}{\text{cov/var}}$$

Under the assumption that the item variances are all equal, this ratio simplifies to the average inter-item correlation, and the result is known as the standardized item alpha (or Spearman-Brown stepped-up reliability coefficient).

$$\alpha = \frac{k r}{k-1}$$

### 1. Factor 1 (Part 1)

#### Reliability Statistics

| Cronbach's Alpha | N of Items |
|------------------|------------|
| .626             | 3          |

Look at the output for the Factor1 items (Part 1). Cronbach's alpha is 0.626, which is an acceptable value for a research instrument.

### 2. Factor 2 (Part2)

#### Reliability Statistics

|                  |            |
|------------------|------------|
| Cronbach's Alpha | N of Items |
| .619             | 3          |

The output for the second Factor items also shows an acceptable alpha 0.619.

### 3. Factor3 (Part3)

#### Reliability Statistics

|                  |            |
|------------------|------------|
| Cronbach's Alpha | N of Items |
| .727             | 7          |

The output for the third Factor items also shows an acceptable alpha 0.727.

### 4. Factor4 (Part 4)

#### Reliability Statistics

|                  |            |
|------------------|------------|
| Cronbach's Alpha | N of Items |
| .846             | 5          |

The output for the fourth Factor items also shows an acceptable alpha 0.846.

**Table 7.6 Summary of Reliability & Validity**

|                | N of items | Reliability | Validity |
|----------------|------------|-------------|----------|
| <b>Factor1</b> | 3          | 0.626       | 0.79     |
| <b>Factor2</b> | 3          | 0.619       | 0.79     |
| <b>Factor3</b> | 7          | 0.727       | 0.85     |
| <b>Factor4</b> | 5          | 0.846       | 0.92     |
| <b>Total</b>   | 18         | 0.846       | 0.92     |

Validity (y)= the square root of reliability (x)

### c) Means by group

**Table 7.7 Means by group**

| Descriptive Statistics |    |      |
|------------------------|----|------|
| Variables              | N  | Mean |
| Q3                     | 62 | 4.13 |
| Q4                     | 62 | 3.53 |
| Q6                     | 62 | 3.82 |
| Q8                     | 62 | 3.58 |
| Q9                     | 62 | 3.76 |
| Q10                    | 62 | 3.94 |
| Q12                    | 62 | 3.74 |
| Q13                    | 62 | 4.35 |
| Q17                    | 62 | 4.02 |
| Q18                    | 62 | 3.39 |
| Q19                    | 62 | 3.97 |
| Q20                    | 62 | 4.06 |
| Q21                    | 62 | 3.63 |
| Q23                    | 62 | 3.81 |
| Q24                    | 62 | 4.02 |
| Q25                    | 62 | 3.90 |
| Q26                    | 62 | 3.76 |
| Q27                    | 62 | 4.05 |
| Valid N (list wise)    | 62 | 3.86 |

*Source: the author*

### d) Likert Scales and Likert-Type Items

According to Bertram (2012), a Likert scale is a psychometric response scale used in surveys to obtain a participant's degree of agreement/ disagreement with the survey statements. Individual items in Likert's sample scale had five response alternatives: Strongly approve, Approve, Undecided, Disapprove, and Strongly disapprove. It is named after Dr Rensis Likert, a sociologist from the University of Michigan, who developed the technique. Likert noted that descriptors could be anything – it is not necessary to have negative and positive

responses. He implies that the number of alternatives is also open to manipulation. Indeed, contemporary work using many classifications exists besides the traditional five point classifications; some researchers use an even number of categories, deleting the neutral response (Likert, 1932).

**Table 7.8 Likert scale**

| Weighted mean    | Level | Attitude            |
|------------------|-------|---------------------|
| From 1 to 1.79   | 1     | Completely disagree |
| From 1.8 to 2.59 | 2     | Disagree            |
| From 2.6 to 3.39 | 3     | Neutral             |
| From 3.4 to 4.19 | 4     | Agree               |
| From 4.2 to 5    | 5     | Completely agree    |

*Source: (Likert, 1932)*

According to Likert scale, all variables can be arranged as follow:

**Table 7.9 List of variables according to Likert Scale**

| Descriptive Statistics |    |      |          |
|------------------------|----|------|----------|
| Variables              | N  | Mean | Attitude |
| Q3                     | 62 | 4.13 | 4        |
| Q4                     | 62 | 3.53 | 4        |
| Q6                     | 62 | 3.82 | 4        |
| Q8                     | 62 | 3.58 | 4        |
| Q9                     | 62 | 3.76 | 4        |
| Q10                    | 62 | 3.94 | 4        |
| Q12                    | 62 | 3.74 | 4        |
| Q13                    | 62 | 4.35 | 5        |
| Q17                    | 62 | 4.02 | 4        |
| Q18                    | 62 | 3.39 | 3        |
| Q19                    | 62 | 3.97 | 4        |
| Q20                    | 62 | 4.06 | 4        |
| Q21                    | 62 | 3.63 | 4        |
| Q23                    | 62 | 3.81 | 4        |
| Q24                    | 62 | 4.02 | 4        |

|                     |    |      |   |
|---------------------|----|------|---|
| Q25                 | 62 | 3.90 | 4 |
| Q26                 | 62 | 3.76 | 4 |
| Q27                 | 62 | 4.05 | 4 |
| Valid N (list wise) | 62 | 3.86 | 4 |

**Source:** the author

## Summary

According to the Likert scale, the four groups can be arranged as follows:

**Table 7.10 List of groups according to Likert scale**

|        | N  | Mean | Level | Attitude |
|--------|----|------|-------|----------|
| Group1 | 62 | 3.95 | 4     | Agree    |
| Group2 | 62 | 3.84 | 4     | Agree    |
| Group3 | 62 | 4.05 | 4     | Agree    |
| Group4 | 62 | 4.19 | 4     | Agree    |

**Source:** the author

## 7.4 STATISTICAL TESTS

### Likelihood chi-squared tests

Agresti (2002, p. 24) stated that '*the likelihood ratio chi-squared is an alternative test for multinomial parameters*'. As such, this test is an alternative to the standard chi-square test. Weaver (2008) stated that this procedure has been around since the 1950s. According to Hays (1963) and Howell (1997), there is reason to believe that likelihood ratio tests are less affected by relatively small sample sizes than the Standard Chi-Square. (Scheaffer, 1999, p.7) Noted that since '*the P- value of the chi-square test of association is very sensitive to the sample size; we need other measures to describe the strength of the*

*relationship*'. Hays suggests that the likelihood ratio test is superior, especially when the degree of freedom –  $df > 1$ .

Accordingly, the Likelihood chi-squared test coupled with the strength of relationship test- Gamma is selected due to its quality as being less affected by the relatively small sample size as is the case with our data. It is used in this research to see whether there is a significant difference between the Delphi findings obtained as a result of the two rounds Delphi exercise and the online survey results. The objective is to quantitatively test and validate the Delphi results according to the data collected as a result of the present survey.

Another reason for not using the standard chi-square test is the condition that data should reflect no more than 25% of cells having expected values less than 5; which could not be met in our case (Saunders *et.al* , 2009). To avoid this shortcoming, the response scale is limited to only a three response options scale instead of the 5 response options suggested by Likert. According to Likert (1932) the number of alternatives forming the response scale is open to manipulation. Therefore, the following 3 options are considered:

- 1- Disagree and strongly disagree;
- 2- Neutral;
- 3- Agree and strongly agree.

This way, the ratio between the sample size and the product of rows and columns (R x C) will become  $N/RC = 62/9 > 5$

- a. **Hypothesis: H0: no relation, H1: have a relation.**



## **Research Hypotheses**

The findings of the two rounds of the Delphi study conducted so far led to five main conclusions which fall under four conceptual dimensions or categories. In order to confirm and validate such results, these five main categories are considered as hypotheses for our factor analysis study. These five hypotheses (H) are:

**H1-** Security risks are now equally as important as safety risks in LNG ports and marine terminals.

This Hypothesis is supported by the following survey questions:

**Q.3** Security risks are now equally as important as safety risks in LNG ports and marine terminals.

**Q.4** The size and accessibility of LNG ports and marine terminal facilities makes them very difficult to protect against terrorist threats. Much more work and international cooperation is required to improve security controls.

**Q.6** Current security frameworks are still treating individual terminal facilities in relative isolation. Enhanced security protection requires a coordinated approach by integrating processes and systems at a local level if not on a regional and global basis.

The above survey questions support the idea that after the 9/11 terrorist attacks in the U.S, security risks have become important as safety risks and hence need to be treated on the same level of importance as safety risks and integrated within the routine risk assessment and management portfolio of LNG ports.

**H2-** There is a need for a standard safety framework to address LNG port offshore and onshore safety operations as well as the ship/ port interface.

Hypothesis 2 is supported by the following survey questions:

**Q.8** Although safety of each individual member of the LNG Port Supply Chain is the responsibility of each individual member, safety of the whole LNG port Supply Chain is a joint responsibility which has to be coordinated and ensured by the port authority.

**Q.9** The IMO's Formal Safety Assessment (FSA) for shipping should be extended to address port safety as well (onshore port operations).

**Q.10** A standard safety framework is necessary to address both LNG port offshore and onshore safety operations as well as the ship/ port interface.

The above survey questions and their results attest to the need for a standard LNG port safety framework capable of addressing both onshore and offshore port operations.

**H3-** Coordinated management of safety and security risks will positively impact the overall RM in LNG port SCs.

**H4-** A unified RM methodology (an all hazards approach) for assessing both safety and security risks is more cost effective than a RM methodology in which security and safety risks are managed separately and with less coordination.

Both hypotheses 3 and 4 belong to the same conceptual dimension 'Interfaces between LNG Ports Safety and security' and share the following survey questions:

**Q.12** Safety and security in LNG ports Supply Chains are closely related issues and may yield better outcome if managed in an integrative manner within the framework of a unified risk management approach and through a single port supply chain entity.

**Q.13** Generally in practice, risk assessment in safety and security follow similar risk assessment and management steps.

**Q.17** Although safety and security risks in LNG port Supply Chains are two disciplines that may have different requirements, their management should be coordinated within the framework of a holistic approach to achieve resilient and cost effective risk management in LNG port Supply Chains.

**Q.18** Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port Supply Chains.

**Q.19** A unified risk management methodology for assessing both safety and security risks and hazards can be more cost effective than a risk management methodology in which security and safety risks are managed separately and with less coordination.

**Q.20** An all-hazards approach in which safety security, natural disasters risks are assessed and managed is needed in LNG Ports supply chains to develop a cost effective and efficient risk management strategy.

**Q.21** Implementation and coordination of such all-hazards approach should be coordinated by the LNG port authority.

It is clear from the above 7 questions, all of them support well both hypotheses 3 and 4. These two hypotheses explain and justify the conceptual dimension related to the interfaces and shared impacts between safety and security RM, which is indeed the central theme of the study. Since safety and security

interfaces and their shared impacts pose a number of questions and issues in connection with the optimal approach to manage them from a port supply chain perspective and from the stand point of an integrated approach, the author finds it necessary to have more than one hypothesis to explain and justify that particular conceptual category.

**H5-** An all-hazards approach needs to be qualitatively assured according to the principles of TQM.

The above assumption is supported by the following survey questions:

**Q.23** Safety and security risk assessment and management need to take advantage of the *Total Quality Management (TQM)* Principles.

**Q.24** Prevention is the key principle in *Total Quality Management (TQM)* and should also be for the case of safety and security management.

**Q.25** Based on the principles of TQM, LNG port supply chains should adopt an integrated risk assessment and management approach capable of dealing with the three types of risks, safety, security and quality.

**Q.26** Adopting such an integrative approach will lead to efficient and cost effective risk management in LNG Ports SCs.

**Q.27** Integrated LNG Port Supply chain risk management should be assured through a quality assurance system based on the TQM.

These survey questions and their results attest to the need for the integrated approach to risks to be qualitatively assured according to the principles of Total Quality Management (TQM).

**a) Testing of Hypotheses:**

Each hypothesis is presented along with descriptive statistics. Corresponding tables are described as well. Likelihood ratio chi-squared coupled with Gamma tests were used to check the five null hypotheses. Significance was tested at the **alpha = 0.05 level**. Therefore, if the probability of occurrence of the calculated test statistic is less than or equal to the probability of alpha, a Type 1 error, the null hypothesis is rejected and it is then concluded that the result supports the research hypothesis with more than 95% confidence. Therefore, it is concluded that there is a relationship between the variables. The data was analysed to produce results for the following research questions.

**Research Question1**

***H1: Security risks are now equally as important as safety risks in LNG ports and marine terminals.***

Is there a relationship between the importance of ***security risks*** and ***safety risks***?

**H1<sub>o</sub>:** There is no relationship between Security risks and Safety risks in terms of importance to the LNG ports SCs

**H1<sub>a</sub>:** There is a relationship between Security risks and Safety risks in terms of importance to the LNG ports SCs

### Likelihood chi-Squared Tests

|                  | Value | df | Asymp. Sig.<br>(2-sided) |
|------------------|-------|----|--------------------------|
| Likelihood Ratio | 9.741 | 4  | .045                     |
| N of Valid Cases | 62    |    |                          |

### Symmetric Measures

|                  | Value | Asymp. Std.<br>Error <sup>a</sup> | Approx.<br>T <sup>b</sup> | Approx.<br>Sig. |
|------------------|-------|-----------------------------------|---------------------------|-----------------|
| Ordinal by Gamma | .369  | .248                              | 1.285                     | .199            |
| N of Valid Cases | 62    |                                   |                           |                 |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The table of likelihood chi-squared tests shows the Asymp. Sig. (or Alpha level of significance) is **.045**, as 0.045 is smaller than  $\alpha=0.05$ , which means that the hypothesis null **H1<sub>o</sub>** is rejected. This confirms our hypothesis that a relationship between Security risks and Safety risks exists in terms of importance to the LNG Ports SCs. Although the likelihood ratio is statistically significant, the gamma value shows a less strong relationship, which means that safety risks and security risks are not equally important within the LNG port SCs RM system.

As explained earlier in chapter 2, security risks in general gained importance after the 9/11 terrorist attacks and became a critical issue to hydrocarbon ports, including LNG. Since there is a demonstrated relationship among the two disciplines of risk such as interfaces and shared impacts, a coordinated and

unified approach in their risk assessment and management is crucial in achieving a robust and resilient LNG port SCs.

**Research Question 2**

**H2.** There is a need for a standard safety framework to address LNG port offshore and onshore safety operations as well as the ship/ port interface.

**H2<sub>o</sub>:** There is no relation between the need for a standard safety framework and the onshore/offshore safety operations.

**H2<sub>a</sub>:** There is a relationship between the need for a standard safety framework and the onshore/ offshore safety operations.

**Likelihood chi-Squared Tests**

|                  | Value  | df | Asymp. Sig. (2-sided) |
|------------------|--------|----|-----------------------|
| Likelihood Ratio | 16.153 | 4  | .003                  |
| N of Valid Cases | 62     |    |                       |

**Symmetric Measures**

|                             | Value | Asymp. Std. Error <sup>a</sup> | Approx. T <sup>b</sup> | Approx. Sig. |
|-----------------------------|-------|--------------------------------|------------------------|--------------|
| Ordinal by Gamma<br>Ordinal | .586  | .181                           | 2.354                  | .019         |
| N of Valid Cases            | 62    |                                |                        |              |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The table of likelihood chi-squared tests shows, the Asymp. Sig. is **.003**, as .003 is smaller than  $\alpha = 0.05$ , which means that the hypothesis null **H2<sub>o</sub>** is rejected. Also Gamma value attests to the existence of a strong relationship in this respect.

So, as per Gamma= .019, there is a strong relationship between the need for a standard safety framework and onshore/ offshore safety operations. This result confirms our hypothesis that a standard safety framework is needed to address LNG port offshore and onshore safety operations as well as the ship/ port interface. In this regards, respondents believe that the IMO's FSA, as a safety framework for shipping, should be extended to address port safety as well.

### **Research Question 3**

Coordinated management of safety and security risks will positively impact the overall RM in LNG port SCs.

**H3<sub>o</sub>**: There is no relation between coordinated management of safety and security risks and the efficiency of overall RM in LNG port SCs

**H3<sub>a</sub>**: There is a relationship between coordinated management of safety and security risks and the overall RM in LNG port SCs.

The table of likelihood chi-squared tests shows, the Asymp. Sig. is **.004**, as .004 is smaller than  $\alpha=0.05$ , which means that the hypothesis null **H3<sub>o</sub>** is rejected. So, there is a relationship between coordinated management of safety and security risks and the efficiency of overall RM in LNG port SCs. Also, Gamma value computed at the level of **.038** attests to the strength of this relationship. This result confirms our hypothesis.



### Likelihood chi-Squared Tests

|                  | Value  | df | Asymp. Sig.<br>(2-sided) |
|------------------|--------|----|--------------------------|
| Likelihood Ratio | 10.927 | 2  | .004                     |
| N of Valid Cases | 62     |    |                          |

### Symmetric Measures

|                             | Value | Asymp. Std.<br>Error <sup>a</sup> | Approx.<br>T <sup>b</sup> | Approx.<br>Sig. |
|-----------------------------|-------|-----------------------------------|---------------------------|-----------------|
| Ordinal by Gamma<br>Ordinal | .892  | .087                              | 2.076                     | .038            |
| N of Valid Cases            | 62    |                                   |                           |                 |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

### Research Question 4

A unified RM methodology (an all hazards approach) for assessing both safety and security risks is more cost effective than a RM methodology in which security and safety risks are managed separately and with less coordination.

**H4<sub>o</sub>**: There is no relation between unified RM methodology for assessing safety and security risks **and** the overall cost effectiveness of such type of management.

**H4<sub>a</sub>**: There is a relation between unified RM methodology for assessing safety and security risks **and** the overall cost effectiveness of such management.

### Likelihood chi-Squared Tests

|                  | Value  | df | Asymp. Sig. (2-sided) |
|------------------|--------|----|-----------------------|
| Likelihood Ratio | 11.124 | 2  | .004                  |
| N of Valid Cases | 62     |    |                       |

### Symmetric Measures

|                  | Value | Asymp. Std. Error <sup>a</sup> | Approx. T <sup>b</sup> | Approx. Sig. |
|------------------|-------|--------------------------------|------------------------|--------------|
| Ordinal by Gamma | .864  | .112                           | 1.998                  | .046         |
| N of Valid Cases | 62    |                                |                        |              |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The table of likelihood chi-squared tests shows the Asymp. Sig. is **.004**, as .004 is smaller than  $\alpha=0.05$  it is statistically significant, which means that the hypothesis null **H4o** is rejected. So, there is a relationship between unified RM methodology for assessing safety and security risks and the cost effectiveness of such management. This result confirms our hypothesis that a unified RM methodology (an all hazards approach) for assessing both safety and security risks is more cost effective than a RM methodology in which security and safety risks are managed separately and with less coordination.

This confirms our earlier findings that an all- hazards approach for LNG ports risk assessment and management is perceived as both cost effective and efficient in addressing safety and security risks and hazards. An all-hazards approach provides a framework for coordinated RM, be them safety or security related risks. As explained in research question 3, the outcome of such coordination is an efficient RM of safety and security risks with less cost during

all stages of RM. This means better protection of LNG port facilities and SC members at the port, as well as less disruption to the LNG supply to international markets.

Such a holistic approach ensures cost effective and timely RM as well as reliable supply of LNG commodity.

### **Research Question 5**

An all-hazards approach needs to be qualitatively assured according to the principles of Total Quality Management (TQM).

**H5<sub>o</sub>**: There is no relation between the all-hazards approach **and** quality assurance as per the principles of TQM.

**H5<sub>a</sub>**: There is a relation between the all-hazards approach **and** quality assurance as per the principles of Total Quality Management (TQM).

### **Likelihood chi-Squared Tests**

|                  | Value | df | Asymp. Sig. (2-sided) |
|------------------|-------|----|-----------------------|
| Likelihood Ratio | 9.810 | 2  | .007                  |
| N of Valid Cases | 62    |    |                       |

### **Symmetric Measures**

|                  | Value | Asymp. Std. Error <sup>a</sup> | Approx. T <sup>b</sup> | Approx. Sig. |
|------------------|-------|--------------------------------|------------------------|--------------|
| Ordinal by Gamma | .847  | .112                           | 2.272                  | .023         |
| N of Valid Cases | 62    |                                |                        |              |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

The table of Likelihood chi-squared tests shows, the Asymp. Sig. is **.007**, as .007 is smaller than  $\alpha=0.05$ , which means that the hypothesis null **H5<sub>o</sub>** is rejected. So, there is a relationship between the all-hazards approach **and** quality assurance as per the principles of TQM. Also, Gamma significance level is .023 which attests to the strength of such relationship. This result confirms our hypothesis that quality assurance of the all-hazards approach is so important to its successful application in the area of LNG Port SCs RM.

Most respondents confirmed that underpinning any continual improvement culture, in terms of security provision, interaction with HSE and mitigation of both sets of risks cooperatively and effectively can only be based on the adoption of quality assurance systems by both parties, namely LNG port security and safety providers in full coordination with the Port authority. Most security providers, which adopt quality assurance management systems, use ISO 9001 that is mostly focused on the management of guard forces and not on operational performance of the guards on the ground, and contributing to the customers operation/ HSE programs. That is why the focus now is on operational performance that adds value to the port business, especially from a joint HSE and Security point of view.

Finally, the above results confirm the fact that LNG Port SCs need to adopt an integrated risk assessment and management approach based on the principles of TQM. Among the key principles of TQM is '*prevention*' which should be applied in both safety and security RM in LNG ports to ensure resilient LNG port SCs.

Generally, risk can be managed by prevention or mitigation. Prevention seeks to avoid an accident or attack; mitigation reduces the effects of an accident or attack. In the LNG industry, combination of these two types of strategies can only improve both safety and security involving either accidental or intentional incidents. According to Sandia (2004, p: 55), RM should be based on developing or combining approaches that can be efficiently and effectively implemented to reduce hazards to acceptable levels in cost-effective manner. Although prevention should be the focus of any LNG RM strategy, mitigation strategies should always be in place to deal with uncontrolled LNG spill incidents whatever their source is.

## **7.5 CONCLUSION**

From the above, it is clear that both safety and security disciplines within the LNG port SC have to work together collaboratively during all stages of risk assessment and management. This is for the benefit of a resilient and cost effective RM enabling smooth handling and storage of LNG through the port to serve the international energy markets without disruption.

However such collaboration needs to be accommodated through the port community led by the port authority. Also, such collaborative work among safety and security departments within LNG ports needs to be qualitatively assured to ensure efficiency and cost effectiveness. By applying a quality system to both safety and security planning and operations, the outcome of risk assessment from both disciplines can be easily auditable to ensure efficiency and avoid redundant or contradictory actions.

It is paramount to ensure that mitigation measures from one discipline (either safety or security) have no negative impact on the other domain of risk. As a practical example of such possible impact, the security department at an LNG port may decide to install a security fence along the port perimeter to prevent unlawful access to the port. While this may be regarded as a legitimate action to strengthen security, it may negatively impact HSE strategy of having a safety emergency gate at that location. In this case, if no coordination is maintained between safety and security departments, implementing the security strategy at the port perimeter may be detrimental to the safety of port users in case of emergency. Furthermore, collaborative actions among safety and security departments within LNG ports will require clear procedures and protocols which need to be agreed upon by all port stakeholders, signed off and then applied and controlled during and after their planning and implementation stages.

Having agreed on the principles which should govern the relationship between safety and security risks assessment and management in LNG ports, the next step in our analysis will be to draw a conceptual model depicting the flows of activities and relationships as well as methods of collaboration between the two professions of RM.

## **CHAPTER 8**

### **INTEGRATED LNG PORT SC RM**

#### **THE CONCEPTUAL MODEL**

### **8.1 INTRODUCTION**

Extant RM in the LNG port SC system reveals a disintegrated management of risks, in which each type of risk is assessed and dealt with independently and without consideration of the interplays, interfaces as well as possible impacts between the other types of risks, for instance safety and security. Such a disintegrated approach may not enable efficient nor cost effective RM which in turn may impact the overall level of risk controls and constitute an obstacle to the objective of achieving a resilient ports SC as a critical node of the global SC delivering LNG commodity to the world. The triangulation conducted so far enabled to confirm the findings from both the extensive literature review and the two rounds of Delphi surveys. These findings confirmed a relationship between safety and security risks in LNG ports which requires high levels of collaboration and interface management within the framework of an all-hazard approach. This is to ensure a resilient and cost effective risk assessment and management to the interest of a resilient LNG Port SC.

In order to show relationships and flows and present the proposed integrated port SC risk assessment and management system in contrast to the existing real-world system of RM, it is decided to build a conceptual model (CM) using a systems thinking approach (STA). Selection of the STA, particularly the soft system methodology (SSM) is due to its attributes in representing the real world complex problems and its ease in depicting relationships, actions and flows of

such problems. All these will assist in proposing a CM for an integrated RM of LNG ports SC.

### **8.1.1 Systems Thinking**

As defined by Marsiglia (2008, p.2),

*'Systems thinking is a holistic approach to understanding reality and our interactions within it. This approach requires that we see beyond the bits and pieces of reality in order to understand systems.'*

Marsiglia (2008, p2) explained that such an approach is actually difficult for many people since *'early in our lives, we are taught to break apart problems to make them more manageable. Consequently, we fail to see the entire effect of our activities'*.

Systems thinking has been defined as an approach to problem solving by looking at the problem as part of an overall system, in contrast with the reductive approach brought originally by Descartes, which recommends breaking down the problem into its component parts, addressing each part and then building the solution up again (Greswell, 1998). Also, Wilson (1984, p.10) asserted that the main objective of systems thinking is *'the attainment of public knowledge of the kind which science accumulates by means of a modified scientific approach in which a form of holism replaces reductionism'*. Furthermore, Anderson, Britt & Favre (1997) characterising successful initiatives to improve SC management (SCM), stated that, among others, such initiatives reflect a holistic approach, viewing the SC from end to end and making sure that the whole improvement achieved in revenue, costs, and asset utilisation is greater than the sum of its parts.



Systems thinking has evolved into a conceptual framework that has been developed over the past fifty years to make the full pattern clearer and help us to figure out how we can change them effectively (Senge, 2006 p7). Furthermore, Checkland (1999, p.14) states,

*“...systems concepts are concerned with wholes and their hierarchical arrangement rather than with the whole”*

Edson (2008, p. 3) argued that much of the world today still persists in the ‘*machine-age thinking*’, rather than the ‘*system-age thinking*’. For him, such an approach is no longer valid in a *system-age* where individual parts do not equate to the system and where the systems’ environment is just as important as its individual components.

As a process, systems’ thinking is generally defined as an ordered and methodical approach to understanding problems and finding solutions to those problems (Edson 2011; Checkland 1999). As part of this process, the problem is assessed within its environment and in due consideration of its context (Senge, 2006). Marsiglia (2008) further stressed that the core link between Checkland and Senge systems thinking is the importance of the learning process within a learning organisation. For them,

*‘Through learning we expand our capacity to create, to be part of the generative process of life’* Marsiglia (2008, p.14).

### **8.1.2 The system in systems thinking**

According to Edson (2011), a system is a set of two or more elements which satisfy three conditions: 1. Each element of the system has an effect on the other elements; 2. Each element impacts the whole system and; 3. The elements of the system are so connected that subgroups of them cannot be

formed. Such a definition prescribes that the system is a whole that cannot be divided into independent parts. Checkland (1981) in Greswell (1998) stated that the system can be defined either from ontological or epistemological viewpoints.

The ontological view of a system stresses that because the system exists in the real world, it is tangible and can be seen and smelt; whereas the epistemological view defines the world in system representation which is an abstract approach to a system used to explain and facilitate the understanding of the system (Greswell, 1998). Edson (2011, p.7) asserted that the system can take the form of a problem as well as the process of assessment and the path used to gain understanding and analysis of the problem. All these aspects and perspectives of the system are critical to understanding systems thinking. Edson (2011) based on Checkland (1999) differentiates between two important parts of the body of systems knowledge; for instance, hard systems methodology (HSM) and SSM approaches. Hard systems correspond to a systems engineering approach while a soft systems approach is linked to the management approach. Engineers seek to understand and explain the problem through quantitative means defined as ‘hard’ methods while managers generally tend to use qualitative and collaborative ‘soft’ methods.

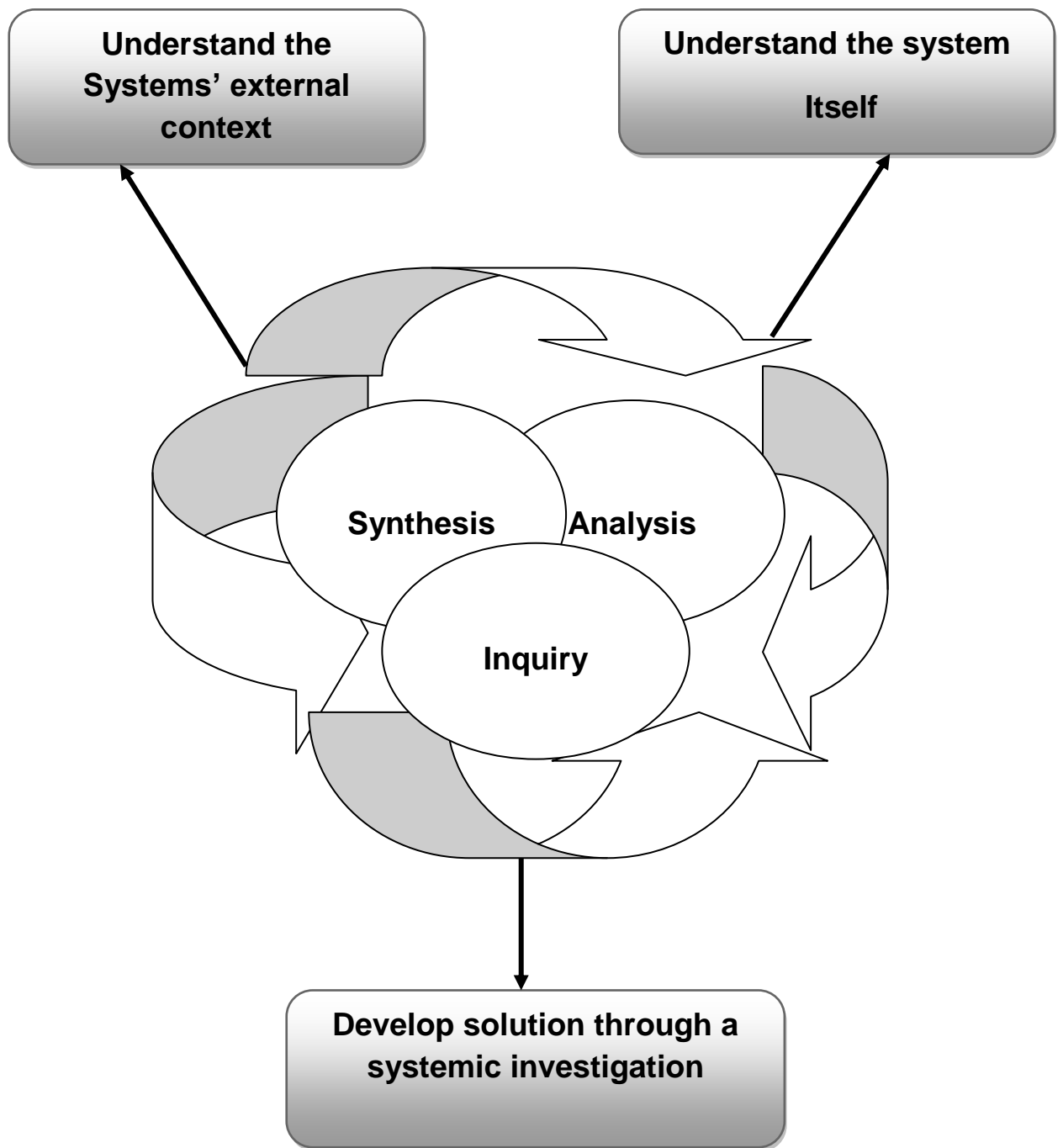
**Table 8.1 Checkland’s definition of hard and soft systems methodologies**

|                                |                                                                                                                                                                                                                                  |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Hard system methodology</b> | Systems- based methodology also known as ‘system engineering’ for tackling real world problems in which an objective or end -to be-achieved can be taken as given. A system is then engineered to achieve the stated objectives. |
| <b>Soft system methodology</b> | Systems- based methodology for tackling real-world problems in which known to be desirable ends cannot be taken as given. SSM is based upon a phenomenological stance                                                            |

**Source:** *Checkland (1999)*

Hard systems thinking (HST) is usually concerned with a problem that is well defined with specific objectives, which assists the analyst in reaching an appropriate solution. Greswell (1998) stated that HST usually uses hard methods to solve such problems. He argued that hard methods are defined as being systemic (holistic) using systematic tools (step by step approach) in solving problems. Wilson (1984) describes such type of systems thinking as the '*optimisation paradigm*'. However, Greswell (1998) argued that the above HST methodology is not suitable for human activity systems which are described by Checkland (1990) as '*ill defined*' and less structured. Meanwhile, controversy still exist between adepts of soft and hard systems approaches which according to Edson (2011) leads to confusion on the value of HSM versus SSM. This led Checkland (1999) to try and provide an interesting perspective by asserting that hard methods are good in designing systems while soft methods provide '*a systemic process of enquiry*' (See Checkland's definition above). However Edson (2011) proposes an alternative solution to this dilemma by asserting that an appropriate methodology to solving human activity problems lies in the '*applied systems thinking*' which is actually an overlap between soft and hard systems thinking.

**Figure 8.1 Systems thinking synergistic activities**

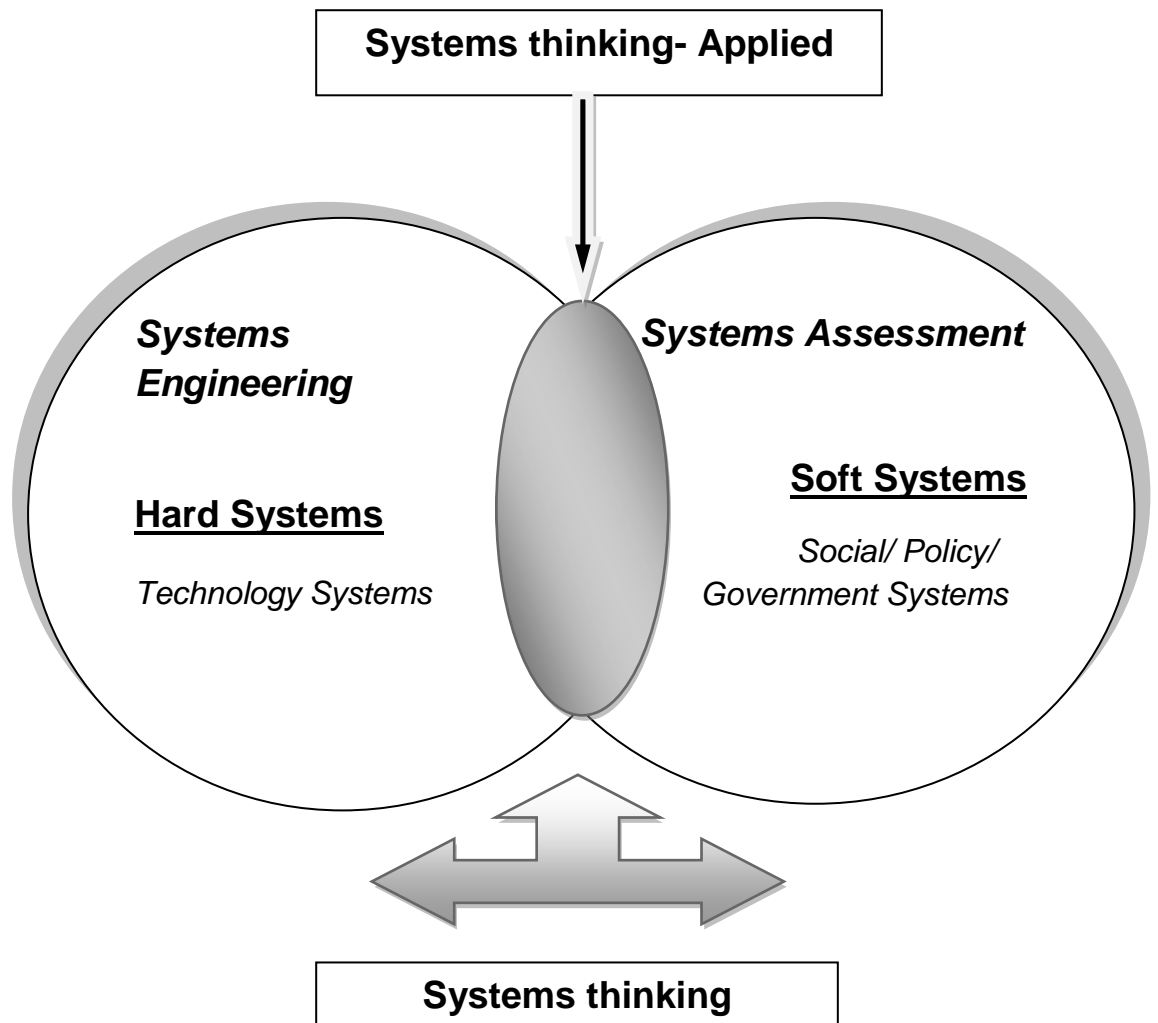


**Source:** *Edson (2011)*

### 8.1.3 Applied Systems thinking

Traditional systems' thinking relies either on HSM or SSM and uses tools exclusively and independently from either area. Applied systems thinking emphasises the integration of the two approaches. Such an approach recognises that both systems thinking approaches fall within the systems thinking construct, but applied systems thinking focuses on the opportunities offered by the intersection and overlap between the two approaches Edson (2011).

Figure 8.2 Systems thinking- Applied



Source: Adapted from Edson (2011)

Considering the power and benefits of using hard and soft systems thinking, it is important for the applied systems thinker to leverage both methods in order to provide adequate explanation and solution to the problem situation under study. This combination provides the power in applied systems thinking. (Edson, Systems Thinking. Applied. A Primer, 2008)

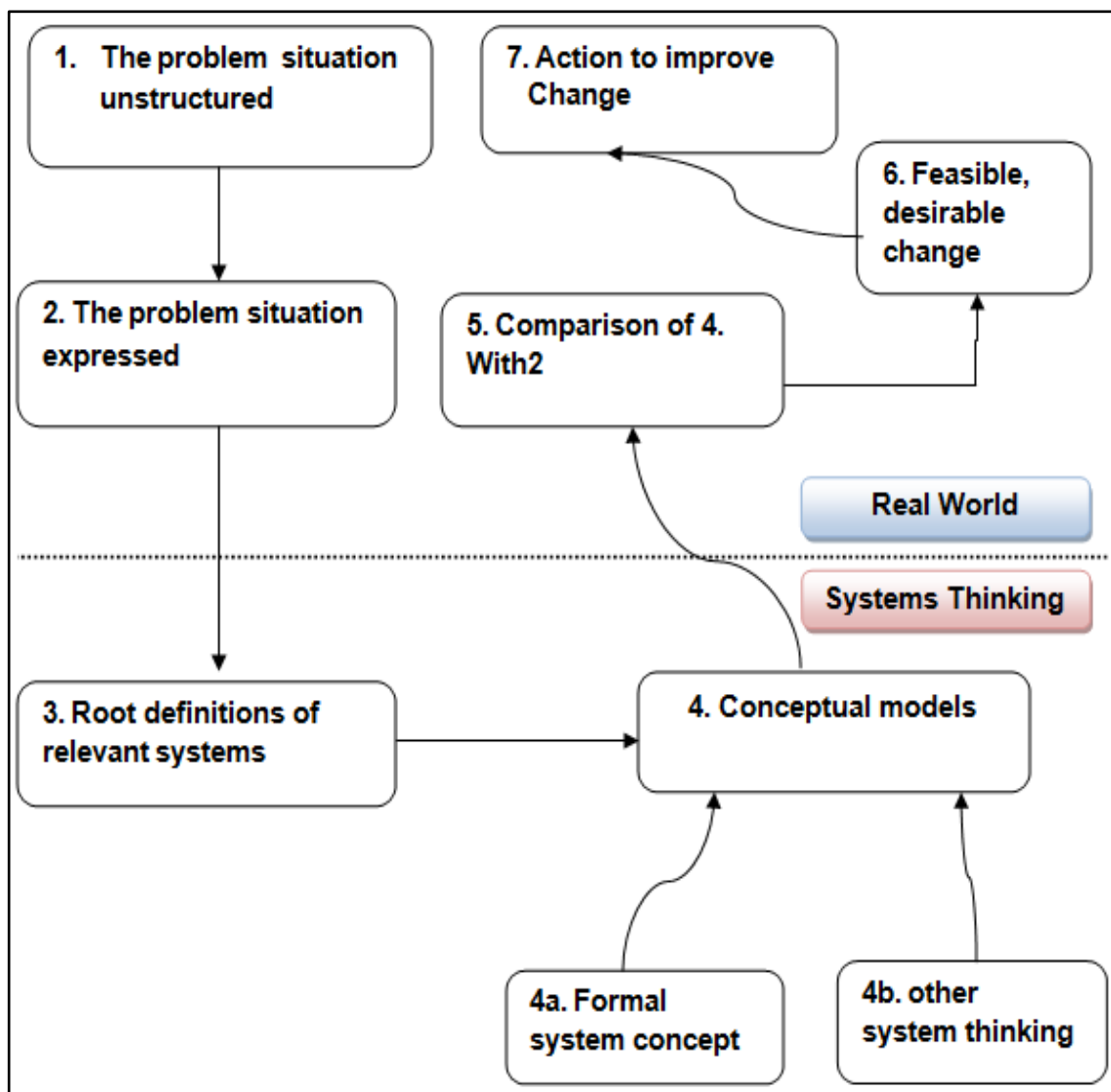
#### **8.1.4 Soft Systems Methodology (SSM)**

SSM was developed by Peter Checkland and others in the late 60's at the University of Lancaster in the UK. The method was originally conceived as a modelling tool, but later on, it has been increasingly seen as a framework for learning and problem solving. It allows the structuring of thinking about the real world through the use of models as a representation of the real world. Like other systems approaches, the core of SSM is a comparison between the world as it is, and some models of the world as it might be (Williams, 2005). The benefit from such comparison is a better understanding of the world and its problems ("research"), which enables finding ways for improvement ("action"). According to Rose, (1997), SSM is variously characterised by Checkland & Scholes (1990) as a 'system of enquiry', 'enquiry process', 'learning system', 'reflection in action', 'an organized version of doing purposeful thinking', and 'structured way of thinking'. SSM process is essentially participative and collaborative. Rose, (1997) stated that most successful modelling, in his experience, necessarily involves the negotiation of meanings between stakeholders.

In classic SSM, the researcher begins with a real-world problem or situation. He studies the situation in a fairly unstructured way, develops some

representations of that problem or situation (models), proposes scenarios for solutions and finally tries to compare this with the real life (Williams, 2005). Checkland's SSM (1993) as presented in Edson (2008) and Williams (2005) identified a seven stage process. Some of them address the real-world and the others represent the conceptual world. Edson (2008) stressed that the SSM process for assessment and improvement concerns mainly human activities systems but it can be applied to technology and hybrid systems as well.

**Figure 8.3 Checkland's Soft Systems Methodology**



Source: (Checkland 1993)

As shown in figure 8.3, Checkland's soft methodology approach (Checkland, 1999) is characterised by seven interconnected stages that form a learning loop. These stages are:

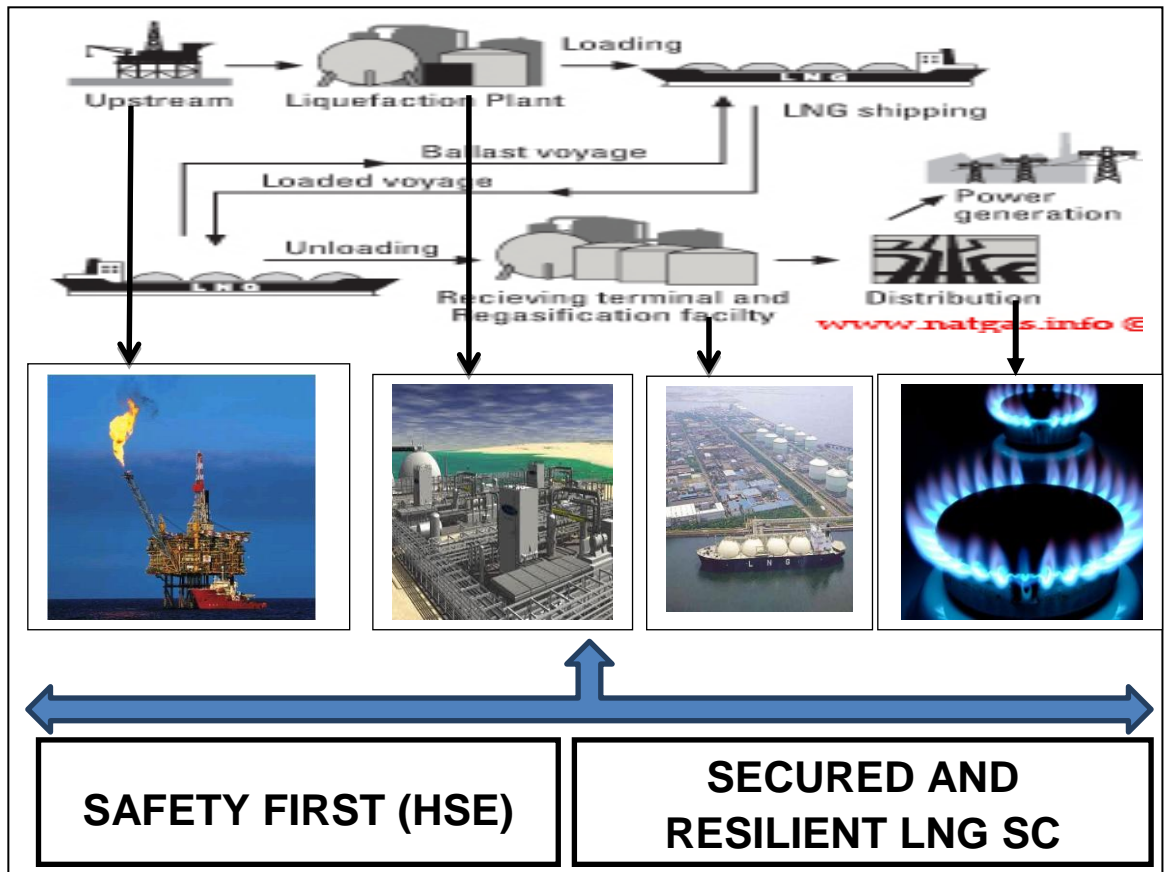
**Stage1** : Learn about the problem situation without intervening into its structure.

**Stage 2:** Describe and explain the problem situation in a comprehensive way.

Stages one and two correspond actually to the first step, which is, in the real world, to acknowledge, explore and define the situation in some way. Peter Checkland called it the "problem situation" since his original purpose of developing SSM was a problem solving one (Williams, 2005). So, the first task is to decide what it is actually to be explored. At this stage the problem is not to be explored, but the general area that interests us needs to be assessed. In Stage Two the issue is "expressed" in some way. Checkland calls this a rich picture for two reasons: Firstly the situation needs to be expressed in all its richness and second he suggests this situation to be expressed in a picture form. Checkland provides some guidelines as to what should be included, such as people, processes, structures, climate, issues expressed by people (Williams, 2005).



Figure 8.4 Rich picture of a typical LNG value chain



Source: the author

Stage3. Develop a root definition of the problem under query. In this stage, we move out of the “real” world and enter into the world of systems. Williams (2005) highlighted the importance of this stage by stating that it is the stage out of which everything else grows.

That is why Checkland called this the “root definition” stage, and it is the unique and most challenging part of the methodology.

Root definition should be a concise description of the problem situation or human activity system. This is expressed in Checkland (1999) in the form of a CATWOE mnemonic. The terms of this mnemonic include, Customers (C) who are the main actors carrying the principal activities of the system; Actors (A)

who facilitate the transformation to these customers; The transformation (T) process which transforms inputs into outputs; Weltanschauung (W) which means world view that makes the root definition meaningful; Ownership (O) of the system that makes main actors having critical interest in the system; and finally, the environmental constraints (E) on the system.

**Stage4.** Construct conceptual models of the system and test them in the real world to confirm their validity and appropriateness to bring valid solutions to the problem situation.

**Stage5.** Compare stage 4 with stage 2.

**Stage6.** Develop the desirable changes. According to Checkland (1999), such change shall be systematically desirable as derived from the root definition of the problem situation and the conceptual models built.

**Stage7.** Suggest improvement to the problem situation.

According to Marsiglia (2008), the key to successful use of SSM is to iterate the seven steps until successful results are achieved. For him each iteration generates new information about the system which in turn provides better learning enabling efficacy of the next system improvement or change.

Commenting on Checkland's SSM, Edson (2008) summarised this approach in three basic phases:

1. Develop an understanding of the problem situation. This includes problem constraints and goals. From Fig.8.3, this includes stages 1, 2 and 3.
2. Use systems tools to determine possible alternative solutions to the problem situation. Such alternative solutions shall be compared to determine the best possible one. Stages 4 and 5 in Fig.8.3.

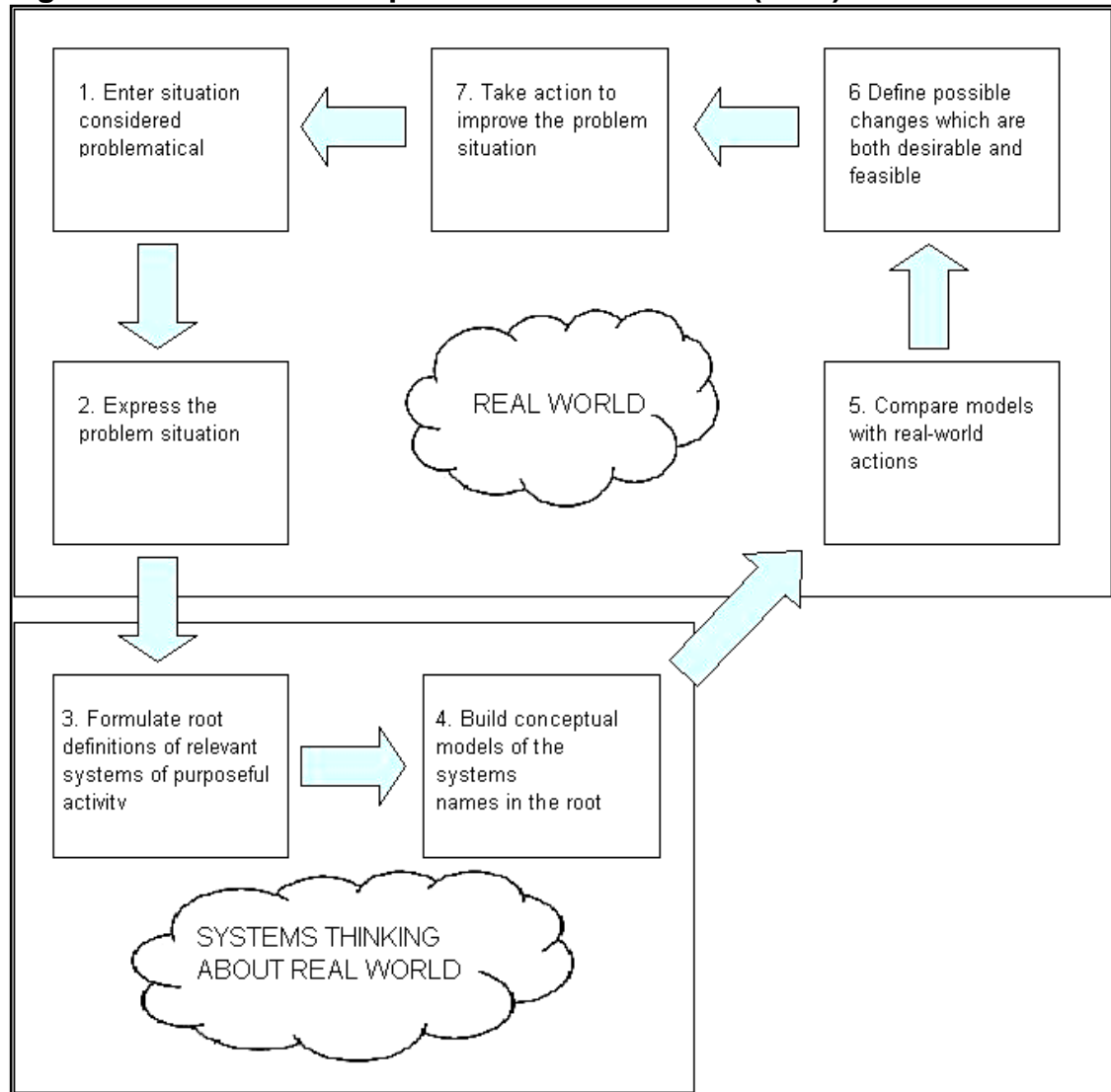
3. Contrast solutions with the real-world problem situation as is to determine its feasibility within the actual constraints and desired outcome. This includes stages 6 and 7 from Fig.8.3.

SSM is a participative process which includes all stakeholders who have an interest in the system under analysis and who may have an impact on any solution intended to change the problem situation. As an example from the subject of this research, stakeholders mean the following:

- The processes: storage, loading and unloading of LNG to tankers, receiving and dispatching the LNG vessel from the jetty...etc.
- People: LNG Port operations, safety professionals, security specialists, port management, LNG shipping managers, LNG terminal operations and LNG shipping agents ...etc.
- Companies involved in the LNG SC: LNG producers and liquefaction firms, LNG shipping Companies, LNG receivers, Insurance companies...etc.

Also, the principle of continuity encourages adopting an approach for continual learning process (Greswell, 1998). This involves considering overall RM as an integrated and collaborative BP.

**Figure 8.5 SSM seven steps based on Checkland (1981)**



**Source:**(Kuhn, 2009)

### **8.1.5 Business Process and Business Process Re-engineering (BPR)**

BPR is another method of approaching the issue under study. The concept of business process (BP) is not new. Adam Smith described processes back in the 18<sup>th</sup> century in his famous 1776 example of a pin factory. Others such as Parnaby (1979) and Hammer (1990) documented the use of the concept. Also, Greswell (1998, p.123) based on Childe (1994) stated that one accepted definition of a BP is ‘a process which starts and ends with the customer’. Based

on Checkland (1981), Weaver (1995) summarised the BP as a process which *'can be used to represent a set of integrated activities and flows that as a whole produces outputs that fulfil a purpose with respect to an external customer'*. According to Greswell (1998), the BPR concept was picked up by a number of authors such as Davenport and Short (1990), Hammer and Champy (1993), Kaplan and Murdoch (1991) who stressed the need for a radical organisational improvement by moving from a functional viewpoint to a BP approach. As a result, a number of organisations embarked on ambitious programmes of radical change and BP re-engineering in the 1990s, in order to achieve targets and objectives which could not be reached through incremental improvements (Greswell, 1998).

Usually companies undertake re-engineering once their current business systems are no longer efficient, or are having difficulty to compete in the market. Corporations see value in streamlining their businesses by investing in technology instead of employees. Hammer and Champy (1993) stressed that the new development in the business environment requires a switch from a task orientation to a process orientation. As such, corporations shall focus on their main BPs instead of organisational business units. *'Reengineering is the fundamental rethinking and radical redesign of BPs to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed'* Hammer and Champy (1993). As a result of this movement, the re-engineering concept became synonymous with downsizing in the mid-nineties when corporations such as Pacific Bell, Apple and others announced the reduction of thousands of jobs as a result of "reengineering" in 1995 (Neidhart, 2012). However, changing the structure of a business from

employees-based to technology-based business strategies can have a disadvantageous effect if implemented without proper systems approach to change (Brandenburg & Binder, 1999).

Neidhart (2012) asserted that Hammer and Champy's approach to reengineering was misconceived and badly implemented by many companies. This approach could work well if implemented using systems approach as well as information technology to assess real needs and streamline processes. According to Neidhart (2012), *'using information technology as a tool to enable a current system to operate more cost-effectively could, and does benefit companies in today's age of information'*. Sheridan (1997) in Neidhart (2012) stated that *'manufacturers who applied the basic concepts of reengineering sensibly to become leaner and more competitive will then shift gears from a cost-cutting mode into a growth mode'*. In an attempt to revive the re-engineering concept, Champy tried recently to introduce a revision of the re-engineering concept. The new version of re-engineering, called X-engineering (or cross-engineering), focuses on transparency, standardisation of processes and technology, and harmonisation, or collaboration between companies (Neidhart, 2012).

The introduction of the BPR concept in the context of this research is beneficial since the application of integrated RM in LNG ports will require some kind of re-engineering of the processes through which safety and security risks are assessed and managed. In our opinion, the processes of risk identification and the implementation of risk control options (RCOs) as well as the relationship between safety and security disciplines within LNG ports should be re-

engineered to enable better communication and exchange of information among specialists of the two disciplines, including the use of the right combination man/machine to enhance risk controls for the benefit of a resilient LNG SC.

Greswell (1998) stated that the principles of re-engineering consist of organising around outcomes not tasks. This research intends to present the RM process in the areas of safety and security from a holistic perspective, integrating safety and security processes to achieve the best protection and resiliency of the LNG logistics and port system. Within such an approach, the focus shall move from tasks and activities of each discipline of risk towards the targeted outcome of safe and secure LNG ports SC. The current RMBP marked by a relative dichotomy between the two disciplines of risk needs to be streamlined towards achieving real integration through better information sharing and enhanced cooperation during all risk assessment and mitigation stages. It is imperative that this integrative and holistic approach to the RM domain evolves with an organisational change to enable the unified risk mitigation strategy to support or lead the outcome of safe, secured and resilient LNG Ports SC.

## **8.2 FORMULATION OF AN INTEGRATED APPROACH TO RM**

The evidence from our earlier analysis and findings during the three enquiry stages of this research, mainly the two rounds of Delphi as well as the quantitative analysis, suggests that safety and security RM within the LNG ports SC is a 'fuzzy' ill structured process within some LNG ports organisations, whilst most individual safety and security RM models, taken separately, are generally well planned processes. The evidence also indicated that integrated

safety and security risk assessment and management is beneficial to the LNG ports SC, in ensuring a resilient and cost effective RM and enabling smooth handling and storage of LNG through the port to serve the international energy markets without disruption. It may be useful to view the development of an integrated RM approach, as a problem situation, which can be improved by using alternative methodologies. Soft systems methodology is a useful tool in developing a conceptual model of safety and security RM in LNG ports which takes into consideration all the useful empirical work and experiences gathered in the RM domain and applies them while considering different worldviews.

SSM has been identified as a suitable concept to tackle the 'problem situation' under study and its use of integrated RM strategy as a concept to improve and add value to the resilience and efficiency of the LNG ports SC. Platt and Warwick (1995) evaluated the methodology and reiterated the usefulness of SSM for dealing with problems of fuzzy nature, with unclear objectives, where there may be several different perceptions of the problem. SSM is seen as being flexible and can be used in a variety of circumstances. Omerod (1992) has discussed the merits of combining HST and SST to enable a systematic, systemic approach which incorporates multiple viewpoints. The main reasons for using SSM and BPR in the context of this research are:

1. Segregating safety and security risk assessment and management is actually reducing the issue of RM as a whole into subparts and trying to achieve resilience of each part separately without considering the interplays and impacts between safety and security in the LNG port system. Through SSM, an attempt is made to put the agenda of RM within a holistic systemic perspective.



2. The principles of participation, debate and coordination will be crucial in the LNG ports which have to deliver safe, secure and resilient logistics and ports SC within a BP environment.
3. The need to revive the role of the port community which facilitates the participation of all concerned stakeholders in the implementation of the integrated RM approach with a shared understanding of how such an integrated and holistic approach can deliver safe, secure and resilient ports SCs, to the benefit of uninterrupted delivery of LNG commodities to the world markets.

Since the basis and characteristics of the integrated LNG ports SC RM system have been already investigated and defined as a result of the earlier research steps, the presentation of the conceptual model based on Checkland (1981) will be undertaken next.

**Table 8.2 Summary of SSM used to construct the RM conceptual model**

| Steps                                                                                                                                                                                   | Purpose                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <p><b><u>Development of rich picture (RP)</u></b></p> <p>RP shows key relationships, issues, contents and influences surrounding the archetype.</p>                                     | <p>To provide a pictorial representation of the 'problem situation' and its linkages</p> |
| <p><b><u>Development of root definition (RD)</u></b></p> <p>To provide a concise statement about the system under investigation</p>                                                     | <p>To ensure focus and provide boundary of the system in question as well as CATWOE</p>  |
| <p><b><u>Identification of systems parameters</u></b></p> <p>To identify the sources, inputs, outputs, transformations, clients and receivers as well as feedback within the system</p> | <p>To enable the development of conceptual models</p>                                    |

|                                                                                                                                 |                                                                              |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| <p><b><u>Identification of systems concepts</u></b></p> <p>To identify the objective, worldview, boundaries and management.</p> | <p>To enable the development of conceptual models</p>                        |
| <p><b><u>Develop conceptual models</u></b></p> <p>To provide process models for integrated LNG Ports SC RM.</p>                 | <p>Useful in the transfer of knowledge from researchers to practitioners</p> |

**Source:** (Greswell, 1998)

Before developing further the above steps leading towards the formulation of the conceptual model, it is important to provide a summary of the main findings of our earlier research. Such findings will form the guiding principles for the integrated RM approach and the type of relationships among the safety and security systems of the LNG port SCs.

Security risks are now equally as important as safety risks in LNG ports and marine terminals. Security risks in general have gained importance after the 9/11 terrorist attacks and constitute a critical issue to hydrocarbon ports, including LNG.

There is a need for a standard safety framework to address both LNG shipping and port networks which could assist in better addressing the ship/ port interface. In this regards, the IMO's FSA, as a safety framework for shipping, should be extended to address port safety.

Although safety and security risks in LNG port SCs are two disciplines that may have different requirements, their management should be coordinated within

the framework of a holistic RM approach. Operation wise, this will enable integrated and efficient RM in LNG ports SCs.

An all-hazards approach provides a framework for coordinated RM, be they safety or security related risks. The outcome of such coordination is a cost effective and timely RM during all stages of risk assessment and management, meaning better protection of the LNG port facilities and the port users, as well as reliable LNG supplies to international markets.

An all-hazards approach needs to be qualitatively assured according to the principles of TQM. This means that underpinning any continual improvement culture, in terms of security provision, interaction with H&S and mitigation of both sets of risks cooperatively and effectively can only be based on the adoption of Quality Assurance systems by both parties, namely LNG port security and safety providers in full coordination with the port authority.

### **Step1. Development of the LNG Ports SC Rich Picture (RP)**

The key issues and factors which make up the rich picture for an integrated safety and security RM in the LNG ports SC system are identified as follows:

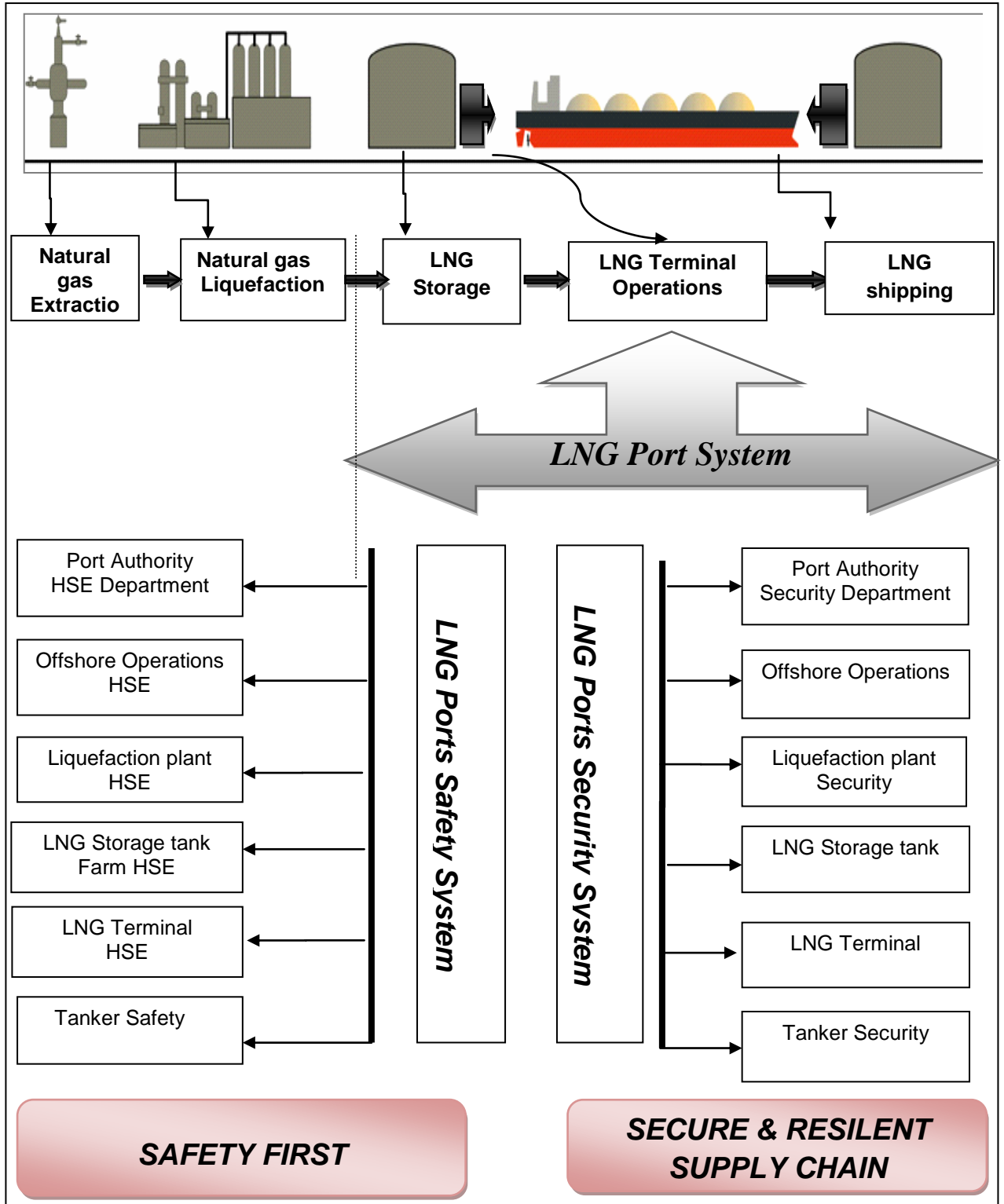
- Safety and security professionals should leave behind existing traditional beliefs whereby they assess and manage risks in isolation and without considering interplays and shared impacts between safety and security, for a new understanding through which safety and security risks and their RCOs are evaluated collaboratively to yield synergized and cost effective safety and security RCOs which shall be implemented in the LNG port system. This requires changing people's attitudes by making them understand that RM

should be approached from a holistic perspective as a collaborative process which can work adequately if performed systematically and through coordinated action.

- Integrate safety, security and environmental RA and mitigation to produce sustainable and resilient port operations through adequate evaluation of shared impacts between safety, security and environmental risks.
- Safety and security RM systems shall be integrated within the overall port management system to produce an overall efficient, cost effective and resilient port operations delivering LNG commodity to the world market without disruption.

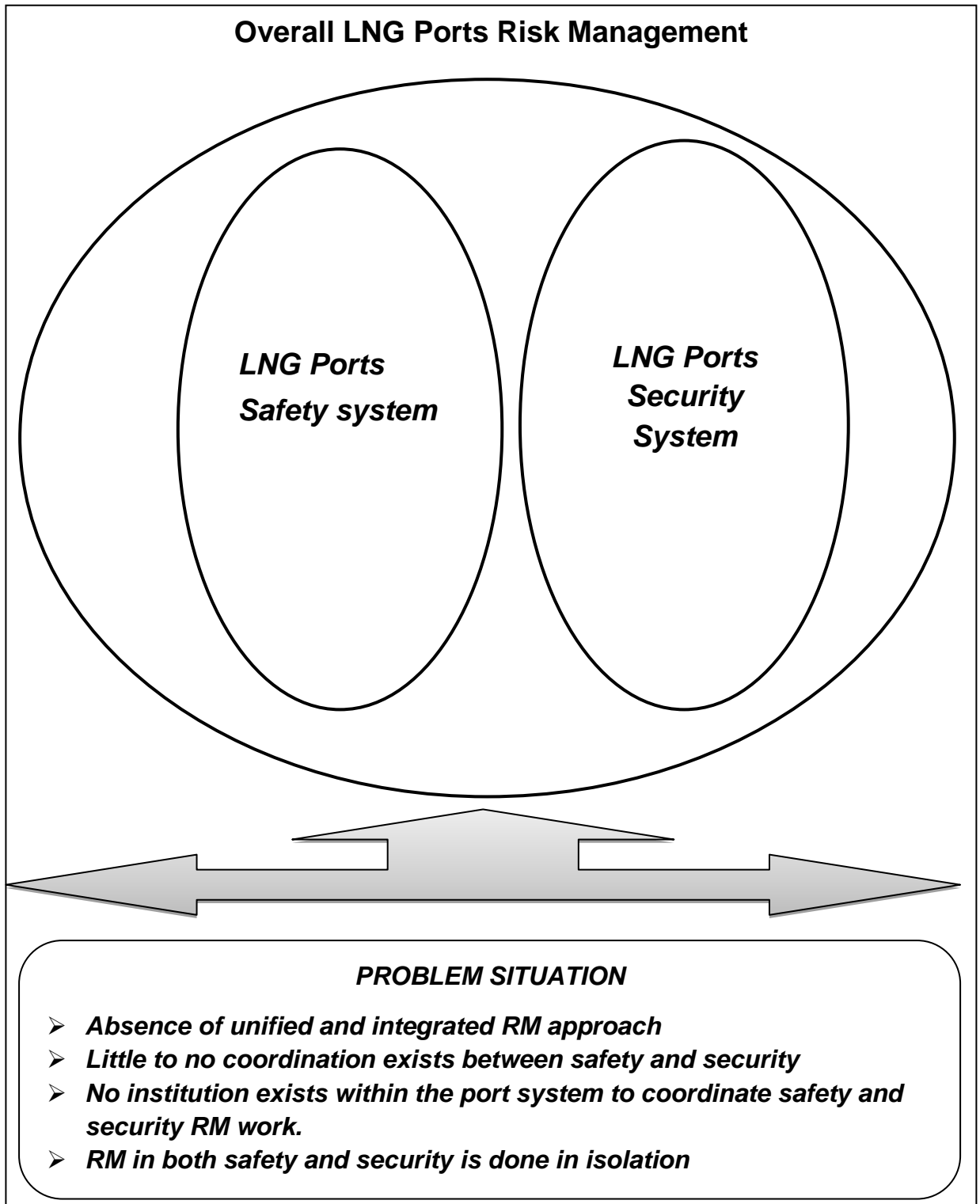
The following rich pictures 1&2 show the existing RM approach characterized by dichotomy and absence of coordination between LNG port safety and security systems. The aim is to present the existing problem situation which shall be compared with the proposed system of integrated safety and security RM.

Figure 8.6 LNG ports safety and security- Rich Picture 1



Source: The author

Figure 8.7 LNG ports safety and security- Rich Picture 2



**Source:** *The author*

## **Step2. Development of root definition**

The root definition for an integrated LNG Ports SC RM is defined as the RM approach and method which enables the LNG port system to have a holistic and integrated system for both safety and security systems to produce a resilient, safe and secured LNG Ports SC. In order for the port system to achieve such an RM approach and achieve resiliency in the port SC, safety and security RM systems shall be transformed into more transparent and cooperative systems, working together collaboratively to achieve cost effective and resilient LNG port SC. CATWOE elements are used to expand upon such a definition in terms of the systems actors, transformations, and worldviews.

### **1. Actors**

The actors of the LNG Ports SC RM system are the HSE and security managers from the liquefaction companies, port authority, the LNG terminal operations, the harbour master, the LNG storage tank farm and the LNG shipping companies. These are the parties responsible for developing and implementing the integrated LNG ports SC RM. Usually, LNG production and liquefaction companies have an interest in the whole LNG SC, including storage and export of LNG through the port, therefore they shall be considered as part of the whole port community and actors within the LNG port system.

### **2. Transformation**

The transformation of the safety and security overall RM system is the changing of such system into an integrated RM systems' approach engaging the whole port community including the actors and stakeholders, and beneficiaries of the

output of such a system. This change should define the methods and procedures to be followed in order to persuade the whole port system to engage in an integrated RM approach.

Changing people's attitudes by making them understand that RM should be approached from a holistic perspective as a collaborative process. Therefore, safety and security professionals should abandon existing traditional beliefs that each profession of risk considers itself the most important within the overall LNG port system. Contrary to the systems approach, this attitude contemplates the segregated and segmented approach to RM. Such an attitude impacts the RM methodology which is usually done in isolation and without considering interplays and shared impacts between safety and security. It is believed that RM professionals from both disciplines should shift from the above traditional approach to a more integrative and holistic approach through which safety and security risks and their control options (RCOs) are evaluated collaboratively to yield synergized and cost effective safety and security RCOs which can be efficiently implemented in the LNG port system.

- Integrate safety, security and environmental risks assessment and mitigation to produce sustainable and resilient port operations through adequate evaluation of shared impacts between safety, security and environmental risks.
- Safety and security management systems shall be integrated within the overall port management system to produce an overall efficient, cost effective and resilient port operations delivering LNG commodity to the world market without disruption.



- The role of the port community within the port management system shall be revived and strengthened in order to participate actively in the implementation of the proposed integrated RM process.

### **3. Weltanschauung/ Worldview**

The worldview is the belief that an integrated RM approach to the LNG port system is the optimal methodology in dealing with safety and security risks. As explained earlier both safety and security RM systems shall be changed and re-considered from a holistic systems perspective. One of the findings of the quantitative survey is that, although safety and security are two disciplines that may have different requirements, their management should be coordinated within the framework of a holistic RM approach (research question 3). This means that each discipline shall undertake its RA process separately; however the outcome of such assessment (RCOs) shall be reviewed and approved, prior to implementation, by an independent RM committee to determine any negative impact, contradictions or redundancies that may arise between safety and security RCOs.

#### **Step3. Identification of systems parameters**

In this step, we shall build on the root definition to add to the systems concepts. The sources, inputs, transformations, outputs, and feedback elements are discussed in more details to enable the development of the integrated RM conceptual model.

##### **1. Sources**

The sources of inputs will come from safety and security disciplines and their specialists who have the necessary knowledge and expertise about the RM processes.

## **2. Inputs**

These are information on the core RM competencies existing within the safety and security systems in particular and the port management system in general.

## **3. Process**

This is related to the activities undertaken to fulfil the integrated RM approach. These include:

- Identification of current RM safety and security processes
- RA and management skills and knowledge audit
- Safety and security RM techniques/ approaches
- Identification of gaps between existing and required RM competencies, skills and approaches.
- Develop the strategy to enhance the core competencies required for an integrated RM approach.

## **4. Outputs**

The output of the process is an action plan to develop the core competencies, skills, attitudes and approaches within the RM community which shall enable the implementation of an integrated RM approach in the LNG ports SC.

More importantly, the output shall be two-fold:

- An integrated RM methodology for both safety and security systems;
- An organisational change along with a procedure to implement such RM methodology.

## **5. Feedback**

The feedback shall include performance measures as well as quality control system to identify and evaluate how the process is performing and any improvement actions required.

### **Step4. Identification of systems concepts**

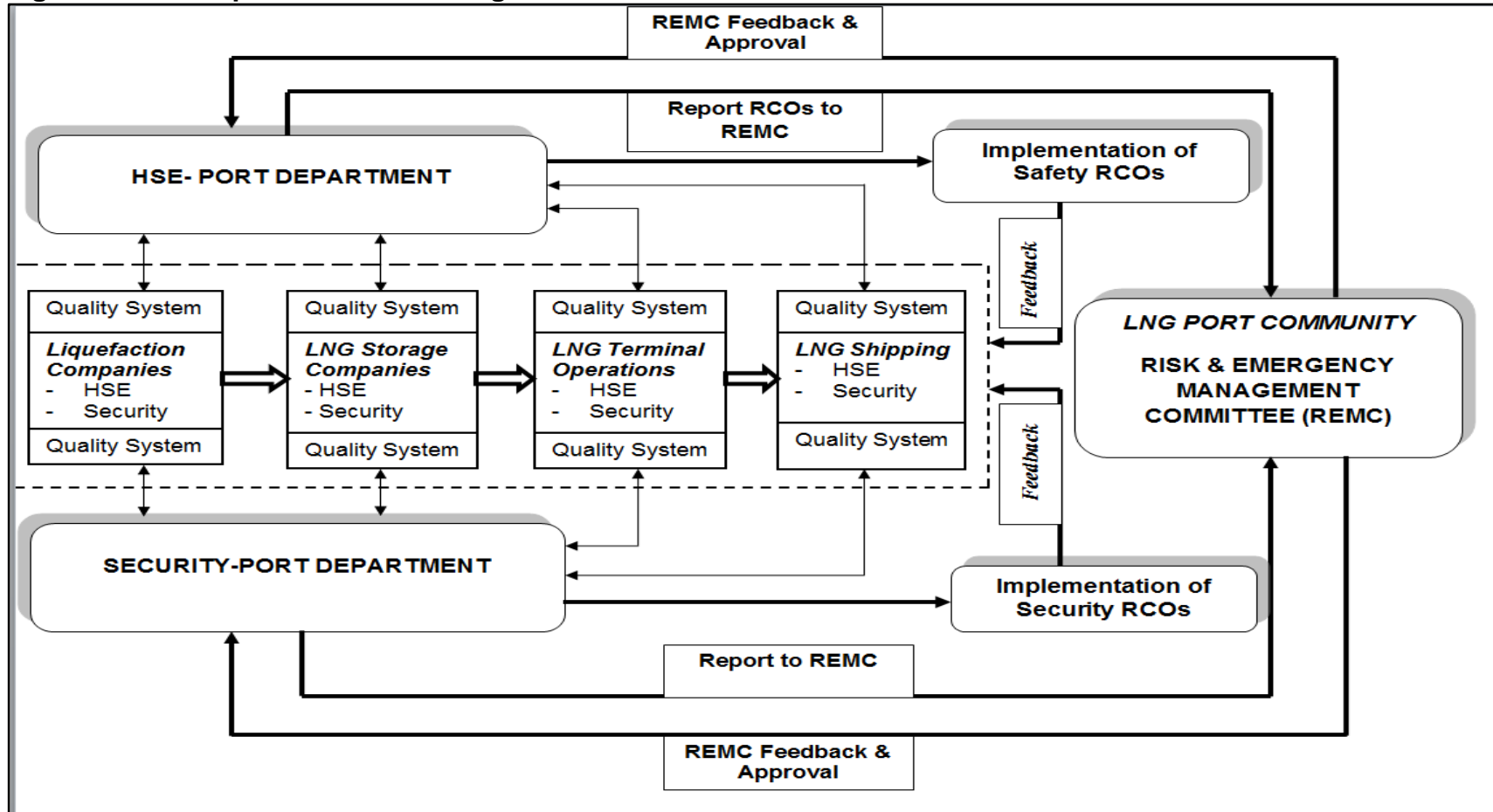
The main systems concepts of the integrated RM model of LNG Ports SC have been identified and some of them already presented. These concepts are:

- ❖ An overall RM system composed of two systems, for instance the safety system and the security system.
- ❖ The RM system versus the port management system.
- ❖ The port community as an important component of the port management system. The port community is composed of representatives from the port authority, port users, port operators and port stakeholders from the private and public domains.
- ❖ Holistic and integrated approach is the approach looking at the LNG port SC system as a whole composed of various ports subsystems fulfilling complementary and competing functions and produce shared impacts. Such subsystems act together to produce services and value added to port users and customers.

### **Step5. The Conceptual Model**

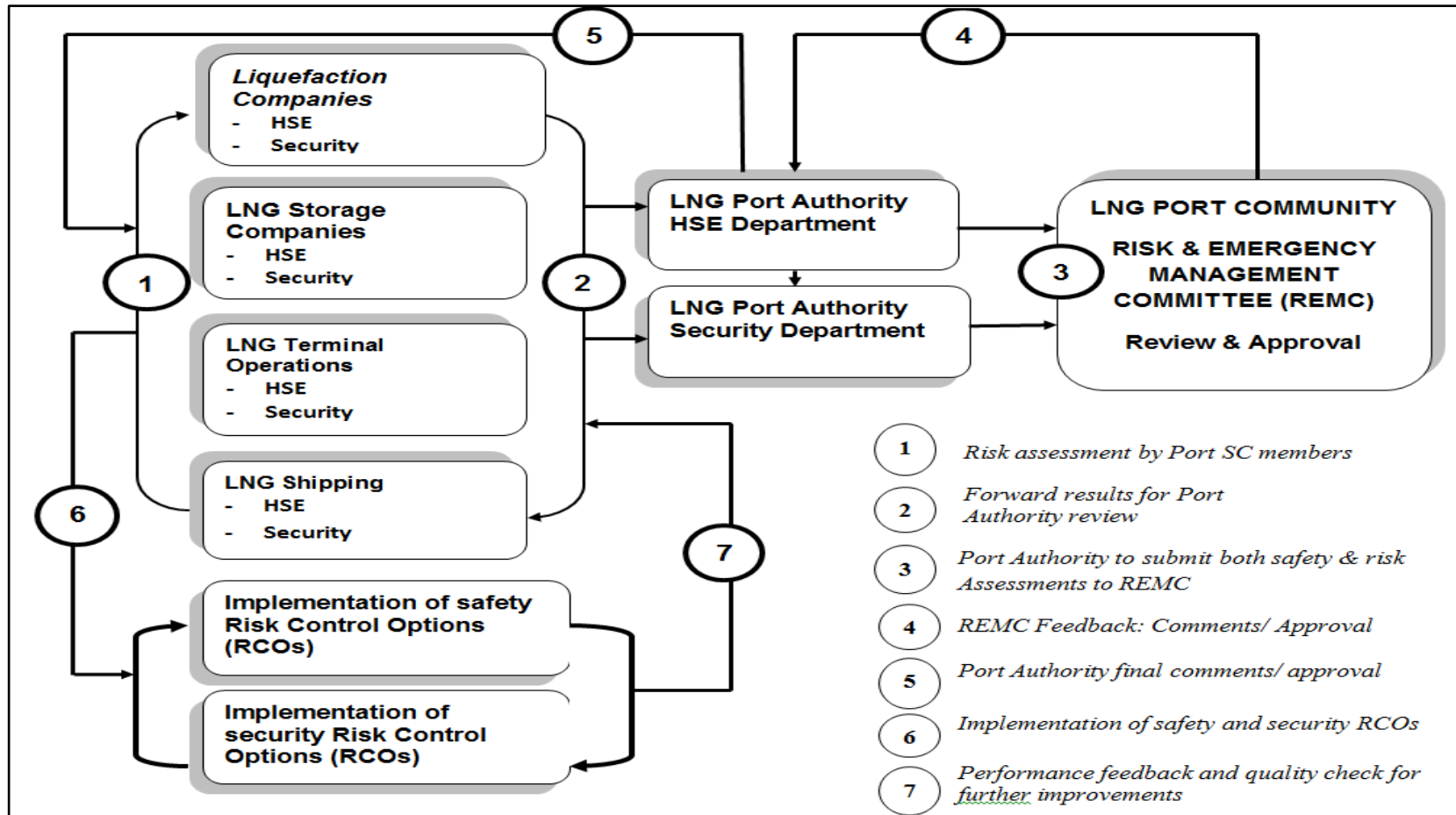
The above steps along with the results of the last quantitative survey form the basis for the proposed CM for integrated LNG Ports SCs RM.

**Figure 8.8 Conceptual Model for Integrated LNG Port SC RM**



Source: The author

Figure 8.9 Work Flow Diagram as per the Conceptual Model (FIG.8.8)



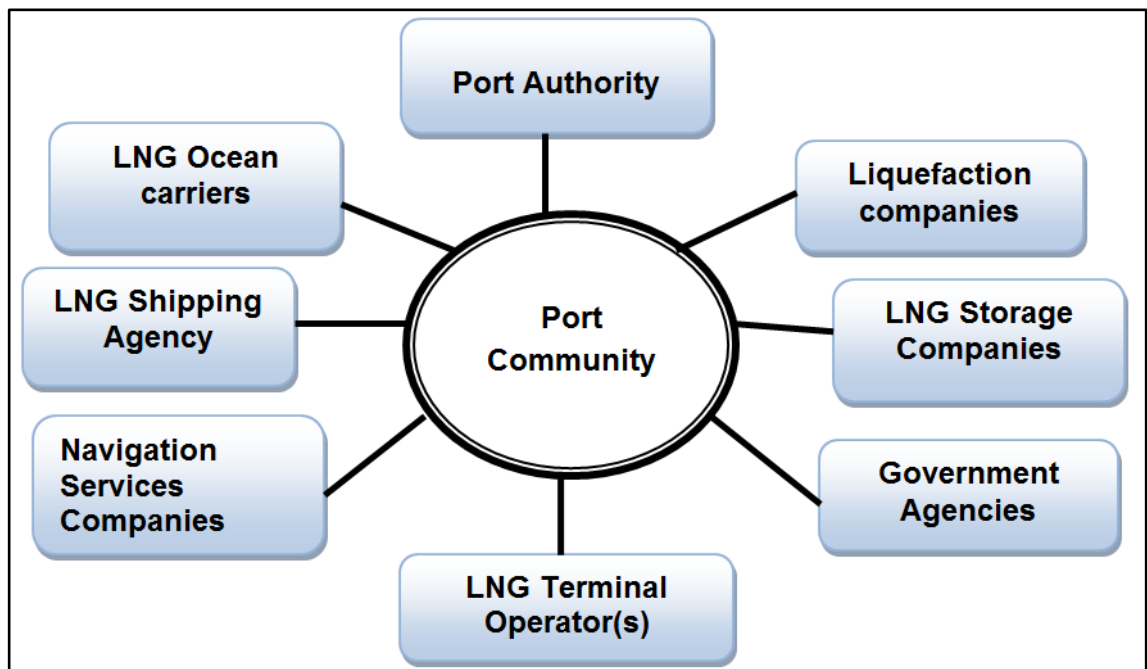
Source: The author

The proposed model (Figure 8.8) provides a clear picture of the work flow, relationships and linkages to be established between the main LNG SC members active within the port system. These are LNG terminal operator (s), LNG Storage Company (ies), LNG shipping company (ies), navigation services providers, shipping agency (ies) as well as the LNG port authority. Only HSE and security departments' roles are highlighted here as main actors of the proposed integrated LNG port SC RM system.

The model emphasises the pivotal role of the port community which is formed by all port stakeholders. In commercial and multi-purpose ports, port community systems (PCSs) are holistic, geographically bounded information hubs in global SCs that primarily serve the interest of a heterogeneous collective of port related companies and port users. These heterogeneous companies often include terminal operators, ocean carriers, freight forwarders, enforcement agencies (i.e. customs), port authorities, and various lobby groups (including workers' unions, environmentalists, and other policy makers). Port community systems that bring these diverse parties together in transaction recordkeeping and information sharing can assist in improving port performance in general.

In LNG Port setting, the port community, led by the port authority, is usually composed of representatives from the following LNG port organisations:

**Figure 8.10 LNG Port Community**



*Adapted from (Rodrigue, 2013)*

Fig.8.10 illustrates the composition of the LNG port community. Representatives of the above port stakeholders meet at regular time intervals to discuss coordinate and decide on issues of common interest to the normal functioning of the LNG port and which require cooperation and coordination among all parties for their swift and smooth implementation.

The port community's role is larger and encompasses all issues related to port activities which are of interest to port stakeholders. It is an important venue for the port community to discuss issues of common interest, provide port technical and business opinions and coordinate actions when required on matters which the port authority cannot handle alone. An important part of the port community mandate shall be the coordination of RM and emergency related actions in full cooperation with responsible parties from the port and government agencies.



In order to fulfil such a strategic mandate, the LNG port community shall create a risk and emergency management committee (REMC), composed of expert representatives from HSE and security departments representing each Member Company/ governmental agency of the port community. Such a committee shall play a central role in reviewing quantitative RAs (QRAs) and terminal/ facility security plans to identify any discrepancies, redundancies or negative impacts that any type of Risk Control Option (RCO) either safety or security related may have on the other. The REMC will have to coordinate closely with the port authority's HSE and security departments which will be receiving RA and management reports from the port community members and forwarding them to REMC for review, discussion and advice. Therefore the REMC committee will play mainly a technical advisory role.

Fig.8.9 explains further how the workflow will be carried out between the LNG Port Community members, the LNG port authority and the REMC. Each member of the port community shall carry out separate safety and security risk assessment and report to the port authority the RCOs recommended as per the RA. The port authority shall review and share the reports with the REMC for study and advice. The REMC shall formally inform back the port authority of its technical opinion which should further study and make decisions on the most appropriate RCOs to be applied. The port authority shall communicate its final decision to the concerned port community member for implementation and feedback. In this respect, the port authority is the responsible party for safety and security risk management within the LNG port area, while the LNG port community REMC will serve as an advisory body for review of safety and security risks assessments of all port community members and facilitate

discussion among all port community risk management specialists, to ensure that redundant or conflicting safety and security RCOs are avoided and that implementation of safety and security RCOs are carried out in full coordination among port community members within a participative approach.

As such, the conceptual model, as a vehicle to a holistic and integrative approach to risks, call for an implementation of safety and security RM in LNG ports integrating safety and security risks assessment and management, emergency response actions and the port business continuity within the framework of a participative approach.

It should be further noted that the above LNG ports RM model is devised according to the particular situation and business model of LNG ports in the Middle East and North Africa region (MENA). Since the central objective of the model is to integrate the safety and security RM, emergency response and port business continuity of LNG ports from a holistic and comprehensive approach, it is believed that such model can fit any similar LNG port setting in other regions of the world which still lacks holistic and integrated approach to risks and vulnerabilities.

### **8.3 VALIDATION OF THE CONCEPTUAL MODEL**

The proposed conceptual model is the culmination of research into the existing safety and security risks assessment and management approaches and practices. This identifies the need for an integrated approach to RM due to several reasons detailed earlier, most importantly the requirement for an integrated and cost effective RM capable of delivering and ensuring a safe, secure resilient and cost effective LNG SC to international LNG markets.

To achieve this objective, a conceptual model (CM) has been proposed to articulate and materialise such an approach at both theoretical and practical levels. This model identified that port SC stakeholders shall work collaboratively within the port community risk and emergency management committee (REMC) led by the port authority to align their safety and security RM plans, programmes and processes with the objective of achieving an integrated and holistic approach to RM. Based on the Systems Thinking Approach (STA), the proposed model sets out a methodology and a process through which the objective of integrated safety and security RM can be applied.

The testing and validation of the model is based on whether the approach is deemed practically useful from the port practitioner's perspective, including port operations and logistics managers as well as safety and security specialists. Although the elaboration of the approach along with the conceptual model have gone hand in hand throughout the various stages of the research and in full interaction with LNG port and RM professionals, it is decided to convene a focus group discussion among a panel of LNG ports and RM professionals from two leading LNG and hydrocarbon ports in the State of Qatar, the world's leading LNG producer and exporter. The objective is to test the theoretical and practical rigour of the model and validate its final construct.

### **8.3.1 The focus group panel**

A focus group discussion is arranged among 6 LNG port professionals representing port operations and logistics as well as safety and security. This sample of experts is selected from two LNG and hydrocarbon ports: Port of

Ras-Laffan (World largest LNG exporting hub) and the port of Mesaieed, one of the leading hydrocarbon and multi- purpose ports of the Arabian Gulf region.

**Table 8.3 Composition of focus group participants**

| <b>Participants</b> | <b>Position held</b>               | <b>Specialty</b>              | <b>Remarks</b>                            |
|---------------------|------------------------------------|-------------------------------|-------------------------------------------|
| <i>Mr. A</i>        | Assist. Manager<br>Port operations | Port operations               | Port authority                            |
| <i>Mr. B</i>        | Head of HSE                        | HSE RA                        | HSE onshore<br>(port and Industrial area) |
| <i>Mr. C</i>        | Head of Logistics                  | Port Logistics                | Port logistics operations                 |
| <i>Mr. D</i>        | Head of port<br>regulations        | PSC (Safety &<br>security)    | Maritime safety<br>enforcement            |
| <i>Mr. E</i>        | Head of port<br>security           | Port Security<br>(Operations) | PFSO - Security<br>operations             |
| <i>Mr. F</i>        | Sr. security RA<br>specialist      | Port Security<br>(RA)         | Port security RA and<br>security plans    |
| <b>Total</b>        | <b>6</b>                           | ---                           | ---                                       |

**Source:** *the author*

Table 8.3 presents the composition of the focus group panel while the group discussions prompt sheet is attached in Appendix 7. The panel is selected from the middle management of two leading LNG and hydrocarbon ports. These are experts in their fields having significant experience in LNG operations and related safety and security requirements and practices.

### **8.3.2 Methodology**

Prior to the discussion session, the participants were invited through email and informed about the subject of the meeting and provided with the prompt sheet outlining the main discussion points. At the meeting the interviewer provided introductory remarks and the session proceeded by asking each participant to introduce themselves to the rest of the group before opening the floor for free responses to the stimulus shown below.

Content analysis is used to analyse data generated as a result of this focus group session.

### **8.3.3 Results**

The material available for analysis is limited to the discussion recorded and transcribed and notes taken during discussions.

#### **What type of management should govern safety and security risks in LNG ports?**

Chapter 6 revealed that safety and security risks in LNG ports SCs need to be managed in full coordination between port SC stakeholders, including the port authority. A number of reasons, including the constantly changing nature of risk both in scope and scale and the importance of LNG as a strategic energy source for importing economies, make this coordination a must.

Most participants agreed to the requirement for applying a coordinated approach to risk, including one respondent who added the need for *'such coordination to be institutionalised in order to be effective'*. It was noticed from their body language that all participants agreed with the later statement meaning that the way in which such coordination is carried out is a determinant of the efficiency of the overall RM.

With regards to the level of coordination among LNG ports safety and security, one participant estimated that this stands only at the level of *'50 to 60% from what is required as coordination to achieve full synergy'*. The rest of the participants declared that *'some coordination exists'*, but this is *'not sufficient'* to yield cost effective and integrated RM. This opinion on the existing level of

coordination and cooperation among LNG port risk safety and security disciplines is consistent with earlier findings reported from both the Delphi exercise and the quantitative survey study.

**Does coordination and cooperation among safety and security constitute the panacea for integrated RM in LNG ports?**

Although all participants agreed to the requirement for coordination among safety and security as a pre-requisite for efficient RM, most of them linked the success of such coordination with other accompanying measures. One participant requires '*clear definition of responsibilities...and then clear interface management procedures*'. Another attached the success of coordination among LNG port safety and security to a balanced allocation of resources among safety and security services, since those services are competing among each other to get the largest part of resources allocation. For him '*in some cases, coordination is the last issue to be considered within such competitive context*'. For a third participant '*it is the silo mentality which prevents coordination and cooperation among safety and security professionals, therefore, more education and awareness is needed to change mind-set*'.

In this regards, participants were unanimous regarding the need for further coordination among port safety and security disciplines, however each one suggested accompanying measures for such coordination to be effective. These views are in line with our earlier recommendations as part of the CM to have each party's role well defined in the process. Participants also mentioned the need for professionals of both risk disciplines to leave the silo mentality and

prepare the ground for fruitful cooperation within the port community to achieve a safe, secure and resilient LNG SC.

**Does the ‘all-hazard approach’ to risk enable efficient safety and security RM?**

Five out of six participants responded positively to this question by asserting that an all-hazard approach is actually a cost effective RM approach. One participant further explained that such an approach embodies a ‘*holistic perspective*’ which provides an effective framework to resolve interfaces and shared impacts among safety and security risks and enable coordinated risk mitigation. Another expert recognized the virtue of such an approach but questioned how this ‘*can be practically applied*’, while a third participant further explained how this approach enables efficient incident reporting, be it intentional or unintentional, since ‘*the reporting of any suspicious event is done by any safety or security agent*’, therefore achieving enhanced overall protection.

**What practical benefits could be expected from the implementation of an all-hazard approach to risks in LNG ports?**

Five out of six responses agreed that such approach, if implemented properly, could lead to practical benefits, such as early detection and reporting of risks and hazards that would lead to timely preventive actions, which in turn enables enhanced resilience of port SCs. However, three fifths of participants warned that on the contrary, if such an approach is not applied correctly, it may lead to severe protection gaps. In explaining such gaps, one participant argued about the possibility that each party at the port, be it safety or security organisation, ‘*may try to take advantage of this approach to rely on one another and widen*

*the interface and grey areas between the two disciplines of risk*'. In the same way, another expert further explained that in the current context of constantly changing risks, these are *'usually addressed through a collaborative process'*. Another participant also emphasised that *'protection from risks is the business of all and this requires change in mind set'*

### **What role could the port community play in the coordination of safety and security risks management?**

Four sixths of participants welcomed the idea that the port community should have a role in the coordination of safety and security risks management. Most of them, however, advised that the port community role should be limited to an advisory one, since legally; the port authority is responsible for ensuring a safe and secured port environment. One participant stated that, in many ports, the port community has experience of being an effective venue which assisted in the implementation of many regulations and standards in the past such as the ISPS code and other port legislation. He added that the proposed involvement of the port community in the coordination of safety and security risks management *'may turn into a specialist RM forum which can play an important role not only in the coordination of risk mitigation activities but in all aspects of RM such as information sharing, training and awareness'*. Although all agreed on the need for the port community to play a role in coordinating RM activities, two participants stressed the necessity for accompanying measures if such role is to produce an added value to the existing RM system. One argued the need for a streamlined process and clear work procedures between the port authority and the port community and the other warned about confusion that may arise



regarding the roles and responsibilities of the port authority and the port community and called for clear demarcation between each party's involvements in the process.

**Do you have any comments on the proposed RM model (CM)?**

All participants expressed their agreement on the work flow process proposed through the CM, since it includes the main port stakeholders involved in RM and emergency response and depicts the main relationships governing their work. Most participants welcomed also the involvement of the port community-REMC in emergency coordination but requested this particular involvement to be further clarified. They agreed that such a role should even be extended to include the port business continuity, since, in their view; this will assist in applying an all-hazards approach to risks and provide further protection and resilience to the LNG port system.

With regards to the involvement of the port community in emergency planning and response, respondents were unanimously positive about such involvement. They qualified this role as important in supporting the port authority and emergency agencies which have the primary responsibility for emergency response. Moreover, all agreed in wanting to see the port community-REMC also involved in the port business continuity during a post-disaster period due to the wealth of expertise and resources the port community may provide and which can play a decisive role in bringing the port to normal operations in minimum time. One participant stated that the REMC can play 'important roles in pre-incident and post-incident phases, as a pre-incident role, REMC can assist in awareness and practical continuing training in safety and security risks

and emergency response'. It has also a role to play in post-incident phase through '*assistance to the port authority emergency and response committees in getting the necessary resources in case of large disaster*' requiring additional rescue, evacuation effort or urgent medical assistance.

Port communities can have an important role in planning and conducting emergency drills, organising continuing trainings and assisting in the provision of technical, medical and rescue/ evacuation resources and assets during emergency evacuation and response. For this collaborative process to succeed, most participants required the port authority to take the lead according to its mandate which is prescribed by international maritime standards. Also procedures should be put in place to define clear roles and responsibilities for all stakeholders within such a collaborative process of coordinated RM, emergency response and port business continuity.

#### **8.4 CONCLUSION**

The usefulness and necessity of applying a holistic approach to RM has been discussed earlier by integrating safety and security systems together to allow efficient and cost effective assessment and management of risks within LNG port SCs. In the U.S. the Coast Guards have recently started applying the so called '*all-hazards approach*' to risk through integration of safety, security and natural disasters sources of risk. Most probably, one of the reasons for being successful in introducing such an approach is a comprehensive mandate in dealing with all sources of risks within the onshore and offshore areas of the port system. This allowed them to develop and apply this approach with relatively less hassle, although, it may be still early to evaluate the experience.

The process suggested by the proposed RM model for the review and validation of security risk plans and HSE QRAs provides an adequate means of synergy between safety and security risk control measures which can allow cost effective, non-contradictory measures to be implemented. It is believed that numerous benefits can be drawn from such an approach, most importantly assurance of the cost- effectiveness of the RM process which shall enable resilient, robust and uninterrupted LNG port SC.

The model calls for a collaborative process led by the port authority within a participative approach. In such a process, all LNG port stakeholders, members of the port community, have to report their HSE and security RA and management plans, respectively to the port HSE and security departments. They have also to defend it in front of the port community REMC. Such RM plans will receive first review from the ports' specialised departments and then be discussed within the Risk and Emergency Management Committee (REMC) of the LNG port community. The RM plans are discussed collectively within the REMC and commented on or approved prior to implementation. Official approval or commentary is communicated back to concerned parties through the port authority.

For the sake of efficiency, this process needs to be planned adequately through change management and BP re-engineering. Below are the main pre-requisites for such a process to be successful:

- First, changing the traditional attitudes of the port safety and security risk professionals. They have to be convinced that the management of all sources of risks needs to be approached holistically from a systems

perspective and that such an approach is an effective way to address the permanently changing nature of risks both in scope and scale.

- Adopting new procedures which make the port community enjoy an advisory role towards the port authority in reviewing and commenting on RA and management plans received initially from port SC members. It should also act as the main venue for HSE and security risk managers from port SC members to debate and exchange information and agree on the best way to synergise the implementation of risk mitigation measures avoiding disruption to port operations.
- The port community in general and the REMC in particular shall adopt and use an electronic port community system which can allow smooth and cost effective management of the process as well as efficient exchange of information among REMC members. This port community system must be implemented as part of an overall BP re-engineering in LNG ports SC RM, emergency response and port business continuity.
- The port authority shall play an active leadership role within the port community's REMC. Its safety and security departments have to lead and coordinate the work of the REMC and ensure that a recognised quality management system is in place and adequately applied throughout the review and validation process of RM plans.

The above remarks are generated as a result of the testing phase of the conceptual model performed through a focus group discussion among a panel of LNG port experts. As discussed in the section above, the panel of professionals selected from two leading LNG and hydrocarbon ports of the Middle East attested to the validity of the model and its practical applicability in

the context of LNG ports SCs, subject to the existence of the accompanying measures listed above.

## CHAPTER 9 DISCUSSION

The previous chapter introduced a CM embodying an integrated approach to the three main components of risk and emergency management, namely the unified safety and security RM, integrated emergency planning and response and port business continuity.

These three domains, although having different requirements in terms of planning and management, are interconnected and share common concepts, information and resources. They belong to the same broad area of emergencies/ disaster planning and management. So, in the port and logistics business, they usually share information and resources, since they require specialists in RA, management and emergency planning, preparedness and response which in most cases require either safety or security backgrounds or both.

This chapter will briefly review the methodology used to address the research problem. It will then identify and discuss the main research findings and analyse the impact of the proposed approach on the RM and emergency planning and response in LNG ports SCs. Further analysis of the implications of the research results on a practical level will be made to qualify the new LNG port management system in light of the changes proposed to the RM and emergency response systems. Finally, a critique of the research will follow to explain and evaluate the difficulties encountered during the administration of both quantitative and qualitative surveys.

## 9.1 INTRODUCTION

This research work has provided a modified approach to the issues of RM, emergency response and port business continuity within the LNG port SCs system which should pave the way and lead the development of an integrated and holistic strategy to prevent, mitigate and recover from safety and security accidents/ incidents impacting the LNG ports SCs.

The proposed approach calls for an integrated and unified management among safety and security risks within each domain of intervention, such as safety and security RM, emergency planning and response as well as port business continuity. The same integration is also needed among these three areas of emergencies management. This approach is proposed instead of the prevailing approach of isolated and segregated management of emergencies. The approach takes a high level systemic view that incorporates both theoretical and practical knowledge and draws on the experience of world leading LNG ports and marine terminals. The proposed approach is largely crafted, checked and validated with involvement of the LNG ports RM industry during all stages of both theoretical and empirical enquiry.

Risk and emergency management in LNG ports SCs is described as a messy situation which needs to be thoroughly understood, appropriately organized and effectively managed in an integrative and holistic manner. Due to the interdisciplinary nature of the research problem, a mixed methods strategy was chosen to explain the current situation and explore ways to resolve and further enhance the problem situation. This research has benefited from such a methodology due to the particularity of the research questions which require

both qualitative and quantitative research techniques for data collection and analysis. A thorough extensive literature review, including regulatory and methodological RM frameworks, was undertaken which helped to formulate the research problem and related research questions; a qualitative empirical two round Delphi study has assisted to explore and delineate the scope of the topic, for which results are confirmed and validated through a quantitative factor analysis coupled with hypotheses testing using SPSS package tests. These research steps provided useful insight and served as a foundation to the formulation of an integrated CM for RM, emergency response and port business continuity. The CM has been developed using SSM which is indeed regarded as a systemic approach to complex problem solving.

Since one of the main aims of this research is to provide an enhanced empirical framework which can be of practical use to solve the disintegrated nature of RM for current LNG port systems, the approach as well as the CM were tested and validated for usefulness using an in-depth focus group discussion with experts from relevant disciplines of risk, emergency planning and response as well as LNG port logistics operation and management. The validation process was extremely beneficial in developing the approach and confirming the practicality of the CM. The feedback was predominantly positive.

## **9.2 THE RESEARCH PROBLEM**

The research problem originated from a practical observation of the status of safety and security risks and emergencies management in the context of LNG ports and marine terminals. Those observations identified issues in the RM



system, especially the approach to the relationship between safety and security disciplines which impact the overall risk and emergency management system and may have a detrimental effect on the port recovery and port business continuity in the aftermath of an emergency. Critical review of relevant literature as well as discussions with safety, security and port professionals revealed that safety and security RM within LNG ports system is a 'fuzzy' ill structured process whilst most individual safety and security RM models, taken separately, are generally well planned processes. The evidence also indicates that integrated safety and security RA and management is beneficial to LNG port SCs, in ensuring resilient and cost effective RM and enabling smooth handling and storage of LNG through the port to serve international energy markets without disruption.

Therefore, the research problem involves mainly the management of safety and security risks but extends to the emergencies/ disaster management system such as emergency planning, preparedness and response and port recovery and business continuity in the aftermath of accidents or attacks.

This research proposed to analyse the current status of RM in LNG Port SCs and investigate ways in which RM can be integrated and looked at holistically to yield a comprehensive integrated RM process which takes into consideration specificities and requirements of both safety and security risks in addressing their interfaces and shared impacts in the areas of assessment and management. It aimed to formulate an integrated 'all hazards' approach to RM, emergency planning and response and port business continuity, which can prove theoretically sound and practically applicable.

### **9.3 THE METHODOLOGY ADOPTED**

As stated earlier, this research adopted a multi- methods approach as ‘a mean of mutual confirmation of measures and validation of findings’ (Berg, 2001). It should be noted that both multi-methods within a single paradigm as well as mixing methods from different paradigms were used as appropriate. The aim is to take advantage of the multiple virtues offered by mixing methods in an attempt to address the research problem and provide answers to the research questions as accurately as possible. Also, an inductive approach is adopted throughout the exploratory and conceptual part of the research while deduction is employed during the testing and confirmatory phases of the enquiry.

In the first part of the research, qualitative methods of data collection and analysis is predominantly used, for instance, critical review of literature and two rounds of qualitative Delphi surveys. Since the literature discussing the relationships and interfaces between safety and security in general and within the LNG ports context in particular has been scarce, a Delphi consultation among safety and security professionals was necessary to examine the assumptions made during the literature review and get some consensus among LNG port and RM professionals on some key ideas around the research problem. The first round of the Delphi exercise was followed by a second round after which consensus was achieved. This has laid the foundation for further research around the conclusions of the Delphi exercise.

During the second part, mixed quantitative and qualitative methods are deployed, namely a quantitative survey analysed through statistical techniques as well as a qualitative SSM analysis and focus group discussions. In an

attempt to triangulate the research findings from the in-depth literature and the two rounds Delphi study, a quantitative survey has been undertaken. The adoption of a quantitative study through an online survey method is selected in the absence of reliable historical data, especially on security incidents involving LNG ports and marine terminals. The available security data is insufficient and reliable statistics on security incidents is difficult to obtain from LNG port terminals since these are generally considered sensitive and highly restricted statistics.

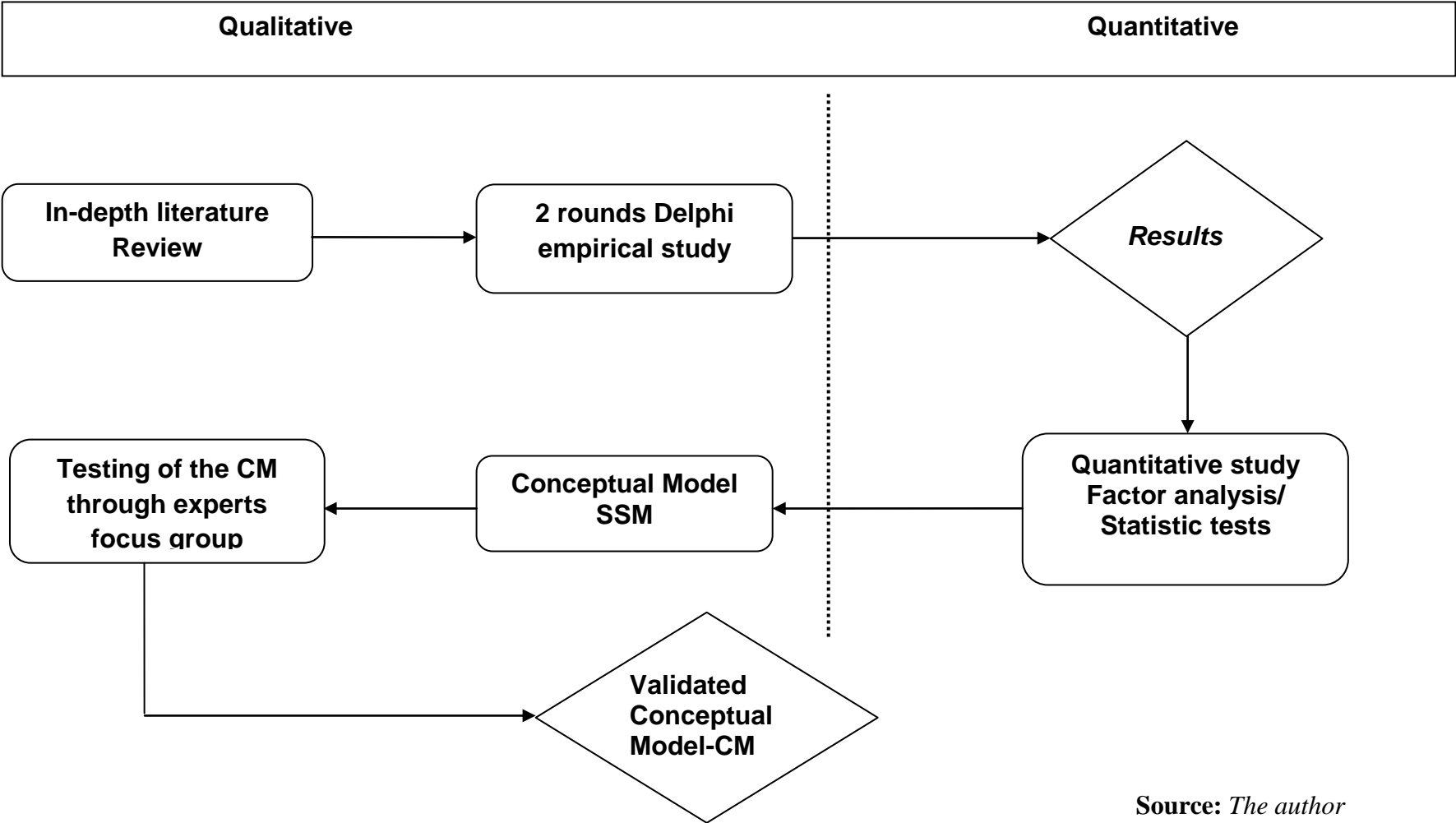
Therefore, an online survey carried out among a sample of representative panel experts was chosen to achieve cost effective research in terms of time and budget as well as higher data reliability. Such data is then quantitatively analysed using factor analysis as well as reliability and validity tests and Chi-squared likelihood ratio coupled with Gamma tests. The objective is to test and validate the hypothesis and results obtained from the two rounds of Delphi and to a lesser extent the insights and assumptions derived from the extensive literature review. The validated data obtained as a result of the quantitative study served as a foundation for the proposed safety and security RM conceptual model (CM).

Soft systems methodology (SSM) is used in developing the conceptual model for safety and security RM in LNG ports which takes into consideration the useful empirical work and experiences gathered in the RM domain and applies them while considering different worldviews. The introduction of SSM and related concepts and methods such as BPR in the context of this research has been beneficial since in our perspective, the application of integrated RM in

LNG ports requires some kind of re-engineering of the processes through which safety and security risks are assessed and managed. The processes of RM, emergency planning, preparedness and response as well as port recovery and business continuity should be re-engineered to enable better communication and exchange of information among specialists of the two disciplines, including the use of the right procedures and technologies to enhance risk controls for the benefit of a resilient LNG SC. Based on SSM, a risk and emergency management conceptual model was proposed and validated through a focus group of experts from all relevant RM, disaster management and port operations experts from leading LNG and hydrocarbon ports of the Arabian Gulf.

Figure 9.1 illustrates the sequence of various methods deployed along this research.

Figure 9.1 Sequence of the multi-methods approach adopted



Source: *The author*

## 9.4 DISCUSSION OF THE MAIN RESEARCH FINDINGS

The followings are the main findings of this research:

- ❖ An '*all-hazards approach*' to risks is more cost effective in addressing both safety and security risks in LNG port SCs.
- ❖ This approach is represented in the form of a CM for integrated RM, emergency response and port business continuity, depicting the work flow, relationships and interfaces among various SC stakeholders from the port community.
- ❖ The port community can play an effective role in assisting the port authority in coordinating RM, emergency response and port business continuity activities among LNG port SC members.
- ❖ Safety and security risks management should be integrated with emergency preparedness and response as well as with port business recovery and continuity since those activities constitute a continuum within the port RM and emergency response domain.
- ❖ RM and emergency response activities should be qualitatively assured according to the principles of TQM.

### 9.4.1 Cost effectiveness of the '*all-hazards*' approach to risks

The practical evidence from some leading LNG ports shows that disintegrated and segregated management of safety and security risks create several difficulties in the day to day efforts of both disciplines to safeguard LNG port SCs and related infrastructure, facilities, people, information and financial flows from accidents and incidents. It also poses barriers to efficient implementation

of mitigation measures from both HSE and security organisations, due to the existence of interfaces and shared impacts between the two disciplines managing risks. Furthermore, absence of coordination and exchange of information among the two disciplines does not allow timely and appropriate response in case of emergency nor allow quick and timely port recovery from either accidental or incidental events. In our multiple discussions with experts of port RM, it was revealed that this deficiency in the safety and security interfaces reflects an underpinning lack of integrated and holistic approach to risks in the minds of many HSE and security professionals in LNG ports.

The appropriate response to such a problem is the necessity of introducing the implementation of an all hazards approach to risk which allows effective coordination of RA and management at all levels, while still respecting the requirements and particularities of each RM discipline. Adequate coordination and information sharing among safety and security professionals regarding risks and threats within the onshore and offshore limits of LNG ports will undoubtedly allow accurate assessment of risks in the shortest time, since RM professionals will get the needed information readily available and in the required format without being required to waste time and effort in searching for such information. Also, information sharing on risks and threats will enable cross checking for data validity and updates which will result in high accuracy and quality of information used in RA. High quality information shared timely among relevant port RM stakeholders enables efficient and cost effective RA and management in the two areas of risk. In this respect, an all-hazards approach provides a framework for coordinated RM, be they safety or security related risks. The outcome of such coordination is a cost effective and timely

RM during all stages of RA and management, meaning better protection of the LNG port facilities and port users, as well as reliable LNG supplies to international markets.

#### **9.4.2 The conceptual model and the all-hazards approach**

The use of SSM facilitated the formulation of a CM representing the way in which an all-hazards approach to risk can be operationalized in the context of a generic LNG port SC system. The proposed CM is an attempt to put the RM agenda back to its normative set up from a holistic systemic perspective.

The transformation of the overall safety and security RM system is the changing of the systems' approach through engaging the whole port community and including the actors, stakeholders, and beneficiaries of the output of such integrated system. This change defines the methods and procedures to be followed in order to persuade and convince the RM stakeholders and engage the whole port system within the new modified approach. Also, for such change towards integrated and holistic RM approach to succeed, the following pre-requisite conditions should be met:

- Changing attitudes of HSE and security RM professionals by convincing them to abandon existing traditional beliefs favouring a segregated and segmented approach to risks. RM professionals from both disciplines should shift from the traditional approach to a more integrative and holistic approach to risks and emergencies assessment, management and response. To achieve such a compelling objective, it is necessary to adopt a gradual strategy for cultural change within the safety and security



disciplines. This strategy should be based on continual training and awareness programmes.

- Safety and security management systems shall be integrated within the overall port management system to produce an overall efficient, cost effective and resilient port operations delivering LNG commodity to the world market without disruption. The RM and disaster management systems should understand the specificities of the LNG port business and act as an integral part of the port management system, to yield unified and informed risk- based port management decisions.
- The role of the port community within the port management system shall be revived and strengthened in order to participate actively in the implementation of the proposed integrated RM process. If the port community has successfully participated until now in actions and initiatives related to some aspects of port activities, it is time for it to actively assist in integrating the RM processes within the framework of a unified and holistic management of risks and emergencies.
- The proposed RM model confers a pivotal role to the port community in coordinating, resolving interfaces and serving as a professional advisory body to the port management. In order for such a role to successfully fit within the overall LNG port management system, an adequate use of information and communication technology (ICT) as well as clear procedures, protocols and standards should be established in order to integrate and synergise such a role within the three systems of RM, emergency management and port management.

### **9.4.3 Integration of RM, emergency response and port business continuity**

If safety and security need to be integrated and managed collaboratively within the framework of a holistic approach, a horizontal integration of the three areas of risks and emergencies need also to be coordinated and managed as a continuum; namely RM, emergency planning, preparedness and response as well as port business continuity.

These three domains of risks and emergencies (also called disaster management) are interrelated and should be considered in a continuum. Generally, disaster prevention, mitigation, preparedness and response are four elements that contribute to the sustainable development policies. As characterised by the UN Yokohama Strategy and Plan of Action for a Safer World (UN, 1994), these four elements along with environmental protection and sustainable development, are closely interrelated.

Risk and disaster prevention, mitigation, preparedness and response constitute an overall package which needs to be planned and implemented from a comprehensive and holistic perspective. Recent experience demonstrated that the focus on response alone is not cost effective since it yields only temporary results at a very high cost (Coppolla, 2007). Integration of RM and emergency preparedness and response is required for two main reasons:

- 1- RA and management focuses mainly on prevention. As RM cannot prevent all risks and hazards, there is always a residual risk which organisations must accept. As discussed in earlier chapters, risk acceptance means that the RA and management system can only

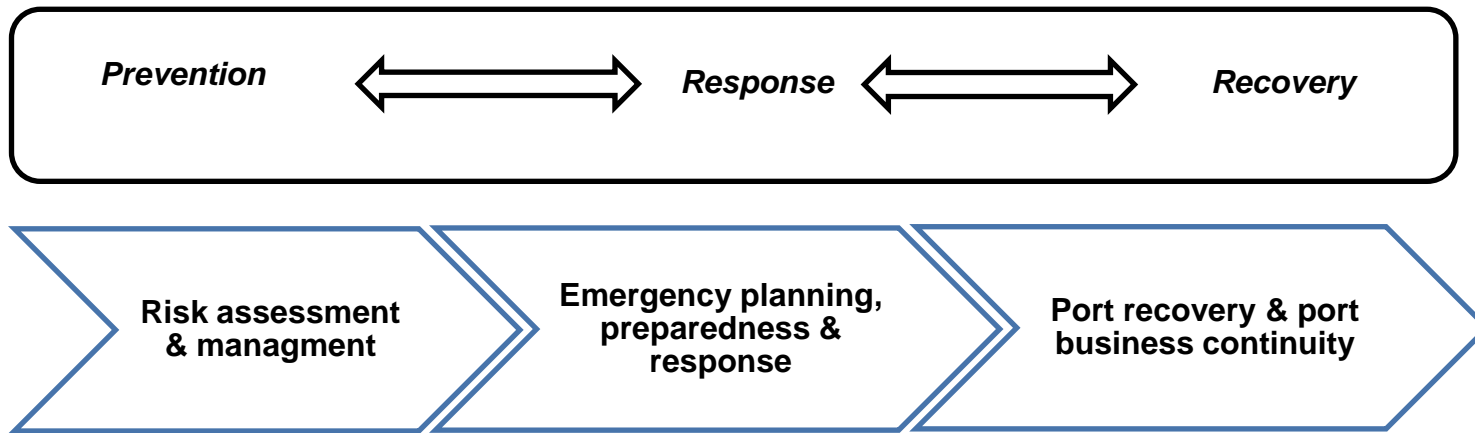
prevent and mitigate risks to a certain level, risk above that level is very unlikely to happen (rare) which means that in the case it strikes, mitigation plans are available to offset or minimise their consequences. Therefore, RM and emergency planning, preparedness and response are closely linked in a way that emergency planning and preparedness needs to understand exactly the risk acceptance criteria as well as the level of risk and corresponding consequences which are out of the scope of RM. A thorough understanding of those aspects is a pre-requisite to adequate emergency planning and response, including the necessary resources and methods required for their effective implementation.

2- In LNG ports, RM strategies, emergency response as well as port business continuity plans usually involve the same port risk organisations and emergency response agencies in their preparation. Therefore, sharing resources and expertise from those port organisations and agencies is required to enable efficient RM and emergency response plans and ensure their successful implementation at a later stage. It should be noted that RM, emergency management plans and strategies require collaborative processes in their planning and implementation.

In the aftermath of a port disaster, usually both the emergency response and the port recovery and continuity plans are immediately activated and simultaneously put into implementation. Although the objectives and focus of the two plans are different, they are still interdependent as the actions under one plan have an effect on the other. It should be noted that emergency response actions have the priority over port recovery

actions but it is always preferred to have the objectives of the two plans simultaneously fulfilled, such as providing effective rescue, relief and salvage actions while making sure difficult and delayed port recovery is avoided. Therefore the objective of quick and efficient emergency response is not contradictory to the objective of swift port recovery and business continuity. Those two strategic objectives can still be achieved through proactive disaster planning and preparedness and effective coordination during all stages of execution. Ensuring swift decision at the on scene commandment level regarding priorities of emergency actions is an important step in this regards. In our proposed CM, the port community REMC shall play a pivotal role in the coordination and exchange of information as well as in assisting the port authority, emergency organisations and the law enforcement agencies, in getting the necessary resources for port emergency response and port recovery in full coordination and under the instructions from the port on scene commandment.

**Figure 9.2 Integrated Pre-incident/ Post-incident RM and Response**



**Source:** *The author*

#### **9.4.4 Quality assurance of RM and emergency response**

Our earlier findings concluded that the all-hazards approach needs to be qualitatively assured according to the principles of TQM. This means that activities and processes related to RA and mitigation as well as emergency planning, preparedness and response have to be certified for being planned and implemented according to updated quality standards. Also underpinning any continual improvement culture, in terms of safety and security, and the interaction among HSE and security to mitigate both sets of risks cooperatively and effectively can only be based on the adoption of quality assurance systems by both parties, namely LNG port security and safety providers in full coordination with the port authority.

In this respect, each RM provider within the LNG port system, either HSE or security has to certify its RA and management processes and activities independently and work together with the port authority as part of a wider port community effort to identify interfaces and common processes among safety, security RM and emergency planning, preparedness and response in order to be qualitatively certified as well. In this regards collaborative processes and procedures in the combined RM and emergency planning and response systems must conform to the principles of applicable quality standards and be auditable internally within the port community as well as from external recognised quality management organisations.

## 9.5 CRITIQUE OF THE RESEARCH

This research attempts to explore an area of research which has not been widely explored and thoroughly analysed, therefore, this attempt can be regarded as a pioneer work in this regards. Due to its pioneering character, this study has encountered several difficulties which can be listed below:

1. The first difficulty is the limited specialist literature on the subject. Most literature discusses in details either safety or security RM but discussed little the relationships and shared impacts between the two disciplines and almost nothing on the impact of segregated management of risks on the overall RM, on the port industry or on the international SC. This scarcity of literature resources obliged the author to undertake a full Delphi study in order to explore the research problem and related research questions.
2. One of the issues confronted during the Delphi study is the reluctance of security professionals in participating to the survey consultations which resulted in a relatively low response rate from security specialists, compared to other discipline specialists consulted. Although the general response rate was encouraging during the first and second Delphi rounds (100% and 70% respectively), from 4 security specialists consulted, only 1 responded (1/4) during respectively the first and second rounds of Delphi surveys. It is noticed that ports and terminal security managers consulted were reluctant to provide opinions on surveys addressing security issues, probably because, from their perspective, such information is considered security sensitive. To

overcome this limitation, it was necessary to adopt a strategy of mutual confirmation of survey results during the successive stages of research enquiry and required further testing of the Delphi results through a quantitative empirical study.

3. Although the survey samples were selected randomly from the population, they are considered non probability samples since the probability of each case being selected from the total population is not known (Saunders et al. 2009). Thus stratified random sampling was the technique used as part of the quantitative study.

From a total of 150 questionnaires emailed, 62 responses were received; a response rate of 41.33% is achieved. This response rate can be explained by the following factors:

- First, it is noticed that the consultation period coincided with the summer holidays (July & August). Since most participants were invited through their business emails, many did not respond back, most probably because they were busy or they usually don't check their business emails during their leave period. Late responses were received a month later of the consultation period and were not considered.
- Second, out of 20 port security professionals initially consulted, only 5 have responded. Similar reluctance of security professionals to participate in surveys was experienced during the Delphi survey. Some security participants clearly declared by return email that they



are unable to participate to the survey without providing specific reasons for their decision.

The relatively low response rate obtained coupled with the lack of precise parametric requirements observed in the vast majority of distributions associated with this quantitative survey, oriented the choice for non-parametric tests. Therefore, it was decided to further test the quantitative results obtained, both on theoretical and practical levels, through a focus group discussion undertaken with a panel of multi-disciplinary expert practitioners, including security experts from world leading LNG ports. The results from such group discussion were beneficial and confirmed the empirical results obtained earlier from both qualitative and quantitative survey consultations.

It is worth mentioning that the relatively low participation of security professionals to both qualitative and quantitative surveys has forced the adoption of a conservative approach through which several testing studies were undertaken for mutual confirmation of results. This research strategy, although demanding in terms of time and effort, has proven to be beneficial in strengthening the study results.

## **CHAPTER 10**

### **CONCLUSION AND RECOMMENDATIONS**

#### **10.1 INTRODUCTION**

This research attempted to study and analyse the relationships and shared impacts among safety and security in the context of LNG ports SCs and investigates ways in which integrated safety and security RM can be applied in all areas of RM, emergencies planning, preparedness and response and port recovery and business continuity. As far as we are aware, this research is, so far, one of the few studies that attempted to investigate safety and security RM interfaces and their mutual impacts and how the approach of integrated safety and security RM can be applied in the context of LNG ports, both on theoretical and practical levels.

This concluding chapter brings together the various discussions and analytical results from previous chapters with a view to providing a comprehensive summary of research results and limitations and concludes with suggestions for further research.

#### **10.2 RESEARCH SUMMARY AND SPECIFIC RESULTS**

The present research aimed to model LNG ports safety and security RM, emergency response and port business continuity from a SC perspective and within the framework of an integrated and holistic RM approach. This approach took advantage of the strategic leadership role played by the port authority to coordinate and integrate the role the LNG port community can play within a participative approach.

In this respect, the research has achieved the following specific results:

- ❖ An analysis of the LNG SC, its main components and flows is made with particular emphasis on the strategic role of ports and marine terminals in the LNG SC. The research highlighted the pivotal role of the LNG port authority in the RM and emergency management processes, as defined by the main safety and security regulations such as SOLAS and the ISPS code. Furthermore, the research identified the port community as a strategic actor whose role has to be integrated within the overall port management system to assist in the coordination of integrated safety and security RM, emergency preparedness and response and port business continuity. The port community's role should be regarded as complementary but critical in assisting in the coordination, in risk communication and in the implementation process of the proposed port *BP Re-engineering* (BPR). According to Hammer and Champy (1993) '*Reengineering is the fundamental rethinking and radical redesign of BPs to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed.*' As such, *undertaking a BPR* in the context of LNG ports RM is necessary in order to apply a radical change to the way combined safety and security RM and emergency response processes are conceived, planned and conducted.

It should be noted that the passage from an existing disintegrated and fragmented safety and security RM approach to an integrated and holistic approach will require a re-engineering of the processes related to RM and emergency response. These radical changes must be introduced with

participation of relevant stakeholders from the port community, in full coordination with the port authority.

- ❖ The relationships and interfaces between port SC safety and security, mainly in terms of assessment and management methodologies and approaches were analysed. This research revealed that although safety and security risks have different requirements in terms of their respective risk factors and related RA methods, they are still interrelated, interfaced and have shared impacts. A cost effective assessment and management of those risks should be approached holistically, integrated and coordinated within the framework of an all-hazard approach. The research revealed also a deficiency in the coordination among safety and security disciplines which reflects an underpinning lack of integrated and holistic approach to risks in the minds of many LNG ports HSE and security professionals. During all stages of this research, consultation with HSE and security professionals also proved the existence of RM gaps due mainly to the silo mentality still prevailing in both disciplines. In this respect, RA should be conducted separately by each discipline and then presented to the port authority as a detailed RM plans. The port authority must share individual safety and security RA reports with the port community's REMC to be collaboratively discussed and evaluated. This way, interfaced, redundant or contradictory risk control measures will be detected and addressed. However, in order for such a process to be applied efficiently, the following conditions need to be fulfilled:

- A change in the RM culture among both safety and security disciplines is necessary. HSE and security professionals need to abandon their respective silo mentalities and agree to act with the minimum required synergy which can allow integrated RM in the LNG ports context. This cultural change must be implemented gradually and involve both disciplines of RM. In our opinion, this concerns not only the port industry and but also must be conceived at a government level. A strategic plan for synergising HSE and security disciplines needs to be put in place at the governmental level and use existing means, including regulations, formal training, workshops and other medians. The aim of such a strategic plan shall be the dissemination of an integrated vision about HSE and security risks which shall assist in applying integrated and holistic approach to safety and security risks in all maritime activities, including LNG ports.
- Definition of clear roles and responsibilities followed by a clear RM work process. Such process shall be documented and linked to a Key Performance Indicators (KPIs) system which shall ensure efficiency and quality of the work flow. In order to achieve efficiency of such work flow, a port community electronic system is necessary to ease communication and reduce work lead time. Port community systems are now common in several ports around the world which assisted in enhancing the productivity of the port community's involvement in several port related processes. It was highlighted before that the involvement of the port community in the RM and emergency response system of LNG ports has been very limited. This research

proposes such involvement to be further expanded to the extent that the port community shall be considered an essential partner of the port authority in the implementation of integrated RM, emergency response and port business continuity.

- ❖ The proposed CM identified the main port stakeholders with direct involvement in RM and emergency response. It also captured the LNG port SC processes and flows. From a thorough understanding of LNG ports' main stakeholders and their relationships regulated by international and industry legislation, the conceptual model has proposed a methodology for integrated and coordinated RM, emergency response and port business continuity within the framework of a collaborative and participative approach. Such an approach allows for the design of an integrated and holistic RM and emergency response strategies within the framework of a holistic approach.

### **10.3 CHARACTERISATION OF THE RESEARCH APPROACH**

The approach used in this research can be characterised by:

- Theoretically, the adopted approach enabled critical evaluation of the relationship, interfaces and shared impacts among safety and security risks and highlighted their critical importance to the resiliency of the whole LNG SC, and how their management could be detrimental to the LNG ports if not fully understood and properly addressed in a timely and cost effective manner. Therefore, the approach was comprehensive and holistic in identifying safety and security management gaps and their underpinning drawbacks.

- This research attempted to adopt a high level conceptual approach with an objective of providing empirical solutions to the research problem. A drawback of such an approach may be its high level analytical framework which would not be disposed to capture the full details of the RM processes. However, by doing so, this approach enabled a focused analysis on the hallmarks of RM and emergency planning and response from organisational and management perspective. It should be noted that adopting the right approach is a pre-requisite to efficient and cost effective RM and emergency response. If the approach enables adequate management of the interfaces among safety and security, then individual RM methods and techniques are well advanced to identify individual and societal risks and their mitigation options. The outcome of the process is ultimately a unified RM strategy free from contradictory or redundant actions or gaps as a result of integrated RM process. Such an integrated process will have a positive impact on emergency management and port business continuity since emergency planning and response is based on the outcome of what may go wrong in case risk mitigation measures are not able to fully mitigate risks and hazards. In this respect, port emergency management agencies will have a clear picture on the risk acceptance criteria and will be in a position to estimate the possible consequences and magnitude of incidents when they strike. Therefore, integration of the whole RM and emergency management processes will be achieved to ensure resilient and robust LNG port SCs.
- Also, the approach adopted can be defined as systemic, since it calls for a radical review of the existing systems in which the RM and emergency response are conceived, planned and applied. It also provides an advanced

methodology to re-engineer the BPs for LNG port RM, emergency response and port business continuity; and apply an integrated RM approach which narrows the gaps between safety and security RM.

- Since a holistic view is necessary to address RM issues in the port and maritime systems, SSM was selected and used as an appropriate methodology in the presentation and analysis of the problem situation as well as in finding an optimal solution for the research problem. Integration, participation and worldview were the hallmarks of this approach and assisted significantly in orienting and proposing a practical solution to the ill-structured LNG ports RM system which was validated with the LNG port RM industry. The soft systems approach fits in well with the *all-hazards* strategy as it is seen as a learning cycle, which enables port organisations to continually adapt to the changing nature of risk and risk profile and facilitates their mutual learning during their collaborative effort to address risks within a participative approach. RM Strategy should be a dynamic and iterative process which would benefit from the soft systems approach.

#### **10.4 LIMITATIONS OF THE RESEARCH**

The research aimed to analyse the current approach to safety and security RM, emergency response and port business continuity in some LNG port SCs; and identify their issues and shortcomings. This has been done in an attempt to provide an enhanced approach and to model its processes and flows for an integrated and cost effective management of those risks and emergencies. The scope and findings of the research were limited in the following ways:



- In general the publications and research activities in the field under study are not abundant.
- The research adopted a high level approach by focusing mainly on the general structure of the methods, processes and flows governing safety and security RM and their interfaces. The research did not discuss in detail the RM process for each discipline nor their respective requirements.
- In the same way, the research highlighted more the organisational part of RM and emergency response in the LNG port System and did not fully analyse the technical side. This way, the research has a more management focus than purely technical RM orientation.
- Although the study used mixed methods, qualitative techniques and methods are predominantly used which did not allow quantitative evaluation of the impact of the proposed RM and emergency response approach and methodology on the efficiency of LNG port performance and on the overall LNG SC.
- Last but not least, the study did not include an evaluation of the '*all-hazards*' approach already implemented in the U.S (by the US. Coast Guard) and in other developed countries. As this has been introduced recently, no data is yet available on its application. Such evaluation would provide further insight on the proposed risk and emergency management model.

Despite these limitations the empirical findings of this research are conclusive and reliable to the situation of the Middle Eastern LNG ports and similar ports and terminals around the world which have not yet applied an integrated

approach to RM and emergencies. This conclusion is based on the fact that the panel members consulted during this research are industry leaders and experts in the field of safety and security RM and LNG SCs, logistics and maritime transport. Their knowledge spans not only the situation of the Middle Eastern hydrocarbon ports but also other export/ import hydrocarbon ports worldwide. Also the methodology applied for the research appears to be a valid option from such a high level conceptual study. Undoubtedly, this methodology would be valid also for further research in the field but with a different focus as stipulated earlier.

## **10.5 RECOMMENDATIONS FOR FURTHER RESEARCH**

This research has the merit to uncover and highlight the issue of the disintegrated nature of the RM approach in LNG port SCs, future research may extend the scope of the research in the following directions:

- Develop a generic model to test the efficiency of RM and emergencies in LNG ports and marine terminals. Such a model would set up criteria for optimal organisation of safety and security risk activities within LNG ports which would allow an optimal level of coordination and exchange of information. One of the criteria for the efficiency of the model shall be the number of risk cases dealt with collaboratively under the port management authority.
- A quantitative model may be developed to assess and evaluate the impact of uncoordinated management of safety and security risks on the overall RM and emergencies planning, preparedness and response. The model shall be able to evaluate the cost of RM and emergencies

response as well as the consequences and impacts of port incidents and accidents.

- Another direction of research in the same field and which is actually needed is a benchmark study of the RM and emergencies management between integrated management of risks and emergencies and segregated/ isolated RM. This study shall develop scenarios of incidents and accidents and show quantitatively and qualitatively what would be the RM results and costs in both cases.
- Another study would be to evaluate the all-hazards approach recently introduced by the US. Coast Guard, to compare it with the former approach used by the same organisation.

## **10.6 CONCLUSION**

LNG ports SCs are strategic to the global LNG SC. The management of their risks and emergencies is central to the resiliency and business continuity of the whole SC. Therefore, both the RM approach and its practice should be conceived and planned holistically within the framework of an all-hazards approach. The port SC should focus on prevention of all kinds of risks, meanwhile contingency plans should also be in place at all times to reduce and minimise the consequences of unwanted manmade events, from either intentional or accidental sources. Integration is required at all levels of plans, actions and processes both vertically (at the safety-security level) and horizontally (along the RM, emergency management and port recovery and

business continuity). Integration of those plans and processes will ensure resilient, cost effective and robust LNG SCs.

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## Appendices

### Appendix1 Brief History of LNG tankers

In January 1959 Methane Pioneer, a converted World War II freighter containing five aluminium prismatic tanks, carried LNG cargo from Lake Charles-LA., to Canvey Island, UK. This demonstrated that the transportation of large quantities of LNG safely across the ocean was possible. By the turn of the century, the industry employed more than \$200 billion in capital.

The LNG industry started in 1964 with the first shipments from Algeria to the UK. By the late 1990s, international trade in LNG increased 50 fold, production capacity has increased 10 fold and the transport capacity of individual ships has increased 5 fold. The first gas carrier tanks that were used in a continuous regular trade in the United States were of the membrane tank design. In 1965 Phillips Petroleum contacted the Coast Guard concerning a proposal it had made to Tokyo Gas for shipping LNG from Alaska. The shipments were to be made in tanks that were designed by Worms and Co., Paris, France. This design later became known as the Gas Transport design. At first, the LNG carriers were envisioned as being 34,000 m<sup>3</sup>, but eventually the design called for the 71,500 m<sup>3</sup> vessels that became the Arctic Tokyo and Polar Alaska (Qatar Gas Operating Company Ltd, 2009).

Höegh built the world's first LNG carrier with spherical tanks in 1973. Norman Lady was delivered in November 1973, from the Rosenberg shipyard in Norway. The vessel was the prototype of the Moss spherical

cargo containment system. Leif Höegh & Co took an active role in the development of this system (Qatar Gas Operating Company Ltd, 2009).

Commencing with its first delivery of an LNG carrier in the early 1990s, Hyundai consecutively expanded its construction capacity for vessels up to 138,000 m<sup>3</sup>, making their shipyard the first in the world available for building both Moss-type and membrane-type LNG carriers, taking ever-increasing orders for high capacity vessels. These include the new membrane-type carrier measuring 280m in length, 43m in width and 26m in depth, made up of four independent insulated tanks, which is the largest LNG carrier of this type ever made. Since the first delivery of LNG carriers back in the early 1990s, Hyundai has played a leading role in building LNG carriers.

In 1999, Samsung (SHI) successfully constructed the world's largest New Membrane-type LNG carrier, which was the largest single hull-form vessel in the world at that time. Lighter and faster than the existing LNG vessels, this vessel measures 278.8m in length, 42.6m in width and 26.0m in depth, and navigates at 20.7 knots. It is the largest single hull-form vessel in the world with a capacity up to 138,378 m<sup>3</sup>.

On October 2, 2003, the Energy Frontier, an LNG carrier owned by Tokyo Gas delivered approximately 67,000 tons of LNG to Tokyo Gas' Sodegaura LNG Terminal from Malaysia. The Energy Frontier is a moss-type carrier, having four spherical-shaped tanks. This carrier was designed on the scale of a conventional LNG carrier, but with 10,000 m<sup>3</sup>

greater load capacity, which at 145,000 m<sup>3</sup> made it the world's largest LNG carrier.

In the first five months of 2005 alone, there were five new LNG carriers added to the fleet with a combined carrying capacity of 699,000 m<sup>3</sup>. The addition of these five LNG carriers represented a 3% net increase in the LNG shipping capacity worldwide and is indicative of the expanding LNG market. The anticipated growth of the LNG market is well represented by the number of LNG carriers scheduled for construction. Throughout the world, as of 2006 shipbuilders had plans to build 115 new LNG carriers, with a combined total carrying capacity of more than 17 million m<sup>3</sup>. There are only nine shipyards in the world building LNG tankers: Three are in Japan, three are in Korea, two are in Europe, and one is in China (Qatar Gas Operating Company Ltd, 2009).

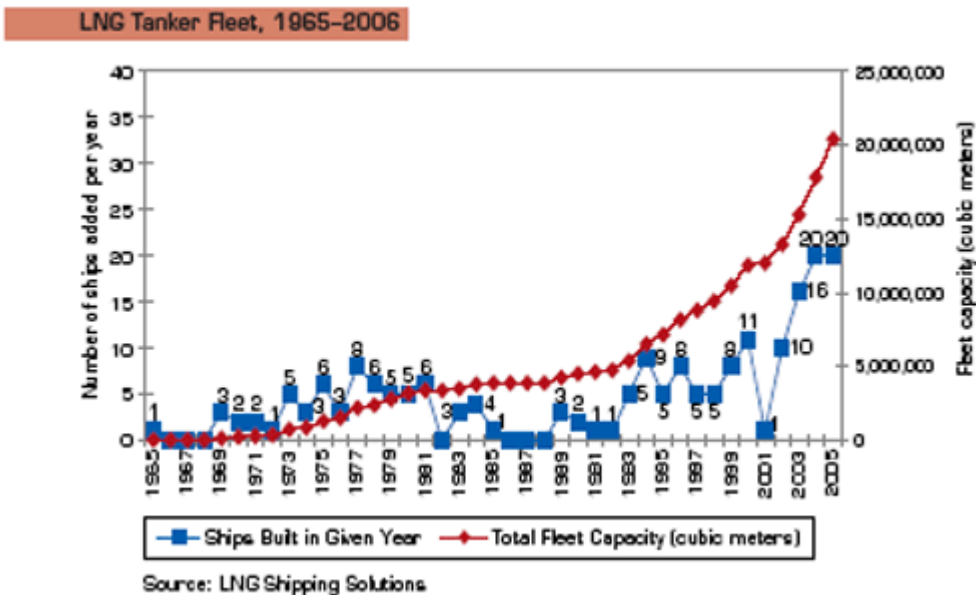
As of 2006 there were approximately 180 LNG carriers in operation, with a total capacity of over 21 million m<sup>3</sup>. All of these were built in Japan, Korea, Europe, or the United States. Of these, 16 ships had a capacity of less than 50,000 m<sup>3</sup>; 15 ships have a capacity between 50,001 to 100,000 m<sup>3</sup>; and 150 ships have a capacity between 100,001 m<sup>3</sup> and 150,000 m<sup>3</sup>. Most of the smaller LNG carriers have been in service for several decades, and it is likely that they will be replaced by much larger ships.

Mitsubishi (MHI), Japan; as well as Daewoo and Samsung Shipbuilding, both in Korea, have focused on the construction of membrane tank LNG

vessels. Meanwhile, Hyundai Heavy Industries has developed a spherical tank design, along with its mobile offshore drilling unit construction program. Other builders in Asia with a proven LNG carrier construction program include Kawasaki (KHI) and Mitsui Shipbuilding.

Since 2006, plans in Qatar, with its reserve of 14 trillion m<sup>3</sup> of natural gas, have included construction of as many as 46 additional LNG carriers.

**Figure 2.11- LNG Tanker Fleet 1965-2006**



The graph above shows the number of new ships commissioned each year which become two digits since year 2000. In 2010, the world LNG fleet accounted for 360 tankers with a capacity in excess of 53 million m<sup>3</sup>. The largest LNG tankers (Q-Max) are mainly operated from Qatar, the single largest LNG exporter with a market share of 27% in 2011 (PFC Energy, 2010).

Qatar not only had reserves in abundance, its geographic location meant that markets in Europe and even North America were potentially available as were

those in the Far East. The economics of profitably doing business in these markets would require serious consideration given the size of the existing plant and vessels currently in service. It was clear that only the benefits of increased economies of scale available from bigger production plants and vessels would make these markets competitively feasible.

In June 2002, a Heads of Agreement (HOA) document was signed between Qatar Petroleum and ExxonMobil to supply LNG to the UK by the winter of 2007/2008. The project and venture agreements were signed in late 2004 and called for the development of two LNG trains to supply 15.6 MTPA of LNG to the UK and North Europe for 25 years. Known as the Qatar gas 2 project (QGII) it was at that time, at almost US\$ 13 billion, the biggest deal in the history of the hydrocarbon industry. This triggered the start of feasibility studies by the QGII teams which soon resulted in the conceptual designs for the large capacity trains and new large ships (Qatar Gas Operating Company Ltd, 2009).

Later, in July 2003, QP and ConocoPhillips signed an agreement for Qatar gas 3, a development that called for delivery of LNG to primarily the USA. The partners decided to base this US\$ 5 billion scheme on the QGII train and ship designs, with a single new train to be built at Ras-Laffan, additional shipping capacity and a receiving terminal in America. This was followed in 2005 when QP and Royal Dutch Shell signed an agreement for the development of yet another 7.8 MTPA project called Qatar gas 4 that would also primarily supply the growing North American gas market, and which would also be based on the same designs (Qatar Gas Operating Company Ltd, 2009).

With the signing of the QG 2 HOA, the catalyst to rethink the LNG tanker status quo had arrived. The new production trains would be almost four times the size of the original capacity of the first three QG trains. The new voyages were now to more distant western markets and the customers were no longer solely power companies with predictable demand. The time for a new breed of ships had dawned (Qatar Gas Operating Company Ltd, 2011).

In order to take advantage of the new market opportunities and demands, Qatar gas realised that the ships needed to become bigger and more efficient to dramatically lower transport costs.

In mid-2002, a team of marine experts from ExxonMobil and Qatar gas was formed within the QGII project to deliver this step change. Radical thinking was employed by this Team. The target was to design the largest size of ship that could be accommodated safely at its home loading port of Ras-Laffan. Thus the target physical dimensions of the ship were derived as being 345 meters long by 55 meters wide with a draft of 12 meters.

It was also suspected that cargo volume should be maximized by using membrane containment technology instead of spherical aluminium containers. The result was the “plan” for a ship with a capacity of 250 - 266,000 m<sup>3</sup>, almost 80% more than the largest LNG tankers built at that date and a swathe of technical and commercial challenges to be met. These are the specifications for the ‘Q-Max’, the largest LNG tanker ever built to date (Qatar Gas Operating Company Ltd, 2011).

In order to maintain economies of scale but allow access to other discharge terminals unable to accommodate Q-Max vessel, a smaller version of the Q-Max has been developed. 30m shorter at 315m and 5m narrower at 50 m with

the same draft of 12m, the 'Q-Flex' has a capacity around 215,000 m<sup>3</sup>. Both Q-Max and Q-Flex have set high standards in LNG ship design; they have changed the industry and reduced the transport cost by over 30% (Dubois-Denis, 2004)



## Appendix2 Amendments to the STCW- 1978

| S/N       | Amendment date | Entry into Force | Content of the amendment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------|----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>01</b> | 22-05- 1991    | 1 -12- 1992      | These amendments concerned mostly additional requirements made necessary by the implementation of the Global Maritime Distress and Safety System (GMDSS).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>02</b> | 25-05-1994     | 01-01-1996       | The amendments replaced Chapter V on special training for crews on tankers, including LNG carriers. This Chapter was designed to ensure that officers and ratings who are to have specific duties related to the cargo and cargo equipment of tankers shall have completed an appropriate shore-based fire-fighting course and have completed either an appropriate period of shipboard service or an approved familiarisation course. Requirements are more stringent for masters and senior officers. Attention is paid not only to the safety aspects but also to pollution prevention. The Chapter contains three regulations dealing with oil tankers, chemical tankers and liquefied gas tankers, respectively. For instance, resolution 12 concerns specifically the training and qualifications of masters, officers and ratings of liquefied gas tankers. |
| <b>03</b> | 07-07-1995     | 1-02-1997        | It is considered a major revision of the convention in response to a recognised need to bring the Convention up to date and to respond to critics who pointed out the many vague phrases which resulted in different interpretations.<br>One of the major features of the revision was the division of the technical annex into regulations, divided into Chapters as before, and a new STCW Code, to which many technical regulations have been transferred. Part A of the Code is mandatory while Part B is recommended. Dividing the regulations up in this way makes administration easier and it also makes the task of revising and updating them simpler: for procedural and legal reasons, there is no need to call a full conference to make changes to Codes.                                                                                            |
| <b>04</b> | June 1997      | 1 -01-1999       | These amendments concern training for personnel on passenger ships. The amendments include an additional Regulation V/3 in Chapter V on Mandatory minimum                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

|           |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------|-------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |             |             | requirements for the training and qualifications of masters, officers, ratings and other personnel on passenger ships other than Ro-Ro passenger ships. Related additions are also made to the STCW Code, covering Crowd management training; Familiarisation training; Safety training for personnel providing direct service to passengers in passenger spaces; Passenger safety; and Crisis management and human behaviour training.                                                                                                                                                                                                                                                                                                                                                   |
| <b>05</b> | 9-12- 1998  | 01-01- 2003 | Amendments to the STCW Code are aimed at improving minimum standards of competence of crews, in particular relating to cargo securing, loading and unloading on bulk carriers, since these procedures have the potential to put undue stresses on the ship's structure. The amendments concern sections A-II/1 and A-II/2 under "Cargo handling and stowage at the operational and management levels.                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>06</b> | May 2006    | 01-01- 2008 | <p>Addition of new minimum mandatory training and certification requirements for ship security officers (SSOs). The amendments to the STCW Convention and to parts A and B of the STCW Code include Requirements for the issue of certificates of proficiency for Ship Security Officers; Specifications of minimum standards of proficiency for ship security officers; and Guidance regarding training for Ship Security Officers.</p> <p>Further amendments to part A of the STCW Code added additional training requirements for the launching and recovery of fast rescue boats. The amendments have been prepared in response to reports of injuries to seafarers in numerous incidents involving the launching and recovery of fast rescue boats in adverse weather conditions</p> |
| <b>07</b> | 25 -06-2010 | 01-01-2012  | <p>These amendments are called the Manila amendments to the STCW Convention. They are aimed at bringing the Convention and Code up to date with developments since they were initially adopted and to enable them to address issues that are anticipated to emerge in the foreseeable future.</p> <p>Among the amendments adopted, there are a number of important changes to each chapter of the Convention and Code, including:</p> <ul style="list-style-type: none"> <li>• Improved measures to prevent fraudulent practices associated with certificates of competency and strengthen the evaluation process (monitoring of Parties' compliance with the Convention);</li> <li>• Revised requirements on hours of work</li> </ul>                                                    |

|  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|--|--|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |  |  | <p>and rest and new requirements for the prevention of drug and alcohol abuse, as well as updated standards relating to medical fitness standards for seafarers;</p> <ul style="list-style-type: none"> <li>• New certification requirements for able seafarers;</li> <li>• New requirements relating to training in modern technology such as electronic charts and information systems (ECDIS);</li> <li>• New requirements for marine environment awareness training and training in leadership and teamwork;</li> <li>• New training and certification requirements for electro-technical officers;</li> <li>• Updating of competence requirements for personnel serving on board all types of tankers, including new requirements for personnel serving on liquefied gas tankers;</li> <li>• New requirements for security training, as well as provisions to ensure that seafarers are properly trained to cope if their ship comes under attack by pirates;</li> <li>• Introduction of modern training methodology including distance learning and web-based learning;</li> <li>• New training guidance for personnel serving on board ships operating in polar waters; and</li> </ul> <p>New training guidance for personnel operating Dynamic Positioning Systems</p> |
|--|--|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Appendix3 Maximum Credible Accidental and non-accidental Releases**

**Table 1 Accidental release case-750mm hole**

|                                                               |                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Scenario                                                      | Hole size = 750mm                                                                             | Collision event with another vessel at 90° angle or serious grounding at sufficient speed so that the double hull is penetrated and additional barriers also breached causing the LNG tank to be deformed to such an extent that it leaks. Above and below waterline holes were considered.                                                                                                                                                                                                                                                                                                                                                                     |
| Modelling                                                     | LNG discharge, pool formation, dispersion, ignition and flash fire back to source, pool fire. | This event is a worst case event in terms of hazard distance as the accidental event may not ignite the LNG immediately, allowing a vapor cloud to form and disperse downwind. The cloud is then assumed to ignite at its maximum flammable extent and flash back to the source where the LNG spill will burn as a pool fire. The sustained pool fire diameter and hence hazard distance will be substantially smaller than would be the case if the un-ignited pool diameter were used.                                                                                                                                                                        |
| Most likely Hazard distances (measured from point of release) | Dispersion and flash fire hazard range = 920m<br>Pool fire hazard range = 440m                | Dispersion distance is based on neutral stability 5m/s Weather case (D5) and provides the distance to maximum flammable extent. The F 2m/s case is less likely and the duration of event would be so long that buoyancy effects of methane could be expected to cause plume lift off as is observed with other buoyant gases. Anyone caught within the flammable cloud would be very seriously burned, but flammable impacts beyond the cloud are likely to be small. The pool fire case is based on 5kw/m <sup>2</sup> which is sufficient to cause serious burns if shelter cannot be found within 40 seconds – this is as recommended in safety regulations. |

**Source** Pitblado et al. (2004, pages 18 & 19)

**Table 2 Non- accidental Release case-1500mm**

|                             |                                       |                                                                                                                                                                                                                                                   |
|-----------------------------|---------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Scenario                    | Hole size = 1500mm                    | This event could be caused by terrorist attack. In order to generate a hole of this dimension, and without disclosing the attack scenario, the energy involved would be so large that immediate ignition would be by far the most likely outcome. |
| Modelling                   | Discharge, pool formation, pool fire. | Discharge and pool formation are as before, but in this case immediate ignition of the pool is almost certain and no dispersion of flammable vapors would occur                                                                                   |
| Most likely hazard distance | Pool fire hazard range = 750mm        | The pool fire case is based on 5kw/m <sup>2</sup> which is sufficient to cause serious burns if shelter cannot be found within 40 seconds – this is as recommended in safety regulations.                                                         |

**Source** Pitblado et al. (2004, pages 18 &19)

## **Appendix4 Delphi survey round one questionnaire and results**

Dear Sir/ Madam

I am undertaking doctoral research at the University of Plymouth, United Kingdom on LNG port supply chain risk management. Port supply chain refers to the set of organisations and firms fulfilling different port and logistics operations which are highly integrated and reliant on each other to deliver port and maritime services. A panel of LNG port experts including port managers, terminal operators, LNG shippers, maritime agencies, and LNG storage facilities managers, managers of LNG shipping companies, LNG marketing managers, specialists in port safety and security as well as consultants are all being consulted in this research.

As part of the research, I am conducting a survey using the Delphi Technique. The questionnaire used in the survey is shown below. The Delphi Technique typically consists of two rounds of questionnaires. In each round you are asked to make judgement about a specific subject, by marking (X) at the left of one of the three options for each statement, labelled as 'Agree', 'Disagree' and 'Unable to Comment'. In the case of 'Disagree' you are requested to give further comments. Such comments form the second round survey.

Your reply will be treated in strict confidence, and names of individual respondents or organisations will not be used in published material or given to third parties. The general findings of the survey may, however, be published. If you participate in the survey, a copy of the general findings will be emailed to you upon your request.

I look forward to hearing from you within two weeks. If you require any further details please do not hesitate to contact me at the address below.

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(2) Briouig@gmail.com

**NB:**

- All the following statements relate to port Supply Chains pertaining to Liquefied Natural Gas (LNG).
- Risks referred to in this questionnaire are related only to safety, security and quality risk types.

**PART ONE: LNG PORT SECURITY**

1. Security risks are now equally important as safety risks in LNG ports and marine terminals.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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2. LNG ports are sufficiently protected against terrorist risks

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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 .....  
 .....

3. Current security legal frameworks (*ISPS & non ISPS security frameworks*) are sufficient to ensure efficient security protection for LNG ports SCs.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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 .....

4. The multitude of existing security frameworks (ISPS and non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG ports SC.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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 .....

5. There are already adequate collaborative security and safety risk arrangements in place among LNG port supply chain members.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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 .....  
 .....

6. There are currently adequate coordinated risk management procedures in place in LNG port SCs.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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7. In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving global terrorism.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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8. Ports are strategically located within the LNG SC and represent the only node within the maritime SC bringing together multiple logistics, port and maritime related organisations and stakeholders, functions, roles, processes and flows. As such, the port organization should be leading coordination efforts towards security risk assessment and response.

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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9. Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of LNG ports

Agree? Disagree? Unable to comment?

If you disagree, please comment as to why

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**PART TWO: LNG PORT SAFETY**

10. LNG Port Safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary.

Agree ? Disagree Unable to comment?

If you disagree please comment as to why

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11. If safety is ensured by each individual member of the LNG Port SC, we can assume that the entire LNG SC will be safe



Agree                                      Disagree                                      Unable to comment?  
If you disagree please comment as to why

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**12.** The IMO's Formal Safety Assessment (FSA) for shipping should be extended to address port safety.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree please comment as to why

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**13.** A standard safety framework is necessary to address both LNG shipping and port safety networks.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree please comment as to why

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**14.** A Standard safety framework is needed to address the ship-port interface more efficiently.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree please comment as to why

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### **PART THREE: LNG PORT SAFETY & SECURITY**

**15.** Safety and Security in LNG ports SCs are closely related issues and may yield better outcomes if managed together within a unified risk management entity.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree, please comment as to why

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**16.** Safety measures (safeguards) are the first line of defence for security in LNG port SCs.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree, please comment as to why

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**17.** There is a need for a standard safety and security risk assessment and management methodology capable of capturing LNG Port SC processes and flows.

Agree?                                      Disagree?                                      Unable to comment?  
If you disagree, please comment as to why

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**18.** Generally in practice, risk assessment in safety and security uses the same methodology.

Agree? Disagree? Unable to comment?  
If you disagree, please comment as to why

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**19.** Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port SCs

Agree? Disagree? Unable to comment?  
If you disagree, please comment as to why

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**20.** Contingency measures are planned more with reference to the outcome of possible events rather than to the outcome of risk.

Agree? Disagree? Unable to comment?  
If you disagree, please comment as to why

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**21.** A unified risk management methodology for assessing both safety and security risks and hazards can be more cost effective than a risk management methodology in which security and safety risks are managed separately and with less coordination.

Agree? Disagree? Unable to comment?  
If you disagree, please comment as to why

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#### **PART FOUR: LNG PORT RISK MANAGEMENT AND QUALITY**

**22.** There is a similitude between Port SC safety, security and quality; mainly in terms of assessment and management methodologies and approaches.

Agree? Disagree? Unable to comment?  
If you disagree, please comment as to why

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**23.** Safety and security risk assessment and management need to take advantage of the quality revolution, especially the *Total Quality Management (TQM) Principle*.

Agree? Disagree? Unable to comment?  
If your disagree, please comment as to why

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 .....  
 .....  
**24.** Prevention is the key principle in *Total Quality Management (TQM)* and should also be for the case of safety and security management.  
 Agree? Disagree? Unable to comment?  
 If you disagree please comment as to why  
 .....  
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 .....  
**25.** Based on the principles of TQM, LNG port SCs should adopt an integrated Risk assessment and management approach capable of dealing with the three types of risks, Safety, Security and Quality.  
 Agree? Disagree? Unable to comment?  
 If you disagree please comment as to why  
 .....  
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.....  
**26.** Adopting such an integrative approach will lead to efficient and cost effective risk management in LNG Ports SCs.  
 Agree? Disagree? Unable to comment?  
 If your disagree please comment as to why  
 .....  
 .....  
 .....

Thank you for completing the survey at the Web link below:  
<https://www.surveymonkey.com/s/2HLP96P>

### Survey Results Round 1

| No | Statements of First Round Delphi                                                                                                                                                                                                | A  | DA | UC | n  | %              |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|----|----------------|
| Q1 | Security risks are now equally important as safety risks in LNG ports and marine terminals                                                                                                                                      | 17 | 1  | 2  | 20 | 85.0A          |
| Q2 | LNG ports are sufficiently protected against terrorist risks                                                                                                                                                                    | 5  | 6  | 9  | 20 | 25.0A<br>30.0D |
| Q3 | Current security legal frameworks (ISPS & non ISPS security frameworks) are sufficient to ensure efficient security protection for LNG Ports SCs.                                                                               | 7  | 6  | 7  | 20 | 35.0A<br>30.0D |
| Q4 | The multitude of existing security frameworks (ISPS & non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG ports. | 8  | 5  | 7  | 20 | 40.0A<br>25.0D |
| Q5 | There are already adequate collaborative security and safety risk arrangements in place among LNG port Supply Chain members.                                                                                                    | 10 | 4  | 6  | 20 | 50A            |

|            |                                                                                                                                                                                                                                                                                                                                                       |    |   |   |           |                |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|---|---|-----------|----------------|
| <b>Q6</b>  | There are currently adequate coordinated risk management procedures in place in LNG port SCs                                                                                                                                                                                                                                                          | 8  | 4 | 8 | <b>20</b> | 40.0A<br>20.0D |
| <b>Q7</b>  | In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving global terrorism                                                                                                                                                                                               | 10 | 3 | 7 | <b>20</b> | 50.0A          |
| <b>Q8</b>  | Ports are strategically located within the LNG SC and represent the only node within the maritime SC bringing together multiple logistics, port and maritime related organisations and stakeholders, functions, roles and flows. As such, the port organization should be leading coordination efforts towards security risk assessment and response. | 18 | 1 | 1 | <b>20</b> | 90.0A          |
| <b>Q9</b>  | Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of LNG ports                                                                                                                                                           | 8  | 4 | 8 | <b>20</b> | 40.0A<br>20.0D |
| <b>Q10</b> | LNG port safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary                                                                                                                                                                                                   | 10 | 7 | 3 | <b>20</b> | 50.0A          |
| <b>Q11</b> | If safety is ensured by each individual member of the LNG port SC, we can assume that the entire LNG SC is safe                                                                                                                                                                                                                                       | 11 | 7 | 2 | <b>20</b> | 55.0A          |
| <b>Q12</b> | The IMO's Formal Safety Assessment (FSA) for shipping should be extended to address port safety                                                                                                                                                                                                                                                       | 13 | 1 | 6 | <b>20</b> | 65.0A          |
| <b>Q13</b> | A standard safety framework is necessary to address both LNG shipping and port safety networks                                                                                                                                                                                                                                                        | 16 | 1 | 3 | <b>20</b> | 80.0A          |
| <b>Q14</b> | A standard safety framework is needed to address the ship-port interface more efficiently                                                                                                                                                                                                                                                             | 16 | 1 | 3 | <b>20</b> | 80.0A          |
| <b>Q15</b> | Safety and Security in LNG ports SCs are closely related issues and may yield better outcome if managed together within a unified risk management entity                                                                                                                                                                                              | 13 | 5 | 2 | <b>20</b> | 65.0A          |
| <b>Q16</b> | Safety measures(Safeguards) are the first line of defence for security in LNG ports SCs                                                                                                                                                                                                                                                               | 13 | 5 | 2 | <b>20</b> | 65.0A          |
| <b>Q17</b> | There is a need for a standard safety and security risk assessment and management methodology capable of capturing LNG port SC processes and flows                                                                                                                                                                                                    | 15 | 1 | 3 | <b>19</b> | 77.0A          |
| <b>Q18</b> | Generally in practice, risk assessment in safety and security uses the same methodology                                                                                                                                                                                                                                                               | 8  | 9 | 3 | <b>20</b> | 45.0D<br>40.0A |
| <b>Q19</b> | Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port SCs                                                                                                                                                                                                                        | 7  | 3 | 9 | <b>19</b> | 36.8A<br>15.7D |
| <b>Q20</b> | Contingency measures are planned more with reference to the outcome of possible events than to the outcome of risk                                                                                                                                                                                                                                    | 13 | 4 | 3 | <b>20</b> | 65.0A          |
| <b>Q21</b> | A unified risk management methodology for                                                                                                                                                                                                                                                                                                             | 14 | 4 | 2 | <b>20</b> | 70.0A          |

|              |                                                                                                                                                                                                         |     |    |     |           |       |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|----|-----|-----------|-------|
|              | assessing both safety and security risks and hazards can be more cost effective than a risk management methodology in which security and safety risks are managed separately and with less coordination |     |    |     |           |       |
| <b>Q22</b>   | There is a similitude between port SC safety, security and quality; mainly in terms of assessment and management methodologies and approaches                                                           | 14  | 2  | 4   | <b>20</b> | 70.0A |
| <b>Q23</b>   | Safety and security risk assessment and management need to take advantage of the quality revolution, especially the Total Quality management (TQM) principle                                            | 17  | 3  | 0   | <b>20</b> | 85.0A |
| <b>Q24</b>   | Prevention is the key principle in Total Quality management (TQM) and should also be for the case of safety and security management                                                                     | 14  | 5  | 1   | <b>20</b> | 70.0A |
| <b>Q25</b>   | Based on the principles of TQM, LNG port SCs should adopt an integrated risk assessment and management approach capable of dealing with the three(3) types of risks                                     | 16  | 3  | 1   | <b>20</b> | 80.0A |
| <b>Q26</b>   | Adopting such an integrative approach will lead to efficient and cost effective risk management in LNG ports SCs                                                                                        | 15  | 4  | 1   | <b>20</b> | 75.0A |
| <b>Total</b> | Total Opinion Expressed - % of total opinion                                                                                                                                                            | 314 | 99 | 103 | 516       |       |

#### First Round Comments for Statements having less than 51% consensus

| Q # | STATEMENT                                                           | % DA | RESPONDENTS' COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|-----|---------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2   | <b>LNG ports are sufficiently protected against terrorist risks</b> | 30%  | <ol style="list-style-type: none"> <li>1) It is very difficult to generalize this statement across world ports</li> <li>2) The sheer size and accessibility of these facilities makes them very difficult to protect against terrorist threats. Much more work and international cooperation will be required to improve controls.</li> <li>3) I believe we are still short of the mark.</li> <li>4) A determined terrorist could enter port secured areas. It is also feasible that port facilities could be attacked from a distance, by air or from seaside.</li> <li>5) Ports tend to gravitate towards a complete port security model, rather than a specialized LNG security cover, especially in multi-cargo ports.</li> <li>6) Will always be vulnerable from see side</li> <li>7) I cannot comment for all the ports worldwide but the ports of Nakilat</li> </ol> |

|   |                                                                                                                                                                                                                                          |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   |                                                                                                                                                                                                                                          |     | involvement have been accessed as secured.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 3 | <b>Current security legal framework (ISPS &amp; non ISPS security frameworks) are sufficient to ensure efficient security protection for LNG Ports SCs.</b>                                                                              | 30% | <ol style="list-style-type: none"> <li>1) ISPS and similar codes such as CT-PAT only require minimum level of protection. In certain environments these may not be sufficient to adequately protect against security threats.</li> <li>2) Depending on the extent of the security framework!</li> <li>3) ISPS only offers the basic framework. Vulnerability still exists from sea ward side of the vessels</li> <li>4) Current frameworks are still treating individual facilities in relative isolation. Efficiency of security protection would be greatly enhanced by integration of processes and systems on local if not regional/ global basis.</li> <li>5) ISPS is a recommended policy and specific country legislation is required to enforce in any port. This legislation is the document that will decide on the adequacy of the security framework.</li> <li>6) To me, ISPS is merely a paper exercise. Security has been in place since the port opened, but I do believe it could be improved.</li> <li>7) Only if these are enforced properly</li> </ol> |
| 4 | <b>The multitude of existing security frameworks (ISPS and non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG ports.</b> | 25% | <ol style="list-style-type: none"> <li>1) ISPS only states that certain requirements are in place, they do not state how these requirements are achieved.</li> <li>2) If integrated system for all the different frameworks is followed, this might enhance the system.</li> <li>3) Cost should always be in proportion to the risk. The ISPS code does not prescribe the physical measures but expect the port to do a RA and based on this put an effective protection in place.</li> <li>4) In fact, I see ISPS and non ISPS initiatives as an advantage, however some areas might need to be reviewed, but I don't see it as having adversary effect on the level of protection in LNG ports.</li> </ol>                                                                                                                                                                                                                                                                                                                                                              |
| 5 | <b>There are already adequate collaborative security and safety risk arrangements in place</b>                                                                                                                                           | 20% | <ol style="list-style-type: none"> <li>1) Especially private stakeholders</li> <li>2) All port and SC members have specific requirements which are sometimes contradictory.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

|   |                                                                                                                                                                                          |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | <b>among LNG port SC members.</b>                                                                                                                                                        |     | <ul style="list-style-type: none"> <li>3) Some arrangements are in place, but they are far from adequate in controlling/ combating today's- let alone tomorrow's- threats.</li> <li>4) There is still a disconnection between the various parties in the LNG SC.</li> <li>5) Piracy risk has not yet been mitigated sufficiently</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                         |
| 6 | <b>There are currently adequate coordinated RM procedures in place in LNG port SCs</b>                                                                                                   | 20% | <ul style="list-style-type: none"> <li>1) From experience, RM activities across the various disciplines take place in isolation.</li> <li>2) There is no joint forum to undertake and review coordination for RM</li> <li>3) These are adequate at the tier-1 and tier-2 (locally controllable risks) levels - NOT at the tier-3 (beyond local control) level.</li> <li>4) Adequate coordinated RM procedures do not involve all parties in the LNG SC</li> <li>5) This requires more coordination and communication to ensure total alignment</li> </ul>                                                                                                                                                                           |
| 7 | <b>In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving global terrorism.</b>                          | 15% | <ul style="list-style-type: none"> <li>1) This depends on the methodology. APRA- SVA methodology* was developed precisely for this reason</li> <li>2) Depending on the type and level of risk involved</li> <li>3) Nothing wrong with the methodology; the limiting factor is our competencies/experiences in putting together credible single or combined event scenarios and imagining the possible consequences &amp; their mitigating actions. (Think about the Japan quake and tsunami!)</li> <li>4) Surely from a safety perspective as anti-terrorism is not included.</li> <li>5) The risk models available are adequate again must ensure that these are commonly applied.</li> <li>6) ISPS covers this aspect.</li> </ul> |
| 9 | <b>Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of</b> | 20% | <ul style="list-style-type: none"> <li>1) I think it's terminal operators who lead such efforts</li> <li>2) Some security apparatus are not within the jurisdiction of port authorities</li> <li>3) Intentions are there, but collaboration/progress is slow and</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

|    |                                                                                                                                                             |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | <b>LNG ports</b>                                                                                                                                            |     | <p>not necessarily addressing the right issues. Good work is being done in this domain by Organizations such as IMO, OCIMF, etc.</p> <p>4) The local legislation dictates responsibility.</p> <p>5) SIGTTO has been leading this</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 10 | <b>LNG Port Safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary.</b> | 35% | <p>1) Depending on the ports involved</p> <p>2) Individual facilities should coordinate and cooperate with the port authority</p> <p>3) No disagreement with statement that each facility needs to manage its own risks, however there will be a number of (major) risks inherent to the operation of one facility or combined activity risks of two/more facilities that will affect one, several or all of the other facilities. Therefore, the Port Authority needs to see to it that the overall combined risk is being managed as well, which means that they need to establish an overall RM approach.</p> <p>4) Port authority is ultimately responsible so they must ensure the LNG facilities are properly risk managed</p> <p>5) RLIC provides guidelines and regulations and follow up on the implementation. Each End user use this as the minimum requirement of their system</p> <p>6) HSE regulations should be applied consistently throughout the Port</p> <p>7) It is a joint responsibility; however, it begins with individual entities.</p> |
| 18 | <b>Generally in practice, RA in safety and security uses the same methodology.</b>                                                                          | 45% | <p>1) Methodologies need to be different as threat environment is entirely different between these two disciplines.</p> <p>2) safety is a different concept, in both theory and practice, than security</p> <p>3) security and safety risks have different definitions and as such different components to consider</p> <p>4) The same methodology can be followed but the scenarios need to be updated to include Security systems as well.</p> <p>5) Requirements for safety RAs can be very different from those for security RAs.</p> <p>6) The threat and the requirement are</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |



|    |                                                                                                                          |       |                                                                                                                                                                                                                                                                                                              |
|----|--------------------------------------------------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                                                                                                                          |       | <p>different.</p> <p>7) The methodology is different in the way that the calculations and modelling used for HSE and QRA is different than that the ones used by security</p> <p>8) Security may have other local concerns including political interference</p> <p>9) Both throw up different challenges</p> |
| 19 | <b>Mitigation strategies are efficiently applied within the framework of a comprehensive RM strategy in LNG Port SCs</b> | 15.8% | <p>1) Not the case mostly.</p> <p>2) Needs more alignment as in most LNG ports various different parties operate in the Port area</p> <p>3) It depends on the safety management system in place and the kind of support received from the management.</p>                                                    |

**NB:** \*APRA-SVA: American Petrochemical & Refiners Association- Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries

## First Round Results- Distilled comments

| Q # | STATEMENT                                                                                                                                                                                                                         | % DA | RESPONDENTS' COMMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2   | <b>LNG ports are sufficiently protected against terrorist risks</b>                                                                                                                                                               | 30%  | <ol style="list-style-type: none"> <li>1. This statement cannot be generalised across world ports, much more work and international cooperation will be required to improve controls.</li> <li>2. The Sheer size and accessibility of these facilities makes them very difficult to protect against terrorist threats. A determined terrorist could access port secured areas and could attack port facilities from a distance by air or from the sea.</li> <li>3. Ports tend to gravitate towards a complete general port security model, rather than a specialized LNG security cover, especially in multi-cargo ports.</li> </ol> |
| 3   | <b>Current security legal framework (ISPS &amp; non ISPS security frameworks) are sufficient to ensure efficient security protection for LNG Ports SCs.</b>                                                                       | 30%  | <ol style="list-style-type: none"> <li>1) ISPS and similar codes such as CT-PAT only require minimum level of protection. In certain environments these may not be sufficient for adequate protection against security threats.</li> <li>2) Current frameworks are still treating individual facilities in relative isolation. Efficiency of security protection would be greatly enhanced by integrating processes and systems on local if not regional and global basis.</li> <li>3) Only if these security frameworks are enforced properly</li> </ol>                                                                            |
| 4   | <b>The multitude of existing security frameworks (ISPS and non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG</b> | 25%  | <ol style="list-style-type: none"> <li>1) ISPS only states that certain requirements are in place, they do not state how these requirements are achieved.</li> <li>2) If one follows an integrated system for all the different frameworks, it might enhance the system.</li> <li>3) Cost should always be in</li> </ol>                                                                                                                                                                                                                                                                                                             |

|   |                                                                                                                                               |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|   | <b>ports.</b>                                                                                                                                 |     | <p>proportion to the risk. The ISPS code does not prescribe the physical measures but expect the port to do a RA and based on this put an effective protection in place.</p> <p>4) In fact, I see ISPS and non ISPS initiatives as an advantage, however some areas might need to be reviewed, but I don't see it as having adverse effect on the level of protection in LNG ports.</p>                                                                                                                                              |
| 5 | <b>There are already adequate collaborative security and safety risk arrangements in place among LNG port SC members.</b>                     | 20% | <p>1) All port and SC members have specific requirements which are sometimes contradictory.</p> <p>2) Some arrangements are in place, but they are far from adequate in controlling/ combating today's- let alone tomorrow's- threats.</p> <p>3) There is still a disconnection between the various parties in the LNG SC.</p>                                                                                                                                                                                                       |
| 6 | <b>There are currently adequate coordinated RM procedures in place in LNG Port SCs.</b>                                                       | 19% | <p>1) From experience RM activities across various disciplines take place in isolation and do not involve all parties in the LNG SC.</p> <p>2) There is no joint forum to undertake and review coordination for RM. This requires more coordination and communication to ensure total alignment</p> <p>3) These are adequate at the tier-1 and tier-2 (locally controllable risk) levels - NOT at the tier-3 (beyond local control) level.</p> <p>4) Adequate coordinated RM procedures do not involve all parties in the LNG SC</p> |
| 7 | <b>In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving</b> | 15% | <p>1) Depends on the methodology. APRA- SVA methodology* was developed precisely for this reason</p> <p>2) Depending on the type and level</p>                                                                                                                                                                                                                                                                                                                                                                                       |

|    |                                                                                                                                                                                                    |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | <b>global terrorism.</b>                                                                                                                                                                           |     | <p>of risk involved</p> <p>3) Nothing wrong with the methodology; the limiting factor is our competencies/experience in putting together credible single or combined event scenarios and imagining the possible consequences &amp; their mitigating actions...</p> <p>4) Agree that the risk models available are adequate again must ensure that this is commonly applied.</p>                                                                                                                                                                                                                                    |
| 9  | <b>Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of LNG ports</b> | 20% | <p>1) I think it's terminal operators who lead such efforts</p> <p>2) Some security apparatus are not within the jurisdiction of port authorities</p> <p>3) Intentions are there, but collaboration/progress is slow and not necessarily addressing the right issues. Good work is being done in this domain by Organizations/Fora such as IMO, OCIMF, etc.</p>                                                                                                                                                                                                                                                    |
| 10 | <b>LNG Port Safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary.</b>                                        | 35% | <p>1) Individual facilities should coordinate and cooperate with the port authority</p> <p>2) No disagreement with statement that each facility needs to manage its own risks, however there will be a number of (major) risks inherent to the operation of one facility or combined risks of two/more facilities that may affect the other facilities. Therefore, the Port Authority needs to make sure that the overall combined risk is being managed as well, which means that they need to establish an overall RM approach.</p> <p>3) HSE regulations should be applied consistently throughout the Port</p> |

|    |                                                                                                                          |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----|--------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                                                                                                                          |       | 4) It is a joint responsibility; however, it begins with individual entities.                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 18 | <b>Generally in practice, RA in safety and security uses the same methodology.</b>                                       | 45%   | <ol style="list-style-type: none"> <li>1) Methodologies need to be different as threat environment is entirely different between these two disciplines.</li> <li>2) The same methodology can be followed but the scenarios need to be updated to include Security systems as well</li> <li>3) Requirements for safety RAs can be very different from those for security RAs</li> <li>4) The methodology is different in the way that the calculations and modelling used for HSE and QRA is different than that used by security</li> </ol> |
| 19 | <b>Mitigation strategies are efficiently applied within the framework of a comprehensive RM strategy in LNG Port SCs</b> | 15.8% | <ol style="list-style-type: none"> <li>1) This needs more alignment as in most LNG ports various different parties operate in the Port area</li> <li>2) That depends on the safety management systems in place and the kind of support received from the management.</li> </ol>                                                                                                                                                                                                                                                             |

## **Appendix5 Second round Delphi survey questionnaire and results**

Dear Sir/ Mme;

Thank you for taking part in the first round survey of the study. There were twenty-six (26) statements in the first round survey questionnaire and 20 panellists participated. The panellists have supplied valuable comments along with agreements or disagreements with the statements. There were twenty-six (26) statements in the first round survey questionnaire and 20 panellists, including you, participated in this round. The panellists have supplied valuable comments, which have enriched this research, along with agreements or disagreements with the statements. There was general consensus on sixteen (16) statements. The remaining ten (10) did not achieve consensus and are used in this second round survey questionnaire. The second round survey questionnaire is formed from the comments of the panellists along with the original ten statements of first round.

The Delphi Technique used for this research consists of two rounds of questionnaires. In this round, please consider the original statement and the comments of the panellists and make a judgement by marking (X) against one of the three options for each statement, labelled as 'Agree', 'Disagree' and 'Unable to Comment'. In the case of 'Disagree' you are requested to give further comments. The questionnaire used in this round is accessible online through the following link: <https://www.surveymonkey.com/s/QZNLDFD>

As promised in the first round, your reply will be treated in strict confidence and names of individual respondents or organisations will not be used in published material or given to third parties. Only the general findings of the survey will be published.

Please read all statements before making your judgement. If you participate in this survey; a copy of the general findings will be emailed to you.

I look forward to receiving your response within one week. If you require any further details please do not hesitate to contact me at the address below.

**Mohamed Briouig**

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(3) [briouig@qp.com.qa](mailto:briouig@qp.com.qa)

**NB:**

- *All the following statements relate to port Supply Chains pertaining to Liquefied Natural Gas (LNG).*
- *Risks referred to in this questionnaire are related only to safety, security and quality risk types.*

**1. Original statement: LNG ports are sufficiently protected against terrorist risks**

**The panellists have expressed** the following opinions disagreeing with the above statement.

1.1 It is very difficult to generalize this statement across world ports  
Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

1.2 The Sheer size and accessibility of these facilities makes them very difficult to protect against terrorist threats. Much more work and international cooperation will be required to improve controls.  
Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

1.3 A determined terrorist could enter port secured areas. It is also feasible that port facilities could be attacked from a distance, by air or from seaside.

Agree

Disagree

Unable to Comment

Please comment if you disagree  
-----

**2. Original statement: Current security legal framework (ISPS & non ISPS security frameworks) are sufficient to ensure efficient security protection for LNG Ports SCs.**

**The panellists have expressed** the following opinions disagreeing with the above statement.

2.1 ISPS and similar codes such as CT-PAT only require minimum level of protection. In certain environments these may not be sufficient to adequately protect against security threats.

Agree

Disagree

Unable to Comment

Please comment if you disagree  
-----

2.2 Current frameworks are still treating individual facilities in relative isolation. Efficiency of security protection would be greatly enhanced by integrating processes and systems on local if not regional/ global basis.

Agree

Disagree

Unable to Comment

Please comment if you disagree  
-----

2.3 ISPS is a recommended policy and specific country legislation is required to enforce in any port. This legislation is the document that will decide on the adequacy of the security framework.

Agree

Disagree

Unable to Comment

Please comment if you disagree  
-----

**3. Original statement: The multitude of existing security frameworks (ISPS and non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG ports.**

**The panellists have expressed** the following opinions disagreeing with the above statement.



3.1 ISPS only states that certain requirements are in place, they do not state how these requirements are achieved.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree---

3.2 If integrated system for all the different frameworks is followed, this might enhance the protection system.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

3.3 Cost should always be in proportion to the risk. The ISPS code does not prescribe the physical measures but expect the port to do a risk assessment and based on this put an effective protection in place.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

3.4 ISPS and non ISPS initiatives as an advantage and some areas might need to be reviewed, but it does not have an adverse effect on the level of protection in LNG ports.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

**4. Original statement: There are already adequate collaborative security and safety risk arrangements in place among LNG port supply chain members.**

**The panellists have expressed** the following opinions disagreeing with the above statement.

4.1 All port and SC members have specific requirements which are sometimes contradictory.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

4.2 Some arrangements are in place, but they are far from adequate in controlling/ combating today's- let alone tomorrow's- threats.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

4.3 There is still a disconnection between the various parties in the LNG SC.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

**5. Original statement: There are currently adequate coordinated risk management procedures in place in LNG port SCs**

**The panellists have expressed** the following opinions disagreeing with the above statement.

5.1 From experience, risk management activities across the various disciplines take place in isolation.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

5.2 These are adequate at the tier-1 and tier-2 (locally controllable risks) levels - NOT at the tier-3 (beyond local control) level.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

5.3 Adequate coordinated risk management procedures do not involve all parties in the LNG supply chain

Agree                      Disagree                      Unable to Comment

Please comment if you disagree  
-----

**6. Original statement: In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving global terrorism.**

**The panellists have expressed** the following opinions disagreeing with the above statement.

6.1 This depends on the methodology. APRA- SVA methodology (American Petroleum and Refiners Association-Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries) was developed precisely for this reason.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

-----

6.2 There is nothing wrong with the methodology; the limiting factor is our competencies/experiences in putting together credible single or combined event scenarios and imagining the possible consequences and their mitigating actions. (Think about the example of the Japan quake and tsunami!)

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

6.3 The risk models available are adequate; again it must be ensured that these are commonly applied.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

**7. Original statement: Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of LNG ports**

**The panellists have expressed** the following opinions disagreeing with the above statement.

7.1 I think it is the terminal operators who lead such effort.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

7.2 Some security apparatus is not within the jurisdiction of port authorities.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

7.3 Intentions are there, but collaboration/progress is slow and not necessarily addressing the right issues. Good work is being done in this domain by organizations such as IMO, OCIMF, etc.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

**8. Original statement: LNG Port Safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary.**

**The panellists have expressed** the following opinions disagreeing with the above statement.

8.1 Individual facilities should coordinate and cooperate with the port authority

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

8.2 There will be a number of (major) risks inherent to the operation of one facility or combined activity risks of two or more facilities. The Port Authority needs to see to it that the overall combined risk is being managed as well, which means that they need to establish an overall Risk Management approach.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

8.3 Port authority is ultimately responsible so they must ensure the LNG facilities are properly risk managed

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

8.4 It is a joint responsibility; however, it begins with individual entities.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

---

**9. Original statement: Generally in practice, risk assessment in safety and security uses the same methodology.**

**The panellists have expressed** the following opinions disagreeing with the above statement.

9.1 Methodologies need to be different as threat environment is entirely different between these two disciplines.

Agree                                      Disagree                                      Unable to Comment

Please comment if you disagree  
-----

9.2 Safety is a different concept, in both theory and practice, to security

Agree                                      Disagree                                      Unable to Comment

Please comment if you disagree  
-----

9.3 The same methodology can be followed but the scenarios need to be updated to include Security systems as well.

Agree                                      Disagree                                      Unable to Comment

Please comment if you disagree  
-----

9.4 Requirements for safety risk assessments can be very different from those for security risk assessments.

Agree                                      Disagree                                      Unable to Comment

Please comment if you disagree  
-----

9.5 The methodology is different in the way that the calculations and modelling

used for HSE and QRA is different from the ones used by security

Agree                                      Disagree                                      Unable to Comment

Please comment if you disagree  
-----

**10. Original statement: Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port SCs**

**The panellists have expressed** the following opinions disagreeing with the above statement.

10.1 Not the case mostly.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

10.2 Needs more alignment as in most LNG ports various different parties operate in the Port area.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

10.3 It depends on the safety management system in place and the kind of support received from the management.

Agree                      Disagree                      Unable to Comment

Please comment if you disagree

-----

## Second Round Delphi results

| Q. No    | Statement                                                                                                                                                                                                                                | A         | DA       | UC       | N         | %           |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|----------|----------|-----------|-------------|
| <b>2</b> | <b>LNG ports are sufficiently protected against terrorist risks</b>                                                                                                                                                                      |           |          |          |           |             |
|          | 1- It is very difficult to generalise this statement across world ports                                                                                                                                                                  | <b>10</b> | <b>2</b> | <b>2</b> | <b>14</b> | <b>71.4</b> |
|          | 2- The sheer size and accessibility of these facilities makes them very difficult to protect against terrorist threats. Much more work and international cooperation will be required to improve controls                                | <b>11</b> | <b>2</b> | <b>1</b> | <b>14</b> | <b>78.6</b> |
|          | 3- A determined terrorist could enter port secured areas. It is also feasible that port facilities could be attacked from a distance, by air or from the sea.                                                                            | <b>13</b> | <b>1</b> | <b>0</b> | <b>14</b> | <b>92.9</b> |
| <b>3</b> | <b>Current security legal framework (ISPS &amp; non ISPS security frameworks) are sufficient to ensure efficient security protection for LNG ports SCs</b>                                                                               |           |          |          |           |             |
|          | 1- ISPS and similar codes such as CT-PAT only require minimum level of protection. In certain environments these may not be sufficient to adequately protect against security threats.                                                   | <b>6</b>  | <b>4</b> | <b>4</b> | <b>14</b> | <b>42.9</b> |
|          | 2- Current frameworks are still treating individual facilities in relative isolation. Efficiency of security protection would be greatly enhanced by integrating processes and systems on local if not regional and global basis         | <b>11</b> | <b>0</b> | <b>3</b> | <b>14</b> | <b>78.6</b> |
|          | 3- ISPS is a recommended policy and country-specific legislation is required to enforce in any port. This legislation is the document that will decide on the adequacy of the security framework.                                        | <b>10</b> | <b>1</b> | <b>3</b> | <b>14</b> | <b>71.4</b> |
| <b>4</b> | <b>The multitude of existing security frameworks (ISPS and non ISPS initiatives) may lead to difficulty and high costs in the implementation of security protection which may adversely affect the level of protection in LNG ports.</b> |           |          |          |           |             |
|          | 1- ISPS only states that certain requirements are in place, they do                                                                                                                                                                      | <b>6</b>  | <b>4</b> | <b>3</b> | <b>14</b> | <b>46.2</b> |

|          |                                                                                                                                                                                                                |    |   |   |    |      |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|---|---|----|------|
|          | not state how these requirements are achieved                                                                                                                                                                  |    |   |   |    |      |
|          | 2- If an integrated system for all the different frameworks is followed, it might enhance the system.                                                                                                          | 10 | 0 | 3 | 13 | 76.9 |
|          | 3- Cost should always be in proportion to the risk. The ISPS code does not prescribe the physical measures but expect the port to do a risk assessment and based on this put an effective protection in place. | 10 | 1 | 2 | 13 | 76.9 |
|          | 4- ISPS and non ISPS initiatives are an advantage, and some areas might need to be reviewed, but it does not have an adverse effect on the level of protection in LNG ports.                                   | 8  | 2 | 3 | 13 | 61.5 |
| <b>5</b> | <b>There are already adequate collaborative security and safety risk arrangements in place among LNG port supply chain members.</b>                                                                            |    |   |   |    |      |
|          | 1- All port and SC members have specific requirements which are sometimes contradictory.                                                                                                                       | 9  | 1 | 3 | 13 | 69.2 |
|          | 2- Some arrangements are in place, but they are far from adequate in controlling/ combating today's- let alone tomorrow's- threats.                                                                            | 6  | 1 | 6 | 13 | 46.2 |
|          | 3- There is still a disconnection between the various parties in the LNG SC.                                                                                                                                   | 7  | 1 | 4 | 12 | 53.8 |
| <b>6</b> | <b>There are currently adequate coordinated risk management procedures in place in LNG Port SCs.</b>                                                                                                           |    |   |   |    |      |
|          | 1- From experience risk management activities across various disciplines take place in isolation and do not involve all parties in the LNG supply chain.                                                       | 9  | 3 | 0 | 12 | 75.0 |
|          | 2- These are adequate at the tier-1 and tier-2 (locally controllable risk) levels - NOT at the tier-3 (beyond local control) level.                                                                            | 6  | 2 | 4 | 12 | 50.0 |
|          | 3- Adequate coordinated risk management procedures do not involve all parties in the LNG supply chain.                                                                                                         | 7  | 1 | 4 | 12 | 58.3 |
| <b>7</b> | <b>In the LNG industry, the methodology for evaluating risks is insufficient to integrate the nature of post 9/11 risk profiles involving</b>                                                                  |    |   |   |    |      |



|           |                                                                                                                                                                                                                                                                                                                        |    |   |   |    |      |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|---|---|----|------|
|           | <b>global terrorism.</b>                                                                                                                                                                                                                                                                                               |    |   |   |    |      |
|           | 1- This depends on the methodology. APRA- SVA methodology* was developed precisely for this reason                                                                                                                                                                                                                     | 7  | 0 | 6 | 13 | 53.8 |
|           | 2- Nothing wrong with the methodology; the limiting factor is our competencies/ experience in putting together credible single or combined event scenarios and imagining the possible consequences & their mitigating actions.                                                                                         | 6  | 1 | 6 | 13 | 46.2 |
|           | 3- The risk models available are adequate; again it must be ensured that these are commonly applied.                                                                                                                                                                                                                   | 9  | 1 | 3 | 13 | 69.2 |
| <b>9</b>  | <b>Generally port authorities are leading collaborative measures to overcome and mitigate security risks among port SC members. This leadership is running adequately in the case of LNG ports.</b>                                                                                                                    |    |   |   |    |      |
|           | 1- I think it is terminal operators who lead such efforts.                                                                                                                                                                                                                                                             | 8  | 2 | 3 | 13 | 61.5 |
|           | 2- Some security apparatus is not within the jurisdiction of port authorities.                                                                                                                                                                                                                                         | 7  | 4 | 2 | 13 | 53.8 |
|           | 3- Intentions are there, but collaboration/progress is slow and not necessarily addressing the right issues. Good work is being done in this domain by Organizations/ Fora such as IMO, OCIMF, etc.                                                                                                                    | 8  | 1 | 4 | 13 | 61.5 |
| <b>10</b> | <b>LNG Port Safety is generally the business of each individual facility inside the port, as each one is required to contain risks within its boundary.</b>                                                                                                                                                            |    |   |   |    |      |
|           | 1- Individual facilities should coordinate and cooperate with the port authority                                                                                                                                                                                                                                       | 12 | 1 | 0 | 13 | 92.3 |
|           | 2- There will be a number of (major) risks inherent to the operation of one facility or combined activity risks of two or more facilities. The Port Authority needs to see to it that the overall combined risk is being managed as well, which means that they need to establish an overall Risk Management approach. | 12 | 0 | 1 | 13 | 92.3 |

|           |                                                                                                                                              |    |   |   |    |      |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------|----|---|---|----|------|
|           | 3- Port authority is ultimately responsible so they must ensure the LNG facilities are properly risk managed.                                | 11 | 1 | 1 | 13 | 84.6 |
|           | 4- It is a joint responsibility; however, it begins with individual entities                                                                 | 12 | 0 | 1 | 13 | 92.3 |
| <b>18</b> | <b>Generally in practice, risk assessment in safety and security uses the same methodology.</b>                                              |    |   |   |    |      |
|           | 1- Methodologies need to be different as threat environment is entirely different between these two disciplines.                             | 9  | 3 | 1 | 13 | 69.2 |
|           | 2- Safety is a different concept, in both theory and practice, to security.                                                                  | 10 | 2 | 1 | 13 | 76.9 |
|           | 3- The same methodology can be followed but the scenarios need to be updated to include Security systems as well.                            | 6  | 5 | 2 | 13 | 46.2 |
|           | 4- Requirements for safety risk assessments can be very different from those for security risk assessments.                                  | 12 | 0 | 1 | 13 | 92.3 |
|           | 5- The methodology is different in the way that the calculations and modelling used for HSE and QRA is different than that used by security. | 7  | 2 | 4 | 13 | 53.8 |
| <b>19</b> | <b>Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port SCs</b>        |    |   |   |    |      |
|           | 1- Not the case mostly                                                                                                                       | 9  | 0 | 4 | 13 | 69.2 |
|           | 2- This needs more alignment as in most LNG ports various different parties operate in the Port area.                                        | 10 | 0 | 3 | 13 | 76.9 |
|           | 3- It depends on the safety management systems in place and the kind of support received from the management.                                | 9  | 2 | 2 | 13 | 69.2 |

**Source:** *The author*

## **Appendix6 Quantitative Survey questionnaire and results**

Dear Sir/ Mme;

I am undertaking doctoral research at Plymouth University, United Kingdom on LNG Port Supply Chain Risk Management. Port supply chain refers to the set of organisations and firms fulfilling different port and logistics operations which are highly integrated and reliant on each other to deliver port and maritime services for the LNG industry. A panel of LNG port experts including port managers, terminal operators, LNG shippers, maritime agencies, and LNG storage facilities managers, managers of LNG shipping companies, LNG terminals risk specialists and LNG marketing managers as well as specialist consultants are all being consulted in this research.

The survey is posted on Survey Monkey website, which you can access through the following web link: ..... The survey should take about 10-15 minutes of your busy time, but your expert response will make the survey successful.

In order to gain a good understanding of LNG Port SC Risk Management, both in terms of safety, security and quality controls, we welcome opinions from a wide range of experts from different related disciplines. Please answer the questionnaire, even if you are not directly involved in safety or security of the LNG port SC, or even if you feel you cannot give an opinion on all the questions. Your views are valued as an informed professional in your particular specialty.

Your reply will be treated in strict confidence, and names of individual respondents or organisations will not be used in published material or given to third parties. The general findings of the survey may, be published, and should be of value to the LNG ports and maritime industry. If you participate in the survey, a copy of the general findings will be emailed to you.

I look forward to hearing from you as soon as possible. If you require any further details please do not hesitate to contact me at the address below.

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*The questionnaire is easy to complete. Please make a judgement about a specific issue/ statement in your area of expertise, which will be measured on a scale, by marking (X) on the left of one of the six options. 5 = Strongly Agree, 4= Agree, 3= neither agree nor disagree, 2= Disagree, 1= strongly disagree, and 0= don't know/ not applicable.*

### **PART ONE: LNG PORT SECURITY**

1. Position or area of specialty

2. LNG ports and marine terminals are strategically located within the LNG Supply Chain.

5            4            3            2            1            0

3. Security risks are now equally as important as safety risks in LNG ports and marine terminals.

5            4            3            2            1            0

1. The size and accessibility of LNG ports and marine terminal facilities makes them very difficult to protect against terrorist threats. Much more work and international cooperation is required to improve security controls.

5            4            3            2            1            0

2. The ISPS code and similar frameworks are an advantage; however they only require minimum levels of protection. In certain environments these may not be sufficient to adequately protect against security threats.

5            4            3            2            1            0

3. Current security frameworks are still treating individual terminal facilities in relative isolation. Enhanced security protection requires a coordinated approach by integrating processes and systems at a local level if not on a regional and global basis.

5            4            3            2            1            0

### **PART TWO: LNG PORT SAFETY**

4. LNG port safety is generally the business of each individual facility inside the port, as each one is required to ensure safety of its own operations within the limit of its boundaries.

5            4            3            2            1            0

8. Although safety of each individual member of the LNG Port Supply Chain is the responsibility of each individual member, safety of the whole LNG port Supply Chain is a joint responsibility which has to be coordinated and ensured by the port authority.

5            4            3            2            1            0

9. The IMO's Formal Safety Assessment (FSA) for shipping should be extended to address port safety as well (onshore port operations).

5            4            3            2            1            0

10. A standard safety framework is necessary to address both LNG port offshore and onshore safety operations as well as the ship/ port interface.

5            4            3            2            1            0

**PART THREE: LNG PORT SAFETY & SECURITY**

11. Safety measures (safeguards) are the first line of defence for security in LNG port Supply Chains.

5            4            3            2            1            0

4 Safety and security in LNG ports Supply Chains are closely related issues and may yield better outcome if managed in an integrative manner within the framework of a unified risk management approach and through a single port supply chain entity.

5            4            3            2            1            0

5 Generally in practice, risk assessment in safety and security follow similar risk assessment and management steps.

5            4            3            2            1            0

6 Risk management across various disciplines such as safety and security takes place in isolation and little or no coordination exists between security and safety assessment and management in the LNG port Supply Chain.

5            4            3            2            1            0

7 In general, no official structure within LNG Ports supply chains exists to enable coordination among safety and security assessment and management.

5            4            3            2            1            0

8 LNG safety and security are two different disciplines which have different requirements in terms of risk assessment. Therefore, their risk assessment methodologies need to be different to cope with their respective specificities and requirements.

5            4            3            2            1            0

9 Although safety and security risks in LNG port Supply Chains are two disciplines that may have different requirements, their management should be coordinated within the framework of a holistic approach to achieve resilient and cost effective risk management in LNG port Supply Chains.

5            4            3            2            1            0

10 Mitigation strategies are efficiently applied within the framework of a comprehensive risk management strategy in LNG Port Supply Chains.

5            4            3            2            1            0

11 A unified risk management methodology for assessing both safety and security risks and hazards can be more cost effective than a risk management methodology in which security and safety risks are managed separately and with less coordination.

**5            4            3            2            1            0**

12 An all-hazards approach in which safety security, natural disasters risks are assessed and managed is needed in LNG Ports supply chains to develop a cost effective and efficient risk management strategy.

**5            4            3            2            1            0**

13 Implementation and coordination of such all-hazards approach should be coordinated by the LNG port authority.

**5            4            3            2            1            0**

**PART FOUR: LNG PORT RISK MANAGEMENT AND QUALITY**

14 There is a similarity between Port SC safety, security and quality; mainly in terms of assessment and management methodologies and approaches.

**5            4            3            2            1            0**

15 Safety and security risk assessment and management need to take advantage of the *Total Quality Management (TQM)* Principles.

**5            4            3            2            1            0**

16 Prevention is the key principle in *Total Quality Management (TQM)* and should also be for the case of safety and security management.

**5            4            3            2            1            0**

17 Based on the principles of TQM, LNG port supply chains should adopt an integrated risk assessment and management approach capable of dealing with the three types of risks, safety, security and quality.

**5            4            3            2            1            0**

18 Adopting such an integrative approach will lead to efficient and cost effective risk management in LNG Ports SCs.

**5            4            3            2            1            0**

19 Integrated LNG Port Supply chain risk management should be assured through a quality assurance system based on the TQM.

**5            4            3            2            1            0**

28. Within an all-hazard approach, the principles of TQM should be applied during each step of risk assessment rather than the final result of the risk assessment being controlled according to quality principles.

**5            4            3            2            1            0**

Thank you for responding to this survey; if you wish to get copy of the findings of this research, copy will be emailed to you. Please indicate here;

Yes

No

## Quantitative Survey Results, Technical details using SPSS

### QUESTIONNAIRE ANALYSIS

Results: 150 Questionnaires sent out- 62 returned responses:  
Response rate: 41.33%

### Frequency Tables

#### Q1- Position/ Area of specialty

|                               | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------------|-----------|---------|---------------|--------------------|
| Valid LNG Terminal Managers   | 13        | 21.0    | 21.0          | 21.0               |
| LNG Shipping Managers         | 8         | 12.9    | 12.9          | 33.9               |
| LNG Port Security Specialists | 5         | 8.1     | 8.1           | 41.9               |
| LNG HSE Specialists           | 6         | 9.7     | 9.7           | 51.6               |
| LNG Quality Specialists       | 4         | 6.5     | 6.5           | 58.1               |
| Academia and LNG Consultants  | 26        | 41.9    | 41.9          | 100.0              |
| Total                         | 62        | 100.0   | 100.0         |                    |

#### Q2

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 9         | 14.5    | 14.5          | 17.7               |
| Agree          | 25        | 40.3    | 40.3          | 58.1               |
| Strongly agree | 26        | 41.9    | 41.9          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q3**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 4         | 6.5     | 6.5           | 6.5                |
| Neutral        | 4         | 6.5     | 6.5           | 12.9               |
| Agree          | 34        | 54.8    | 54.8          | 67.7               |
| Strongly agree | 20        | 32.3    | 32.3          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q4**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 1         | 1.6     | 1.6           | 1.6                |
| Disagree                | 4         | 6.5     | 6.5           | 8.1                |
| Neutral                 | 22        | 35.5    | 35.5          | 43.5               |
| Agree                   | 31        | 50.0    | 50.0          | 93.5               |
| Strongly agree          | 4         | 6.5     | 6.5           | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q5**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 3         | 4.8     | 4.8           | 8.1                |
| Neutral                 | 12        | 19.4    | 19.4          | 27.4               |
| Agree                   | 30        | 48.4    | 48.4          | 75.8               |
| Strongly agree          | 15        | 24.2    | 24.2          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |



**Q6**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 1         | 1.6     | 1.6           | 1.6                |
| Neutral        | 17        | 27.4    | 27.4          | 29.0               |
| Agree          | 36        | 58.1    | 58.1          | 87.1               |
| Strongly agree | 8         | 12.9    | 12.9          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q7**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 3         | 4.8     | 4.8           | 4.8                |
| Disagree                | 13        | 21.0    | 21.0          | 25.8               |
| Neutral                 | 12        | 19.4    | 19.4          | 45.2               |
| Agree                   | 22        | 35.5    | 35.5          | 80.6               |
| Strongly agree          | 12        | 19.4    | 19.4          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q8**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 6         | 9.7     | 9.7           | 9.7                |
| Neutral        | 18        | 29.0    | 29.0          | 38.7               |
| Agree          | 34        | 54.8    | 54.8          | 93.5               |
| Strongly agree | 4         | 6.5     | 6.5           | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q9**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 2         | 3.2     | 3.2           | 6.5                |
| Neutral                 | 20        | 32.3    | 32.3          | 38.7               |
| Agree                   | 23        | 37.1    | 37.1          | 75.8               |
| Strongly agree          | 15        | 24.2    | 24.2          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q10**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 4         | 6.5     | 6.5           | 9.7                |
| Neutral                 | 6         | 9.7     | 9.7           | 19.4               |
| Agree                   | 34        | 54.8    | 54.8          | 74.2               |
| Strongly agree          | 16        | 25.8    | 25.8          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q11**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 4         | 6.5     | 6.5           | 9.7                |
| Neutral                 | 15        | 24.2    | 24.2          | 33.9               |
| Agree                   | 33        | 53.2    | 53.2          | 87.1               |
| Strongly agree          | 8         | 12.9    | 12.9          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q12**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 18        | 29.0    | 29.0          | 32.3               |
| Agree          | 36        | 58.1    | 58.1          | 90.3               |
| Strongly agree | 6         | 9.7     | 9.7           | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q13**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 1         | 1.6     | 1.6           | 1.6                |
| Neutral        | 4         | 6.5     | 6.5           | 8.1                |
| Agree          | 29        | 46.8    | 46.8          | 54.8               |
| Strongly agree | 28        | 45.2    | 45.2          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q14**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 3         | 4.8     | 4.8           | 4.8                |
| Disagree                | 14        | 22.6    | 22.6          | 27.4               |
| Neutral                 | 23        | 37.1    | 37.1          | 64.5               |
| Agree                   | 16        | 25.8    | 25.8          | 90.3               |
| Strongly agree          | 6         | 9.7     | 9.7           | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q15**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 10        | 16.1    | 16.1          | 19.4               |
| Neutral                 | 33        | 53.2    | 53.2          | 72.6               |
| Agree                   | 16        | 25.8    | 25.8          | 98.4               |
| Strongly agree          | 1         | 1.6     | 1.6           | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q16**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 2         | 3.2     | 3.2           | 3.2                |
| Disagree                | 12        | 19.4    | 19.4          | 22.6               |
| Neutral                 | 18        | 29.0    | 29.0          | 51.6               |
| Agree                   | 23        | 37.1    | 37.1          | 88.7               |
| Strongly agree          | 7         | 11.3    | 11.3          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q17**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Neutral  | 14        | 22.6    | 22.6          | 22.6               |
| Agree          | 33        | 53.2    | 53.2          | 75.8               |
| Strongly agree | 15        | 24.2    | 24.2          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q18**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 5         | 8.1     | 8.1           | 8.1                |
| Neutral        | 35        | 56.5    | 56.5          | 64.5               |
| Agree          | 15        | 24.2    | 24.2          | 88.7               |
| Strongly agree | 7         | 11.3    | 11.3          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q19**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 12        | 19.4    | 19.4          | 22.6               |
| Agree          | 34        | 54.8    | 54.8          | 77.4               |
| Strongly agree | 14        | 22.6    | 22.6          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q20**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Neutral  | 9         | 14.5    | 14.5          | 14.5               |
| Agree          | 40        | 64.5    | 64.5          | 79.0               |
| Strongly agree | 13        | 21.0    | 21.0          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q21**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 1         | 1.6     | 1.6           | 1.6                |
| Disagree                | 5         | 8.1     | 8.1           | 9.7                |
| Neutral                 | 20        | 32.3    | 32.3          | 41.9               |
| Agree                   | 26        | 41.9    | 41.9          | 83.9               |
| Strongly agree          | 10        | 16.1    | 16.1          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q22**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 3         | 4.8     | 4.8           | 4.8                |
| Disagree                | 8         | 12.9    | 12.9          | 17.7               |
| Neutral                 | 13        | 21.0    | 21.0          | 38.7               |
| Agree                   | 22        | 35.5    | 35.5          | 74.2               |
| Strongly agree          | 16        | 25.8    | 25.8          | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q23**

|                         | Frequency | Percent | Valid Percent | Cumulative Percent |
|-------------------------|-----------|---------|---------------|--------------------|
| Valid Strongly disagree | 1         | 1.6     | 1.6           | 1.6                |
| Disagree                | 1         | 1.6     | 1.6           | 3.2                |
| Neutral                 | 13        | 21.0    | 21.0          | 24.2               |
| Agree                   | 41        | 66.1    | 66.1          | 90.3               |
| Strongly agree          | 6         | 9.7     | 9.7           | 100.0              |
| Total                   | 62        | 100.0   | 100.0         |                    |

**Q24**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 1         | 1.6     | 1.6           | 1.6                |
| Neutral        | 10        | 16.1    | 16.1          | 17.7               |
| Agree          | 38        | 61.3    | 61.3          | 79.0               |
| Strongly agree | 13        | 21.0    | 21.0          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q25**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 11        | 17.7    | 17.7          | 21.0               |
| Agree          | 40        | 64.5    | 64.5          | 85.5               |
| Strongly agree | 9         | 14.5    | 14.5          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q26**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 4         | 6.5     | 6.5           | 6.5                |
| Neutral        | 16        | 25.8    | 25.8          | 32.3               |
| Agree          | 33        | 53.2    | 53.2          | 85.5               |
| Strongly agree | 9         | 14.5    | 14.5          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q27**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 9         | 14.5    | 14.5          | 17.7               |
| Agree          | 35        | 56.5    | 56.5          | 74.2               |
| Strongly agree | 16        | 25.8    | 25.8          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Q28**

|                | Frequency | Percent | Valid Percent | Cumulative Percent |
|----------------|-----------|---------|---------------|--------------------|
| Valid Disagree | 2         | 3.2     | 3.2           | 3.2                |
| Neutral        | 10        | 16.1    | 16.1          | 19.4               |
| Agree          | 35        | 56.5    | 56.5          | 75.8               |
| Strongly agree | 15        | 24.2    | 24.2          | 100.0              |
| Total          | 62        | 100.0   | 100.0         |                    |

**Source:** *The author*

## Appendix7 Focus group prompt sheet

### **Focus Group prompt sheet.**

#### *Opening statements*

I am researching RM in LNG port SCs with a focus on the optimal way of management safety and security risks in LNG ports and how such management of risks can be best approached from a holistic and integrative perspective to address the interfaces and shared impacts of safety and security within the LNG ports domain.

All details are confidential but I may need to reproduce a transcript of some or all of your replies anonymously in an Appendix to a publication.

The *main question* is:

As LNG port experts, I would like to discuss with you the issue of safety and security RM and how it can be best streamlined, coordinated and integrated from a holistic perspective, so RM within the LNG port domain is performed efficiently and cost effectively following a participative approach.

Please provide your expert opinion in relation to the following prompts and in the context of LNG ports and marine terminals.

1. Interfaces between safety and security.
2. Current RM approach privileges safety and security RM be done in isolation
3. An all-hazards approach is a more cost effective and efficient RM approach
4. A change management process is necessary to assist in the implementation of an all-hazard approach to RM.
5. This change management should be implemented by all LNG ports organisations, including the port authority.
6. The port authority should lead the implementation of unified and integrated RM in LNG ports.
7. The port authority shall structure the port community and use it as an important tool in the coordination of safety and security RM.
8. The port community shall create a specialised risk and emergency management committee (REMC) to review and discuss RCOs for both safety and security.
9. The port community shall enjoy an advisory role to the port authority with regards to RM issues.
10. The port community-REMC shall play a coordination role between safety and security.
11. Safety and security departments of main port organisations shall be represented within the port community- REMC.
12. What is your impression about the proposed RM conceptual model?
13. Do you think the proposed RM conceptual model can be practical in the context of LNG ports?
14. What are the main factors for the proposed CM to be successfully implemented?
15. How can cooperation within the port community- REMC be best enhanced?
16. Do you think representation within REMC should be limited only to the main LNG port organisations or should this membership be open to all port users and public agencies?

**Source:** *The author*