ASSESSING THE PERFORMANCE AND EFFECTIVENESS OF THE SOLAS VERIFIED GROSS MASS REGULATION

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Abstract

The issue of container weight misdeclaration is a major concern in the entire supply chain. In fact, a huge problem that seemed inevitable to the industry and a situation that had affected shipping lines, ports and other stakeholders, is that of overweight containers and the improper stowage plans due to the misdeclared weight. This has led to major accidents, loss of lives and cargoes, damage to ships, environmental disasters and in general, posed a major safety threat in the maritime industry.

Discussions on the issue, led to the introduction of the IMO SOLAS Verified Gross Mass (VGM) Regulation in July 2016, which provides the mandatory weighing of every container before loading them into vessel. The purpose of this research is to analyse the effectiveness of the SOLAS VGM regulation and measure the implementation performance of the affected maritime stakeholders to assess if it has reached its goal of eliminating the problem of misdeclared container weights.

To achieve this, this research addresses all the key issues of the regulation, and it is divided into three parts. It begins, firstly, by investigating the selection of the most suitable Container Weighing System (CWS) for port operators using a combination of multi-criteria decision-making tools, namely the Analytical hierarchy process (AHP) and the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). Secondly, in order to monitor the performance of the regulation's effectiveness, this research conducts a measurement of the implementation performance using a framework based on Balanced Scorecards and Fuzzy Analytical Hierarchy Process (FAHP), with an application on the Nigerian Maritime and Safety Agency (NIMASA) as a case study. It also presents the extended framework, which can be used to evaluate the total performance of the regulation taking into account a number of relevant stakeholders. Finally, an economic appraisal is conducted using Cost-benefit analysis (CBA) to analyse ports' decisions on investing in CWS, and the decisions of shippers related to the VGM document provider. To our knowledge the above are novel and have a significant contribution into better understanding the performance of the VGM regulation. The presented work could help achieve better decisions, and also focus on areas where governmental agencies could increase their performance.

We hope that this research activity will make a significant contribution to the field by providing an accurate description of the implementation and enforcement of the regulation through empirical research.

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List of Abbreviations

Abbrev.	**Meaning**
AI	Artificial Intelligence
AHP	Analytic hierarchy process
AMIS	Abuja MOU information system
AMSA	Australia maritime safety authority
BSC	Balanced Scorecard
CBA	Cost benefit analysis
CCOHS	Canadian centre for occupational health and hazard
CFL	Container handling Forklift trucks
CI	Consistency index
CODECO	Container gate in/gate-out message
CR	Consistency ratio
CWS	Container weighing system
DAW	Dynamic Axle weighbridge
DFT	Department for transport
DMA	Danish maritime authority
DTs	Decision trees
EDI	Electronic data information
EDIFACT	Electronic data interchange for administration commerce and transport
EMV	Expected monetary value
eVGM	Electronic verified gross mass
FAHP	Fuzzy analytic hierarchy process
FAQ	Frequently asked question
GSF	Global shipper's forum
ICHCA	International cargo handling coordination association
ICS	Institute of chartered shipbrokers
IMO	International maritime organization
IMCO	Intergovernmental maritime consultative organization
ISM	International safety management code
ISO	International organisation for standardization

ISPS	International ship and port facility security code
MCA	Maritime and Coastguard agency
MCDM	Multi-criteria decision method
MCGDM	Multi-criteria group decision making
MEM	Maritime environment management
MHC	Mobile harbour crane
MIRO	Mass in running order
MLS	Maritime labour service
MSC	Maritime safety committee
MSO	Marine survey office
MSSS	Maritime safety and seafarer's standard
NIMASA	Nigerian maritime administration and safety agency
NIS	Negative ideal solution
NPV	Net present value
NVOCC	Non vessel operating common carrier
OSHA	Occupational safety and health administration
PIS	Positive ideal solution
PV	Present value
RI	Random index
RM	Rate of measures
RMRS	Russian maritime register of shipping
RS	Rate of stakeholders
RS	Reach stackers
RTGs	Rubber-tyre gantry cranes
SAMSA	South Africa maritime safety authority
SC	Straddle carriers
SOLAS	Safety of life at sea
STCW	International convention on standards of training, certification and watchkeeping for seafarers
STS	Ship to shore cranes
TEU	Twenty-foot equivalent unit
TFN	Triangular fuzzy number
TOPSIS	Technique for order of preference by similarity to ideal solution

TR	Total rate
USCG	Unites State and coast guard agency
VERMAS	Verified gross mass message
VGM	Verified gross mass
WGM	Weighted geometric Mean
WM	Weight of measures
WP	Weight of perspective
WS	Weight of stakeholders
WSC	World shipping council

Chapter 1

Introduction

Summary

This chapter introduces the research background and the research problem. It also highlights the research justification by looking at how other maritime studies focused on the legal and regulatory aspects of the industry. The research objectives and hypotheses are also highlighted. They lay out an analytical platform focused on meeting the identified problems. The main research methodology is briefly described along with the scope and structure of the research.

1.1 Background of research

The maritime industry is the backbone of the global trade and the world's economy (UN, 2016). There have been different inventions of navigation technologies that has helped in improving safety at sea and ashore. Around 80% of the world's goods are transported safely and cheaply by sea each year (UNCTAD, 2020). Such trades promote the wealth of countries. However, besides the rewards of sea transportation, seafarers and their ships are still exposed to looming threats at sea (King 2005). For instance, some of the threats faced by seafarers are pirate hijackings, mental health problems, stormy seas, electromagnetic waves, vessel damage, loss of cargo and lives, etc (JPS, 2019). Over centuries, no action was taken regarding the dangers of shipping, there was no regulatory regime backing up the system of sea transportation. The limited number of nations that set up regulations only did so for ships under their flag states.

In the 20th Century, there was a change when nations recognized the significance of having a common regulatory framework that would ensure and improve safety at sea. This goal became a reality when the United Nations adopted the International Maritime Organisation (IMO), which was originally the Inter-governmental Maritime Consultative Organisation (IMCO) (Smith 1999). Over the decades, the rules established by the IMO paved a joint and conventional ground for all sea transport workers and improved safety. Because of safe shipping, there was a parallel rise in the productivity of sea trade. The IMO has amended various conventions and codes that are termed as maritime rules. The purpose of the regulation is to ensure a high rate of safety ethics at sea and ashore, reduce or avoid pollution produced by vessels and to form a secured and conducive atmosphere for vessels and ports.

Most countries from different continents are registered members of the IMO (they are referred to as IMO member states). The IMO brings its rules to the awareness of the member states by organizing global meetings attended by representatives from each member state. Odeke (2005) stated that the implementation and enforcement of a maritime regulation is the responsibility of each member state. The expectation is that most member states would implement and meet the requirements of the maritime regulation, which is not always the case. This could be due to no general awareness, individual guidelines, checks in ports and on board to ensure it is being implemented.

One of these IMO amendments was to resolve the misdeclaration of container weight, which resulted in the loss of lives and properties at sea and ashore. Misdeclaration happens when the real weight of the loaded container differs from the value stated on the shipping document. The aspect of misdeclared container weight was addressed by an amendment to the SOLAS Convention under regulation 2 of Chapter VI, Resolution MSC.380 (94). From the 1st of July 2016, the regulation allows the use of two approved methods to declare the Verified Gross Mass (VGM) for each container (CMA CGM, 2016; Fitzgerald, 2016; WSC, 2017).

1.2 Research justification

Over the years, researchers have seen maritime regulations as a potential research study angle. Such studies have majored on different studies on the influence of maritime codes and conventions, implementation and enforcement processes of various regulations, performance and examination of ship associated operations. Some examples of such studies are Belete (2018); Jimenez (2018); Panlogo (2018); Ntungwe (2018); Akama (2017).

The problem of misdeclared container weights has been a centre of focus in the shipping industry for years. However, despite the regulations and steps aimed at addressing the problem, the reason why container weights were misdeclared was to reduce cost. There has been no analysis on the effectiveness of the SOLAS VGM regulation to verify how it is being implemented and if it has met its goal of eliminating the problem of misdeclared container weight. Since the regulation was enforced from July 2016, there has been limited information about how it is implemented by the major participants involved. An in-depth search of the relevant literature makes it apparent that besides some articles in newsmagazines and some guidelines published by commercial participants (rewrite). Most of the literature consists of unpublished articles in newspapers and industry reports especially from the World Shipping Council (WSC) and the International Chamber of Shipping (ICS), which brought the matter forward to the IMO back in 2010. IMO is the most important source of information for this research; see for example the following IMO submissions doc. MSC 89/25; MSC 89/22/11; MSC 89/22/17; DSC 16/2/1; DSC16/14; and DSC 16/15. All the related documents that culminated in the approval of the Guidelines (MSC.1/Circ.1475) and the adoption of the amendment to SOLAS regulation VI/2 for the mandatory VGM of packed containers (resolution MSC.380(94)) (IMO, 2016). However, on the other hand, there is not much academic literature addressing the issue. There have been some papers especially on legal aspects and national enforcement, for example King (2016) reviews the issue through its legal aspect and provides some perspectives from New Zealand and implications for its law. Apart from that, there is no academic literature that assesses the effectiveness and performance of the SOLAS VGM regulation.

As a result, this research aims to assess the effectiveness of this regulation and proposes several best practices and additional requirements that will improve its effectiveness and thus improve the overall safety and environmental protection of container shipping. To that effect, the results of this work can bring some very useful insights to the participants, including the regulators, carriers, shippers, port authorities and terminal operators.

1.3 Aims, objectives and hypothesis of the research

The overall aim of this project is to assess the performance and effectiveness of the container weighing verification requirements.

The compliance of shippers, including the selection of the appropriate weighing method, and terminals, as well as the enforcement by the national authorities, will be at the centre stage of our investigation. Also, all past and future submission to the IMO will be reviewed and critically assessed. We envisage arriving at a framework that could be used to assess the effectiveness of the VGM requirements and through case studies to identify best practices and ways to improve the verification, compliance, and enforcement of the requirements.

The following objectives have been identified to fulfill this aim:

- Investigate the problem of misdeclaration of container weights and its effect on safety in the shipping industry.
- Investigate all the issues related to the container weighing verification requirements; those involved, the weighing process, weighing system, method of weighing, etc.

- Investigate and assess how different participants in the maritime sector are implementing the SOLAS VGM regulation.
- Demonstrate the applicability of a model that would measure the implementation performance of major participants using the Nigerian Maritime Administration and Safety Agency (NIMASA) as a case study.
- Develop a methodology to conduct an economic appraisal on the regulation implementation.
- Identify best practices and, if any, possible ways to strengthen compliance, verification, and enforcement of the SOLAS VGM requirements.

1.4 Research limitations

The process of implementing maritime regulations can be quite complicated. The SOLAS VGM regulation was drafted in the format of a convention. Henceforth, a resolve to explore the implementation process presents some difficulties. These difficulties are worsened due to the vast number of people in the industry involved in fulfilling the requirements of VGM. Lack of previous related research and concrete evidence of accidents caused by misdeclared container weight is also a challenge. The setting of the research is to analyse the outcome and problems encountered by the shipping experts in dealing with the container-weighing regulation.

Another limitation is related to the high number of stakeholders involved in the regulatory process and in the requirements or guidelines set out. Despite this challenge, five major stakeholder groups (shippers, port/terminal operators, freight forwarders, maritime national authorities and carrier) that are highly affected by the VGM regulation were identified and included in this study. A model that can be applied to measure the implementation performance of the VGM regulation for the five key stakeholders was developed. Due to extremely demanding process, in terms data gathering and analysis, the model was applied to one of the major participants (maritime national authority) as a case study and to illustrate the applicability.

Furthermore, it is necessary to investigate the implementation of the VGM regulation by the five key participants because they are more likely affected by the regulation. This investigation would be done using Balanced Scorecards, which would help these key participants assess their performance in other future regulations investigation.

Seeing the highlighted limitations, it is still significant to utilize a technique that will estimate the performance of the SOLAS VGM regulation. This technique will contribute to the implementation of the regulation by exploring the challenges of the key participants in complying with the regulation. Also, any unnecessary burden on a participant would be a sign that the participant will try to either constrain the burden or avoid it.

1.5 The research methods

Firstly, a literature review is conducted. It begins with a brief review of the maritime industry and container shipping and is divided into four major sessions. The first session focuses on the reason behind the regulation and consists of key items mentioned on the regulation guidelines. The second session discusses how different sectors in the industry are implementing and enforcing the VGM regulation. The third part looks at the different available container weighing systems. Lastly, the fourth session focuses on approaches to measuring the effectiveness and performance of a regulation.

The next step of the thesis is the formulation of the technical chapters. The reason behind the ideas of each technical chapter is to enable the author to meet the research aim. To achieve this, all related key issues concerning the SOLAS VGM regulation ought to be discussed and analysed. Three models are used in this research. The first one is a model designed to select the most suitable weighing system. Making the choice of a weighing system is paramount to every port, hence the importance of developing a model (using AHP-TOPSIS) which would assist port operators in making their choice and promoting the performance of the regulation. To achieve this, a Multiple-Criteria Decision-Making (MCDM) or Multiple-Criteria Decision Analysis (MCDA) method can be used. These helps evaluate multiple conflicting criteria in decision making. In our case, among the different methods that could be used, we have selected to utilize the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which to work satisfactorily across different application areas. One of the steps of TOPSIS, and indeed of most MCDA methods, is the incorporation of the relative weight of the criterion importance. Weight could be assigned either directly or through, the use of another method. Here, we have selected the use of the Analytic Hierarchy Process (AHP), another popular MCDA approach, to derive this weight; see Section 3.2 for the advantages of using the combined AHP-TOPSIS approach.

The second adopted methodology consists of many steps and focuses on the key participants in the maritime industry that are connected to the VGM regulation. It is appropriate to make the second analysis specific due to the vastness of maritime stakeholders involved by conducting a case study of one major stakeholder after looking generally at all those involved. The case study focused on the organization

NIMASA and can be applied to other member states or VGM participants. These analyses were conducted through surveys sent to different industry experts. We present the methodology behind a model to measure the implementation performance of the VGM regulation. We propose the use of the Balanced Scorecard (BSC) method and the Fuzzy AHP (FAHP) technique to help evaluate each of the key industry stakeholders' performance using a number of different perspectives and measures (performance indicators); see Section 3.2 for more details. We argue that BSC, a framework for measuring organizational performance using a more balanced set of performance measures developed by Dr. Robert Kaplan of Harvard University and Dr. David Norton, is a well-known tool used by companies across the world. The framework we propose is adapted following the approach presented in the work of Karahalios et al. (2011). Fuzzy AHP is used due to the inherit advantage of fuzzy numbers overcoming the vagueness of human thought; modeling using fuzzy sets is more effective where the information available is subjective and imprecise. The process is more complicated though; thus, a similar approach could have been easily utilized in the previous problem. Section 3.3 explains the process and outlines the advantages of using the selected methods.

Finally, we acknowledge that businesses need to be profitable as well. To that extend, we present a set of tools related to the economic aspect. We present a method that can be used to make economic decisions taking into account the various alternatives and also a more systematic approach, namely the Cost-Benefit Analysis (CBA), which is an accounting model for pointing out the pros and cons of a project or policy in monetary terms. Examples of economic appraisals are presented to show how these methods can be used to guide shippers and port operators in their VGM implementation process.

1.6 Thesis structure

The thesis is structured as illustrated in Fig. 1.1. A brief description of each chapter is also provided below.

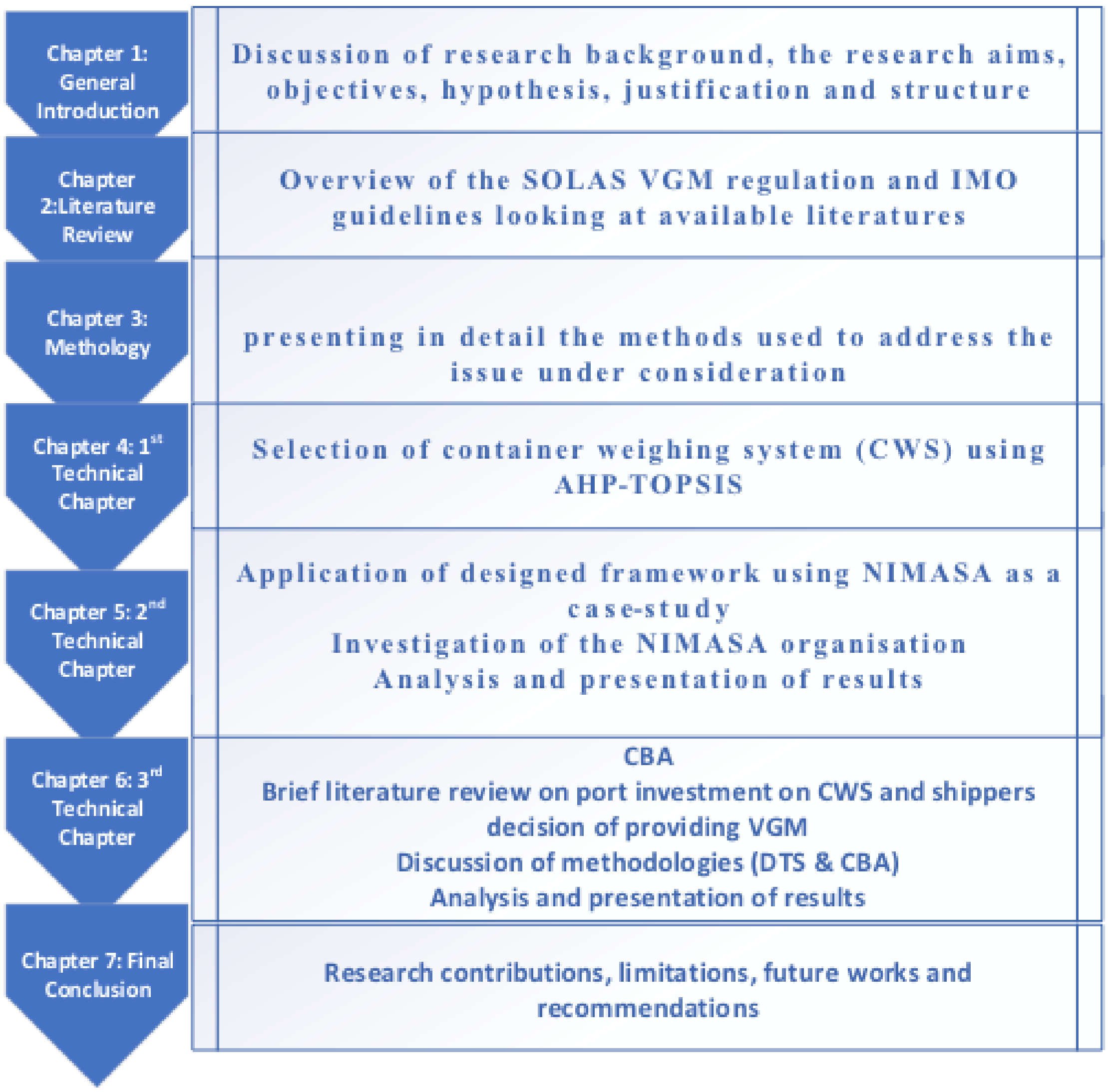

Figure 1.1: Thesis structure flow chart

Chapter 1 – Introduction: This chapter gives a general overview of the research background, its aim/objectives, the research questions/scope and methodologies adopted and the thesis structure. It also briefly describes the requirements for the research giving an outline of how the research will be carried out.

Chapter 2 – Background and Literature Review: This chapter comprehensively reviews different available literature on the current knowledge of the problem of overweight containers, relevant study on ship and port safety. This chapter presents a discussion on the current existing studies in association with the implementation of the VGM regulation by different sectors and its application in the supply chain. It further reveals, the reason for its amendment, assesses the recent knowledge and development of the VGM regulation. Lastly, it also states and explain the contribution to knowledge made by this research.

Chapter 3 – Methodology: This chapter explains and justifies the selection of AHP-TOPSIS, Balance Scorecard (BSC), Fuzzy AHP, Cost benefit Analysis (CBA), as the appropriate methods to assess the effectiveness and performance of the SOLAS VGM regulation.

Chapter 4 – An AHP-TOPSIS framework to aid the selection of container weighing system: This chapter presents the selection of the most suitable container weighing system (CWS) that would enable port operators and VGM providers meet the requirements of the VGM regulation. Based on the suggested model, the framework is developed by the combination of AHP and TOPSIS while following six main steps.

Chapter 5 - Application of the Model for the assessment of SOLAS VGM regulation implementation performance in NIMASA: The BSC-FAHP model discussed in Chapter three is applied in this chapter using the NIMASA as a case study. It was carried out by developing Balanced Scorecards for each department of NIMASA and following some highlighted steps. It demonstrates and validates the suggested methodologies illustrating the steps of deriving the total rate of performance for both the industry participants and NIMASA. The results of the survey are presented and discussed in this chapter. A sensitivity analysis was also conducted on the designed model to test its rationality and ability to detect sensitive changes to input.

Chapter 6 - Economic appraisal on the SOLAS VGM implementation: In this chapter, an appraisal is conducted on the economic issues of the SOLAS VGM regulation. One of these issues is a follow-up on the analysis conducted in chapter 4 on CWS selection.

Chapter 7 – Discussion and conclusion: This chapter gives a summary of the research findings on the surveys conducted on the selection of CWS, economic appraisal on the SOLAS VGM implementation, implementation performance of the SOLAS VGM regulation for the NIMASA departments and industry participants. It also discusses the limitations encountered in the thesis and provides direction and recommendations for future research work.

Chapter 2

Background and Literature review

Summary

This chapter reviews the literature that has shaped the present research beginning with an introduction to the research area. It provides an overview of container shipping, the SOLAS VGM regulation and the reason for the amendment, looking at all that the regulation entails and its requirement. It also addresses how it is implemented and enforced by some specific sectors in the industry. Lastly, it looks at Approaches to Measuring the effectiveness and performance of a regulation.

2.1 Introduction

Ocean transport plays a critical role as being the key enabler of global trade. Merchandise trade keeps expanding, and there is clearly a need for more transport and modernization of the transport configurations (Nurtjahjo, Rianto, 2016). Worldwide Trading with ocean transportation might be the most broadly utilized on the planet particularly container shipping, yet this industry is additionally the most hazardous. Even though, containerization has revolutionized the transportation business, there are still several safety and security considerations. For such a significant sea business, guaranteeing its safety and security and limiting the risks and the potential damage brought about by the incidents in shipping operations is without doubt an important issue (Chang, Xu, and Song, 2014). According to the World Shipping Council (WSC) the average number of containers lost at sea excluding catastrophic events was 612, which is about 16% less than the average of 733 units lost every year for the past three-year period. When disastrous losses are incorporated, the annual average of the containers lost at sea rises to 1,390, with 56% of those lost being attributed to disastrous events. This is a 48% reduction from the average annual total losses of 2,683 estimated for 2014 (World Shipping Council, 2017).

According to the United Nation Trade Statistic Compilation Data (1997 – 2015), container transportation with an incorrect weight is increasing yearly; in 2015, it is estimated that 16,300,000 TEUs of cargo were shipped without an accurate weight (i.e., “misdeclaration”). Misdeclaration occurs when the actual weight of a packed container is different from the weight on the shipping document. When the declared weight by the shipper is more than the real weight then, there is "overweight" which may have serious effect on the stability of the vessel and can raise safety worries at the port. Regulation is needed to accomplish compliance with safety and decrease the risks. Regulation has a significant role in export activities. Therefore, IMO has amended the regulation of the Safety of Life at Sea (SOLAS) Chapter VI, Part A, regulation 2 about VGM.

2.2 Literature review

Before discussing the reason for the regulation amendment, it is important to discuss the studies that have explored the context and impacts of VGM implementation. King (2015) focused on the issue of misdeclared container weights, which have the potential to cause serious accidents on land and sea. It investigates the current international and New Zealand domestic law, and the arrangements to mandate verification of container weight in the Safety of Life at Sea (SOLAS) convention. It concludes that the VGM regulation is insufficient by itself in resolving the problem. It considers the points in the supply chain where obligation could be placed for weighing and proposes a “chain of responsibility” approach with initial weighing by the shipper and check weighing later, particularly at ports, with misdeclared containers being reportable as incidents. Such a process should free New Zealand of the problem (King, 2015).

Tai (2016) analysed the implementation of the VGM rules in Hong Kong. The findings inferred that the drafting of the Hong Kong Guidelines is not as clear and definite as the IMO Guidelines. This infers that shipping companies should audit their sea carriage contracts to see whether new clauses ought to be embedded to tackle problems emerging from the VGM requirement (Tai, 2016).

In 2016, an expert survey investigated the VGM compliance and concluded the existence of under-reporting and wrong weight declarations (BMT SURVEY 2017). Rahmatika et al. (2017) studied the effect of VGM implementation at port of Tg. Priok, using qualitative descriptive method, it was inferred that there are a few contrasts before and after the VGM regulation implementation and the implementation also affects the port charge for the shipping process at Port of Tg. Priok (Rahmatika et al. 2017). Fedi, Lavissiere and Russell (2017) listed the position of innovation to understand how VGM implementation processes used by industry stakeholders were shaping the VGM acceptance rate (Fedi, Lavissiere, and Russell 2017). Jagelčák, Kiktová and Stopková (2018) in their paper focus on methods for acquiring VGM of packed containers or other Intermodal Loading Units in Slovakia considering requirements of section 4 to 6, Regulation 2, Part A, chapter VI SOLAS and article 10f of the EU directive 2015/719/EU. The paper additionally suggests the utilization of specific weighing methods for the selected loading associations as appropriate procedures to obtain VGM of packed containers or other Intermodal Loading Units.

Aras and Chen (2019) study the effects of the VGM implementation by surveying key stakeholders engaged in international containerized trade in Australia, including shippers, container shipping companies and terminal operators. The impacts of VGM execution researched included relationships, organizational practices, obligation, monetary expense, time delay, safety and the accuracy of VGM data. The discoveries uncovered industry's positive insight towards the VGM revisions and affirmed its positive effect on safety for shipping companies and terminal operators. However, there are a few issues in executing the VGM rules. The organizational practices have been impacted, with a significant challenge of clarifying the obligation regarding the VGM implementation. Shippers have been impacted the most in terms of financial costs, which mostly occurred in outsourcing the weighing service; and additional means required for subcontracting the VGM data have been found as the top reason for time delays. The result also uncovered that in Australia, erroneous VGM had been caused by the imported and transshipped containers (Aras and Chen, 2019).

Fedi et al. (2019) examine the technical issues around the verification of container mass in seaports and how Port Community Systems (PCS) can allow viable and full compliance. Their discoveries were threefold firstly; the study demonstrated that VGM implementation involves a critical change in the maritime supply chain, subjecting it to an additional mandatory compliance process in the present complex field of port operations. Secondly, it showed that structuration (check correct spelling) of port networks through a solid digitalization of data exchange, such as Port Community Systems (PCS), simplified the transition and the compliance towards another obliging maritime regulation. Thirdly, this work reveals that hypothetically, PCS not only has positive effect on the adoption of compulsory regulation, but also that communication channels, compatibility and infrastructure are key factors to be overseen during implementation Fedi et al. (2019). Schramm et al. (2018) clarify the implementation process of execution of VGM in Australia, the Netherlands and Czech Republic upheld by a fundamental review of 106 trade press articles in English and German, followed by an online survey with a total of 136 participants. Therewith, they recognized the expected challenges and costs related with the adoption of the VGM requirement for container fares and contrast them and the difficulties and costs organizations face (rewrite). Their results are arranged into three classes. In the first place, they examine whether there are critical differentiations in expected and genuine difficulties and expenses between carriers, freight forwarders and sea transporters. Secondly, they look at whether there are immense contrasts reliant upon the pace of adoption to the VGM requirement as an Institutionally Driven Administrative Innovation (IDAI). Thirdly, they identify differences between organizations in the three nations of the online overview (Schramm et al. 2018).

Rekanar et al. (2018) in their article sought for an agreeable solution, which is in accordance with the current cycles at the port in a reliable way. In this article, they propose a Decision Support System that can line up with the typical databases and use Artificial intelligence (AI) strategies to conform to the regulations. They likewise propose a Mobile Application (APP) to tell the user about the situation with the container at various levels in the port (Rekanar et al. 2018). Hartati and Nurhayati (2018) did a case study on PT. Albasia Batang to find out the obstacles faced in fulfilling the requirements for the VGM regulation implementation. There were two obstacles experienced by PT. Albasia, the first obstacle is the addition of production costs, namely in the form of VGM fees. The second obstacle is the length of the weighing process which results in delays in the arrival of goods to the destination country (Hartati and Nurhayati, 2018).

Pakpahan et al. (2020) did a study to discover how the VGM process affects the palm oil exports in Belawan Port, Indonesia. Thong Lim Phor (2020) investigated the perception, adjustment model, benefits and effects of VGM in the freight forwarder's perspective. The discoveries uncovered that the VGM measures led to the redundant working process. Most of the problems are rooted from the communication and the stakeholder's access of the shared information. The study suggests the possible solution that the use of information technology system can be used to advance the effectiveness in the information exchange among the stakeholders in the maritime transportation supply chain as well as to facilitate the implementation of the VGM measures.

2.3 The Reasons for this amendment and implementation of VGM?

The new requirements provided a formal amendment to the IMO's existing regulations and intend to lessen the quantity of accidents caused globally by containers whose weights have been misdeclared by shippers and their agents (Marle 2015). About 33% of the 130 million containers shipped each year are estimated to have erroneous weights (Manaadiar, 2016). Deck stacks are lashed for stability, and lashings may break with impromptu weight distribution on the stack. The ship will be at risk of becoming unstable or even breaking if the weight distribution is not as the declarations the master was led to believe. Some examples of related container weight hazards are described in Table 2.1.

Table 2. 1: Accidents caused by container weight misdeclaration

Related accidents	**Root cause**
MSC Napoli **January 2007**	The 4419 TEU MSC Napoli's hull buckled. The ship was subsequently beached on the south coast of England. About 660 dry (unsubmerged) containers were weighed; 20% (137) differed from the declared weight by over 3 tonnes (King, 2014).
Container ship Deneb in Algeciras, Spain **June 2011**	An investigation after the occurrence discovered that out of the 168 containers on the load list, 16 or around 1 in 10 containers had its real weight higher than the declared weights. The total, actual weight of these 16 containers was more than 278 tons over their total, declared weight of about 93 tonnes or 4 multiple times higher than their announced weight (Manaadiar, 2016).
Near miss at an Australian wharf at the port of Darwin **- February 21st, 2011,**	The container that fell 12 metres and barely missed two labourers was seriously overloaded. The container was recorded as four tonnes, yet the Maritime Union says it weighed 28 tonnes and surpassed the crane's load limit (Manaadiar, 2016).

There could be different causes of accidents, and one of the most common reasons is human error. Most shippers, state the wrong weight on the bill of lading, maybe due to sloppiness, carelessness or purposeful intent to transport more cargo than permitted for the same rate. The impact of this on the safety of seafarers, ships and cargo can be disastrous, as the examples indicated. Misdeclaration involves weight and cargo descriptions, although the IMO VGM rule focuses only on weight. When the wrong weight of cargo is stated, since the cargo itself cannot be seen and the ship master's knowledge of the cargo is limited to what is stated on shipping documents, there is a significant danger inherent in shipping the container. This rule aims to break down one aspect of misdeclarations, that applying to weight, in the hope that the safety of container shipping will be improved and overall risk is reduced (JOC 2015).

2.4 The sea transport process

Sea transportation can be described as the way toward arranging, executing and dealing with the transfer of cargoes and information incorporated in the sea carriage, it is foundation of "*world trade and globalization*" (Tapaninen, 2020). However, this industry is also complex besides the shipping, transport and port services involved, there are countless services co-operating together to meet the demands of multimodal transportation procedures (Singh and Sengupta, 2020). Figure 2.1 introduces the sea coordination process. The container shifting happens in seven stages from the shipper to the customer, consecutively linked in Figure 2.1 by thick arrows. The connections between the maritime personnel are shown by the thin arrows. There is an immediate connection between the terminal and its customer shipping lines. The end customer in maritime logistics are shippers looking for shipping line service. Freight forwarders acts as intercessors between the shipper and shipping line, and provide extra administration, for example, booking and data reports on cargo, and assistance with documentation. If a shipper contracts a freight forwarder, an immediate relationship is formed between them. If a shipper does not contract a freight forwarder, there will be a direct connection between it and a shipping line. Logistics companies can give different services at various phases of the procedure. Their commitment is flexible and is shown by the dotted arrows in Figure 2.1.

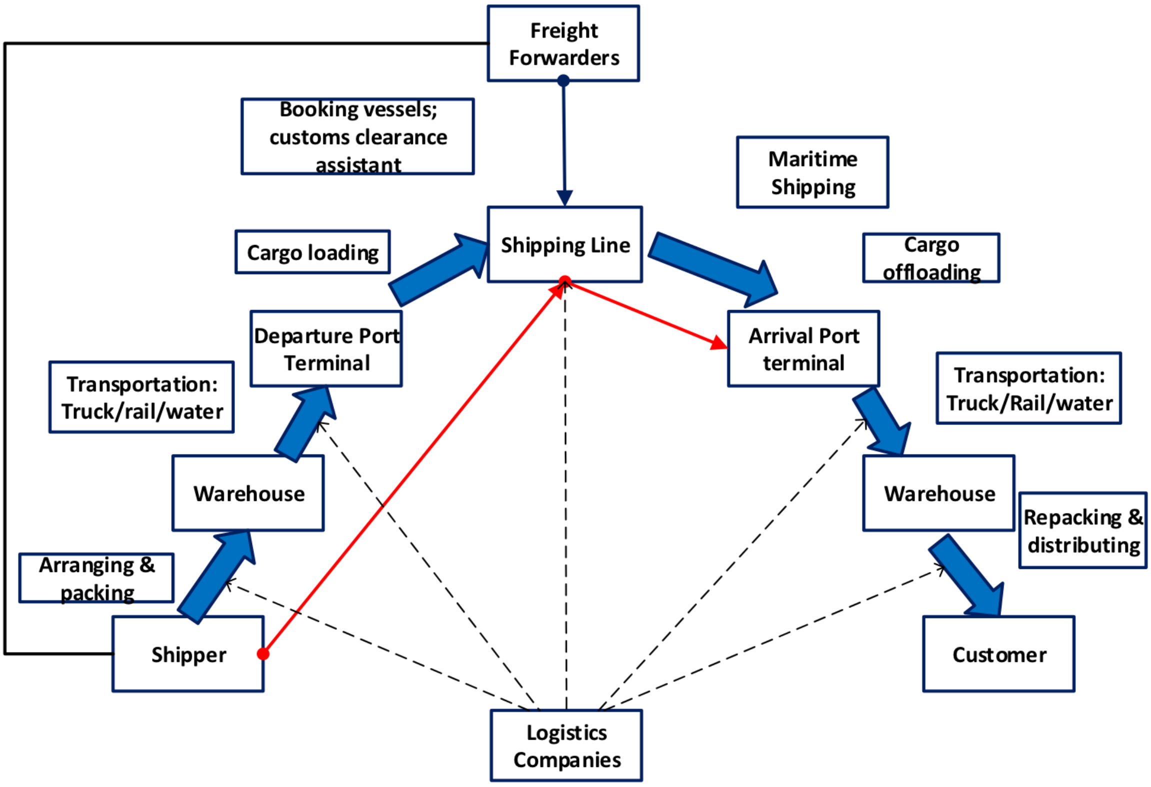

Figure 2-1: Flow diagram of sea transportation participants

2.4.1 The MSC.1/Circ. 1475 regulation guideline

The Maritime Safety Committee (MSC), which is the top specialised body of the IMO at its 96th session in May 2016 agreed on a set of guidelines regarding the VGM of a container carrying cargo (MSC.1/Circ. 1475) (Almonte, 2016; Cwl Law Firm, 2018; Göteborg, 2016; IMO, 2016; Lamb, 2016; MCL, 2016), which requires the declaration of the VGM of a packed container before loading on-board vessels.

The motivation behind these Guidelines is to build up a typical methodology for the execution and implementation of the SOLAS requirements with respect to the verification of the gross mass of packed containers. The Guidelines give suggestions on the most proficient method to decipher and apply the provisions of the SOLAS requirements. They also recognize issues that may emerge from the use of these requirements and give direction to how such issues ought to be settled. Adherence to these Guidelines will work consistently with the SOLAS requirements by shippers of containerized shipments and will help different organisations in global containerized supply chains including shipping organizations, port terminal facilities and their representatives. Such organisations would be able to understand their individual duties in achieving the improvement of the safe handling, stowage and transport of containers.

Definitions

The following definitions were highlighted in the IMO VGM regulation guidelines (IMO, 2016) to provide more clarity to maritime stakeholders for effective administration:

- *"Container Gross mass is* the combined mass of a container's tare mass and the mass of the cargo, including packages and cargo items, pallets, packing material etc.
- *Tare mass* means the mass of an empty container that does not contain any cargo items or other weight components, as stated above.
- *Package* implies cargo that are integrated, stuffed, wrapped, boxed or distributed for transportation.
- *Packed container* implies a container stacked with *"fluids, gases, solids, bags, and cargoes, including pallets, dunnage, and other packing and securing material*".
- *Packing material* means any material used to prevent damage, including, crates, packing blocks, cases, boxes, barrels etc. Securing material means all dunnage, lashing and other equipment used to block, brace, and secure packed cargo items in a container.
- *Ship* means any vessel to which the SOLAS regulation applies. Omitted from this definition are roll on/roll off (ro-ro) ships engaging in short international voyages where the containers are carried on a chassis or trailer and are stacked and emptied by being driven on and off such a ship.
- *Shipping document* means a document used by the shipper to communicate the verified gross mass (VGM) of the packed container. This document can be part of the shipping instructions to the shipping company or a separate communication (e.g., a declaration including a weight certificate produced by a weight station). "

2.4.2. Who is responsible?

According to the regulation guideline IMO (2014), the shipper oversees the verification of the gross mass of a container conveying cargo. The shipper is in charge of guaranteeing that the confirmed gross mass is conveyed in the transportation document adequately ahead of time to be utilized by the carrier or his agent and the terminal delegate in the planning of the ship stowage plan. Without the shipper giving the confirmed gross mass of the packed container, the container ought not to be stacked on to the ship unless the shipper or his agent and the terminal delegate have acquired the verified gross mass through different means (IMO 2014).

2.4.3 Agreed methods of weighing

The VGM regulations prescribe two methods by which a shipper may obtain the verified gross mass of a packed container, as follows (IMO, 2014;2016):

*"**<u>Method No.1:</u>** Upon the conclusion of packing and sealing a container, the shipper may weigh, or have arranged that a third-party weighs, the packed container.*

<u>Method No.2:</u> *The shipper (or, by arrangement of the shipper, a third party), may weigh all packages and cargo items, including the mass of pallets, dunnage and other packing and securing material to be packed in the container, and add the tare mass of the container to the sum of the single masses using a certified method. Any third party that has performed some or all of the packing of the container should, inform the shipper of the mass of the cargo items, packing and securing material, the party has packed into the container in order to facilitate the shipper's verification of the gross mass of the packed container under Method No.2. As required by SOLAS VI/2 and paragraph 5, the shipper should ensure that the verified gross mass of the container is provided sufficiently in advance of vessel loading. How such information is to be communicated between the shipper and any third party should be agreed between the commercial parties involved.*

The method used for weighing the container's contents under Method No.2 is subject to certification and approval as determined by the competent authority of the State in which the packing and sealing of the container was completed

How the certification is to be done will be up to the State concerned and could pertain to either the procedure for the weighing or to the party performing the weighing or both." (IMO Guidelines regarding the VGM - IMO doc. MSC.1/Circ.1475)

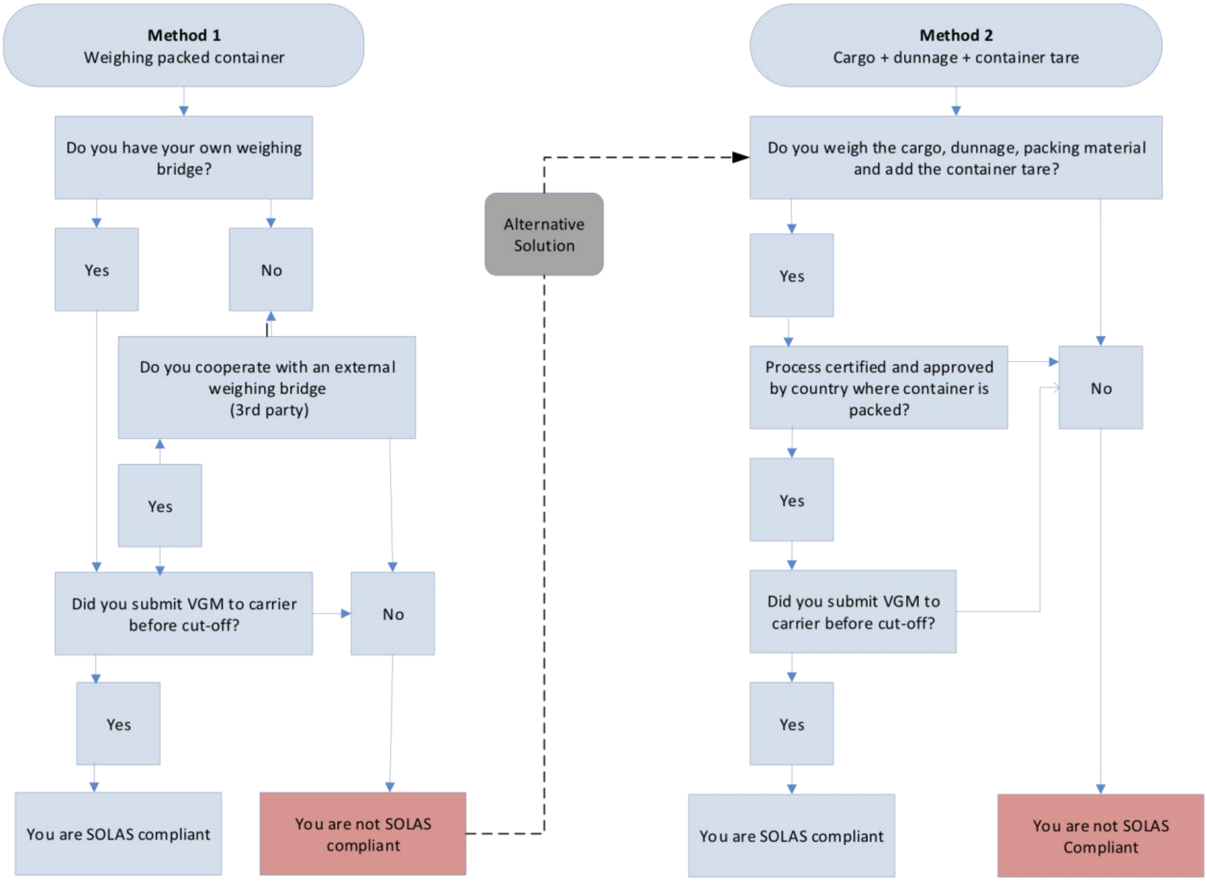

Figure 2- 2: Flow diagram of VGM submission process – Source (Mukherjee, 2016)

2.4.4 Process of communicating VGM

The regulation requires the VGM to be shared only with the carrier and other attached documents and certificates remain with the shipper for auditing and investigation purposes. Due to international auditing guidelines, the shipper should endeavor to keep documents for up to seven years. When communicating VGM, most carriers prefer to receive the VGM by Electronic Data Interchange (EDI) (CNA HARDY, 2017). The Verified gross mass Message (VERMAS) has been created as an accepted global standard. It is an Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT) message that contains not just the VGM but includes the signature of the party providing the VGM, date, name of the shipper and other references such as ocean carrier number and container ID (Mukherjee, 2016). Most companies have created websites through which the shipper can communicate the VGM. Sharing VGM through email is also possible. In some countries, further requirements have been made for the VGM to be shared with the carrier. For example, the UK brought in a requirement that the party handling the weighing be certified and the certification number will be required in the data field.

2.5 Implementation and enforcement of the SOLAS VGM regulation by different companies

Weighing at ports gives a basic checkpoint in the vehicle chain. There are a couple of different focuses where checks are made once the container is loaded and fixed. The weight check at the port should build weight for containers to be weighed and loaded legitimately, on the off chance that they are declined by terminal administrators following the usage of the SOLAS verification. Notwithstanding, all shippers must assume liability for what goes into a container, and that implies how it is stacked, the amount it weighs and legitimate affirmation of load. The innovation is as of now accessible to measure containers rapidly at terminals with a few frameworks having the capacity to send cautions if the heap appropriation is not focused for instance, twist-lock stack sensors, DAW, C-Legs etc. Below we briefly present the way some ports, shippers and carriers approach the implementation of the regulation. These few companies were randomly selected.

Liverpool Peel Port: Port of Liverpool has attempted a long discussion process with the Maritime Coastguard Agency (MCA) and its customers to build up a model that will help maintain a strategic distance from potential fare interruption for exporters. The Port of Liverpool will be able to measure all containers as a feature of a procedure-measuring plan, which will not affect profitability. (Peel Port Group, 2016) The container terminals will introduce Dynamic Axle Weighbridges (DAW) at the terminal indoors to offer an in-process measuring administration (Peel Port Group, 2016).

A DAW is a framework, which both measures the discrete mass as it disregards the measuring stage and amasses an aggregate weight. The hub weighbridge is ordinarily 3m wide x 0.7m long and it is reasonable for weighing at speeds in the range 0 km/h to 15 km/h. A controlled speed amid weighing of 5 km/h is determined in most national enactment and will be implemented at the Port of Liverpool and Dublin. The achievable exactness class on the kind of DAW picked by Peel Ports Group is inside 0.5%. The most widely recognized mistake with the DAW framework is a vehicle rolling over the framework too quickly. The authorized speed for the framework is 5km/h (Peel Ports Group, 2016). This DAW in combination with the Mass in Running Order (MIRO) of the vehicle will be utilized to give the VGM (Peel Port Group, 2016). All HGV vehicles conveying compartments into the terminal will be required to enlist a MIRO before touching base at the terminal. (MIRO is Mass in Running Order - a weight-recording necessity for business products vehicles and trailers in the UK) (Peel Ports Group, 2016). At the in-gate, the vehicle will move gradually on the weighbridge where the framework will decide the pivot weights and, in this way, the aggregate gross weight of the vehicle. The proclaimed MIRO will then be connected to decide the VGM of the loaded fare holder (Peel Ports Group, 2016). Comparable methodologies will be adjusted at Peel Ports' other UK compartment terminals in Dublin, Glasgow, and Manchester (Peel Ports Group, 2016).

DP World London and Southampton Gateway: Both London and Grangemouth container terminals have invested heavily in weighing technology that ensures the integrity of the existing operational procedures for both landside and shipside operations, providing flexible options for customers to submit or acquire a VGM ahead of loading cut off times. They will be equipped to provide weights that will be fully compliant with the new International Maritime Organisation legislation (Forth Ports, 2016).

Hapag-Lloyd: The Company has executed different framework upgrades and administrations to guarantee consistent collaboration through different e-channels and arrangements accessible universally. Submission should be possible through the new VGM arranged VERMAS (EDI) message, EDI associations, or by means of the Hapag-Lloyd site (Online Business) or by means of entrance arrangements, (for example, INTTRA, GT Nexus, Cargo Smart) (Hapag-Lloyd, 2016).

COSCO Shipping: All Marine Terminal Operators (MTO) that COSCO ships call, have weight scales at the passage to their gates. The majority of their MTO partners have consented to enable this strategy to be utilized as the VGM for compartments travelling through their gates. Shippers that do not give a VGM through EDI or contribution to COSCO site will, according to COSCO duty and furthermore OCEMA's tax, concur that by utilizing the terminal scale weight they have guaranteed this weighting technique as the VGM and are not required to supply a composed mark. At the point, when the VGM weight is given by the MTO for the benefit of the shipper, the shipper might stay obligated to the Carrier for any harms, costs, misfortune, fines, or punishments to bearer or MTO emerging out of administrative expert's refusal to acknowledge this VGM ascertained in this way. COSCO Shipping Lines (UK) Limited imposes a charge for VGM presentations from USD 10.00 for each container to USD 20.00 for every container due to an increase in organizational cost. The re-examined charge commenced on 15 May 2017 and is compulsory for all container stacking/weighing (COSCO Shipping, 2017).

Kuehne + Nagel: The world's biggest NVOCC, Kuehne + Nagel, communicated worries that unless worldwide VGM correspondence measures and practices are received rapidly, the VGM prerequisites may cause confusion and upheaval while being actualized. Otto Schacht, Kuehne + Nagel's worldwide chief of Sea freight operations, completely bolsters INTTRA's electronic VGM (eVGM) endeavours by making the organization's Assets accessible to the advancement of eVGM. For this framework to work productively and dependably, shippers, cargo middle people, and sea transporters need to take a shot at arrangements which are down to earth and in full consistency with the VGM necessities," Schacht expressed (MarineInsight, 2O17). Kuehne + Nagel groups all around intently collaborated with partners and online business centres to have norms and procedures set up. On the off chance that customers have any inquiries in regard to the SOLAS container weight confirmation necessity, they can contact their neighborhood Kuehne+Nagel delegate (Kuehne Nagel, 2016).

2.5.1. The application process in the UK

Note that when each IMO member state accepts an IMO regulation, they agree to make it part of their own national law and to enforce it as they do with any other national law. The way that IMO instruments become national law is therefore not uniform and there are variations between countries. As an example, we present some information on the enforcement of the regulations in the UK.

UK (Maritime and Coastguard Agency, MCA): The enforcement agency in the UK is the MCA, which is an executive agency of the Department for Transport (DFT). MCA authorizes norms for delivering wellbeing, security, contamination, anticipation and seafarer wellbeing as well as, security and welfare for seafarers through study and examination administration. They also work with key partners to advance sea guidelines, support monetary development, and limit the sea segment's ecological effect. They do this through their help to the industry by means of the UK Ship Register.

Execution designs have been set up. New gatherings joining the advancement procedure; industry has built up an FAQ record. There is outside and inside examining for method 2 users. 80% of shippers are utilizing method 1 while 20% are agreeing to method 2. There is a remittance of resilience on weights of - 5% or +5% in the UK (MCA,2016). Fines and different punishments will be enforced under the UK Merchant Shipping (Carriage of Cargoes) Regulations 1999.

2.5.2 Decision making for shippers

In the process of weighing the containers, the shipper in charge of weighing the containers is left with the two options either to;

- weigh the container (inhouse) or
- contact a third party to conduct the weighing

With both options, there is a probability that the verified weight would either be accurate or inaccurate. To guide the shipper towards making the right decisions, a decision tree can be introduced. This tool can also be applied when shipping companies are faced with a complex decision of buying or installing container weighing equipment. The decision tree would help solve these complex and sequential decisions. Decision trees are quantitative figures consisting of branches and nodes that represent different possible decision paths and chance events. This would make it easier to identify and calculate the value of all the best possible alternatives, so one can choose the best option with no doubt. These considerations are presented in more detail in Chapter 6.

Table 2.2: VGM Charges of different VGM providers in the supply chain
Data Source: Prices were obtained from the companies' websites.

Freight Forwarders	**Kuehne+Nagel**	**DHL**	**UPS**	**DB Schenker**
Portal fee	$12.75 Via email: £25	21.50	£39	0
Customer (Provide VGM)	0	£20.50	0	FCL=£15,LC =£5
late submission	0		0	£25
Misdeclaration	0	£15	0	FCL=£28.50, LCL=£5.50
Fee(FF charge)	0	£35.00	0	0
prior to cut off time	00	£17.50	0	0
Ports	**Port of Felixstowe**	**Forths ports (Grangemouth)**	**DP World (Southampton**	**Port of Tyne**
Source:	**Port of Felixstowe (2016)**	**Forth ports (2016)**	**Forth ports (2016)**	**Port of Tyne (2016)**
Admin fee	£1	£1	£3	
Fee (Provided VGM)	£20	£16.50 + £1	£17.50	£17.50
Submission				
Misdeclaration	£20+£20+£1	£11+£16.50+£1 Per Container	£10	£10.00
late submission	£20+£20			
Shipping Company	**Maersk**	**CMA-CGM**	**OOCL**	**COSCO**
Weighing Cost	0	0	0	0
Admin fee	0	25	0	$15
Fee (Provided VGM)	0	16.50/17.50/19.50/2 25	0	$20
late submission	0	0	Eur 80(manual)	0
Misdeclaration	0	0	0	0
Submission	0	0	Eur 40 (manual)	0
Independent	**CaroTrans**	**ECU**	**Shipco Transport**	**Vanguard**

Companies				Logistics Services
Weighing Cost				
Admin fee	$15	$15 FCL	LCL=$15 FCL= $25, $8	0
Fee (Provided VGM)	0	0	0	0
Late submission	0	0	$25	$25
Misdeclaration	0	0	0	0
Fee(Company charge)	$25	$25 + 7$(additional shipment)	$25 LCL and FCL	0

2.6 Conclusions

There is insufficient academic literature on the SOLAS VGM regulation, most of the available sources of information were derived from maritime news articles, google scholar, the Journal of Commerce, maritime blogs, and shipping websites. This chapter presents a breakdown of the regulation and its related factors. It discusses different literatures and provides an overview of container shipping, the reason for the SOLAS VGM regulation was also discussed.

Chapter 3

Methodology

Summary

This Chapter aims at presenting in detail, the methods used to address the issue under consideration. We present the methods also arguing on their suitability. The methods have been appropriately selected to provide answers to the main research questions; see research objectives as presented in Section 1.3.

3.1 Introduction

Our first area of research is related to the selection of a suitable container weighing system that will meet the needs of the port and VGM providers without undermining the requirements of the SOLAS VGM Regulation. This can be achieved by using a Multi-Criteria Decision Analysis method. We have chosen to combine AHP and TOPSIS in analysing each of the available CWS with a set of criteria from experts' evaluation and coming to a stand of which of the alternatives are cost-effective and beneficial to VGM providers; see Chapter 4.

In Chapter 5, we present the methodology behind a model to measure the implementation performance of the VGM regulation. We propose the use of the Balanced Scorecard (BSC) method and the Fuzzy AHP (FAHP) technique to help evaluate each of the key industry stakeholders' performance using a number of different perspectives and measures (performance indicators). This can provide a tool to measure the current Total Rate (TR) of implementation performance for each stakeholder. This model was used to assess the performance of the Nigerian Maritime Administration (NIMASA).

Finally, in Chapter 6 we present a set of tools related to the economic aspect. We present the theory around Decision Trees (DT), a type of advanced method used to make decisions. In this research, this could be utilised in selecting from alternatives such as, a shipper choosing whether to provide the VGM declaration themselves (using their own weighing equipment) or leave it to a third party (such as the carrier or the port operator. We also present the theory related to preforming an economic assessment, namely Cost-Benefit Analysis (CBA), which is simply an accounting model for pointing out the pros and cons of a project or policy in monetary terms. As an application, in Chapter 6, we present the use of CBA by a port operator investigating the potential to invest money to acquire a weighing equipment, where we assess both the costs and the expected benefit e.g., profit they could make from VGM fees.

3.2. A combined AHP-TOPSIS method to select the most suitable CWS

Our first area of research is related to the selection of a suitable container weighing system that will meet the needs of the port and VGM providers without undermining the requirements of the SOLAS VGM Regulation. This can be achieved by using a multi-criteria decision analysis method. We have chosen to combine AHP and TOPSIS in analysing each of the available CWS with a set of criteria from experts' evaluation and coming to a stand of which alternatives are cost-effective and beneficial to VGM providers. The appropriate framework or procedures that were set out in establishing the methodology for selecting the suitable container weighing system follow the seven steps mentioned below.

I. Define the Problem statement
II. Identify potential alternatives
III. Identify the criteria for evaluating a CWS
IV. Develop a hierarchical structure
V. Determine the weight of criteria (using AHP)
VI. Utilise the TOPSIS methodology to derive the ranking of the alternatives
VII. Conduct a sensitivity analysis

Chapter 4 presents the selection of the most suitable Container Weighing System (CWS) to comply with the SOLAS VGM regulation using the suggested methodology that combines AHP and TOPSIS. Here we focus on the port or terminal operators and their preferences of alternatives to comply with the regulation. The data used in this case study come from seven experts.

The following sub-sections present the development of the suggested model, showing the steps in creating the model such as the definition of the problem, including the development of hierarchical structure, identification of potential alternatives and their criteria, the estimation of weights using AHP and the rank of alternatives using TOPSIS.

AHP (Analytic Hierarchy Process)

AHP is a well-established decision-making methodology centred on additive synthesis; Saaty introduced it in 1980. AHP simplifies complex decision-making problems in the way that it utilizes a decision tree structure of objective or goal, criteria, sub-criteria, and alternatives. Generally, the judgements of experts in AHP are utilized to quantify the total weights of certain factors (Yang et al., 2011). Ghosh (2011) suggested that the AHP could be utilized to compute the weight of the elements or the measures, just as the total weight in each attribute. Due to the easy to adopt characteristics of the AHP, it has been received as a dynamic tool in numerous applications (Huoa et al., 2011; Zheng et al., 2012). For instance, in around 190 research papers distributed around 2004 and 2016, AHP has been utilized to an enormous extent of applications together with different methodologies (Kubler et al., 2016). Many studies have clearly shown that the AHP method is applicable in the shipping industry. (Jumandono and Singgih, 2019; Anggani and Baihaqui,2017; Chang et al. 2019).

The following six essential steps presented below are required to successfully carry out the analytic hierarchy process procedures.

1. Give a general definition of the unstructured complex problem, clearly define the objectives and the outcomes.
2. Break down the multifaceted problem into a hierarchical structure of levels with decision elements (criteria, sub-criteria and alternatives).
3. Conduct a pairwise comparison among decision attributes and use the comparisons to form decision matrices. Fundamentally, the principle of the AHP works with completing an $n \times n$ matrix $A = (a_{ij})$ at each level of the decision hierarchy.
4. Using the eigenvalue method, evaluate the relative weights of all the decision elements. This matrix A is of the form;

$(a_{ij}) = 1/(a_{ji}), (a_{ij}) > 0$,

where (a_{ij}) is an estimation to the relative weights w_i/w_j of the n criteria viable (Harker, 1987), Given the n (n -1)/2 estimation to these weights which the decision maker provides when finishing the matrix, A, the weights w = $(wi)$are found by resolving the accompanying eigenvector problem (Saaty, 1977):

$$AW = \lambda_{max} W (3.1)$$

whereλ_{max} = the main eigenvalue of the matrix A.

If matrix A is a positive reciprocal one, then $\lambda_{max} \geq n$

Generally, in an unsystematic reciprocal matrix, A, there exist some i, j and k for $aijajk - aik$

Then the average of normalized columns of the reciprocal matrix provides a good estimate of the eigenvector (Vargas, 1982):

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} akj} (3.2)$$

5. Determine the consistency ratio of matrices to check whether the judgment of decision makers is consistent.

This is because it is expected that some extent of inconsistency could exist in a large number of pairwise-comparisons when they are evaluated. The AHP technique proffers a solution to measure the consistency of experts' judgments in a set of pairwise comparisons by introducing consistency index (CI) and consistency ratio (CR). The CI and CR can be calculated using Equations. (3.3) and (3.4) below (Ung et al., 2006

$$CI = \frac{\lambda_{max} - n}{n - 1} (3.3)$$

The λ_{max} is the highest eigenvalue of an n ×n comparison matrix and is calculated by Eq. (3.1) (Vargas, 1982).

$$\sum_{j=1}^{n} a_{ij} w_j = \lambda_{max} w_i \ (3.4)$$

where

$$CR = \frac{CI}{RI} (3.5)$$

In addition, RI is the random index for the matrix capacity which varies on the number of items being compared, and is shown in Table 3.1 below (Saaty, 1994). Where n is the number of items being compared in the matrix and the average consistency index of randomly generated pairwise comparison matrix of similar size.

Table 3. 1: Random index values

N	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.19	1.51	1.48	1.56	1.57	1.59

As suggested by Saaty (1994), if CR is estimated less than or equal to 0.1 then consistency is indicated, and the pair-wise comparisons are assumed acceptable. In addition, the upper threshold CR values are 0.05 for a 3 × 3 matrix, 0.08 for a 4 × 4 matrix, and 0.10 for larger matrices. If the consistency test is not passed, the decision maker must amend the original values in the pairwise comparison matrix.

6. Determine overall priority for all alternatives by aggregating the relative weights of decision elements.

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)

The ranking of the alternative is assessed with the help of TOPSIS. TOPSIS is a quantitative MCDM method that applies complete and full information set on factors. The method is very helpful for solving critical and practical problems and also it solves the alternatives ranking and optimal solution (Bathrinath et al., 2021).

AHP-TOPSIS has been selected in this research due to the following strengths:

a) The weights are derived using AHP, while TOPSIS can rank the elective areas dependent on their general performance, since it might distinguish the best solution that is nearest to the positive ideal solution and distant from negative ideal solution (Choudhary and Shankar, 2012). Thus, an ideal solution is derived from both low cost and regulatory concerns about the selection of a CWS.
b) The numerical and computational properties of the models are straightforward. The main advantage here is that the calculations can be easily performed using a spreadsheet software and can be easily understood (due to their simplicity) by the relevant decision makers.
c) The data necessities of the suggested framework are defined into a hierarchy to simplify data input and allow a ship operator to focus on a small part of the bigger problem.
d) Inconsistencies of the participants can be calculated with CR values.

The procedure of **AHP-TOPSIS** can be summarised in the following series of steps (Oelcer and Majumder, 2006, Shyur and Shih 2006, Iç and Yurdakul, 2010, Yang et al., 2011) as follows:

Step 1: Creating a mathematical model to the problem that represents all the alternatives and criteria associated with the available weighing systems under study. This can be done by establishing a decision-making matrix format D as simply expressed below:

$$D = \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1n} \\ Y_{21} & Y_{22} & \dots & Y_{2n} \\ \cdots & \vdots & \vdots & \vdots \\ Y_{m1} & Y_{m2} & \vdots & Y_{m1} \end{bmatrix} \text{Where } W = [w_1, \dots, w_i, \dots, w_n]$$

where W represents the criteria weights and W_j, j = *1, 2*...n; the number of criteria and Y_i indicates represents the aggregated rating of the alternatives, in this case, these are the average number of CWS $(n), i = 1,2 \dots$ the number of criteria.

Step 2: Apply AHP to obtain the importance of weights representing each criterion by pairwise comparisons.

Step 3: Calculate the normalized decision matrix. The elements of the normalized decision matrix X_{ij} are calculated using the following formula:

$$X_{ij} = \frac{Y_{ij}}{\sqrt{\sum_{i=1}^{n} Y_{ij}^2}} \quad (3.6)$$

Step 4: Calculate the weighted normalized decision matrix by multiplying each row of the normalized decision matrix(X_{ij}) with its related attribute weightW_j. The weighted normalized value P_{ij} is derived as below:

$$P_{ij} = x_{ij}w_j (3.7)$$

where $j = 1,2, \cdots, n; i = 1,2, \cdots, m.$

Step 5: The ideal positive solution (A_i^+) is calculated for all the best performance scores and the negative-ideal solution (A_i^-) is calculated for all the worst performance scores at the measures in the weighted normalized decision matrix where$i = 1,2..N$.

The numerical expression can be given as

$$A^+ = \{p_1^+, \cdots p_2^+, \cdots p_i^+, \cdots p_n^+\} (3.8)$$

where $p_j^i = \left\{\left(\max_{iv}\left\{p_{ij}\right\} \middle| i\epsilon J\right) i = 1, \cdots m\right\}$ (3.9)

and $A^- = \{p_1^-, \cdots p_2^-, \cdots p_i^-, \cdots p_n^-\} (3.10)$

where $p_j^- = \left\{\min_i\left\{p_{ij}\right\} | i\epsilon J) i = 1, \cdots m\right\}$ (3.11)

Step 6: The n-dimensional Euclidean distance metric can be used to calculate the distance of an alternative j to the ideal solutions. Separation of each alternative from the positive ideal solution (S_i^+) is then given by the following

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^+\right)^2} (3.12)$$

where $j = 1,2, \cdots, n and i = 1, \cdots m$

Likewise, separation from the negative ideal solution $(S_i^-)$is then given by

$$S_i^- = \sqrt{\sum_{j=i}^{n} \left(v_{ij} - v_i^-\right)^2} (3.13)$$

Step 7: Calculation of the ranking score (T_i^+) as

$$T_i^+ = \frac{S_j^-}{S_j^+ + S_j^-} (3.14)$$

when (T_i^+) is close to 1, the alternative is regarded as ideal; and when (T_i^+) is close to 0, the alternative is regarded as non-ideal.

The methodology used in this paper is in line with similar applications. The interested reader is referred to Behzadian et al. (2016), who present the results of a state-of-the-art literature survey of more than 250 papers to classify the research on TOPSIS applications and methodologies. Figure 3.1 illustrates the steps in carrying out the AHP-TOPSIS analysis.

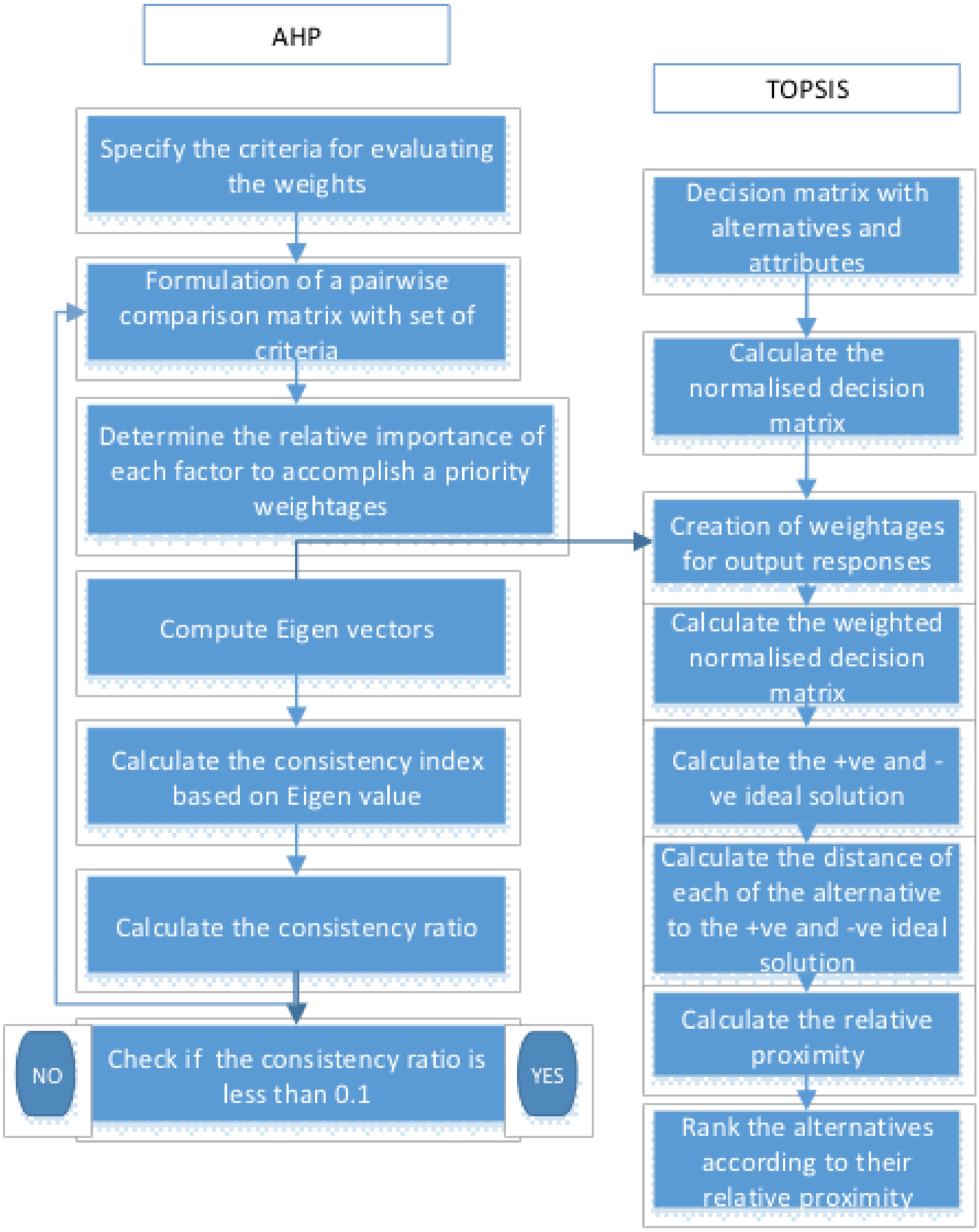

Figure 3-1: Step by step procedure of performing AHP-TOPSIS,
Source: Babu and Venkataramaiah (2015)

3.3 The Balanced Scorecard (BSC)

The BSC is a performance measurement tool (Kaplan and Norton, 2001a; Niven, 2002) which has been used in strategic management (Kaplan and Norton, 1996a; b) and as a communication tool (Kaplan and Norton, 1992; Niven, 2002). Kaplan and Norton have developed a performance measurement framework the so-called 'Balanced Scorecard' more than 20 years ago. As the name suggests, the idea of the framework is to keep score of a number of measures that maintain a balance between *"short-term and long-term objectives, between financial and non-financial measures, between benefits and costs, between lagging and leading indicators, between internal and external business performance perspectives"* (Kaplan & Norton, 1996b).

Figure 3- 2: BSC diagram – Source: Asiaei and Bontis (2019)

The objectives of the scorecards and measures (i.e., performance indicators) are decided based on the organizational visions and strategies, and within the context of this work aim to measure the regulation performance of the organization (i.e., stakeholders); see Figure 3.2 above. We study four perspectives, as originally defined in the seminal works of Kaplan and Norton: the financial perspective, customer satisfaction, internal business process and, learning and growth. Kaplan and Norton (1996b) emphasized the three principles that must be followed while developing BSC. These are keeping linkage to monetary measures, maintaining cause-and-effect relationships and encompassing sufficient performance drivers. In The authors highlighted that the BSCs must be carefully studied and customized for the elements of an organization or industry. In this work we have modified them to fit to our objective which is a method to evaluate the implantation of the VGM regulations in various stakeholders.

Various studies that have employed the BSC technique suggested that each sector of an organization should have its own cascade BSC (Kaplan and Norton, 2005; Mearns and Havold, 2003). The weakness of a stakeholder to achieve the desired goal can be measured and improved when applying the BSC as a strategic monitoring system. Therefore, in measuring the implementation performance of the SOLAS VGM regulation each selected stakeholder involved would have its own BSCs.

The BSC has been used by different sectors as a strategic management system since its initiation. It has also been adopted in a couple of maritime studies about safety and maritime regulations. The supply chain in the shipping industry comprises many participants with divergent interests. There are, however, some consistent identical factors such as safety, profit, competitiveness and human resources that bind them together. The BSC is a suitable and acceptable worldwide method for performance measurement that covers these factors which is ideal for assessing the VGM regulation.

3.3.1 Limitations

Various studies (Fletcher & Smith, 2004; Rickards, 2007) have criticized the BSC, presenting a number of limitations such as that BSC applies many variables that create complex optimization problems. Moreover, Banker, Potter, & Srinivasan, (2000) argue that a BSC does not provide a common scale of measurement, and it lacks a standardized baseline or benchmark to compare performance. We also agree with Rickards, (2007) this approach is not based in a concrete mathematical model or a weighting scheme. In addition, Banker et al., (2004); Neves & Lourenco, (2008) argue that the BSC does not have a comprehensive index to review the interaction between measures of performance.

Several studies as Chen & Chen, (2007), Rickards, (2007) and Karahalios (2009) have proposed ways to address these limitations of BSC. To that extent, and we have decided to follow the approach of Karahalios et al. (2011) which combine BSC with a mathematical solid MCDA technique. Using the same key perspectives, we also aim at addressing the limitation of the lack of a standardised approach.

3.4 Fuzzy AHP

To evaluate the performance implementation of the SOLAS VGM regulation and due to the lack of concrete performance indicators (metrics) we have to rely on expert judgement. This involves verifying the validity of the scorecards produced by the BSC method as well as evaluating the current performance rate (i.e., as a proxy of a performance indicator) of the regulation using the BSC measures using linguistic terms. It has been recognised in the literature that the in practical cases, experts might not be able to assign exact numerical values to their preferences as required to perform the pairwise comparisons due to "limited information or capability" (Liu et al., 2020).

A way to overcome this is to replace exact numbers with fuzzy numbers representing the linguistic expressions in fuzzy AHP.

Therefore, to overcome the know limitations related to the degree of uncertainty involved (see Tsaur, Chang, & Yen, 2002) a fuzzy approach has been utilized.

The procedure of building a fuzzy AHP model follows establishing the comparison matrix, aggregating multiple judgements, measuring the consistency and defuzzifying the fuzzy weights. The main difference, in comparison to the classical AHP, is that exact numbers are replaced with fuzzy numbers representing the linguistic expressions in fuzzy AHP. This tolerates the vague judgements by assigning membership degrees to exact numbers to describe to what extent these numbers belong to an expression. However, introducing fuzzy sets to AHP makes the calculation process less straightforward. The techniques for AHP such as eigenvector method and geometric mean cannot directly be used to derive the weights/priorities from a fuzzy comparison matrix. Many techniques for building a fuzzy AHP model have been proposed. They vary in terms of essential features, strengths and weakness (Liu et al., 2020).

Linguistic terms describe the relative importance of a criterion or an alternative over another (e.g., 'equal importance', 'moderate importance' and 'absolutely preferred'). In fuzzy AHP, such a term is represented by a fuzzy set which consists of two components, a set of elements x and an associated membership function (Klir & Yuan, 1995). The membership function assigns to each element a value between 0 and 1 as its membership degree to the set. The mappings between the fuzzy set and the linguistic term must conform to a scale so that the same judgement produces the same measurable value. Such a scale is called fuzzy scale. As complicated fuzzy numbers may cause important difficulties in data processing, like hard to define arithmetic operations, therefore, several simple and representative fuzzy numbers have been proposed (Yeh, 2008, Yeh, 2017, Ban and Coroianu, 2012;).

Triangular fuzzy number (TFN) and trapezoidal fuzzy number (TraFN) are two kinds of such fuzzy numbers that have been well studied. TFN is the mostly popular means of judgement representation. The triangular fuzzy numbers (TFN) are used for the suggested method because of their simplicity. Numerically, a fuzzy number is a unique fuzzy set expressed as $\tilde{M} = \{(x, \mu_{\tilde{m}}(x)), x \in R\}$where (x) takes its qualities on the real line R: $-\infty < x < +\infty$

and $\mu_{\tilde{m}}(x)$ is a continuous mapping from R to the close interval [0,1].

A TFN $\tilde{M}$ can be characterized by a triplet (a, b, c) as illustrated in Fig.4.3.

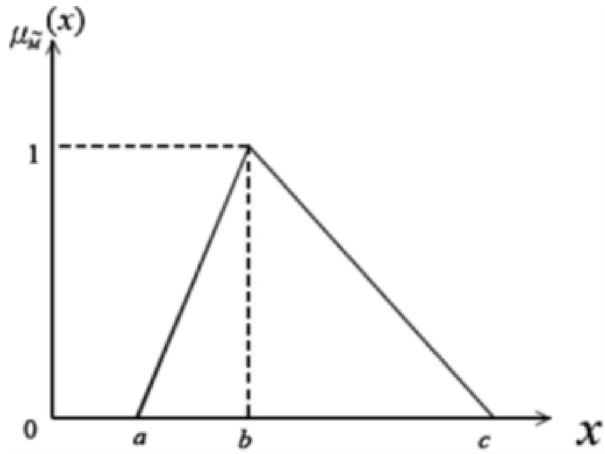

Figure 3- 3: Membership function of a triangular fuzzy number - Source: Cheng et al. (1999)

Below we present the basic arithmetic operations of Triangular Fuzzy Numbers (TFN) such as addition, multiplication and division (Kwong and Bai, 2003; Chen and Chen, 2005). The process of obtaining a crisp number (a real number corresponding to a fuzzy numberer) the so-called defuzzification process is also presented.

Fuzzy number addition:

$$(a_1 b_1 c_1) + (a_2 b_2 c_3) = (a_1 + a_{2,} b_1 + b_{2,} c_1 + c_2)(3.1)$$

Fuzzy number multiplication:

$$(a_1 b_1 c_1) \times (a_2 b_2 c_2) = (a_1 a_2 b_1 b_2 c_1 c_2)(3.2)$$

Reciprocal fuzzy number:

$$(a_1 b_1 c_1)^{-1} = (1/c_1\ 1/b_1\ 1/a_1)(3.3)$$

Defuzzification of Triangular Fuzzy Numbers:

Each element of matrix $a_i = (x_a, x_b, x_c)$ can be converted to a crisp value (the actual element of the decision matrix) to get a single value. For the fuzzy numbers, a defuzzification procedure proceeds to derive their crisp numbers (M_crisp). One of the methods of calculating the crisp numbers for a TFN is to calculate the centre of the fuzzy number's triangular area by Eq. (9) and it is shown in Fig. 3.4 (Wang and Parkan, 2006).

$$M_{Crisp} = \frac{(b + a + c)}{3}(3.4)$$

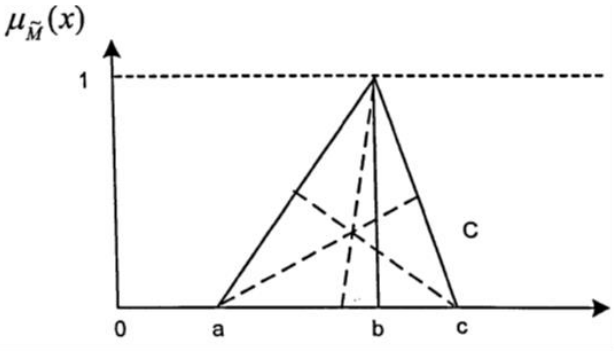

Figure 3- 4: The defuzzification of a triangular fuzzy number - Source: Cheng et al. (1999

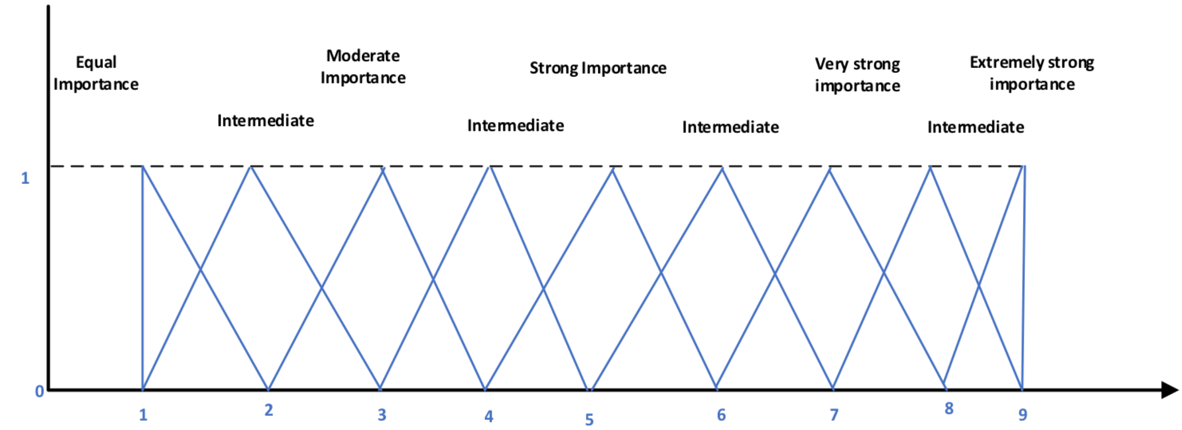

Figure 3- 5: The membership functions of the fuzzy numbers used in this work - Source: Author

Table 3. 2: Membership functions

Rate of Intensity	**Fuzzy number**	**Explanation**	**Membership operation**
1	$\tilde{M}_1$	Equal importance	(1,1,2)
2	$\tilde{M}_2$	Equal to Moderately importance	(1,2,3)
3	$\tilde{M}_3$	Moderate Importance	(2,3,4)
4	$\tilde{M}_4$	Moderate to Strong Importance	(3,4,5)
5	$\tilde{M}_5$	Strong Importance	(4,5,6)
6	$\tilde{M}_6$	Strong to Very strong importance	(5,6,7)
7	$\tilde{M}_7$	Very strongly Importance	(6,7,8)
8	$\tilde{M}_8$	Very to extremely strong Importance	(7,8,9)
9	$\tilde{M}_9$	Intermediate value of Importance	(8,9,9)

In the proposed methodology, experts rate the importance of each BSC item on a scale of nine linguistic terms, where each term corresponds to a fuzzy number as is shown in Table 3.2. The membership functions of fuzzy numbers were decided taking into account the opinion of the experts and the literature.

A nine-point scale is used in line with the AHP process as Saaty argues that people find it simpler to compare items on a 9-point scale (Harker and Vargas 1987).
Fuzzy numbers $\tilde{M}_1$, $\tilde{M}_3$, $\tilde{M}_5$, $\tilde{M}_7$ and $\tilde{M}_9$ symbolize linguistic terms from equal to absolute while fuzzy numbers $\tilde{M}_2$,$\tilde{M}_4$, $\tilde{M}_6$ and $\tilde{M}_8$ symbolize the relating middle values. A TFN $\tilde{M}_x = (a_x, b_x, c_x)$ is used where$(z = (1,2, \ldots ,9)$ and where a_x and c_x are the lower and upper estimations of the fuzzy number$\tilde{M}_x$ respectively.b_x is the centre value of the fuzzy number $\tilde{M}_x$ with a membership value equal to 1. Each linguistic term ought to be denoted by a triangular number $\tilde{M}_x$ $(z = (1,2, \ldots ,9)$ where the value that is closest to their comprehension for that term will be the centre-value b_x.

In agreement with the modelling approach used in Hsu and Chen (1994), consider that each expert $Er(r = 1,2,3, \ldots y)$ shares their opinions on a specific criterion dependent on their expertise by a set of linguistic factors, which are depicted by fuzzy numbers. The fuzzy numbers provided by each expert need to be combined to obtain a single value; this is referred to as 'aggregation of expert opinion'. In this work, and without loss of generality, we use the average values.

The average of r experts' opinions, $E_{\tilde{m}_x}$ is used to determine the fuzzy number for each linguistic term:

$$E_{\tilde{m}_x} = \frac{\sum_{i=1}^{r} E_i}{r} \quad (3.5)$$

3.5 Performance measurement model development

Based on the seminal work proposed by Karahalios (2009) and Karahalios et al. (2011) we develop a model to measure the implementation performance of the VGM regulation. We propose the use of the BSC method and the Fuzzy AHP (FAHP) technique to help evaluate each of the key industry stakeholders' performance using a number of different perspectives and measures (performance indicators). This can provide a tool to measure the current total rate (TR) of implementation performance for each stakeholder.

Adopting such a framework from Karahalios et al. (2011) could help at:

1. Evaluating the benefits and cost for each of the concerned participants at different perspectives and measures with their level of responsibility while implementing the SOLAS VGM regulation. This will point to a participant that he may possess some positive commercial benefits by implementing the regulation as well as providing a balance of the costs and benefits for implementation.
2. Designing a performance management tool that would measure the current total rate of performance in the Maritime industry. This tool would be beneficial to the IMO itself and the key stakeholders for monitoring the regulation implementation.

The methodology utilizes the combination of the BSC and FAHP as outlined in figure 3.6 below. The reason behind this choice is that the BSC can provide a strategy to obtain the desired result by creating scorecards that can measure performance, AHP determines the variables with the highest priorities while the fuzzy set theory deals with any imprecision. This combination of methods has been widely applied in different sectors of transportation, private and public finance and others. Hereafter, four fundamental aspects, also termed perspectives, (see figure 4.1) have been identified in respect to the costs and benefits, which the SOLAS VGM regulation generates for the participants in the Maritime Industry. Industrial experts test the BSC scorecards' validity and provided data through conducted interviews and surveys. The FAHP is used as the best way to assess experts' judgments. The AHP method is used to rank the judgments of experts by making pairwise comparisons.

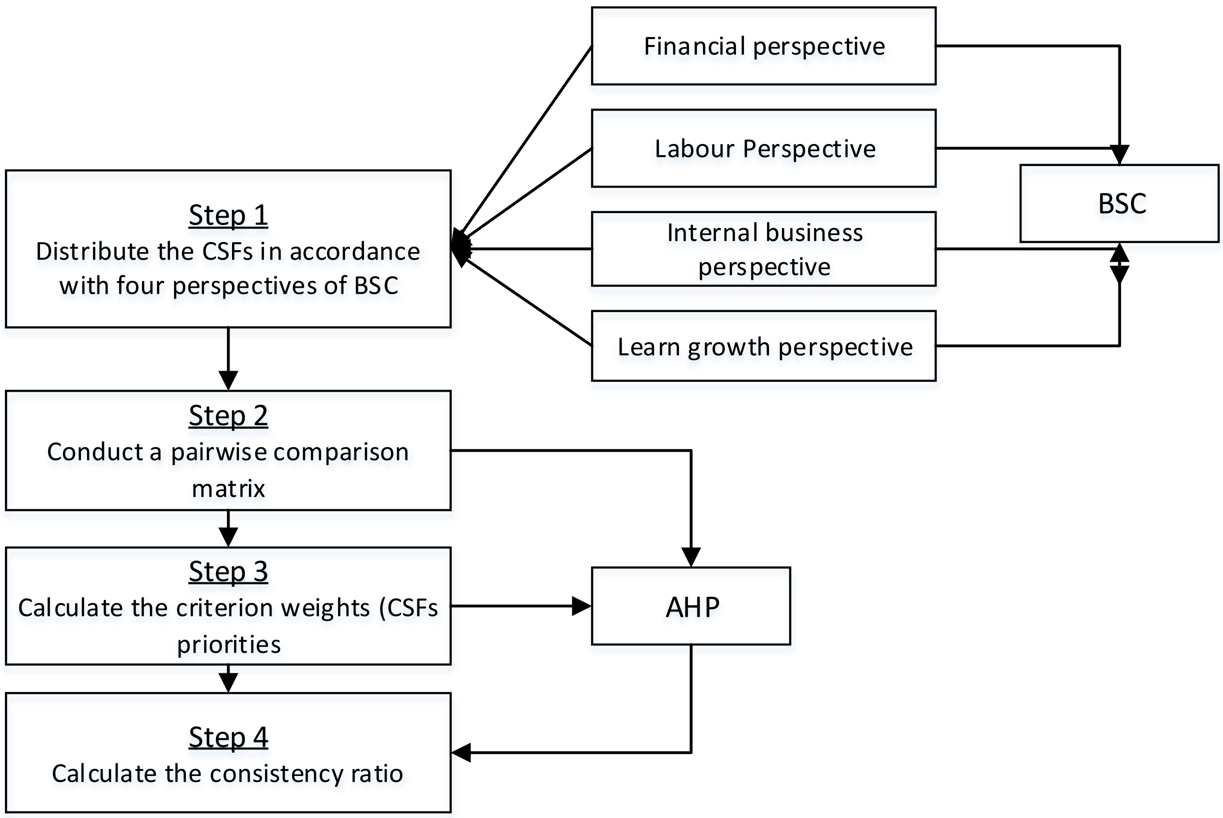

Figure 3- 6: Flow diagram of the suggested model- Source: Karahalios (2013)

This stage of the research centres on devising a well-structured procedure that can assess the effective implementation performance of the IMO VGM regulation focusing on the main stakeholders in the regulatory process and assessing their costs and benefits. The methodology for analysing the worldwide performance implementation of the SOLAS VGM regulation has been adapted from Karahalios (2009) and Karahalios et al. (2011) and consists of the following steps:

I. Problem definition
II. Selecting the key industry participants that are concerned with the implementation of the VGM regulation in the Maritime industry.
III. Determining the perspectives and measures for each participant that can assess the costs and benefits of the application of the regulation.
IV. Creating the hierarchy structure for evaluating the VGM regulation performance.
V. Evaluating the weight of each stakeholder, its perspectives, measures and determine the overall priority of their weights for the level of their responsibility in the regulatory procedure.
VI. Creating a tool capable of assessing the implementation performance of the shipping sector in compliance with the SOLAS regulation.

3.5.1. Step I -Problem definition

The hypothesis to be investigated is whether the VGM Regulation has been successfully implemented and whether the benefits and costs related to the regulation are balanced between the key stakeholders in the regulatory process. The total implementation performance rate of the regulation would be evaluated successfully by measuring the cost and benefits for each of the key participants combined with their level of responsibilities in the regulatory process. The outcome of the evaluation is considered as the total performance implementation rate of the VGM regulation.

3.5.2. Step II - Selection the key industry participants

To select the sample of representative key industry participants that are most concerned with implementing the regulation; a participant analysis was carried out based on literature and the regulatory requirements. The sources of literature are the analysis of Villarroel, (2016) which lists the key stakeholders whose operations would be disrupted by the VGM requirements and the regulatory reaction to the maritime industry. In addition, various documents compiled by the World Shipping Council on container weight requirement and IMO guidelines related to the implementation process have also been considered (see WSC, 2015; IMO, 2016).

It is expedient to reduce the number of participants used in this study in a sizeable manner as the maritime industry is very large and comprises both minor and major stakeholders like union, media, employee, Port/terminal operators, ship builders, government & regulators etc. The adopted approach is that the operations of the participants that are mostly affected by the requirements of the SOLAS VGM regulation were selected. That is, participants are selected based on their significance to the implementation process of the SOLAS VGM regulation.

Five key industry participants were selected to be taken into consideration in our approach, which is designed to measure the implementation performance of the regulation. These five key participants in the industry are mainly responsible for implementing the regulation and they are the shipper, port/terminal operator, freight forwarder, national authority, and carrier. Their responsibility in the supply chain and how it concerns implementation compliance of the regulation is discussed below.

The Shipper

According to the SOLAS VGM regulation, the shipper (or by the arrangement of the shipper, a third party) has a responsibility to weigh the packed container or to weigh its contents (WSC, 2015). The shipper takes the responsibility to make sure the cargo gets to its intended destination without any accident or mishap. The shipper gathers all the containers and crates, pack goods to be shipped, identifies and prepares information and shipping instructions. (Marineinsight, 2016; CCOHS, 2017). He also deals with all necessary documents that would complete the transhipment procedure of cargoes in order to circumvent complications that may arise in the whole process. An example of such necessary documentation is the bill of lading. This receipt contains the shipment details and all the parties involved. The bill of lading may also serve as a legal transportation contract. (Raunek, 2019). After deriving the VGM the shipper sends the information to the carrier to create the stowage plan.

The Port/terminal operator

The private port operators just like the central government and port authorities hold indispensable responsibilities in the port communities. Some examples of such private operators are stevedoring firms, cargo handling companies, and terminal operators. Generally, the port operators' primary objective is to seek and attain traditional microeconomic goals such as growth, profit maximization and, additional market share. The benefit of a market-oriented system can only be attained when the port operator is free to pursue such objectives. (PPIAF, 2008) A port operator likewise serves other functions to the shipping business: it does the documentation to get approaching shipments through customs and uses its computer system to help connect the goods with expected beneficiaries.

The port/terminal operator also renders cargo weighing services using different kinds of container weighing systems as well as the loading and unloading of cargoes. However, the reputation of an operator is determined by its competence at loading and unloading that is, how many “crane-moves” the operators make per hour, how long it takes for a ship to get into the port, offload and get out of the port (Engber, 2006). The SOLAS VGM regulation demands (No-VGM, No entry) that the port/terminal operator must reject any container that enters into the port without a VGM. A port can provide VGM with additional charges in cases where the weight provided by the shipper is in-correct.

The Freight forwarder

The freight forwarder is a forwarding agent who is a key member of the international trade and transport process. Just like the travel agent deals with passengers, so the freight forwarder deals with cargoes. The freight forwarder strategizes for the international movement of cargoes. They use their expertise of modifying freight rates to give the shipper the best “package deal”. Freight forwarders deal with a number of aspects for example the plan the most appropriate route for the product, make the relevant reservations and arrange the transportation of the goods. They are also responsible for customs-related procedures.

The Carrier

A Carrier is a person or company that conveys the cargoes by sea for any person or company and is accountable for any possible loss of the goods during the voyage (KKFreight, 2011). They are a party in the supply chain that is contracted by the shipper to transport the cargoes by sea. In situations such as in liner shipping where the carrier offering shipping services does not own any vessels; the carrier with whom the seller or the seller’s agent makes a contract of cargo carriage is not necessarily the carrier that is actually performing the transportation by sea. As required by the regulation, once the VGM is provided by the shipper or a third party, it should be sent on time to the relevant authority or carriers early enough so that it can be used to create a stowage plan before commencing loading.

The National authority

In this study, the national authority is the regulatory body or maritime organisation controlling the maritime sector of any country under the IMO member states. For every IMO member state, there is a maritime body, which ensures that maritime laws and conventions are enforced. Some examples of such organizations are the Maritime and Coastguard Agency (MCA) of the United Kingdom, the Nigerian Maritime Administration and Safety Agency (NIMASA) of Nigeria and the National Maritime Center (NMC-42) of the United States; and there are many more.

3.5.3. Step III - Determining the perspectives and measures for each selected stakeholder

The general principle of designing perspectives and measures of the scorecards is to provide notable items, which are in line with objectives of the organization, in such a way that the items can serve as a guide for any division within the organization to effectively implement the goals. Similarly, to measure the effective implementation performance rate; a list of significant items which are in line with the requirements of SOLAS VGM regulation that also reveals the cost and benefits of implementing the regulation for each of the five key industry participants were used to design the perspectives and measures for each of them. The list comprises essential functions of the regulation as required by IMO such as implementation procedure, availability of resources, cost assessment, risk assessment and performance monitoring. Furthermore, it is important to stress that the inventor of the BSC advised that an organization should utilize a moderate value of measures that can be controlled.

3.5.3.1 BSC Perspectives to Assess the SOLAS VGM Implementation Performance

It is necessary for any organization that wants to apply the BSC method either as a tool for management, communication, or strategic planning to carefully select the appropriate perspectives and measures that will achieve the desired goal.

The definitions for each of the perspectives that were originally suggested in Kaplan and Norton (1996a;1996b) and subsequently used with the maritime regulatory domain in Karahalios (2009) were adapted to fit into the SOLAS VGM regulatory context and are defined as follows:

Financial Perspective(P_1^s): Illustrates traditional monetary performance measures. It is concerned with the cost and profit associated with implementing the regulation.

Customer perspective (P_2^s) : The customer perspective is the approval of a participant's customer because of implementing the regulation. The outcomes include all the issues pointing that an organisation or a company fulfils the requirements of the SOLAS VGM regulation

Internal business Perspective(P_3^s): The objective of this perspective is to gratify participants by succeeding at some commercial procedures that have highest influence. It involves the procedures that should be followed to implement the regulation. The aspects of this perspective are training, planning and review.

Learning and Growth Perspective$(\boldsymbol{P_4^s})$**:** This perspective involves the resources that are needed in order to implement the regulation. These includes human resources, technology and knowledge.

3.5.4 Identifying BSC measures to assess SOLAS VGM Implementation performance

The measures of performance are essential to be identified with respect to the purpose of all the selected perspectives under their respective participants so that they would be able to understand the goals of the perspectives. These would be used as vital parameters to measure the performance progress towards the overall objective of the regulation because leading and lagging measures would be identified, expected targets & thresholds would be developed and baseline & benchmarking data are established. This is highly beneficial for local managers, operators and employees because the BSC breaks down all the corporate level measures for them, to the extent they can see what must be done well in order to improve effectiveness of the regulation (Sharma, 2009). Furthermore, as asserted by Kaplan and Norton (2000, 2004) many firms use the same measures to assess their perspectives. Even though these measures have already been proven and used in various fields, they should be used with caution when analysing the cost and benefit of a regulation implementation with regards to the perspectives of any stakeholder in the maritime industry. Karahalios (2009) highlighted a stable approach to modify the performance measures to suit each perspective under a stakeholder in the maritime industry when implementing a maritime regulation. The generic perspectives/measures and how they are linked together are presented in Appendix A. Hence, performance measures were developed for each perspective (financial, customer, internal business and learning and growth) for all identified stakeholders with regards to their individual objectives. These were adapted and redefined from by Kaplan and Norton (1996a, b) to fit the context of the implementation of the VGM regulation. The process follows four important steps as shown in Appendix A.

3.5.5 Step V - Identify main performance measures to assess SOLAS VGM in the maritime industry

A generic BSC as presented in appendix A may not be very effective in producing the intended results for the study, as the shipping industry is complicated. Thus, a structure of the main performance measures in the maritime industry was formulated to recognise the influence and performance of all the five identified key industry participants in the regulation implementation process. It is worthy to note that each of the industry participants chosen for this research has its own characteristics. Therefore, different main performance measures should be applied to every perspective. The participants were considered to be different types of non-profit organizations, groups of people and private companies in the supply chain of the maritime industry. The measures of each perspective for a representative stakeholder were carefully addressed from the review of the literature according to its unique responsibility and needs while implementing the SOLAS VGM regulation. Also, interviews and surveys were conducted to validate the performance measures.

The performance measures for the *'Learn & Growth perspective'* are the same for all participants because they reveal the standards of successful management. Similarly, the performance measures of the internal business perspective are customary to all the participants as they encompass basic issues of risk evaluation and analysis. However, the *'Financial perspective'* measures may differ because they concern the mainstream of income and expenses of each participant while implementing the regulation. Likewise, the performance measures of the *'Customer perspective'* vary; they are developed on the grounds of stakeholder analysis to determine the regulatory link between participants. The participants with more authority are considered as the customers of those participants with lesser authority level. The complete main performance measures of the BSCs for all the five key participants, with their perspectives for an assessment of the implementation performance of the SOLAS VGM regulation in the maritime industry, are presented in Table 3.3-3.7

Table 3. 3: The main performance measures of the perspective for port/terminal operators

Shipper		
Perspective	**Generic Measures**	**Main Performance Measures**
Financial	Profit	Grow revenue by successful transfer of the container
	Revenue	Grow revenue by preventing charges of inaccurate VGM provided
	Cost	Limit the expense of weighing
	Use of Assets	Limit the requirement for cash expenditure to meet regulations guidelines
Customer	Productivity	Grow Market share
	Competitiveness	Enhance reputation and trust by meeting regulation guidelines
	Quality	Rase quality of VGM provided
	Productivity	Lessen the cases of accidents due to misdeclared VGM
Learning and Growth	Human Capital	Lessen the need to hire additional employees
	Information capital	Lessen the need to purchase extra IT applications
	Organisation Capital	Lessen the number of misdeclared container incidents.

	Innovation	Present enhanced concept of transportation guidelines
Internal Business	Risk analysis	Limit endeavours to carry out a risk assessment for the VGM rule
	Planning	Limit endeavours to create plans to implement the VGM rule
	Training	Limit endeavours to give training regarding meeting the VGM rule
	Review	Limit endeavours to review the internal business procedure

Table 3. 4: The main performance measures of the perspective for shippers

Port/ Terminal operator		
Perspective	**Generic Measures**	**Main Performance Measures**
Financial	Profit	Increase revenue from new fees or charges of container weighing services.
	Revenue	Increase revenue from providing other existing VGM services
	Cost	Minimize the cost of acquiring container weighing equipment, administration and other services
	Use of Assets	Limit the requirement for guaranteed money use to meet guidelines prerequisite
Customer	Productivity	Increase contract with transporters and different members of the supply chain.
	Competitiveness	Increase competitiveness by improving the status and credibility of Port/terminal operations.
	Quality	Improve quality and standard of VGM services
	Productivity	Reduce the number of claims for misdeclared Container weights.
Learning and Growth	Human Capital	No need to recruit extra workers
	Information capital	Avoid the need to buy extra IT systems
	Organisation Capital	Diminish the rate of misdeclared container issues
	Innovation	Present new guiding principles
Internal Business	Risk analysis	Limit endeavours to carry out a risk evaluation for the VGM regulation.
	Planning	Limit endeavours to create plans to actualize the VGM regulation.
	Training	Limit endeavours to provide training regarding implementation of the VGM regulation.
	Review	Limit endeavours to review the internal business process

Table 3. 5: The performance measures of the perspectives for freight forwarders

Freight Forwarder		
Perspective	**Generic Measures**	**Main Performance Measures**
Financial	Profit	Increase revenue due to faster shipments of cargoes.
	Revenue	Increase revenue from safer shipments of goods.
	Cost	Minimize losses due to delayed shipping from the penalty of misdeclared containers.
	Use of Assets	Limit the requirement for guaranteed money use to meet guidelines prerequisite
Customer	Productivity	Increase market share
	Competitiveness	Increase reputation and credibility
	Quality	Increase quality of service provided to customers
	Productivity	Reduce the number of delivery failures due to hiccups in the transhipment process.
Learning and Growth	Human Capital	No need to recruit extra workers
	Information capital	Avoid the need to buy extra IT systems
	Organisation Capital	Diminish the rate of misdeclared container issues
	Innovation	Present new guiding principles
Internal Business	Risk analysis	Limit endeavours to carry out a risk evaluation for the VGM regulation.
	Planning	Limit endeavours to create plans to actualize the VGM regulation
	Training	Limit endeavours to provide training regarding implementation of the VGM regulation
	Review	Limit endeavours to review the internal business process

Table 3. 6: Performance measures of the perspective for national authorities

National authority		
Perspective	**Generic Measures**	**Main Performance Measures**
Financial	Profit	Increase revenue from accreditation and licensing
	Revenue	Increase revenue from existing services provided
	Cost	Reduce administration cost
	Use of Assets	Limit the requirement for guaranteed money use to meet guidelines prerequisite
Customer	Productivity	Grow operations efficiency of the maritime sector
	Competitiveness	Grow commercial advantages in the supply chain
	Quality	Increase excellence in standards of VGM enforcement
	Productivity	Improve track record of VGM enforcement
Learning and Growth	Human Capital	No need to recruit extra workers
	Information capital	Avoid the need to buy extra IT systems
	Organisation Capital	Diminish the rate of misdeclared container issues
	Innovation	Present new guiding principles
Internal Business	Risk analysis	Limit endeavours to carry out a risk evaluation for the VGM regulation.
	Planning	Limit endeavours to create plans to actualize the VGM regulation
	Training	Limit endeavours to provide training regarding implementation of the VGM regulation
	Review	Limit endeavours to review the internal business process

Table 3. 7: The main performance measures of the perspectives for carriers

Carrier		
Perspective	**Generic Measures**	**Main Performance Measures**
Financial	Profit	Grow revenues due to faster transport of cargoes.
	Revenue	Grow revenue from safer Cargo transhipment by reducing cost of possible losses.
	Cost	Reduce direct and indirect costs of compliance such as cost of training, documentation and other administration costs.
	Use of Assets	Reduces the requirement for immediate cash expenditures to meet VGM regulation requirements.
Customer	Productivity	Grow market share
	Competitiveness	Grow image and credibility
	Quality	Grow value of service provided
	Productivity	Decrease the number of claims due to delayed voyage, accidents, etc. from misdeclared weights
Learning and Growth	Human Capital	No need to recruit extra workers
	Information capital	Avoid the need to buy extra IT systems
	Organisation Capital	Diminish the rate of misdeclared container issues
	Innovation	Present new guiding principles
Internal Business	Risk analysis	Limit endeavours to carry out a risk evaluation for the VGM regulation
	Planning	Limit endeavours to create plans to actualize the VGM regulation
	Training	Limit endeavours to provide training regarding implementation of the VGM regulation
	Review	Limit endeavours to review the internal business process

Validation of BSCs

After creating the scorecards, industrial experts are required to test the suggested BSCs for their validity. Most researchers use the Delphi method but, in this study, the BSC was validated through a series of interviews with industry experts that are very knowledgeable on the VGM implementation and enforcement process. Similar studies have also followed this type of validation (Ahmed Al-Ashaab1, 2011; Wilsey, 2012).

3.5.6 Step IV - Creating a hierarchy structure for evaluating the VGM regulation performance from the industrial aspect

The aim of this step is to design a structure of hierarchy for evaluating the VGM regulation, where appropriate levels must be set that could break the defined problem into simpler solutions at different levels (Forman and Gass 2001).

The hierarchy for the five major industry participants was constructed based on the concept of BSC, literature review and interviews with industry experts that are involved in the implementation process. Therefore, the designed system of scorecards for all the selected participants, their perspectives and generic measures are graphically presented in a hierarchical structure as shown in Figure 3.7 below.

Level 1 is the overall desired goal, which is the performance measurement of the SOLAS VGM regulation. Level 2 is the five-selected industry participants. Level 3 is the perspectives of each stakeholder. A perspective is then further sub-divided into four measures in Level 4.

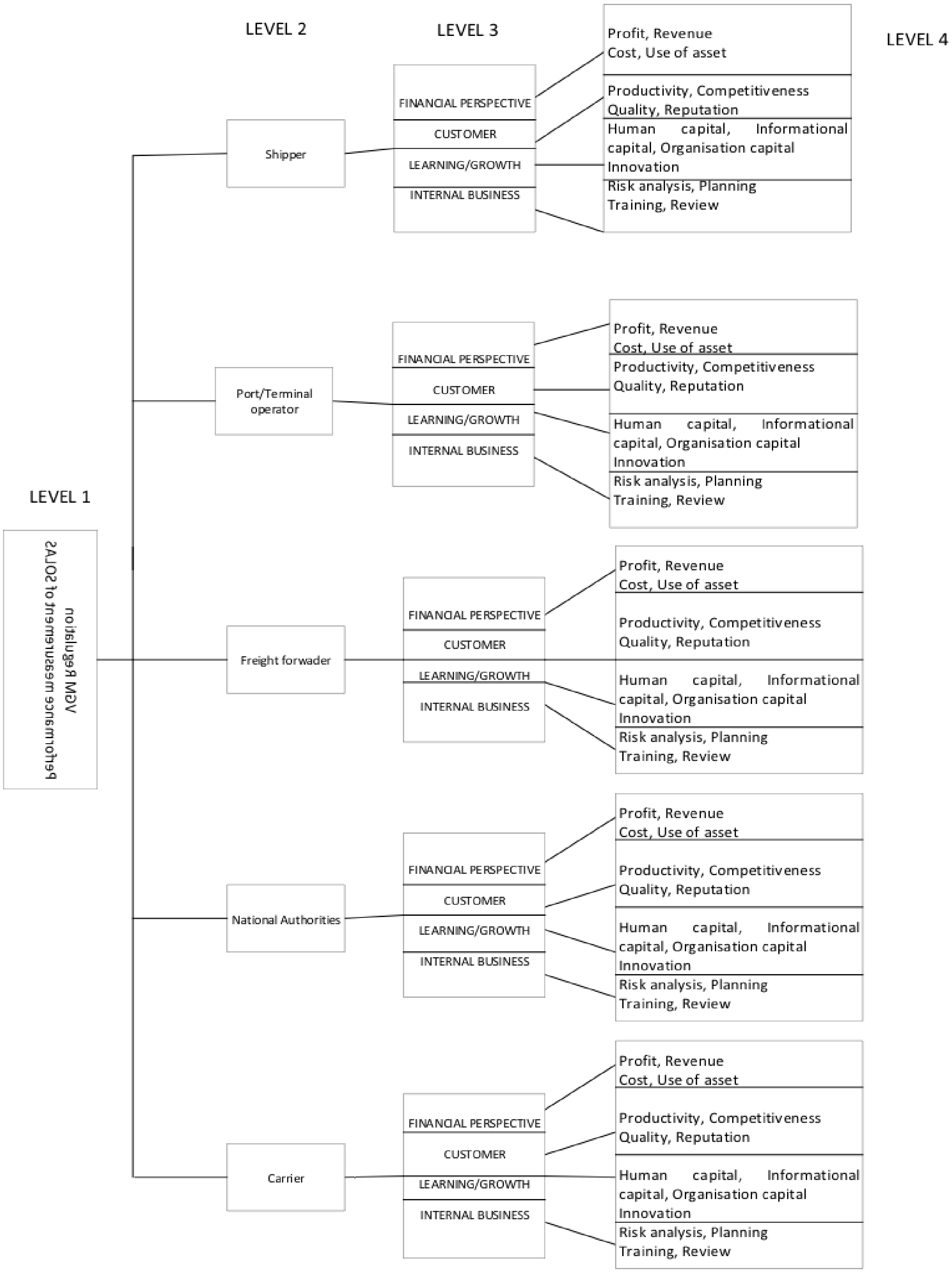

Figure 3- 7: Performance evaluation hierarchy of participants in the maritime industry - Source: author

3.5.7 Evaluating participant weight, perspective, measures and ranking

The elements of the BSCs can be evaluated to obtain the order of their priorities in the regulatory process based on their importance in the hierarchy by using the fuzzy AHP (FAHP) technique. Besides evaluating the BSCs for their validity by experts, the scorecards for all the participants, perspectives and their measures would be ranked according to their weights of importance. As shown in Figure 3.7, the relevant weights of implementation performance for the five selected industry participants in the SOLAS VGM implementation process can be estimated using pairwise comparisons at level 2. Applying the same approach to the level 3 elements -that is by conducting pairwise comparisons and ranking them in terms of their importance- the perspectives that are more important to the stakeholder can be identified. Furthermore, the pairwise comparisons between measures of a stakeholder at level 4 reveal the weight of each measure, which is important for evaluating their parent perspectives. It is expected that due to the size of the suggested hierarchy, many pair-wise comparisons will be carried out especially at level 4.

Some of the necessary stages to note for analysing the weight of each stakeholder, perspectives, and measures to arrive at their overall priorities in the regulatory process include estimating the weights, averaging expert's judgement, the defuzzification stage and finally obtaining the ranks.

Note that in this work all experts are treated equally. There is literature (e.g., Karahalios, 2009) where factors such as the academic and professional qualifications, and years of experience are used to weigh the opinion of experts. We consider these approaches a bit arbitrary, and we believe that a sensitivity analysis can factor in all the relevant concerns related to the obtained weights.

After obtaining, through pairwise comparison, the expert opinion uses the fuzzy number definitions to obtain the fuzzy values and the averages are obtained (expert aggregation). The AHP process is followed with the defuzzifying stage involving converting all the linguistic TFN presented in the decision matrix back into single values. The result of the process is to obtain the weights of the perspectives and measures and ranking their overall priority in the regulatory process while implementing the SOLAS VGM regulation.

Furthermore, from these weights when combined with the current implementation measures, the total implementation performance measurement (TR) can be determined.

3.5.8 Creating an implementation performance tool to evaluate industry VGM compliance

This research seeks to calculate the weight of each participant, their perspective, measures and ranking for their level of responsibility in the regulatory procedure. It also seeks to create a robust implementation performance measurement and management system for the SOLAS VGM regulation that could be updated based on new feedback. In this way the implementation can be monitored.

Furthermore, rather than using TFN, single values of the same scale would be used to score the performance of all the measures that are under different perspectives and participants for the framework since the scorecards are designed for industrial use and industry experts may not be familiar with fuzzy numbers. By using the performance scores of each measure in the framework, there will be a relative success in terms of their achievement, termed as the performance rate of the measures. Therefore, it will be practical to calculate the performance rate of each participant by utilizing the weights of its perspectives and rate of measure and consequently the total performance rate of the VGM regulation in the maritime industry.

In addition to the pairwise comparison of level 2, 3 and 4, experts would be required to give performance scores of all the measures from a scale of 0-10 that would be used to derive the total performance rate (TR) of a stakeholder and effectively evaluate the worldwide implementation performance rate in the maritime industry. Where 10 is the best performance and 0 is the worst performance score as shown in table 3.8 below. We feel that further work is needed to determine which level of performance is acceptable but at the same time we believe that this approach can offer substantial managerial insights as it will be easy to compare across departments and the different performance areas.

Table 3.8: Performance score for measures (Karahalios, 2014)

Performance Intensity	**Performance score**
Very high performance	9-10
High performance	7-8
Medium performance	4-6
Low performance	2-3
Very Low performance	0-1

The design of the suggested tool that would be capable of evaluating the implementation performance of the SOLAS VGM regulation should be functional and straightforward for industry use, so that it can be employed by IMO and industry players to easily estimate their performance rates. To design such a tool, the previous scorecards would be reviewed to accommodate the calculated weights of participants, their perspectives and measures, such that whenever a new performance score of all the measures is determined, the system would be able to calculate its effect in the regulatory process. This tool can be designed by following these six essential steps. Take note of the following notations: R is rate, P is perspective or performance, c is criteria, a is alternative, g is geometric, m is measure, b, w is weight, S is stakeholders.

Step 1: Obtain Performance score of measures ranging from 0 to 10

Step 2: Calculate the rate of measures Rm by multiplying its weight with performance scores of Step 1 and sum them up.

Step 3: Calculate each perspective rate $RP_a^c$by multiplying its weight wP_a^c with the average rate of its measures.

$$RP_a^c = \frac{1}{g^a}\sum_{b=1}^{g^a} Rm_{b^{a,c}}^{a} \times wP_a^c \, (Eq. 3.8)$$

Step 4: Sum up the perspectives rates of each stakeholder to find its performance pS^c.

$$pS^c = \sum_{a=1}^{4} RP_a^c \, (Eq. 3.9)$$

Step 5: Multiply a stakeholder's weight $wS^c$with its performancepS^c to find its rateRS^c.

$$RS^c = pS^c \times wS^c (Eq. 3.10)$$

Step 6: Sum up the stakeholder's ratesRS^c to calculate the total rate TR.

$$TR = \sum_{c=1}^{d} RS^c \, (Eq. 3.11)$$

3.6 Decision making under uncertainty using Decision Trees (DTs)

Among a few elective situations, the choice of a specific course of action is a reasoning procedure called "decision making" (McLean and Biles 2008). There is a last alternative in the wake of the decision-making procedure which is either an action or an attitude or an estimation (Reason 1997).

The method utilized in this section is a technique of the DT; a powerful graphical tool to guide the analysis. The decision tree is a type of advanced method used to make decisions (Janssens et al. 2006). It is additionally a typical technique used to decide and develop the connection among observed and quantified data to create a numerically basic model (Dale et al. 2007). DTs allows the decision-maker to see all key segments of the problem in one goal: the decision alternatives, the uncertain outcomes and their probabilities, the economic effects, and the sequential order of events. According to Anderson et al. (1985), DTs are especially valuable when managing moderately few possible solutions. For example, Kim et al. (2000) use DTs to select storage strategies for transhipments. Although DTs have been adopted for years, often constructed on paper, this study shows how they can be built in Excel with an effective and flexible add-in from Palisade named Precision Tree.

Numerous instances of decision-making under uncertainty exist in the business world. An organisation in a bidding competition for a contract will be faced with the uncertainty of what the other organisation offers, as well as possible uncertainty regarding their cost to complete the project if they win the bid, and the decision is between offering low to win the offer and offering high to make a bigger benefit. At whatever point an organization examines bringing another item into the market, there are a few vulnerabilities that influence the choice, most presumably customers' response to the item. At whatever point producing companies settle on limited development choices, they face unsure outcomes (Clintworth, Boulougouris and Lee, 2018). This choice includes a totally different set of uncertainties, including building new plants, trade rates, work accessibility, social solidarity, rivalry from nearby organizations, and others (Khezrimotlagh and Chen, 2018). Banks must regularly settle on choices on whether to give loans to organizations or people. Service organizations must settle on numerous decisions that have huge ecological and monetary outcomes. Sports groups constantly settle on choices under uncertainties. One may be amazed at the degree of quantitative complexity in pro-athletics nowadays. The executives and mentors ordinarily do not settle on significant choices by hunch. They utilize different sorts of decision-making tools, for example, the DTs method utilized in this study.

Besides business decisions, which is the approach presented in this study, the decision tree technique can also be applied on important personal decisions by an individual. For instance, a student that has just finished an undergraduate degree could be faced with two choices; either to start a graduate programme or work for several years before deciding to pursue a graduate programme. Other examples are changing of jobs/career, relocation etc. Probably, one may not use the formal method discussed in this study to analyse personal decisions, yet the findings given here would at any rate inspire such an individual or organisation to think in an organized manner prior to settling on ultimate conclusions.

3.6.1 Components of DTs Analysis

According to Albright and Winston (2016) the key steps of decision making under uncertainty are as follows:

1. An issue has been recognised that needs to be resolved.
2. A few potential decisions have been recognised.
3. Every decision prompt to a couple of potential results.
4. There is uncertainty about which result will happen, and probabilities of the potential results are surveyed.

5. For every decision and every conceivable result, a pay-off is received, or an expense is caused.
6. A "best" decision must be picked using a suitable decision criterion.

These six components are discussed below.

Identifying the Problem

When something triggers the need to resolve an issue, one should contemplate about the issue that needs to be solved prior to making a plunge. Basically, indicating the impact of the issue and how the issue would be resolved (Ishizaka and Nemery, 2013).

Possible Decisions

The possible decisions depend on the previous step: how the issue is presented. But after identifying the issue, all potential choices for this issue should be listed. If a potential decision is not in this catalogue, it will not have a chance of being selected as the ultimate decision later, so this catalogue should be as exhaustive as possible. Some issues like the one presented in this study are of a multistage nature. In such cases, a first-phase choice is made, then an uncertain outcome is noticed, next a second-phase choice is made, afterward a second uncertain outcome is noticed, etc. (Frequently there are just two phases, yet there could be more). A decision analysis that involves only one decision is referred to as a single-stage decision problem whereas a decision analysis that involves two or more decisions is referred to as a multistage decision problem. Thus, a "decision" is a "strategy" or "contingency plan" that recommends what step to take at each phase, depending upon decisions and noticed outcomes (Haimes, 2004).

Potential Results

One of the primary reasons why decision making under uncertainty is tough is that a choice has to be taken before uncertain consequences are uncovered. For instance, a gambler must put down a wager at a roulette wheel before the wheel is spun. A person could also decide what type of auto insurance to buy prior to seeing if a mishap will happen or not. Notwithstanding, prior to choosing, the potential results that may happen should in any event be noted down (rewrite). In most instances, the results will be a small set of discrete likelihoods, for example, "the 11 possible sums (2 through 12) of the roll of two dice". In most cases, the results will be a continuum of options, for example the likely loss sums up to a car in an accident (Albright, Winston and Zappe, 2010).

In this research, just a small discrete set of likelihoods were allowed as there are mainly two possible outcomes (either correct or incorrect) of providing VGM despite different methods and approaches to the weighing process.

Likelihood of Results

A rundown of all potential results is not sufficient. A decision maker should likewise evaluate the likelihoods of these results with probabilities. Note that these results are commonly similarly likely. For instance, if there are just two potential results, (downpour or no downpour), when choosing whether to carry an umbrella to work, there is commonly no motivation to expect that every one of these results has a 50-50 possibility of happening. Depending on the weather forecast, it may be 80-20, 30-70, or other potential results. There is no simple method to evaluate the probabilities of the potential results. In some cases, they will be resolved by past information, "experience, experts and regulation guidelines" (Kirkwood, 1997).

Pay-offs and Costs

"Decisions and outcomes have consequences", either fortunate or unfortunate. These must be evaluated before savvy choices can be made. In this study, these will be "monetary pay-offs or costs", however in many other decision problems, they can be non-monetary, for example natural harm or death toll. Clearly, non-monetary consequences can be exceptionally hard to measure, yet an endeavour must be made to do as much. Otherwise, it is difficult to make important compromises or trade-offs (Boardman et.al 2018).

Decision Criterion

When every one of these components of a decision problem has been determined, it is time to make some difficult trade-offs which depends on different factors such as attitude towards risk by the decision-maker and probability of outcomes. In any case, for each possible decision, the decision-maker is usually faced with unsure results with given probabilities, and every one of these prompts a result or an expense. The outcome is a likelihood conveyance of adjustments and expenses (Parnell, 2012).

The measure that has been utilized frequently, and the one that has been utilized for the greater part of this study is the mean of the likelihood dispersion also known as "expected value". Since it manages money related results, this basis is commonly known as the "expected monetary value", or "EMV, criterion" (Ishizaka and Nemery, 2013). "The expected monetary value", for any choice, is a weighted average of the potential payoffs for this choice, weighed by the probabilities of the results. Utilizing the EMV standard, you pick the choice with the biggest EMV. The EMV basis has a long-standing custom in decision-making analysis, both at a hypothetical level (several academic journal articles) and at a useful level (utilized by numerous organizations). It gives a balanced method of deciding, at any rate when the monetary payoffs and costs are of "moderate" size comparative with the decision-maker's resources.

The EMV criterion does not assure favourable results. Certainly, no criterion can assure favourable results. The very nature of decision making under uncertainty is that one decides, and afterwards holds on to see the effects. They may be good or bad, however in any event by utilizing the EMV, the decision-maker knows that he/she had continued sensibly (Keisler, 2008). The EMV rule is straightforward to initiate in a spreadsheet. For any decision, list the conceivable pay-off/cost rates and their probabilities. Then the EMV can be calculated with a "SUMPRODUCT function" in Excel. The advantage of calculating EMVs in a spreadsheet is that sensitivity analysis on any of the inputs can be easily performed.

The EMV criterion was chosen against all the other methods of evaluating probability distribution of payoffs and costs for this study because the EMV criterion represents a long-run average. This means that the EMV is the "long-run average of the outcomes" that will be observed when the decision is repeated many times with the same monetary values and probabilities. In every transhipment of Cargo, the shipper routinely makes almost the same but not identical economic decisions on cargo weighing with respect to VGM implementation. Long-term averages are more practical and profitable for the shipper as the designed tool can be easily used as a guide for better choice of cargo weighing approach that has economic value.

3.6.2 DTs Conventions

It is valuable to show the components of the decision problem, including the timing in a decision tree diagram. DTs do not just permit everybody required to see the components of the decision problem in an instinctive arrangement, they also give a clear method of making necessary calculations.

DTs have been used for over 50 years. DTs can simply be well created in different ways; by drawing on a piece of paper*, or "Excel by using its built-in shape tools on a blank worksheet"* and software, such as Palisade Precision Tree (Haimes, 2004). To demon**s**trate the decision tree interpretation, a simple decision tree has been created and presented in Figure 3.8 below.

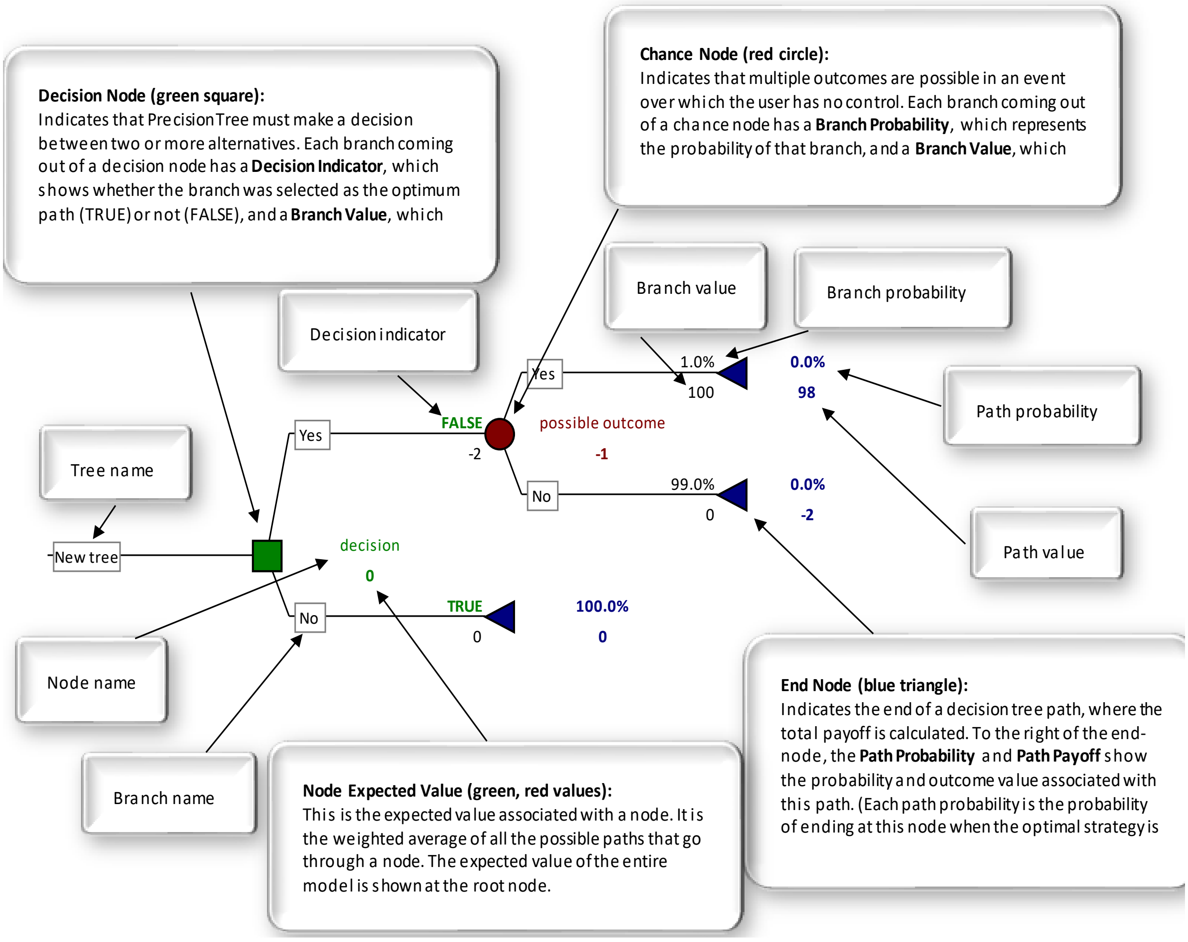

Figure 3- 8: DT Layout - Source: Palisade Precision Tree software manual

Decision trees use the following basic conventions (Palisade, 2020);

1. *DTs are made out of nodes (circles, squares, and triangles) and branches (lines).*
2. *The nodes represent points in time. A decision node (a square) represents a time when a decision is made. A probability node (a circle) represents a time when the result of an uncertain outcome becomes known. An end node (a triangle) indicates that the problem is completed; all decisions have been made, all uncertainty has been resolved, and all payoffs and costs have been incurred.*
3. *Time progresses from left to right. This implies that any of the branches driving into a node (from the left) have just happened. Any of the branches leading out of a node (to the right) have not yet happened.*
4. *Branches driving out of a decision node stand for the possible decisions; a decision-maker gets to choose the preferred branch. Branches leading out of probability nodes represent the possible uncertain outcomes; the decision-maker has no control over which of these will occur.*
5. *Probabilities are listed on probability branches. These probabilities are conditional on the events that have already been observed (those to the left). Also, the probabilities on branches leading out of any probability node must sum up to 1.*

6. *Monetary values are shown to the right of the end nodes. Some monetary values can also be placed under the branches where they happen in time.*
7. *EMVs are calculated by a "folding-back" process. They are shown above the various nodes. It is then customary to mark the optimal decision branch(es) (usually with a small notch) in some way. DTs provide a framework for doing all the EMV calculations. Specifically, they allow the decision maker to use the following folding-back technique to discover the EMVs and the best choice. Beginning from the right of the DT and working back to the left:*

a. *At each likelihood node, calculate an EMV, a "sum of products" of monetary values and probabilities.*
b. *At every decision node, take a maximum of EMVs to know the ideal decision."*

3.7 Cost Benefit Analysis

A cost-benefit analysis (CBA) is based on welfare theory (Boardman et al., 2011). This theory is about achieving as much benefit as possible with the scarce resources available. The concern is the well-being of society, including all individuals, all firms, and the public sector (Grønsedt, 2014). The aim of a cost-benefit analysis is to provide a basis for decisions to maximise the total welfare in society. Since resources are scarce, only changes where the benefits exceed the costs should be implemented. All parties that are affected in one way or another by the studied change (often called a project), should be included in the CBA. The valuation should if possible be based on the involved actors' own preferences. A central part of CBA is opportunity cost, i.e. the cost of resources used in a project is equal to the value of their best alternative usage (Clintworth, Boulougouris and Lee, 2018).

CBA is simply an accounting model for pointing out the pros and cons of a project or policy in monetary terms. This project can be by the public or private sector either on an infrastructural development, regulations, demonstration, medical intervention, or any other government measure (Layard and Glaister, 1994). As the general technique illustrates, the focus is to maximise the difference between benefit and cost: $B - C$. The higher the difference the higher the contribution of the project.

For instance, if B is 150 and C is 110, such a project should be accepted, but if B is 100 such a project should be avoided**.** Deducting cost from benefit produces the net benefits to society. Most professionals refer to CBA as social cost-benefit analysis (Snell, 2010). Decisions that would enhance societal welfare or safety are better than those that reduce it. The basic principle is that if the discounted present value (PV) of the benefits surpasses the discounted present cost then the action is valuable. It is also said that the net benefit must be positive or the ratio of the PV of the benefits to the PV of the cost must be greater than 1;

$$B - C > 0 or \frac{B}{C} > 1$$

The aim of the CBA is to aid social decision making and to make it more realistic (Boardman, Greenberg, Vining and Weimer, 2018). In general, the cost components consist of the initial or capital cost, and operating expenses and maintenance costs. The benefit part is more complicated; it focuses on the advantages of the project. It can be a reduction of fatalities on-shore or off-shore, accurate container weight distribution, damage to vessel etc. Cost is usually expressed using monetary units. To be able to use a common denominator, a monetary value must be used for the benefit too. Using this approach, various effects of the project/investment can be considered such as effects on human life, emissions, noise etc. Suppose, for example, that an operator wants to invest on a CWS. They need to estimate the costs to purchase the equipment, expenses related to maintenance, operations etc. The benefit is related to the fees that you receive for producing VGM declarations. At the same time, they can use the price of one tonne of carbon dioxide emitted or avoided (referred to as the 'Carbon Price' or the 'Shadow Price of Carbon') and consider in their calculations the emissions that the system will produce (due to energy consumption). See, for example, Kontovas (2011) who describes how CBA can be used to assess investments considering effects related on human health, ship air emissions and oil spills.

Cost-effective analysis can be used instead of CBA to avoid placing a monetary value on benefit. Cost is typically expressed by assigning monetary values. CBA answers the question of; "Is this intervention worth it" (Maoxuan, 2006)?

The steps of CBA can be summarised as follows (Boardman, Greenberg, Vining and Weimer, 2017):

1. *"Identify the set of option projects*
2. *Decide whose benefits and costs are standing*
3. *Catalogue the effects and choose measurement indicators (units)*
4. *Predict the impacts quantitatively over the life of the project*
5. *Monetize all effects*
6. *Discount costs and benefits to acquire present values*
7. *Compute net present values (NPV) for all options*
8. *Conduct a sensitivity analysis*
9. *Give suggestions"*

3.8 Conclusion

All techniques proposed for this research have been presented in detail on this chapter. The reasons for the choice of techniques have been highlighted and the steps of applications were discussed.

Chapter 4

An AHP-TOPSIS framework to aid selection of container weighing system

Summary

This chapter focuses on the selection of the most suitable weighing system compliant with the SOLAS VGM regulation using a combination of multi-criteria decision-making techniques. The results from the analysis conducted are presented and discussed and a sensitivity analysis was conducted to test the robustness of our results.

4.1 Introduction

The shipping industry is at the point where there is an urgent need and demand for robust systems built for checking and verifying the weight of containers. Also, there are recent technological advancements, particularly in the areas of accuracy and robustness, which significantly improve the existing systems.

This chapter focuses on the selection of the most suitable container weighing system (CWS), to weigh containers in order to comply with the VGM regulations, among a set of available alternatives using Multi-Criteria Decision Methods (MCDM). A tool is proposed, to assist port operators and other VGM providers in the selection of the optimal alternative by combining the Analytical Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The reason for this choice of method is that the AHP is an effective MCDM technique that is notable for solving decision problems in different research fields. It reduces complex decision problems to a series of pairwise comparison and it checks the consistency of the decision maker's decision. The processes are not complicated and are therefore easy to be communicated with the decision-makers. Combining AHP and TOPSIS would make the results more concrete and reduce the bias in the decision-making process.

For each of the weighing systems, five criteria are used for the evaluation: cost, accuracy, technical characteristics, reliability and safety; see Section 4.3.3 for the selection of the criteria. This chapter shows the potential of the methodology to evaluate the choice of weighing systems for ports and other VGM providers.

Various alternatives can be used to weigh a container and, thus, comply with the VGM regulations. It is of great value to analyse the challenges and opportunities involved in selecting the most suitable weighing system with respect to the current regulatory framework. This will support the operators in selecting the most cost-effective solution to meet the requirements of container weight verification regulations.

Note that in reality, the decision of the best solution will be decided by a small number of decision-members, e.g., the terminal management teams; the low number of experts used. We feel that due to the special needs of each port there is no solution that fits all ports; the system should address the needs of each individual port. To illustrate how our method works, we outline the decision process using a small number of decision-makers. Seven participants with extensive experience have been selected; see their profiles in Table 4.1.

Table 4. 1: Qualifications of the experts

	Academic qualification	**Industrial position**	**Years of experience**
Expert 1	BSc	Manager	11-30 years
Expert 2	HND	Freight forwarder	11-30 years
Expert 3	MSc	Manager	11-30 years
Expert 4	BSc	Manager	>30 years
Expert 5	MSc	Manager	11-30 years
Expert 6	MSc	Manager	11-30 years
Expert 7	MSc	Vice President	>30 years

4.2 Motivation

Although the VGM regulation is expected to be enforced worldwide in all IMO member states, there has not been much analysis on the weighing systems used in implementing the regulation, their technical properties, and their cost-effectiveness. Presently, there are not enough data on the application of the weighing systems in the supply chain making it an obstacle to meeting the approved requirement by some states. Therefore, this chapter is significant as it focuses on the systems that would aid the compliance of VGM providers (JOC, 2015).

The Port Equipment Manufacturing Association (PEMA) stated that it cannot advocate or decide which solution, or combination of solutions, is the right choice for any facility. Hence, the intent of this chapter is to contribute to industry awareness of the available possibilities, proffer the most suitable weighing equipment and the issues that port and terminal operators should take into consideration when deciding their selection. It is the intention of this chapter to review the various weighing systems and select the most suitable cost-effective and beneficial system (TT Club, 2013). There is no 'one-size-fits-all' solution. Using the approach presented in this chapter by analysing the key selection criteria for CWS will not only provide possibly a safer and more environmentally supportable future for the shipping sector but will also stand as a fundamental promoter for a much higher process integration and automation. In addition, it will also help to enable VGM providers like port and terminal operators, etc. to obtain the maximum total return on their investment while attaining effective compliance with the implementation of the VGM regulation.

4.3 Selection of CWS – Data Inputs

The steps of selecting the container weighing systems using the proposed AHP-TOPSIS methodology are as follows:

4.3.1. Problem statement

Most ports were prepared before the regulation came into force and have stipulated weighing charges. For instance, DP World has set up weighing solutions on its automated stacking cranes at London Gateway and on board its straddle carriers at Southampton. The administration at London Gateway and Southampton costs about £17.50 pounds per weighing. Felixstowe, the United Kingdom's largest container port dealing with more than 4 million TEUs each year, weighs containers coming by both train and truck. The port is charging £21 for VGM provision. Shippers are charged £19.50 ($27.50) for every container weighed at Liverpool and Greenock and 23 euros ($26) at the Dublin terminal (Strainstall, 2016). As mentioned earlier, this chapter focuses on the selection of the most suitable CWS, a system that would not only provide VGM but meet the regulation standards. This would be achieved by using the suggested methodology for the equipment selection, among a set of available alternatives by combining AHP and TOPSIS using five criteria: cost, accuracy, technical characteristics, reliability, and safety. This study shows the potential of the methodology to evaluate the choice of weighing systems for ports and other VGM providers.

4.3.2. Identification of potential alternatives

Through discussions with a number of port experts including (Peel Ports group, DP World Southampton and Port Equipment Manufacturer's Association) and also considering the relevant literature, we have identified the following eight alternatives. Table 3.2 summarizes the advantages and disadvantages of each system based on information provided by the PEMA (2013).

4.3.2.1. Weighbridges

This is one of the simplest vehicle weighing arrangements. The approaching truck moves on-top of a weighbridge and the complete weight can be estimated. To derive the container mass, the tare mass of the truck is subtracted from the total weight. Weighbridges ought to be recalibrated occasionally by an authorized expert to guarantee exact weighing.

Weighbridges can be combined with driver-controlled consoles, which empower maximum mechanization of the weighing procedure. They have a high accuracy yet to accomplish this the truck has to halt on the bridge (rewrite). Axle weighbridges are likewise accessible, enabling vehicles to be weighed while moving at slow speed, at a lower accuracy than a standard weighbridge. Weighbridges can be surface-mounted, with a slope driving up, a short separation and the weighing apparatus underneath, or pit-mounted, with the weighing apparatus and stage in a pit so that the weighing surface is level with the road.

Entrance to a surface-mounted weighbridge requires the option of slopes which, when added to the vehicle turning circle required, implies that over-the-ground weighbridges take up a critical amount of space on site. Pit-mounted weighbridges will take up less surface space. Weighbridges weigh the total vehicle and cannot distinguish the individual loads of two containers stacked on a similar track. In these cases, both containers must be restocked and weighed separately. Containers landing via train, or via ocean for transhipment, should be sent to a weighing station.

Figure 4. 1: Sample of a weighbridge - Source: Strainstall (2016)

4.3.2.2. Load Cells on STS Cranes

Load cells on Ship-To-Shore (STS) cranes are fixed at the line finishes on the crane trolleys or booms, in the sheave pins, or somewhere else in the line system. Load cells have a weighing inaccuracy of around 3-5% of the maximum STS Crane lift weight and should be frequently re-calibrated (PEMA,2013). Nowadays, new invented STS cranes possess an overload assurance system fixed as standard. There are likewise a few providers that give such frameworks to retrofit establishment on previous STS cranes. Load cells are not in every case simple to fix, particularly on the off chance that they are fixed into the line sheave shafts. Cranes should be removed from operation and the refixing of the line sheave shafts can be difficult, particularly if the shafts elements are not known ahead of time. In this instance, shafts need to be estimated while the cranes are out of operation and new shafts may likewise be fabricated to suit the load cell system. Crane-climbing load cell weighing system cannot weigh each container exclusively, nor can they effectively identify container load unconventionality. However, rope end-climbing load cells can be utilized to measure and amend rope strain, which is an extra favourable position to guarantee equivalent wear ropes. Consideration should be taken to change the weight values reliant on whether the spreader is at ground level or raised. The weight of the ropes can have an extensive effect on the complete weight, contingent upon the height of the spreaders. In addition, on the off chance that overhead casings or cargo hooks are utilized, the tare weight change must be considered.

4.3.2.3. Load cells on RTGs

Load cell systems are also accessible for use on Rubber-Tyre Gantry cranes (RTGs). In this application, the load cells are fixed in the shafts of rope stacks on the trolley or in the rope grapples. This system has an inaccuracy of around 3-5% and should be recalibrated normally (PEMA, 2016). On the off chance that the cranes are outfitted with twin lift spreaders, the load cells cannot measure every container independently. For 4-high or 5-high stacking RTGs, the rope weight can have an extensive effect if the system is aligned with the spreader at ground level or hoisted, except if the lift height is considered in the weighing system.

Figure 4. 2: Typical Load Cells RTG -Source: Strainstall (2016)

4.3.2.4. Weighing Systems on MHC

A Mobile Harbour Crane (MHC) requires a weighing system to control the steadiness of the crane, as the load weight is carefully constrained relying on the boom outreach. These systems are consequently combined by the crane makers during the manufacturing process. MHC weighing systems regularly measure the hydraulic pressure in the boom lift cylinders or might be incorporated with the rope systems.

4.3.2.5. Load Cells on Straddle carriers

Load cell weighing systems have additionally been fixed on straddle carrier hoist systems. Nevertheless, its level of inaccuracy is huge. Like the container crane load cell system, these systems cannot weigh containers separately if the straddle carrier is fitted with a twin lift spreader, neither can they determine container stacking unconventionality. Mishaps are frequent with straddle carriers in twin lift tasks if one container is stuffed and one is empty or clumsily loaded.

Figure 4. 3: Load Cells on Straddle carriers - Source: Strainstall (2016)

4.3.2.6. Weighing systems on Reach stackers

Most reach stacker makers give built-in systems that utilizes the hydraulic oil pressure in the boom lift cylinders to quantify load weight. The systems are rather constrained in accuracy, and execution may differ contingent upon whether the reading is taken after a hoist movement or after the bringing down of a load. The friction in the cylinders can cause a serious distinction in result. The telescopic boom expansion is regularly considered as it has impact on weight results. Reach stacker load cell systems are also accessible and are incorporated into the rotator-boom head climbing shafts. Regardless, the spreader should hang openly exclusive of the tilt being actuated to have the centre of gravity of the spreader and container lined up and guarantee the highest accuracy. (rewrite)

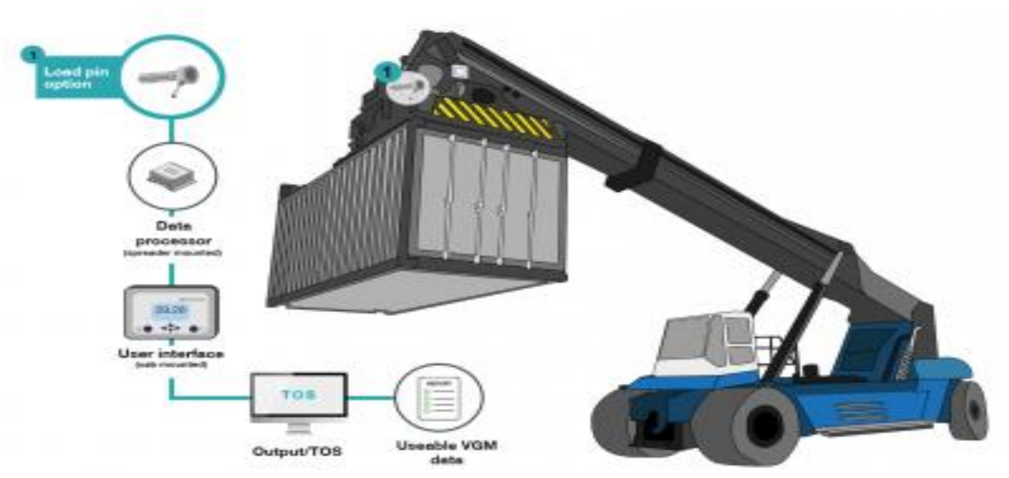

Figure 4. 4: Load Cells on Reach Stacker - Source: Strainstall (2016)

4.3.2.7. Weighing systems on Container Handling FLTS

Weighing systems for container handling forklift trucks (FLTs) ordinarily work by estimating the hydraulic oil pressures in the lift cylinders. Alternatively, load cells may be introduced under the chain anchor. The error of these systems is normally because of friction in the hydraulic cylinders. Presently, it is not typical for weighing systems to be installed on container handling FLTs.

Figure 4. 5: Sample of Container Handling Flts - Source: Strainstall (2016)

4.3.2.8. Weighing systems using Spreader Twist Locks

Weighing systems have been created which measure the load weight and eccentricity on the crane spreader twist locks (check and rewrite). These systems are much more precise than any of the previously stated innovations, except for weighbridges. They can likewise weigh each container separately in twin lift mode and establish container weight eccentricity. Furthermore, they have an assortment of safety features to help prevent accidents during handling operations. Twist lock-based frameworks require no infrastructure changes to the terminal and can be installed on all kinds of spreaders at the time of manufacture or as a retrofit. Utilization of this weighing innovation means that the terminal must fix the system on all the spreaders used together with the crane(s) in question.

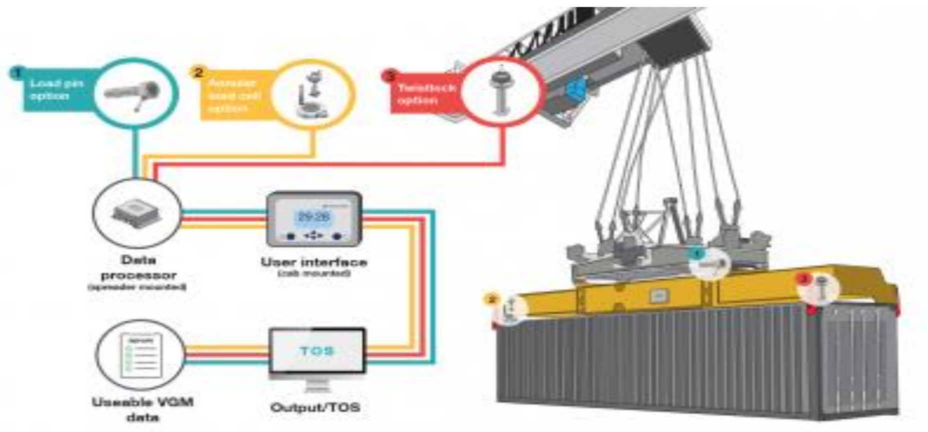

Figure 4. 6: Sample of Spreader twist lock - Source: Strainstall (2016)

Table 4.2, taken from PEMA (2013), below summarises the advantages and disadvantages of the various systems.

Table 4. 2: Typical CWS – Adapted from PEMA (2013)

Alternatives	**Weighing systems**	**Advantages**	**Disadvantages**
A1	Weighbridges	An attractive possible solution that could allow shippers confirm that their declared weights are accurate before shipment to the port.	- Expensive - Can cause disruption in terminals and cannot weigh individual containers on the same vehicle
A2	Load cells on Ship-to-shore cranes	It is non-disruptive to terminal operations	- Average accuracy level -Cannot weigh individual containers on twin lift spreader
A3	Load cells on Rubber tyred gantry crane (RTG)	(RTGs) installed weight measurement systems may offer an exceptionally adaptable solution with little or no disruption to existing port procedures and container logistics	- Average accuracy level - If cranes are fitted with twin lift spreaders, the load cells cannot measure each container individually.
A4	Weighing systems on a mobile harbor crane (MHC):	This weighing system controls the stability of the crane because the weight of the container is severely limited relying on the boom outreach, it measures during the standard lift cycle and the process is non-disruptive to operational flow of port terminals. **(Check and rewrite)**	- Less accurate - Cannot separately measure individual containers handled with twin-lift spreaders.
A5	Weighing system in Reach stackers (RS)	High chance of relatively low-cost to measure the weight of cargoes as it is usually combined with vehicle systems – e.g. the measurements are deduced from hydraulic pressure.	- Low accuracy
A6	Load cells on straddle carriers (SC)	Measures through the standard lift process and the process is non-disruptive to the operational flow of port terminals.	- Average accuracy level - If the cranes are equipped with twin lift spreaders, the load cells cannot measure each container individually.
A7	Weighing systems for container handling forklift trucks (CFL)	- The forklift trucks generally function by quantifying the hydraulic oil pressures in the lift cylinders. Otherwise, load cells might be fixed under the chain anchors. - Non-disruptive to the terminal operations	- The inaccuracy of these systems is often because of the friction in the hydraulic cylinders. - Presently, it is common for weighing systems to be installed on container handling FLTs. - It cannot separately measure individual containers handled with twin lift spreaders

A8	Load sensing systems using spreader twist lock (STS)	- Can weigh each container individually in a twin-lift mode - Unlike MCH, determine container weight eccentricity, and have various safety features to prevent accidents during handling operations. - Twist-lock based systems do not need infrastructural changes to the terminal and can be installed on any type of spreaders at point of manufacture or as a retrofit.	The terminal must install the system on all of the spreaders used together with the crane(s) in question.

4.3.3. Identification of the criteria for evaluating a CWS

During discussions with experts, the following key aspects of the various available systems were considered:

a) Estimation at or near the point of lifting ought to be incorporated with the twist-locks or preferably, as a cutting-edge solution combined with the non-consumable twist-lock collar – hence empowering the load detecting segments to surpass the life of each twist-lock

b) One may consider the cost of investing in purchasing the systems but should not select solely based on the cost. It is not necessarily the most expensive weighing systems, that would best meet the requirement.

c) The mechanical integration is another aspect to consider; this entails the container weight measurement solutions combining with existing standard pieces of the lifting system to which it is applied

d) Data integration solutions is a synergy between smart port management systems and the weighing equipment which allows data integration is an essential criterion when making the choice of container weight verification technology.

e) Regular calibration of weighing systems is important, as consistent use would cause the accuracy of the system to drift to a certain extent.

f) Compliant with SOLAS; although the standard of accuracy and equipment type varies for different countries, one must ensure the equipment is certifiable and acceptable in the region where it would be installed. This means that the system cannot be relied on to provide a valid VGM for SOLAS compliance.

Based on the discussions with experts and a review of limited available literature - mainly following Strainstall (2016)- we have identified a number of criteria that are important in selecting the weighing equipment (i.e., the CWS) as follows:

- **Cost:** The equipment's cost including the capital cost, operating expenses, and other cost components associated with repairs and maintenance.

- **Accuracy:** This is the degree to which the result of the weight verified by the equipment, calculation, or measurement aligns with the actual value or a standard. It includes the stoppage - (i.e., a period when the equipment or machine is not in operation or cannot function), no disruption to the terminal workflow and if the equipment can weigh individual containers.
- **Technical properties:** Includes equipment's expected lifetime or durability, robustness and re-calibration. This criterion requires that the equipment must be satisfactorily strong to endure continuous loading cycles and excess weights while also keeping its calibration accuracy.
- **Reliability:** It can be described as the probability that the condition of a container weighing system will function at a stipulated performance level of efficiency and productivity for a specific period.
- **Safety:** This is the condition of the equipment being protected from (rewrite) or being unlikely to cause danger, risk, or injury when in operation.

4.3.4. Developing a hierarchical structure

A hierarchical relationship has been developed in three different levels and is presented in Figure 4.7. The goal of our analysis is to select the most suitable weighing system that would meet the regulation requirements (level 1). It also illustrates the criteria (level 2) that will be used to rank the alternatives (level 3).

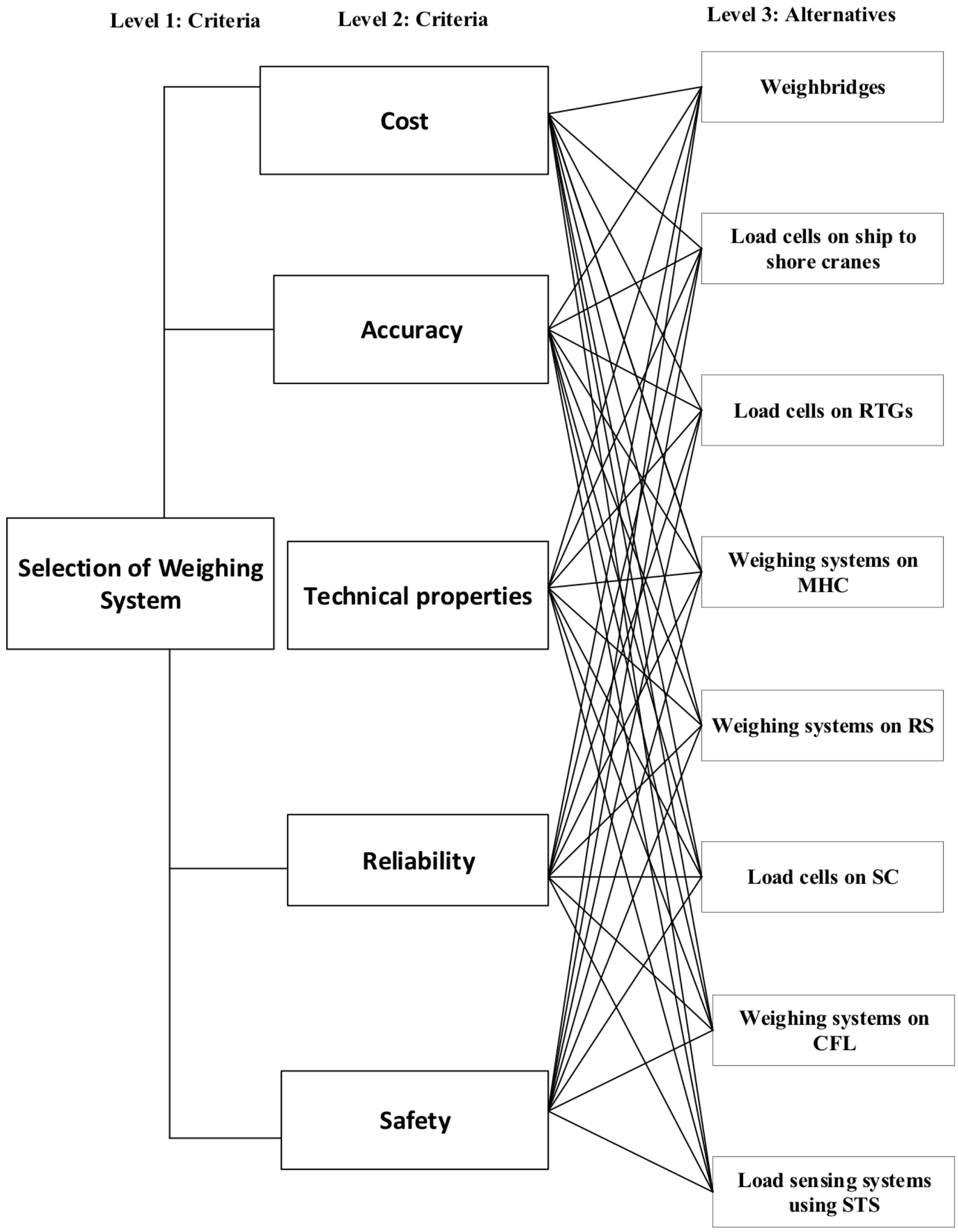

Figure 4. 7: AHP structure for container weighing systems - Source: Author

4.3.5. Determining the weight of the criteria

One of the most important inputs to the TOPSIS is the weight matrix, which we obtain by using the AHP methodology as outlined in Section 3. The 7 experts evaluated, compared and rated the five different selection criteria used for the analysis on a scale of 1 to 9 relative to the intensity of importance.

As a decision is often made by a group of people, like in our case here, standard AHP has been adjusted so that it can be applied to group decision-making. There are numerous approaches to aggregate the preferences into an agreement rating; see Saaty and Vargas, 2005. Clearly some methods, like simple arithmetic mean are unacceptable. The geometric mean method is more preferable and should be used in place of the arithmetical mean to preserve the reciprocal property (Aczel and Saaty, 1983).

For example, if one person enters 9 in the comparison and another one enters 1/9, then by intuition, the mathematical consensus should be the geometric mean and not the arithmetic one which is (9 + 1/9)/2 = 4.56.

In our analysis, the aggregation of the procedure is carried out by using the Weighted Geometric Mean method (WGM) (Tomashevskii, 2014). The aggregated judgment matrix is presented in Table 4.3 below; the values appear in fractions.

Table 4. 3: The aggregated comparison matrix

Matrix		Cost	Accuracy	Properties	Reliability	Safety	**normalized principal Eigenvector**
		1	2	3	4	5	
Cost	1	1	1/7	1/6	1/7	¼	3.67%
Accuracy	2	7 1/3	1	2	1/4	5/6	19.05%
Properties	3	5 7/9	½	1	1/4	2/3	13.08%
Reliability	4	7 3/7	3 5/6	4	1	1 ½	43.46%
Safety	5	4 1/3	1 1/5	1 4/7	2/3	1	20.74%

Using the AHP method, we receive the following weights for the assessed criteria; see Table 4.4. Note that only the criterion related to cost should be minimized; the rest of the criteria are to be maximized i.e., we prefer CWSs that have low costs and high accuracy, safety etc.

Table 4. 4: Weights of the selected criteria

Criterion	Cost	Accuracy	Properties	Reliability	Safety
	MIN	MAX	MAX	MAX	MAX
WEIGHTS	0.037	0.19	0.131	0.435	0.207

One of the things to be noted here is related to Consistency Ratio (CR). This ratio measures how consistent the judgements have been relative to large samples of purely random judgements. Based on relevant literature, there seems also to be a tendency of increasing CR with the number of criteria. In our case CR is equal to

5.1% and therefore within the acceptable limits. However, for some of the experts the CR was high which indicates some inconsistency in their opinion. We should note that in cases where there is not much consensus among the experts, the decision makers should be asked to adjust their judgments to obtain more consistent input during the pairwise comparisons. In addition, a direct assignment of weight – thus eliminating the need to use the AHP method altogether- could be considered as an alternative.

4.3.6. Utilizing the TOPSIS methodology to obtain the ranking of the alternatives

The experts evaluated and rated each of the eight different CWS, the alternatives A, for each of the 5 criteria (see also Figure 3.2) using the given criteria using a linguistic scale of 1 to 5. The linguistic variables - very low (VL), low (L), medium (M), high (H) and very high (VH) were used. Again, there is a need to aggregate the opinion of the experts into one to construct a decision matrix. In this case, the aggregated decision matrix is based on the simple geometric mean method i.e., we have calculated the aggregated ratings using the geometric mean method, that is equal to $\sqrt[n]{x_1.x_2.,,x_n}$ where xi is rating of each of the n experts. Another alternative would be the simple average.

Note that there might be cases where the experts involved might not be able to provide a rating e.g., because they feel the option is not relevant or due to limited expertise with the specific solution. This is for instance the case with expert 2; '-' in the table below denotes lack of rating.

Table 4. 5: Ratings of alternatives

EXPERT 1	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	5	5	4	3	3	2	2	4
	Accuracy	5	4	3	3	3	3	2	3
	Properties	3	3	3	3	2	2	2	3
	Reliability	4	5	4	5	3	3	3	4
	Safety	5	4	4	5	4	3	3	3
EXPERT 2	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	3	4	-	-	4	4	-	-
	Accuracy	4	3	-	-	3	3	-	-
	Properties	3	4	-	-	4	3	-	-
	Reliability	3	4	-	-	3	4	-	-
	Safety	4	4	-	-	4	4	-	-
EXPERT 3	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	2	4	4	2	5	3	3	1

	Accuracy	4	3	4	3	4	4	4	3
	Properties	4	3	3	2	3	2	3	4
	Reliability	4	4	3	2	3	2	3	4
	Safety	5	3	4	2	1	1	1	5
EXPERT 4	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	3	4	5	3	5	3	3	1
	Accuracy	4	3	4	2	4	4	4	3
	Properties	4	2	3	2	4	3	3	4
	Reliability	4	3	3	2	3	2	2	4
	Safety	4	2	2	1	3	3	3	4
EXPERT 5	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	2	3	4	2	5	3	2	1
	Accuracy	5	3	4	3	4	4	4	3
	Properties	4	2	3	2	4	3	3	4
	Reliablity	4	3	3	2	3	3	2	4
	Safety	5	2	2	1	1	2	2	5
EXPERT 6	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	2	4	4	3	4	3	3	2
	Accuracy	4	3	4	2	3	4	3	3
	Properties	4	2	3	3	3	3	3	4
	Reliability	3	3	3	2	3	2	2	3
	Safety	5	3	2	1	2	1	2	4
EXPERT 7	**ALTERNATIVES**								
	CRITERIA	A1	A2	A3	A4	A5	A6	A7	A8
	Cost	2	5	4	3	5	3	3	1
	Accuracy	4	3	4	2	4	4	4	3
	Properties	4	3	2	3	3	3	3	4
	Reliability	4	3	2	3	3	2	2	4
	Safety	5	3	2	2	2	1	3	5

CRITERIA	**1**	**2**	**3**	**4**	**5**
NAME	**Cost**	**Accuracy**	**Properties**	**Reliability**	**Safety**
Alternative 1	2.560	4.263	3.684	3.684	4.691
Alternative 2	4.092	3.126	2.627	3.504	2.901
Alternative 3	4.152	3.813	2.804	2.942	2.520
Alternative 4	2.621	2.449	2.449	2.493	1.648
Alternative 5	4.361	3.536	3.337	3.000	2.119
Alternative 6	2.950	3.684	2.831	2.479	1.842
Alternative 7	2.621	3.397	2.804	2.289	2.182
Alternative 8	1.414	3.000	3.813	3.813	4.263

4.3.7 Normalize the decision matrix

Using the vector normalization approach as presented in equation 3.6 (i.e., the ratings of each element in the decision matrix are divided by their average) we obtain Table 4.7 below.

Table 4. 7: Normalized decision matrix

CRITERIA	**1**	**2**	**3**	**4**	**5**
NAME	**Cost**	**Accuracy**	**Properties**	**Reliability**	**Safety**
Alternative 1	0.279	0.437	0.423	0.424	0.559
Alternative 2	0.446	0.321	0.302	0.403	0.346
Alternative 3	0.453	0.391	0.322	0.338	0.301
Alternative 4	0.286	0.251	0.281	0.287	0.196
Alternative 5	0.476	0.363	0.383	0.345	0.253
Alternative 6	0.322	0.378	0.325	0.285	0.220
Alternative 7	0.286	0.348	0.322	0.263	0.260
Alternative 8	0.154	0.308	0.438	0.438	0.508

4.3.8 Determining the Weighted Normalized Decision Matrix

A weighted normalized decision matrix is, then, constructed by multiplying the normalized scores by their corresponding weights, which have been obtained by using the AHP methodology. As an example, the weighted normalized operating cost for A1 is given as follows:

$$P_{ij} = 0.037 \times 0.379 = 0.010$$

Following the same approach, the weighted normalized decision matrix is calculated and presented in Table 4.8.

Table 4. 8: Weighted Normalized decision matrix

	Cost	**Accuracy**	**Properties**	**Reliability**	**Safety**
Alternative 1	0.010	0.083	0.055	0.184	0.116
Alternative 2	0.017	0.061	0.040	0.175	0.072
Alternative 3	0.017	0.074	0.042	0.147	0.062
Alternative 4	0.011	0.048	0.037	0.125	0.041

Alternative 5	0.018	0.069	0.050	0.150	0.052
Alternative 6	0.012	0.072	0.043	0.124	0.045
Alternative 7	0.011	0.066	0.042	0.115	0.054
Alternative 8	0.006	0.058	0.057	0.191	0.105

4.3.9 Obtaining the distances of the positive and negative ideal solution

A+	**0.0057**	**0.0831**	**0.0573**	**0.1907**	**0.1158**
A-	**0.0176**	**0.0477**	**0.0368**	**0.1145**	**0.0407**

The ideal positive solution (A_i^+) is calculated for all the best performance scores and the negative-ideal solution (A_i^-) is calculated for all the worst performance scores at the measures in the weighted normalized decision matrix.

Table 4. 9: Representation of positive and negative ideal solution values

Criteria	**PIS**	**NIS**
Cost	0.06	0.013
Accuracy	0.063	0.032
Technical properties	0.069	0.040
Reliability	0.069	0.041
Safety	0.251	0.018

The positive and negative distances obtained using Eq. 3-11 are used to calculate the ranking that is also known as the closeness coefficient of the ideal solutions. These factors help to rank the weights of the different CWS compared to which the most suitable alternatives can be selected easily; see Table 4.10.

Table 4. 10: Rank

(A_i^+)	(A_i^-)	**Pi**	**Rank**	

0.0081	0.1103	0.931	**1**	**A1**
0.0558	0.0695	0.554	**3**	**A2**
0.0721	0.0476	0.397	**4**	**A3**
0.1082	0.0124	0.103	**8**	**A4**
0.0780	0.0450	0.366	**5**	**A5**
0.0989	0.0275	0.218	**6**	**A6**
0.1009	0.0243	0.194	**7**	**A7**
0.0268	0.1032	0.794	**2**	**A8**

The ranking order of the different alternative weighing systems based on the results presented in Table 4.10 (as also illustrated in Fig. 4-x) is as follows:

$$A_1 > A_8 > A_2 > A_3 > A_5 > A_6 > A_7 > A_8$$

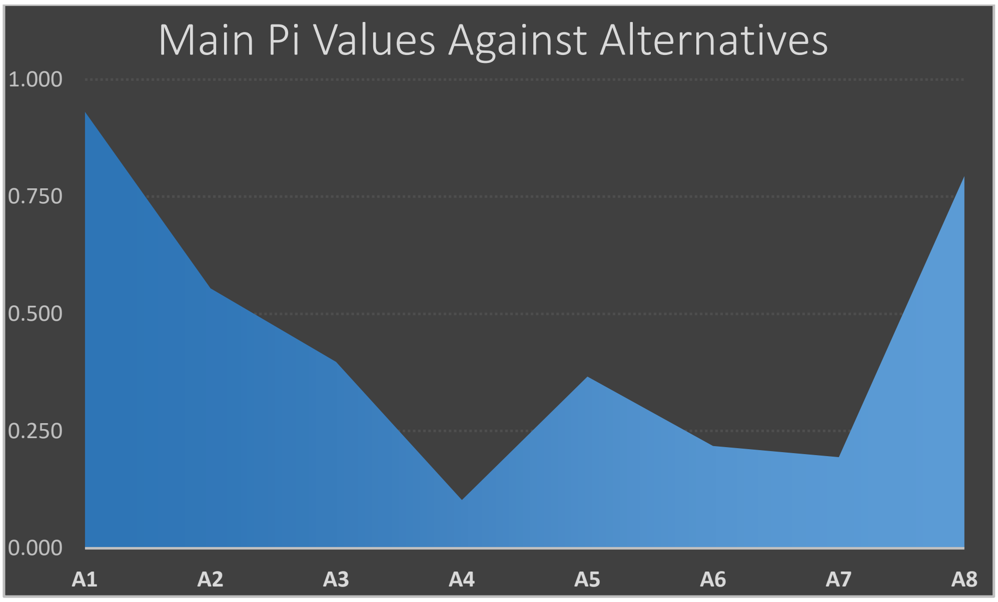

Figure 4. 8: Weighing system ranking, source: Author

Therefore, the three best alternatives based on the expert opinion are Weighbridges, Load sensing systems using spreader twistlock (STS) and Load cells on ship-to-shore cranes.

These results are actually in line with the current practice; many ports have already installed weighbridges, which is ranked the best alternative in this study. A truck carrying a container is driven onto a weighbridge, and the tare weight of the vehicle is deducted to get the container's weight. While weighbridges are often used at ports and may easily be an option for warehouses, however, many shippers baulk at the cost of acquiring one.

4.4 Sensitivity analysis

It is important to stress that all these methodologies are heavily reliant on expert judgement. Based on the results of Table 4.10 (see also Figure 4.9 below) that present the calculated weights with error indication, the experts considered reliability (i.e., the condition of a container weighing system operating at a specified performance level of efficiency and productivity) and safety (i.e. the equipment being protected from or being unlikely to cause danger, risk, or injury when in operation), as the most important criteria in the selection of the equipment. The weights are 43.5% and 20.7% respectively (rewrite and break into 2 sentences, it's too long). At the same time, the accuracy of the equipment as well as the technical properties, which includes expected lifetime, durability and re-calibration, are not considered as important. The corresponding weights are 19% and 13.1% respectively.

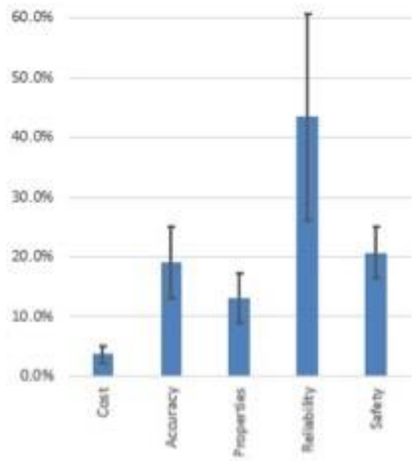

Figure 4. 9: Weights of the selected criteria and their error margins - source: Author

We believe that this needs further investigation as these scores are not rationally explained. We would assume that port operations consider cost as an important parameter, as they can make some profit by providing this service. Furthermore, accuracy is something very important, but it is also a fact that most certified equipment has a high level of accuracy; the error margins are in the area of 5%. Note that there is no agreement within the SOLAS VGM regulations for any margin of error. This means that each IMO member state will decide how the VGM issues are regulated although several countries have published variance guidelines, including the UK, where the enforcement threshold is ±5 percent of the VGM of the container. We assume though that the operators believe that the accuracy of any equipment they consider purchasing would be within the acceptable limits and is thus not an important factor in their decision.

As per the VGM regulation, the shippers are responsible for the verification of the packed container's weight. Some terminals may opt for the "No VGM, No Gate-In" rule and may not allow entry to their terminal without VGM. The shipper can provide VGM verification individually or contact a third-party logistics provider. The weighing equipment must be certificated by the local region and meet the applicable accuracy standards. In this paper, we have analysed the parameters that affect the selection of weighing equipment by port and terminal operators, and these might not be the same for other VGM data providers.

Given the strong influence of the expert opinion on our results, we have performed a sensitivity analysis to check the robustness of our approach. A critical study of the AHP-TOPSIS model structure for the purpose of sensitivity analysis suitability reveals that the input variables of interest in the model to perform the analysis are the criteria and alternatives of the system. In addition, the output response to be observed, is the overall priority rankings. The overall rank of alternatives in the final results obtained from the modelled framework in this chapter, (which deals with the selection of appropriate container weighing systems with respect to the SOLAS VGM regulation requirements), will be highly affected by the weights given to their individual criteria. The sensitivity study will give an understanding of how robust the original decision is in selecting the most suitable CWS and it reveals which criteria led to the original results. It is, therefore, needful to perform a "What-If" scenario analysis to see whether the results would have been different if the criteria weights changed. The important questions that would come to mind are; Will A1 still be the best CWS if the importance of criteria is changed? What if the same importance is given to all the criteria? What if more importance is given to cost or is safety as important as cost?

In this study, the changes in the overall priority ranking of the alternatives were observed when each criterion weight was increased. The sensitivity of the results was analysed when the weight of Cost, Accuracy, Technical properties, Reliability, and Safety were increased by 15% each. The results are presented in Table 4.11 below.

Table 4. 11: Changes to the overall priority ranking of the alternatives

(A)	MAIN Pi VALUE	RANK	COST	RANK	ACCURACY	RANK	TECH. PROPERTIES	RANK	RELIABILITY	RANK	SAFETY	RANK

A1	0.931	1	0.928	1	0.933	1	0.931	1	0.928	1	0.937	1
A2	0.554	3	0.553	3	0.548	3	0.550	3	0.600	3	0.535	3
A3	0.397	4	0.397	4	0.412	4	0.396	4	0.404	4	0.382	4
A4	0.103	8	0.107	8	0.101	8	0.102	8	0.110	8	0.094	8
A5	0.366	5	0.365	5	0.375	5	0.369	5	0.388	5	0.340	5
A6	0.218	6	0.219	6	0.242	6	0.218	6	0.202	6	0.202	6
A7	0.194	7	0.197	7	0.211	7	0.195	7	0.170	7	0.192	7
A8	0.794	2	0.794	2	0.768	2	0.795	2	0.819	2	0.801	2

The results obtained from the sensitivity analysis have been presented both in table 4.11 above and figure 4.10 below. Increasing the cost of equipment by 15% modifies the rank as A1 (0.928), A8 (0.794) and A2 (0.553). Increasing the Equipment Accuracy by 15% modifies the rank as A1 (0.933), A8 (0.768) and A2 (0.548). Increasing Technical properties of equipment by 15% modifies the rank as A1 (0.931), A8 (0.795) and A2 (0.550). Increasing the Reliability of equipment by 15% modifies the rank as A1 (0.928), A8 (0.819) and A2 (0.600). Similarly, increasing the Equipment Safety by 15% modifies the rank as A1 (0.937), A8 (0.801) and A2 (0.535).

Despite that, there were noticeable changes of the output response in a systematic manner as depicted in the graph below; the analysis revealed that none of the changes in the weight of each criterion changes the final ranking and position of the CWS analysed. Thus, asserting the robustness of the modelled framework for selecting the most suitable CWS in view of VGM regulation compliance as well as other cost and benefit criteria which are taken into consideration.

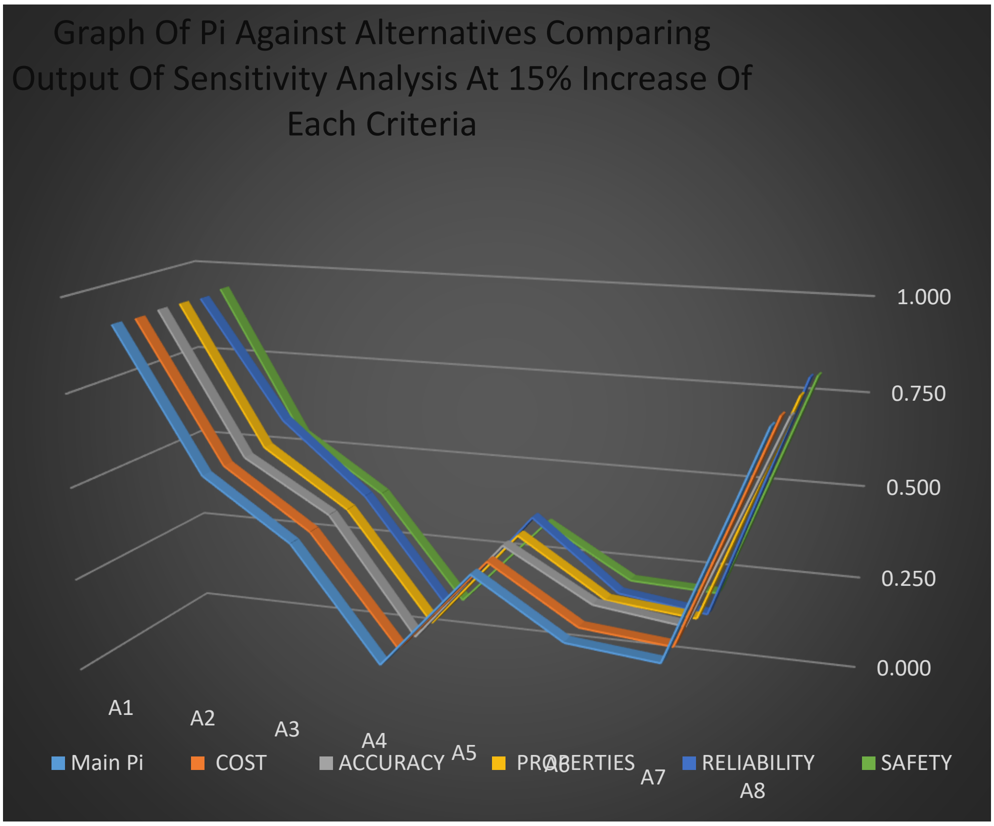

Figure 4. 10: Sensitivity analysis graph - Source: author

This means the choice of A1 A8 and A8 remains the same as the most suitable weighing systems. Hence, ports, shipping companies and logistics providers should invest in these suitable weighing systems that are not only cost-effective but meets the standard of the regulation.

VGM providers looking for a suitable CWS should consider the following approach (4):

- Discuss the options experts or a container weighing system manufacturers or dealers (check and rewrite)
- Review the market, to know which weighing systems are available.
- Conduct an analysis to know which system is cost-effective and would also benefit their company.

In a situation whereby, the port or the VGM provider already has a weighing system in place, they must ensure the following.

- Ensure that the container weighing system meets the standard of the local authority where the system is being used, in agreement with SOLAS VGM regulation

- Ensure they establish a platform that would enable easy access to its users and direct submission of the VGM
- The port or VGM providers must ensure the system undergoes calibration and regular maintenance for the effective operation

4.5 Conclusion

In this chapter, a methodology that could be used for the selection of equipment, CWS that would provide VGM data in compliance with the updated SOLAS regulations was presented (check and rewrite). There is no previous literature on this aspect of VGM, neither has the methodology been applied in the selection of CWS. The method used in this study can deal with the decision-making of choosing a suitable CWS. The application of AHP-TOPSIS with the contribution of participants produced a decision-making model that can be used by a port, a terminal operator or any other VGM provider. The shipper can do the weighing themselves or engage a third-party certified for such a service. This can be a port/terminal operator, (which is the case in our analysis), a freight forwarder, a third-party logistics 3PLs provider or any other third party certified for such a service. Therefore, future research is necessary to revalidate the findings of the suggested model.

As seen from the analysis, the criteria related with benefits such as safety and reliability prevailed in the decision making of a port operator for selecting a CWS. In a recession, these additional costs generated by the SOLAS VGM regulation enforcement may be a significant burden for the port operators, especially in local ports, where the maintenance costs are relatively high. Another huge angle that the methodology is addressing is the potential human error from the wrong use of CWS. Complicated devices may need significant efforts and time from the operators or logistics provider until some level of competency is achieved.

Based on the above, although the methodology is robust, it seems that the results are heavily based on the experts' opinions. It is therefore important to obtain the opinions only of those that are involved into the actual decision e.g., the management team.

The VGM should be as accurate but there are no international set limits. For example, the UK coastguard, which is responsible for compliance in the UK, has set an enforcement tolerance of ±5% or ±500kg, whichever is the greater value, to avoid disruption within the supply chain. Many ports also charge a penalty for false VGM data. Parameters like these severely affect the evaluations provided by the experts, and as a result, grossly affect the ranking. These should be carefully considered by the experts.

In any case, the suggested methodology is mathematically sound and could be used with great accuracy by any party who wishes to purchase equipment to comply with the VGM regulation. In this case, a group of experts should be used to derive the weights based on the company's priorities and then evaluate alternatives.

The AHP step to derive the weights could be skipped if weights are assigned directly by the experts. This could help eliminate issues related to the consistency of the opinion provided by the experts; see discussion on the Consistency Ratio above. A sensitivity analysis to study how changes in the assigned weights can change the ranks could be used to further strengthen the obtained results.

Chapter 5

Assessment of SOLAS VGM Regulation implementation performance in NIMASA

Summary

This chapter focuses on the application of the BSC-AHP model presented in Chapter 3 to measure the SOLAS VGM implementation performance in the Nigerian maritime sector using NIMASA as a case study. The aim of applying the model to NIMASA is to create a framework that can enable maritime authorities to measure their performance. It presents the results of the analysis carried out by the selected departments involved in the regulatory process following the steps of the model as highlighted in the previous chapter. The total performance is derived and results are discussed.

5.1 Introduction

The primary goal of this study is to critically illustrate an application of the combination of BSC and FAHP frameworks in designing a tool that will assess the implementation performance of the SOLAS VGM regulation for a major stakeholder in the maritime industry (national authority), using the Nigerian Maritime Administration and Safety Agency, NIMASA, as a case study. NIMASA is the authority responsible for the implementation of the VGM regulation in Nigeria and has been selected due to easy access of data (being a co-sponsor of this research).

Designing a tool that will assess the implementation performance of the SOLAS VGM regulation using NIMASA as a case study would require the participation from all NIMASA departments involved in the regulatory process. This study seeks to focus on three key departments in NIMASA associated with the regulatory process i.e., the Maritime Labour Service, Marine Environment Management and Maritime Safety and Seafarer's Standard. An auxiliary goal is to produce a tool that can also be applied by other national authorities under IMO implementing the regulation, to assess their performance on VGM from time to time and possibly other future maritime regulations. It also seeks to broaden the usefulness of both BSC and FAHP by applying those systems to a specific aspect of the maritime industry and using

NIMASA as a case study. The study focuses on the practical implementation of a co-ordinated framework, uniting two well-settled techniques for performance analysis and decision-making.

5.2 Data collection for NIMASA departments

The respective questionnaires developed for the 3 key departments were distributed to about 50 experts including managers, assistant managers and other officers. However, the experts had difficulty providing enough feedback within the period of the research. They had time constraints, so couldn't participate in the survey, because it was quite bulky. Another difficulty was that most of the experts did not have much knowledge of pairwise comparisons using Saaty's scale.

Out of the 17 experts who responded, 14 responses were fully complete and were used in our analysis. These experts responded to a questionnaire that has been sent out to the selected experts, who work in the three NIMASA departments, to provide significant feedback about the BSCs and their implementation of the regulation. The questionnaire follows a conventional AHP questionnaire format (nine-point scale pairwise comparisons) based on the derived hierarchy and is divided into five different sections as follows:

I. Section One - General questions; through these, we can ascertain the weight of each expert.
II. Section Two - Table of pairwise comparison on the different departments; to get the department weight.
III. Section Three - Table of pairwise comparison on the Perspective; to derive the weight of the perspective.
IV. Section Four - Table of pairwise comparison on the measures; to derive the weight of the measures.
V. Section Five - Table for scoring the measures.

5.3 Framework

At this stage, our research focuses on devising a well-structured procedure that can access the effective implementation performance of the SOLAS VGM regulation by a national authority, using NIMASA and its three major departments in the regulatory process (with respect to their cost and benefit) in implementing the regulation. The framework was developed focusing on NIMASA which is Nigeria's National authority and has the total responsibility for introducing and monitoring the effective implementation of maritime regulations in the Nigerian maritime industry per the responsibilities of an IMO member state. Each of its departments is therefore considered a part of NIMASA in the implementation process.

Following Ch.4 below are the steps to assess the performance of NIMASA. as:

I. Problem Definition
II. Selection of the major NIMASA departments that are concerned with the implementation of the VGM regulation in the Maritime industry.
III. Determining the perspectives and measures for each department that can assess the costs and benefits of the implementation of the regulation.
IV. Creating the hierarchy structure for evaluating the VGM regulation performance.
V. Evaluating the weight of each department, its perspectives and measures and determining the overall priority of their weights for the level of their responsibility in the regulatory procedure.
VI. Creating an industrial tool capable of evaluating the implementation performance of NIMASA in terms of compliance with the SOLAS regulation.

5.3.1 Step I - Problem definition

The hypothesis to be investigated is whether the VGM Regulation has been successfully implemented and whether the benefits and costs generated by the regulation are balanced between the NIMASA departments in the regulatory process. The total implementation performance rate of the regulation would be evaluated successfully by measuring the costs and benefits for each of the departments combined with their level of responsibilities in the regulatory process. The outcome of the evaluation is considered as the total performance implementation rate of the VGM regulation for NIMASA.

5.3.2 Step II - Selection of the major NIMASA departments

The second step is to select the major departments in NIMASA that are concerned with the implementation of the SOLAS VGM regulation. To select the sample of representative major departments that are most concerned with implementing the regulation, a department analysis was carried out based on the literature and the regulatory requirements. It is expedient to limit the number of departments used in this study to a manageable number as NIMASA is a very large organisation and comprises both major and minor units in different parts of the country. The adopted approach is that the operations of the departments that are mostly affected by the requirements of the SOLAS VGM regulation were selected. That is, departments were selected based on their significance to the implementation process of the SOLAS VGM regulation.

Among the various departments in NIMASA that were found from the sources mentioned above, three units were selected for evaluation of the suggested method, which is designed to measure the implementation performance of the regulation. These three key departments in NIMASA are mainly responsible for implementing the regulation and they are the Maritime labour service unit, Maritime safety and seafarer's standard, and marine environment Management. Their responsibility in NIMASA and how it concerns implementation compliance of the regulation are discussed below.

Review of NIMASA:

The Nigerian Maritime Administration and Safety Agency (NIMASA) is the highest regulatory and promotional maritime agency. The Agency was formed from the merger of the National Maritime Authority and Joint Maritime Labour Industrial Council (previous parastatals of the Federal Ministry of Transport) on the 1st of August 2006. The commitment of controlling the Maritime industry in Nigeria lays on the Agency through the important instruments.

The Agency was set up essentially for the management of Maritime Safety Seafarers Standards and Security, Maritime Labour, Shipping Regulation, Promotion of Commercial Shipping and Cabotage exercises, Pollution Prevention and Control in the marine conditions; the Agency additionally enforces the International Maritime Organization (IMO) and International Labour Organization (ILO) Conventions.

The core responsibilities of NIMASA are (NIMASA,2020):

I. *"Pursue the advancement of shipping and regulatory issues relating to merchant shipping and seafarers.*

II. *Administration and regulation of shipping licences as well as seafarers' certification.*

III. *Institution of Maritime Training and Safety Standards*

IV. *Regulation of safety of shipping as regards the construction of ships and navigation.*

V. *Setting up Maritime Search and Rescue Services*

VI. *Give guidance and guarantee compliance with vessels' security measures*

VII. *Carry out air/coastal surveillance and control and avoid maritime pollution*

VIII. *Create and actualize strategies and projects, which will enhance the development of local capacity in ownership, operating and construction of ships and other maritime infrastructure.*

IX. *Enhance and administer the provision of the Cabotage Act. 2003*

X. *Carry out Port/Flag State obligations and provide maritime security.*

Create the process for the implementation of conventions of the IMO and the ILO, and other global conventions to which the Federal Republic of Nigeria is a party *on Maritime Safety and Security, Maritime Labour, Commercial Shipping, and for the implementation of Codes, Resolutions and Circulars emerging from there."*

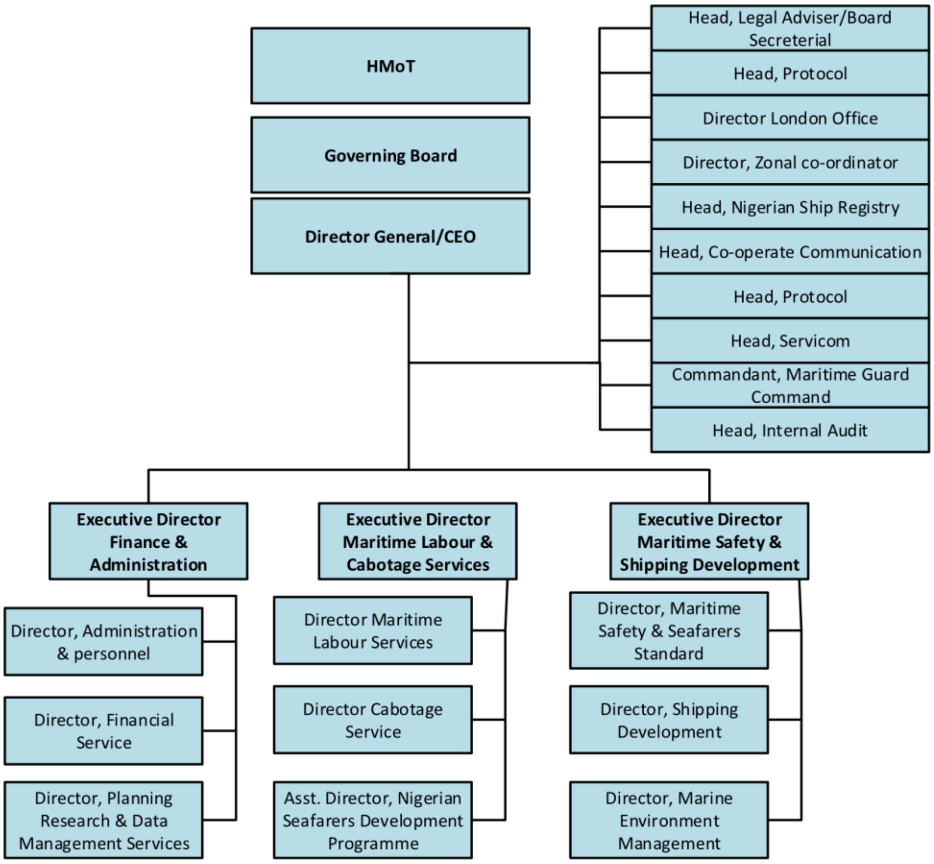

Figure 5. 1: The NIMASA Organogram - Source: NIMASA (2020)

The agency is structured into three directorates; see Fig. 5.1. Each directorate is under the leadership of an Executive Director (EDs). Each Directorate has two or more Departments, headed by a director.

Maritime Environment Management (MEM)

The functions of the Marine Environment Management Department are generally derived from the IMO Conventions and are related to the protection of the marine environment. Broadly, the department implements and enforces compliance with the said Conventions. To accomplish its mandate, it requires careful study of the conventions so that the framework and strategies for their implementation in the short, medium and long terms could be drawn.

Maritime Labour Service (MLS)

The Maritime Labour Department of the Agency is mandated to pursue the development of Shipping and regulate matters relating to Merchant Shipping and Seafarers. Some of its functions are as follows:

- *"Regulates the Implementation of Seafarers and Dockworkers employment, as well as Safety and Health Standards in relation to the provision of Maritime Labour in the Nigerian Maritime Zone, International Maritime Labour Market and ILO Conventions.*
- *registers every Maritime Labour Employer and ensures that they comply with existing regulations and standards relating to crewing, wages, safety, welfare and training at Ports and on-board vessels.*
- *provides direction on qualification, certification, employment and welfare of seafarers and undertakes the general system management for the production and issuance of the Seafarers Identity documents;*
- *develops and implements policies and programmes including Cabotage Act 2003, which will facilitate the growth of Local capacity in operating ships;*
- *performs flag and Port State duties and establishes the procedure for the implementation of ILO/IMO Conventions, Codes, Circulars and resolutions to which Nigeria is a party;*
- *implements the provisions of the Maritime Labour Convention, 2006 (MLC, 2006) and ensures its employers engage only registered seafarers and dockworkers in any port, terminal, jetty or offshore platform in Nigeria or on board any Nigerian Vessel"* (NIMASA, 2020).

Maritime Safety and Seafarers Standard (MSSS)

The Maritime Safety and Seafarers Standard Department (MSSS) manages shipping exercises in Nigeria through the execution of important IMO Conventions, which have been endorsed, structured and published. The department is subdivided into the following units; Maritime survey and certification, seafarers' standards and training division, emergency services division, marine casualty investigation/accident investigation bureau and, hydrographic survey service unit. Among others, the department is responsible for (NIMASA, 2020):

- *"Maritime surveys and certification: investigations completed in the office incorporate (check and rewrite), Flag State Surveys and Port State Surveys.*
- *Flag State Inspections: this is the Agency's authority over vessels flying the Nigerian flag. This investigation can either be planned or unscheduled and intends to guarantee consistency with the provision of the Merchant Shipping Act 2007, NIMASA Act 2007 and International Conventions and Codes which Nigeria has endorsed and cultivated., For example, SOLAS, MARPOL 73/78, STCW, ISPS and ISM Codes. This inspection system is completed by both selected surveyors.*
- *Port State Control (PSC): this covers the Agency's authorized duty, control and the management of foreign vessels calling and exchanging inside Nigerian Ports with a view to keeping unacceptable vessels from entering Nigerian ports. This*

investigation is done as per the Memorandum of Understanding on Port State Control for West and Central Africa (Abuja MoU). The PSC report is typically entered online through the Abuja MoU Information System (AMIS)".

5.3.3 Step III- Determining the main performance measures to assess the implementation of SOLAS VGM regulation in NIMASA

A structure of the main performance measures in the maritime industry was produced to identify the contribution and performance of all three departments in the regulation implementation process. It is worthy to note that each of the three representative departments chosen for this research has its own unique characteristics. Therefore, different main performance measures should apply to every perspective. The departments were diverse kinds of units in different locations and a group of people in the supply chain of the Nigerian maritime industry.

The measures of each perspective for the representative department were based on a review of the literature and an analysis of the department's responsibilities and needs while implementing the SOLAS VGM regulation. The complete main performance measures of the BSCs for all the departments with their perspectives for the evaluation of the implementation performance of the SOLAS VGM regulation in the maritime industry are presented in Tables 5.1-5.3.

Table 5. 1: Perspective and measures for the Maritime Labour Service department

Maritime Labour Service	
Perspective	**Measures**
Financial	Increase revenue from regulating the implementation of new safety standards through VGM requirements in relation to the provision of maritime labour in Nigeria.
	Increase revenue from existing cost of inspection due to risk of mis-declared weights to ensure maritime labour employers compliance to maintain safety.
	Reduce administration costs.
	Minimize the need for immediate cash expenditure to meet regulations requirements.
Customer	Achieve IMO standard of implementation as member state.
	High-level playing field in the maritime industry.
	Increase quality of regulation enforcement and compliance
	Increase reputation and credibility
Learning and growth	Reduce the need to hire additionally employees
	Reduce the need to purchase additionally IT applications
	Reduce number of misdeclared container incidents.
	Introduce new shipping standards
Internal business	Minimize efforts to carry out risk assessment for the VGM regulation.
	Minimize efforts to develop plans to implement the VGM regulation.
	Minimize efforts to provide training regarding implementation of the VGM regulation.
	Minimize efforts to review the internal business process

Table 5. 2: Perspectives and measures for the Marine Environment Management department

Marine Environment Management	
Perspective	**Measures**
Financial	Profit- Increase Profit from implementation and enforcement services
	Revenue - Increase revenue from reduced costs associated with response and laboratory analysis functions wrecks due to mis declared weights
	Cost - Reduce administration cost
	Use of Assets - Minimize the need for immediate cash expenditure to meet regulation requirement
Customer	Productivity - Increase available solutions for wide variety of problems associated with coastal and maritime transport especially in marine pollution.
	Competitiveness- Increase performance of the organization
	Quality - Achieve a sustainable and healthy shipping environment
	Reputation - Increase in reputation and credibility of the organization
Learning and growth	Human capital - Reduce the need to hire additional employees
	Information capital - Reduce the need to purchase additional IT applications
	Organisational capital - Reduce number of mis-declared container incidents.
	Innovation - Introduce new shipping standards
Internal Business	Risk analysis - Minimize efforts to carry out risk assessment for the VGM regulation.
	Planning - Minimize efforts to develop plans to implement the VGM regulation.
	Training - Minimize efforts to provide training regarding implementation of VGM regulation.
	Review - Minimize efforts to review the internal business process

Table 5. 3: Perspective and measures for Maritime Safety and Seafarers Standard department

Maritime Safety and Seafarers Standard	
Perspective	**Measures**
Financial	Profit - Increase profit from newly improved safety standards in flag state and port state control services.
	Revenue- Increase revenue from reduced existing cost of surveying unseaworthy ships caused by mis declared weights of cargo.
	Cost - Reduce administration cost of maritime safety functions such as casualty investigations resulting from misdeclared weights
	Use of Assets - Minimize the need for cash to meet regulation requirement
Customer	Productivity- Increase the demand of international maritime safety services as IMO member state
	Competitiveness- Increase in standard of maritime safety and shipping development
	Quality - Increase implementation and enforcement quality of SOLAS convention gratified in Nigeria
	Reputation - Increase in reputation and credibility
Learning and growth	Human capital - Reduce the need to hire additional employees
	Information capital - Reduce the need to purchase additional IT applications
	Organisation capital - Reduce number of mis declared container incidents.
	Innovation - Introduce new shipping standards

Internal business	Risk analysis - Minimize efforts to carry out risk assessment for a new regulation.
	Planning - Minimize efforts to develop plans to implement a new regulation.
	Training - Minimize efforts to provide training regarding implementation of a new regulation.
	Review - Minimize efforts to review the internal business process

5.3.4 Step IV – Creating the hierarchical structure

The hierarchical structure is presented in Fig. 5.2, which includes the following four levels:

Level (1) is the overall desired goal, which is the performance measurement of the SOLAS VGM regulation.

Level (2) is the implementation performance of the three-selected NIMASA departments.

In level (3), each of the performance measures of a department is divided into four different perspectives.

A perspective is sub-divided into four measures in Level (4).

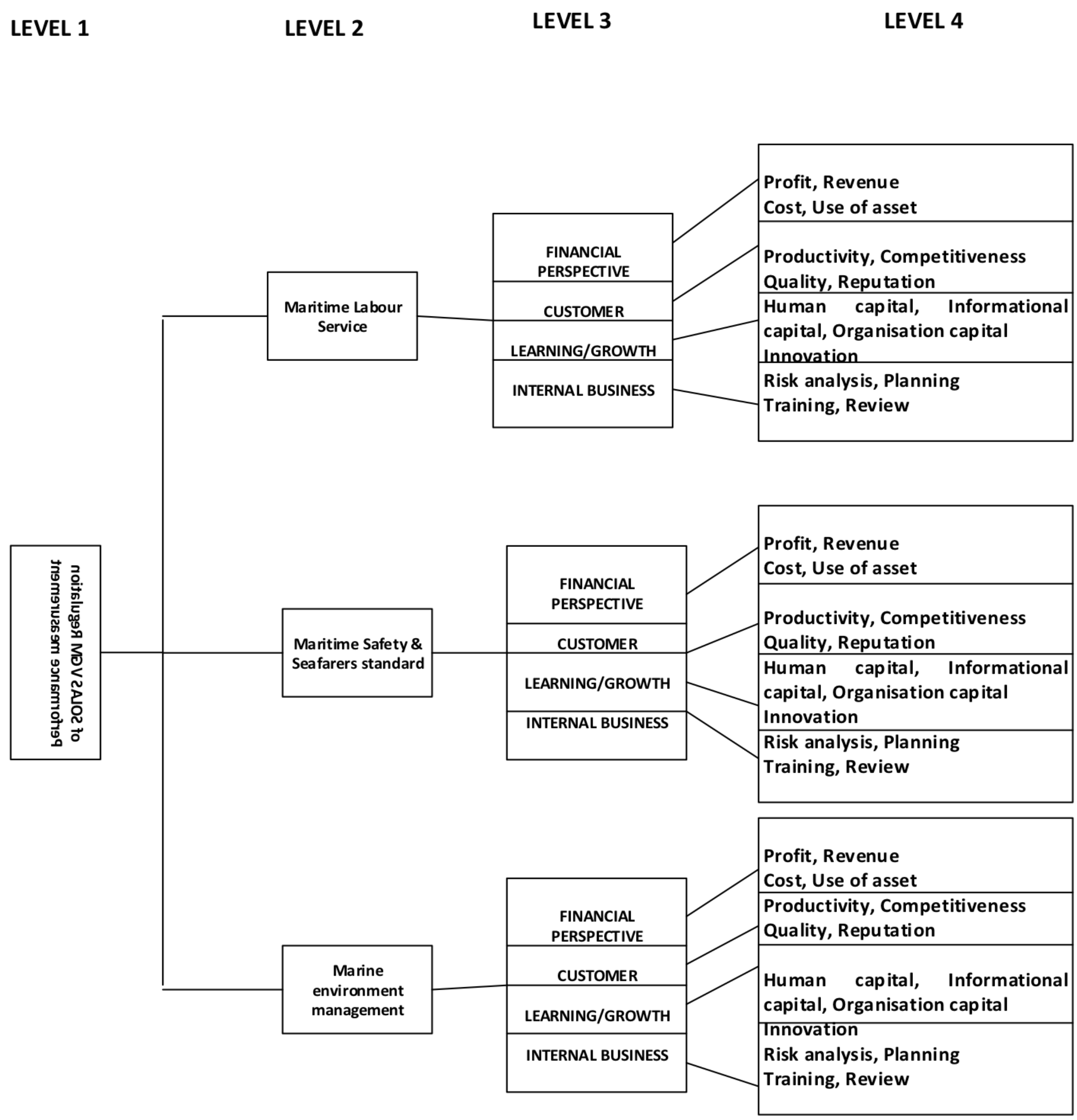

Figure 5. 2: Performance evaluation hierarchy for NIMASA department

5.3.5 Step V.1 – Calculating the overall priority of the weights

Using the steps presented in Section 4.4.8 the weights of all the departments, their perspectives and measures are evaluated and are ranked for their overall priority in the regulatory process while implementing the SOLAS VGM regulation. This enables NIMASA and its departments to understand their level of responsibility and needs on areas to improve in the regulatory process as the costs and benefits, strengths, and weaknesses of implementing the regulation would be realised. Furthermore, from these weights when combined with the current implementation measures, the total implementation performance measurement can be determined.

5.3.5.1 Evaluation of the Perspective weight for the departments

Similarly, to the previous step, experts were asked to make pairwise comparisons for the four perspectives of each department (see section 3 of the questionnaire). The judgments of the experts were used to produce pairwise comparison tables for all the perspectives of the three departments.

Table 5.4 below shows the comparisons of a detailed example for the pairwise comparisons between the perspectives of the Maritime Labour service department that was carried out.

(Note: Pairwise matrices are symmetric: For reasons of simplicity in the table below we present the upper diagonal).

Table 5. 4: Pairwise comparisons of the perspectives (MLS)

Perspectives	Financial			Customer			Internal business			Learn/growth		
Financial	1	1	1	6	7	8	4	5	6	1/8	1/7	1/6
	1	1	1	1/8	1/7	1/6	6	7	8	4	5	6
	1	1	1	6	7	8	6	7	8	8	9	9
	1	1	1	8	9	9	8	9	9	8	9	9
Customer				1	1	1	4	5	6	4	5	6
				1	1	1	8	9	9	6	7	8
				1	1	1	6	7	8	5	6	7
				1	1	1	1/9	1/9	1/8	1/9	1/8	1/7
Internal business							1	1	1	6	7	8
							1	1	1	4	5	6
							1	1	1	1/5	¼	1/3
							1	1	1	8	9	9
Learn/growth										1	1	1
										1	1	1
										1	1	1
										1	1	1

Table 5. 5: Pairwise comparisons of the perspectives (MSSS)

Perspectives	Financial			Customer			Internal business			Learn/growth		
Financial	1	1	1	1	1	1	2	3	4	2	3	4
	1	1	1	1/3	½	1	1/4	1/3	1/2	1/5	1/4	1/3
	1	1	1	7	8	9	7	8	9	1/5	1/4	1/3
	1	1	1	1/9	1/9	1/8	1/9	1/9	1/8	1/8	1/7	1/6
Customer				1	1	1	1/4	1/3	1/2	1/4	1/3	½
				1	1	1	1/4	1/3	1/2	1/4	1/3	½
				1	1	1	1	1	1	5	6	7
				1	1	1	1/9	1/9	1/8	1/8	1/7	1/6

Internal business							1	1	1	1	2	3
							1	1	1	1	2	3
							1	1	1	1	2	3
							1	1	1	8	9	9
Learn/growth										1	1	1
										1	1	1
										1	1	1
										1	1	1

Table 5. 6: Pairwise comparisons of the perspectives (MEM)

Perspectives	Financial			Customer			Internal Business			Learn/growth		
Financial	1	1	1	1/8	1/7	1/6	1/8	1/7	1/6	8	9	9
	1	1	1	1	1	1	4	5	6	1/6	1/5	1/4
	1	1	1	6	7	8	6	7	8	7	8	9
	1	1	1	1/3	½	1	3	4	5	2	3	4
	1	1	1	1/6	1/5	1/4	4	5	6	1/5	1/4	1/3
	1	1	1	6	7	8	6	7	8	7	8	9
Customer				1	1	1	6	7	8	8	9	9
				1	1	1	1/6	1/5	1/4	1/6	1/5	1/4
				1	1	1	8	9	9	8	9	9
				1	1	1	1/5	1/4	1/3	2	3	4
				1	1	1	6	7	8	1/6	1/5	1/4
				1	1	1	8	9	9	8	9	9
Internal Business							1	1	1	8	9	9
							1	1	1	6	7	8
							1	1	1	8	9	9
							1	1	1	2	3	4
							1	1	1	6	7	8
							1	1	1	6	7	8
Learn/growth										1	1	1
										1	1	1
										1	1	1
										1	1	1
										1	1	1
										1	1	1

Then a fuzzy decision matrix was designed after the experts' knowledge and experience proficiency was analysed with respect to their judgement by multiplying the above table with the weight of experts with their respective judgements.

To save space, we illustrate how the results can be obtained using the fuzzy AHP approach by presenting MEM department only. Although the calculations have been carried out in the same way for the other 2 departments as well.

The fuzzy decision matrix for the MEM is shown in table 5.7 below. Note that Table 5.7 is the complete matrix of Table 5.6 presented above.

Table 5. 7: Fuzzy Matrix of the perspectives (MEM experts)

Measures	Financial	Customer	Internal Busin	Learn & Growth
Financial	(1,1,1)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(8,9,9)
	(1,1,1)	(1,1,1)	(4,5,6)	(1/6,1/5,1/4)
	(1,1,1)	(6,7,8)	(6,7,8)	(7,8,9)
	(1,1,1)	(1/3,1/2,1)	(3,4,5)	(2,3,4)
	(1,1,1)	(1/6,1/5,1/4)	(4,5,6)	(1/5,1/4,1/3)
	(1,1,1)	(6,7,8)	(6,7,8)	(7,8,9)
Customer	(6,7,8)	(1,1,1)	(6,7,8)	(8,9,9)
	(1,1,1)	(1,1,1)	(1/6,1/5,1/4)	(1/6,1/5,1/4)
	(1/8,1/7,1/6)	(1,1,1)	(8,9,9)	(8,9,9)
	(1,2,3)	(1,1,1)	(1/5,1/4,1/3)	(2,3,4)
	(4,5,6)	(1,1,1)	(6,7,8)	(1/6,1/5,1/4)
	(1/8,1/7,1/6)	(1,1,1)	(8,9,9)	(8,9,9)
Internal Business	(6,7,8)	(1/8,1/7,1/6)	(1,1,1)	(8,9,9)
	(1/6,1/5,1/4)	(4,5,6)	(1,1,1)	(6,7,8)
	(1/8,1/7,1/6)	(1/9,1/9,1/8)	(1,1,1)	(8,9,9)
	(1/5,1/4,1/3)	(3,4,5)	(1,1,1)	(2,3,4)
	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)
	(1/8,1/7,1/6)	(1/9,1/9,1/8)	(1,1,1)	(6,7,8)
Learn & Growth	(1/9,1/9,1/8)	(1/9,1/9,1/8)	(1/9,1/9,1/8)	(1,1,1)
	(4,5,6)	(4,5,6)	(1/8,1/7,1/6)	(1,1,1)
	(1/9,1/8,1/7)	(1/9,1/9,1/8)	(1/9,1/9,1/8)	(1,1,1)
	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)
	(3,4,5)	(4,5,6)	(1/8,1/7,1/6)	(1,1,1)
	(1/9,1/8,1/7)	(1/9,1/9,1/8)	(1/8,1/7,1/6)	(1,1,1)

The triangular fuzzy numbers from Table 5.7 are averaged using Eq. 3.5 and their results are presented in Table 5.8. To illustrate the calculations, take for example the pairwise comparison between the 'Financial' perspective and the 'Customer' perspective made by the four different experts in the MEM department as per Table 5.8. The logical systematic concessions between the three opinions can be determined by calculating their average as shown below:

$$E_{\tilde{m}_x} = \frac{\sum_{i=1}^{r} E_i}{r} = \begin{Bmatrix} \dfrac{\frac{1}{8}+1+6+\frac{1}{3}+\frac{1}{6}+6}{6} \\ \dfrac{\frac{1}{7}+1+7+\frac{1}{2}+\frac{1}{5}+7}{6} \\ \dfrac{\frac{1}{6}+1+8+1+\frac{1}{4}+8}{6} \end{Bmatrix} = (2.271,2.640,3.069)$$

Table 5. 8: Aggregated values (MEM department)

	Financial	Customer	Internal Business	Learn & Growth
Financial	**(1,1,1)**	(2.271,2.640,3.069)	(3.854,4.690,5.528)	(4.061,4.742,5.264)
Customer	(2.042,2.548,3.056)	**(1,1,1)**	(4.728,5.408,5.764)	(4.389,5.067,5.250)

Internal Business	(1.131,1.323,1.528)	(1.245,1.585,1.931)	**(1,1,1)**	(6.000,7.000,7.667)
Learn & Growth	(1.264,1.616,1.985)	(1.431,1.778,2.146)	(0.141,0.164,0.208)	**(1,1,1)**

The defuzzification stage follows using Eq. 3.4. Therefore, the crisp numbers for the elements of the above fuzzy decision matrix are demonstrated using the comparison of financial perspective against the 'Financial' perspective of the MEM department as follows:

$$M_{Crisp} = \frac{(b+a+c)}{3} = \frac{2.271 + 2.640 + 3.069}{3} = 2.660$$

Table 5. 9: Defuzzified results of fuzzy matrix for the perspectives of the MEM department

	Financial	**Customer**	**Internal Business**	**Learn & Growth**
Financial	1	2.660	4.691	4.689
Customer	2.548	1	5.300	4.902
Internal Business	1.327	1.587	1	6.889
Learn & Growth	1.622	1.785	0.171	1

The λ_{max} of the perspectives decision matrix above is calculated by using Equation 3.1 as 9.237 and RI value is 0.9 by reference to Table 3.1.
When n= number of Perspective = 4, the CI and CR values are calculated from Equations 3.3 and 3.5 respectively as,

$$CI = \frac{\lambda_{max} - n}{n-1}$$
$$where \lambda_{max} = 9.237$$
$$CI = \frac{9.237 - 4}{4-1} = 1.746$$
$$CR = \frac{CI}{RI} = \frac{1.746}{0.9} = 1.94$$

Please see further below for a comment on the high CR ratios.
The procedure described regarding the MEM perspectives ranking is followed for the other two departments and their perspectives. Table 5.10 shows the relevant weights of the various perspectives for each department, which indicates their relative importance in the implementation process.

Table 5. 10: The weight of each department's perspectives in the implementation regulatory process

Department	PERSPECTIVES	WEIGHT	RANK
Maritime Labour Service	Financial	0.387	1
	Customer	0.278	2
	Internal business	0.157	4
	Learning & growth	0.178	3
Maritime Safety and seafarers Management	Financial	0.261	2
	Customer	0.174	4
	Internal business	0.340	1
	Learning & growth	0.226	3
Marine Environment Management	Financial	0.305	2
	Customer	0.322	1
	Internal business	0.228	3
	Learning & growth	0.144	4

5.3.5.2 Aggregation of the Perspectives for all experts

The overall priorities of the four different perspectives under each of the three key departments were calculated to reveal their level of responsibility in the regulatory process by using Eq. 3.3. The results of the aggregated weights of the perspectives for all departments are presented in Table 5.11.

Table 5. 11: Overall priority of perspectives for all departments

Perspective Weights	MLS	MSM	MEM	Overall priorities	Rank
Financial	0.387	0.261	0.305	0.316	**2**
Customer	0.278	0.174	0.322	0.235	**4**
Internal business	0.157	0.340	0.228	0.252	**3**
Learning &Growth	0.178	0.226	0.144	0.784	**1**

One can notice that the perspective that has the highest overall priority in the implementation of the regulation in NIMASA is the 'Learning & growth' one (a weight of 0.784). The second priority for the departments is the financial perspective with a weight of 0.316, followed by the internal business perspective with a weight of 0.252. Consequently, it can be inferred that NIMASA's departments are more concerned with issues related to 'Learning and growth' and finance rather than with the internal business and customer satisfaction perspective of the regulatory implementation process. This indicates that the economic consequences the departments may suffer, as well as the required knowledge to comply with the regulation, are more important to them than how the outcome of implementation would improve their customer satisfaction and the availability of the right resources required by departments to effectively implement the SOLAS VGM regulation. However, it should be emphasised that these conclusions of the overall priorities of perspectives for all three departments are generic to other national authorities in the maritime industry with respect to the implementation of the regulation. Thus, a single department may have different priorities or perspectives. For example, the internal business perspective has a higher weight than the financial perspective in the case of the MSM department.

5.3.5.3 Step V.2- Evaluation of measures for all perspectives for each department

The experts from the different participants were requested to make pairwise comparisons for the four measures of each perspective (see Section 4 of the questionnaire; Appendix C). The judgments of the experts were used to produce pairwise comparisons tables for all the measures of the four perspectives under each department. Table 5.12 below shows the comparisons of a detailed example for the pairwise comparisons between the measures of the monetary perspective under the MEM department that was carried out.

Table 5. 12: Expanded pairwise comparisons for measures of financial perspectives of the MEM department

Measures	Profit	Revenue	Cost	Use of Asset
Profit	(1,1,1)	(1,1,2)	(1/5,1/4,1/3)	(1/6,1/5,1/4)
	(1,1,1)	(1/9,1/9,1/8)	(1/9,1/9,1/8)	(1/9,1/8,1/7)
	(1,1,1)	(1/3,1/2,1)	(1/4,1/3,1/2)	(1/6,1/5,1/4)
	(1,1,1)	(6,7,8)	(6,7,8)	(6,7,8)
	(1,1,1)	(1/9,1/9,1/8)	(8,9,9)	(4,5,6)
	(1,1,1)	(8,9,9)	(6,7,8)	(4,5,6)
Revenue	(1/2,1,1)	(1,1,1)	(6,7,8)	(4,5,6)
	(8,9,9)	(1,1,1)	(1/9,1/8,1/7)	(1/9,1/8,1/7)
	(1,2,3)	(1,1,1)	(1/4,1/3,1/2)	(1/5,1/4,1/3)
	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)	(6,7,8)
	(8,9,9)	(1,1,1)	(8,9,9)	(4,5,6)
	(1/9,1/9,1/8)	(1,1,1)	(1/9,1/9,1/8)	(1/8,1/7,1/6)
Cost	(3,4,5)	(1/8,1/7,1/6)	(1,1,1)	(1/3,1/2,1)
	(8,9,9)	(7,8,9)	(1,1,1)	(1/9,1/8,1/7)
	(2,3 1/33,4)	(2,3 1/33,4)	(1,1,1)	(1/4,1/3,1/2)
	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1,1,1)	(6,7,8)
	(1/9,1/9,1/8)	(1/9,1/9,1/8)	(1,1,1)	(4,5,6)
	(1/8,1/7,1/6)	(8,9,9)	(1,1,1)	(1/6,1/5,1/4)
Use of Asset	(4,5,6)	(1/6,1/5,1/4)	(1,2,3)	(1,1,1)
	(7,8,9)	(7,8,9)	(7,8,9)	(1,1,1)
	(4,5,6)	(3,4,5)	(2,3 1/33,4)	(1,1,1)
	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1,1,1)
	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1,1,1)
	(1/6,1/5,1/4)	(6,7 3/71,8)	(4,5,6)	(1,1,1)

The fuzzy decision matrix for the measures of financial perspective under the MEM department is shown in Table 5.13

Table 5. 13: Aggregated matrix for the measures of financial perspectives under MEM department

	Profit	Revenue	Cost	Use of Asset

Profit	(1,1,1)	(2.593,2.954,3.375)	(3.427,3.949,4.326)	(2.407,2.921,3.440)
Revenue	(2.956,3.542,3.715)	(1,1,1)	(3.412,3.928,4.295)	(2.406,2.920,3.440)
Cost	(2.227,2.738,3.076)	(2.894,3.405,3.743)	(1,1,1)	(1.810,2.193,2.649)
Use of Asset	(2.576,3.090,3.611)	(2.743,3.264,3.778)	(2.382,3.062,3.736)	(1,1,1)

Table 5. 7: Defuzzified results of fuzzy matrix for the perspectives of MEM experts

	Profit	**Revenue**	**Cost**	**Use of Asset**
Profit	1	2.974	3.901	2.923
Revenue	3.405	1	3.878	2.922
Cost	2.680	3.347	1	2.217
Use of Asset	3.093	3.262	3.060	1

The λ_{max} of the perspectives decision matrix above is 10.397

In addition, RI value is 0.9 by reference to Table 4.1.

When n= number of Perspectives =4, the CI and CR values are calculated:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$where \lambda_{max} = 10.397$$

$$CI = \frac{10.397 - 4}{4 - 1} = 2.132$$

$$CR = \frac{CI}{RI} = \frac{2.132}{0.9} = 2.369$$

As I remark, although we have received a good number of responses across the departments, there is enough evidence (high CR ratios) that the experts do not fully comprehend the tasks given and more research is needed. At the same, assigning weights directly or changing parts of their responses to satisfy the criteria could have helped. We feel that the first approach might work better and therefore we propose further research on that front.

Table 5. 15: Performance rate of Maritime Labour Service measures

P	Measures	Performance Rate	WM	Rm	$\sum_{b=1}^{g} Rm$
	Profit	5.667	0.370	2.096	
Financial	Revenue	7.083	0.257	1.821	6.707
	Cost	6.250	0.196	1.222	
	Use of Asset	8.833	0.177	1.566	
	Productivity	9.333	0.396	3.699	
Customer	Competitiveness	8.417	0.300	2.527	8.780
	Quality	8.333	0.204	1.698	
	Reputation	8.583	0.100	0.855	
	Risk analysis	5.417	0.317	1.716	
Internal Bussiness	Planning	7.417	0.278	2.064	6.571
	Training	7.250	0.271	1.966	
	Review	6.167	0.134	0.825	
	HumanCapital	3.500	0.412	1.442	
Learning & Growth	Information Capital	3.250	0.202	0.657	4.768
	Organisation Capital	6.917	0.126	0.872	
	Innovation	6.917	0.260	1.797	

Table 5. 16: Performance rate of Maritime Safety Management measures

P	Measures	Performance Rate measures	WM	Rm	$\sum_{b=1}^{g} Rm$
	Profit	6.000	0.209	1.254	
Financial	Revenue	5.750	0.336	1.931	5.776
	Cost	6.250	0.252	1.576	
	Use of Asset	5.000	0.203	1.016	
	Productivity	6.500	0.169	1.100	
Customer	Competitiveness	6.750	0.172	1.159	7.009
	Quality	7.000	0.387	2.707	
	Reputation	7.500	0.272	2.042	
	Risk analysis	7.000	0.327	2.287	
Internal Bussiness	Planning	6.000	0.235	1.413	6.288
	Training	6.000	0.281	1.687	
	Review	5.750	0.157	0.901	
	HumanCapital	4.000	0.199	0.797	
Learning & Growth	Information Capital	4.000	0.186	0.744	5.537
	Organisation Capital	6.500	0.298	1.935	
	Innovation	6.500	0.317	2.061	

Table 5. 17: Performance rate of Marine Environment Management measures

P	Measures	Performance Rate	WM	Rm	$\sum_{b=1}^{g} Rm$
Financial	Profit	7.000	0.258	1.805	6.813
	Revenue	6.667	0.270	1.798	
	Cost	7.111	0.227	1.616	
	Use of Asset	6.500	0.245	1.594	
Customer	Productivity	7.111	0.345	2.456	7.089
	Competitiveness	6.778	0.235	1.596	
	Quality	7.389	0.204	1.506	
	Reputation	7.111	0.215	1.531	
Internal Bussiness	Risk analysis	7.556	0.433	3.268	7.725
	Planning	7.889	0.198	1.563	
	Training	8.056	0.248	1.999	
	Review	7.389	0.121	0.896	
Learning & Growth	HumanCapital	6.333	0.348	2.203	6.254
	Information Capital	7.000	0.237	1.661	
	Organisation Capital	5.000	0.265	1.327	
	Innovation	7.111	0.149	1.063	

The rate of each perspective RP_a^c is calculated by using equation 3.8. The weight of a given perspective wP_a^c is multiplied by its corresponding total rate of measures $Rm_{b^{a,c}}^{a}$ in order to give a perspective rate as demonstrated for the financial perspective rate of MEM below using Eq. 3.8.

$$RP_{MEM}^{financial} = \sum_{b=1}^{g} Rm_{b^{a,c}}^{a} \times wP_a^c = 6.813 \times 0.305 = 2.079$$

Similarly, the rates of the other perspectives for the MEM - customer, internal business and learn and growth were calculated to be 2.286, 1.765 and 0.900 respectively.

Using Eq. 3.9 to aggregate the total performance (i.e., all perspectives considered) performance of each department can be calculated. Therefore, for the MEM it is calculated by the sum of all the rates of the department perspective:

$$P_{MEM} = \sum_{a=1}^{4} RP_a^c = 2.079 + 2.286 + 1.765 + 0.900 = 7.030$$

Again, the performance of each department is normalized by applying Eq. 3.10 to calculate the department's rate. For example, the rate of the MLS department is calculated by multiplying the overall rate of the MEM perspective with the weight of the department:

$$R_{MEM} = P_{MEM} \times w_{MEM} = 7.030 \times 0.134 = 0.942$$

The procedure was followed for all departments to determine perspective rates, performances and department rates. The results are presented in Table 5.15-5.18.

Finally, to calculate the total implementation performance rate (TR) of the SOLAS VGM regulation in NIMASA with respect to the selected key departments, we simply add all the department rates using Eq. 3.11 as follows:

$$TR = \sum_{c=1}^{d} = 2.748 + 2.861 + 0.945 = 6.554$$

$$\therefore TR \approx 6.554$$

Table 5. 18: Showing implementation performance of SOLAS VGM regulation in NIMASA

Departments	PERSPECTIVES	$\sum_{b=1}^{g} Rm$	WP	RP	$\sum_{b=1}^{g} RP$	WS	RS	$TR = \sum_{b=1}^{g} RS$
MLS	Financial	6.707	0.387	2.595	6.916	0.397	2.748	6.554
	Customer	8.780	0.278	2.442				
	Internal Business	6.571	0.157	1.029				
	Learning & Growth	4.768	0.178	0.850				
MSM	Financial	5.776	0.261	1.505	6.111	0.468	2.861	
	Customer	7.009	0.174	1.221				
	Internal Business	6.288	0.340	2.136				
	Learning & Growth	5.537	0.226	1.249				
MEM	Financial	6.813	0.305	2.079	7.030	0.134	0.945	
	Customer	7.089	0.322	2.286				
	Internal Business	7.725	0.228	1.765				
	Learning & Growth	6.254	0.144	0.900				

The performance rates of all the measures for the three departments presented in Table 5.23 above are between 7.030 and 6.111. This indicates that although there is a reasonable implementation performance of the SOLAS VGM regulation by NIMASA, they are also faced with tolerable difficulties while implementing the SOLAS VGM Regulation with respect to its requirements as six out of ten represents 60% of the desired goal and seven out of ten represents 70% of the desired goal.

As a result, all the five participants' rates add up to give an overall total implementation performance rate (TR) of 6.554. This means that the costs and benefits of implementing the regulation are well known by industry participants and other responsible parties in the regulatory process despite the fact that the SOLAS VGM regulation came into effect five years ago. The suggested methodology also provides explanations and evidence of the limitations and reactions of participants with respect to the regulation implementation.

5.4 Policies

From the study of the SOLAS VGM regulation, the following are some suggested policies that can be adopted by NIMASA which will improve the implementation of the VGM regulation and other related regulations yet to be established in the maritime industry.

The maritime industry and its participants are vast, which explains the purpose of the IMO. Over years, the IMO has introduced maritime regulations that would enhance safety both at sea and on land, for the benefit of every sector, economic, health, political etc. However, what happens after the dispatch of such regulations, is that the onus is upon every concerned member to ensure that they are well implemented. Not much is focused on monitoring regulation enforcement or implementation. Proof of this conclusion is the fact that since the release of the VGM regulation there have not been any reports of violations, it seems the implementation process is going smoothly. Although most articles have specified that, there are still cases of the inaccuracy of VGM declarations.

It is advisable that NIMASA and every IMO member state monitor the VGM regulation implementation and other future regulations. Each member state should ensure that every participant involved in the regulation is aware of its requirement and all implementation processes involved. Strict measures should be employed like penalties and fines, which not all member states specified or adapted for the VGM regulation. Following the analysis in chapter 4, attention should be focused on equipment being used by every VGM provider to see if it meets the authorized standard. While safety is the major reason for maritime regulations, if it seems that a regulation is a burden to a particular set of stakeholders, such regulations should be reconsidered for the benefit of all involved.

5.5 Conclusion

In summary, as presented in the above sections of this study, the methodology that can evaluate the implementation performance of the SOLAS VGM regulation in the maritime industry using NIMASA and its collective departments in the regulatory process as a case study is developed and tested for its applicability. The methodology adopted the combination of the Balanced Scorecards (BSC) and the Fuzzy Analytic Hierarchy Process (FAHP). On developing the model, three key NIMASA departments - Maritime Labour Service, Maritime Safety and Seafarers' Standards and Marine

Environment Management were selected for the study based on their significance for the SOLAS VGM regulatory process. The BSCs were based on four different perspectives which were suggested for the scorecards of each of the three departments and were used to prepare a list of performance evaluation indicators (called the measures for the perspectives) under each department after modifying the list from interviews with some NIMASA officials.
The feedback was analysed through a constructed FAHP program to obtain the relative importance of the four perspectives, the relative importance of the key performance indicators under each perspective for their burden in the regulatory process and the current total implementation performance rate of the SOLAS VGM regulation.

An important conclusion from the case study is that the SOLAS VGM regulation is satisfactorily implemented by the departments at a total performance rate of 6.554 in the Nigerian maritime industry even though they were faced with some challenges of meeting all the requirements during the regulatory process. It was found from the analysis that some of these challenges are related to the economic consequences they may suffer and the right resources they would require to effectively implement the regulation. Further analysis reveals more specific indication of the mentioned challenges such as profit generation, revenue in their business practice, reduction of administration cost, productivity, the high-level playing field in the maritime industry (competitiveness), improved quality of their product and services, the effort needed to minimize risk for meeting the regulation requirement etc.

Another interesting conclusion that can be drawn from the study is that the designed system can be used as a tool that can measure the implementation performance of the SOLAS VGM regulation over time for the whole maritime industry and its key participants as well. Providing a periodic assessment of the regulation and therefore contributing to identifying the progress level of implementation. Using it as a monitoring tool for the maritime industry and its participants with the assumption of making the current TR as a benchmark, an improved target of TR could continuously be achieved in such a way that an increase in the total performance rate in later assessments will be a good indication of the overall progress of the industry. Thereby, success in the high-performance rate of all the participants will result in the successful implementation of the regulation.

However, the tool could be limited by the possibility that the TR may reach a point (i.e., a performance) that cannot be exceeded. In such an occasion, it may be a sign that some of the challenging requirements of the regulation are too difficult to be met by the industry participants.

Chapter 6

Economic appraisal on the SOLAS VGM implementation

Summary

In this chapter, we present some economic appraisals related to the implementation of SOLAS VGM regulation. These issues are the shipper's choices on how to provide VGM and the ports/terminal investment costs and benefits on CWS to meet the regulation requirements. The research methods suggested were the decision tree and Cost benefit analysis combined with Monte Carlo simulation. The analysis is presented in the following sections.

6.1 Introduction

The loss of more than a hundred containers from CMA CGM George Washington two years prior to the amendment of the SOLAS VGM regulation proves that there is the best approach to implementing VGM before the SOLAS VGM guideline can be very effective. However, the significant loss of 342 containers from MSC Zoe in 2019 could likewise end up being one of the more significant container episodes caused by container weight issues. VGM non-compliance is a serious issue for the industry, aside from the safety component of the rules, which is obvious and must be the main priority for the industry, the economic effect of such accidents as well as implementing the regulation is likewise food for thought (TT Club,2020).

A reason why the regulation might be difficult to implement is that there are various methods for calculating the weight of containers (method one or two). To some extent, this is on the grounds that the industry is populated with participants that have a differing level of financial capacity to invest in container weighing systems and processes (TT Club,2020). The recognised Container weighing systems (CWS) are weighbridges, Load cells on MHC, RTGs, STS, straddle carriers, FLT, reach stackers as discussed in chapter three above. They are compact, lightweight, simple to access, and completely transferrable container load weighing solutions for the container freight industry. CWS is in effect explicitly created to meet the IMO amendments to SOLAS guidelines, which conveys precise weight verified data consistently, as a major aspect of a port's normal container lifting cycle. For example, if a port or terminal is sufficiently fortunate to have a weighbridge the calculation is straightforward (TT Club, 2020). The container alongside its cargo packages is weighed with a deduction for the weight of a truck and its fuel. This can be arranged by a shipper or a third party. Therefore, this study is important as it investigates the financial aspect of implementing the VGM regulation. In the previous chapters, the SOLAS VGM regulation has been discussed in great length but another aspect of the regulation that would be focused on in this chapter is the economic aspect.

In this chapter, Cost-Benefit appraisal (CBA) is conducted on the port/terminal investment on CWS and the shipper's decisions to provide VGM or contract a third party using any of the prescribed methods. This analysis was conducted to attain the financial impact of implementing the regulation and also to ascertain whether investment on any of the approved CWS by a port/terminal is beneficial and worth the sacrifice.

6.2. A Decision Tree model for VGM weighing process

Based on the provisions of the guidelines provided in the VGM regulation requirements as well as literature, Figure 6.1 presents a model of the decision tree revealing the various decisions a shipper would have to make in the weighing process.

Problem identification

To design a decision tree that will help the shipper or forwarder whose name is on the bill of lading to decide on the best approach to provide VGM using the highest EMV value through the folding back calculation. This will be done by using real data to assess the Palisade Precision Tree tool.

Possible decisions

The tree comprises "nodes and branches". Each node is symbolized by a square, circle, or triangle, which are decision, chance, and end note, respectively. In Figure 6.1 The first node on the left-hand side is a decision node that shows that the shipper has the decision of providing the VGM documentation (in-house).

This could be by contracting a third-party logistics company or a freight forwarder for the packing and derivation of the VGM of a container. The node on the left-hand side shows that the shipper has the decision of providing VGM at the port terminal using its container weighing scale. Other possible outcomes that would spring up flow through from left to right.

Possible outcomes

Each branch results in an optional strategy or decision. To the end of each branch or elective course is another node leading to a possible outcome – using method 1 or method 2. Regardless of the shipper's choice of providing VGM in-house or using a third party, he also needs to decide on which weighing method to use. This method would depend on the type of cargo and the locality, as most regions do not approve method 2. Any shipper using Method 2 must be approved by the MCA. The application of approval costs £147 and must be renewed every six months (Maritime and Coastguard Agency, 2015). Using either method 1 or 2 would lead to an elective outcome of this opportunity – either the VGM is accurate or inaccurate. Going for an in-house option to provide VGM will give rise to containers' rejection/fines including additional charges for re-weighing.

Related with each complete optional course through the tree is a result, which appears toward the finish of the furthest right or terminal part of the course. A DT of any size will consistently consolidate action decisions with various potential outcomes or consequences of actions that are incompletely influenced by some coincidence or other uncontrollable conditions.

Data collection/Payoffs and costs

To carry out quantitative analysis on the tree, a questionnaire was prepared to obtain realistic data such as the probability of outcomes, pay-offs, costs etc. from different industry experts in shipping companies and port/terminals operators like Port of Felixstowe and Peel Ports Liverpool.

Table 6. 1: Decision tree pay-offs and cost

Decision 1: Provide VGM in-house		
Fixed cost	£1	
Method 1&2 outcome	Probability	Monetary values
Accurate	0.95	£1
in-accurate	0.5	-20
rejection/fine	0.5	-200
additional charges	0.5	-20
Decision 2: Provide VGM (Terminal)		
Fixed cost	£20	
Method 1&2 outcome	Probability	Monetary values
Accurate	98%	£20
in-accurate	2%	-£20

However, the process of using a questionnaire was not successful; due to the pandemic, telephone interviews were conducted with some MCA approved VGM providers (shippers and freight forwarders) who were kind enough to give their time. These providers are: Inovyn Europe Limited, Mannasol Products Limited, Trilogy Freight Limited, Hinks Haulage HH Logistics, Southampton Freight Service Limited, Seafast Cold Chain Logistics PLC, Cargo Marketing Services Ltd, Nippon Express (UK) Ltd, Seaspace International Forwarders Ltd, Maritime Service Line Ltd, JAS Forwarders Ltd and Agility Logistics limited. The questions asked during the interview were the same questions written in the questionnaire. The questionnaire is attached to Appendix C. Information from news articles, ports and logistics company websites was also sourced. From the feedback, the cumulative average of each data was obtained.

Decision criterion analysis using the Palisade add-in tool and the completed DT diagram.

This is the stage to work out which alternative is the best option. This is done by placing a monetary value on every conceivable outcome. The measure that will be used in deciding is the EMV. If the shipper decides to weigh a container in-house using method 1, it will cost £1. If the shipper arrives at the terminal and there is any discrepancy with the weight, the weight provided by the terminal would be used but will result in an additional charge of £20 or in some rare cases rejection or fine supposing the shipper does not meet the cut-off time or declares a loaded container, empty (Port of Felixstowe, 2016; Peel Ports, 2019).

Likewise, the container without VGM may not be permitted at the terminal and this may incur delays or additional charges. These charges may include repacking cost, administration fees, demurrage charges etc. Some countries may also impose fines or different penalties for failure to provide an accurate VGM that is within permitted tolerances (CMP VGM, 2016).

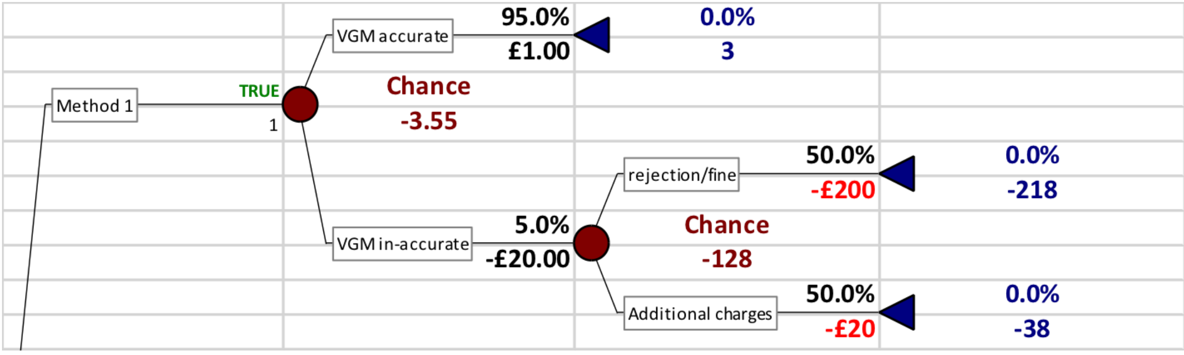

Figure 6. 1: DT sample 1 (in-house)

In-house∴ $VGMaccurate: 0.95(3) + 0.05(-128) = -3.55$

$$VGMinaccurate: 0.5(-200) + 0.5(-38) = -128$$

Terminal∴ $VGMaccurateinaccurate: 0.98(60) + 0.02(20) = 59.2$

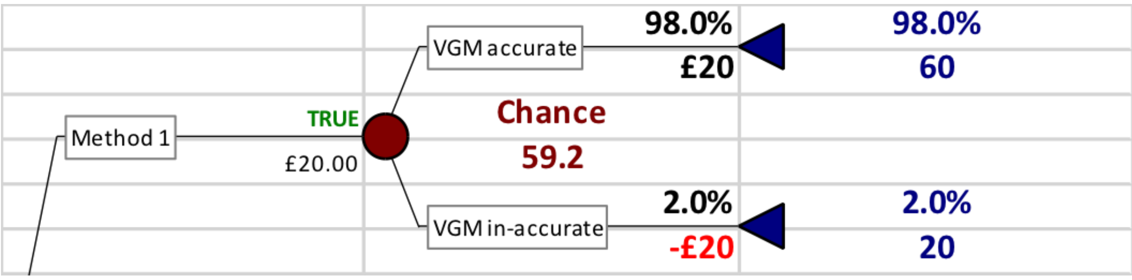

Figure 6. 2: DT Sample 2 (In-house)

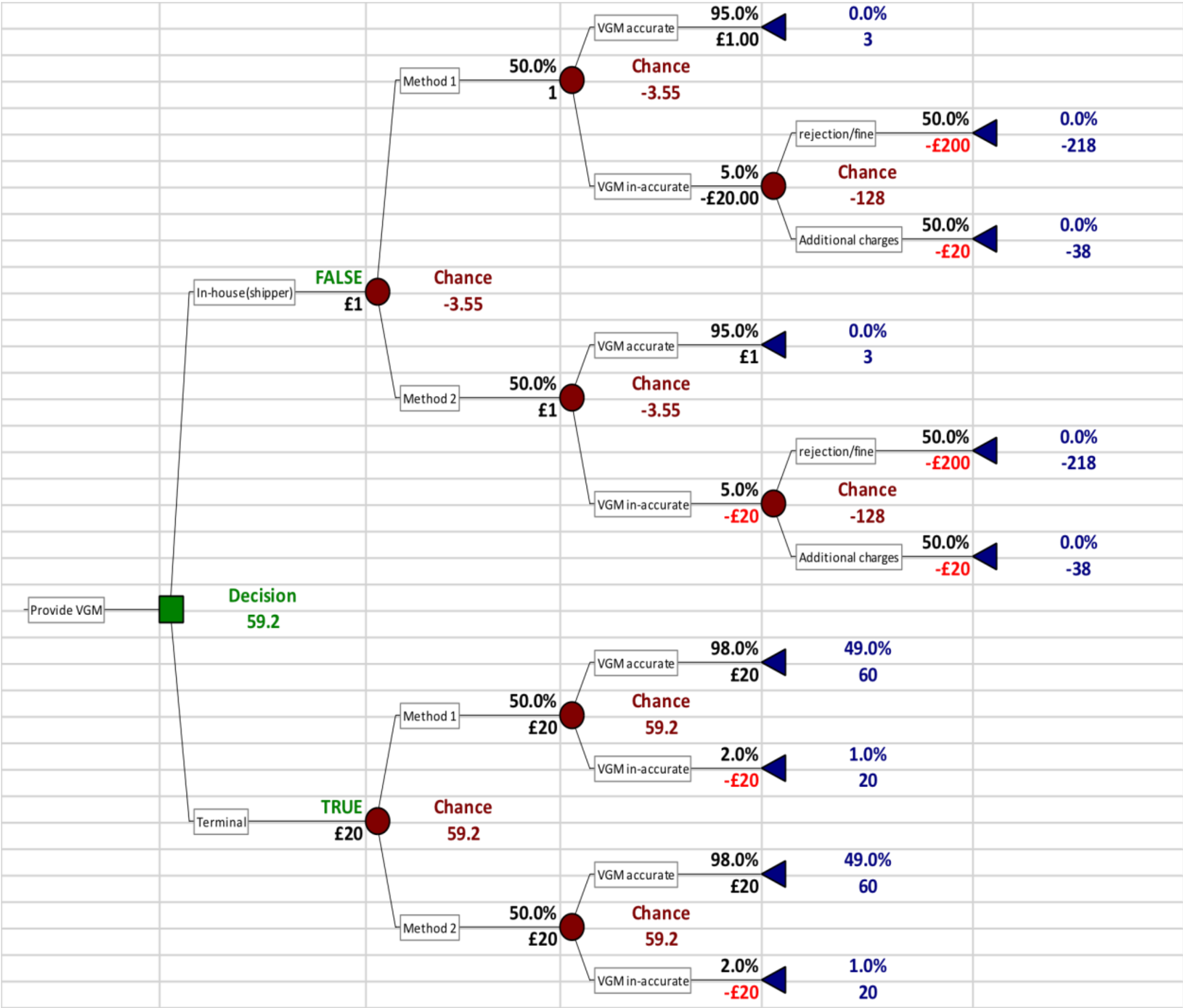

Figure 6. 3: Decision tree analysis

6.2.4 Sensitivity analysis

Given the values in Table 6.1, we can see whether the best choice continues to be "proceed with using terminal" if the EMV is reduced. Each of the potential values is reduced by a similar percentage and the EMV is monitored. The results of the percentage decrease are shown in Table 6.2.

Table 6. 2: Sensitivity analysis presentation

	Input		**Method 1**		**Method 2**	
	EMV Value	**Change (%)**	**Value**	**Change (%)**	**Value**	**Change (%)**
1	44.4	-25.00%	59.2	0.00%	59.2	0.00%
2	47.36	-20.00%	59.2	0.00%	59.2	0.00%
3	50.32	-15.00%	59.2	0.00%	59.2	0.00%
4	53.28	-10.00%	59.2	0.00%	59.2	0.00%

5	56.24	-5.00%	59.2	0.00%	59.2	0.00%
6	59.2	0.00%	59.2	0.00%	59.2	0.00%
7	62.16	5.00%	59.2	0.00%	59.2	0.00%
8	65.12	10.00%	59.2	0.00%	59.2	0.00%
9	68.08	15.00%	59.2	0.00%	59.2	0.00%
10	71.04	20.00%	59.2	0.00%	59.2	0.00%
11	74	25.00%	59.2	0.00%	59.2	0.00%

6.2.5 Discussion of results

Although the result has shown that using the terminal is more expensive compared to providing VGM in-house, using the terminal is the best decision for the shipper to make as it has the highest EMV. However, most shippers often provide VGM in-house, ensuring they have the correct VGM so they can avoid delay at the port. Peel Ports,2020 also confirms that with all containers arriving at the ports to be loaded on ships, terminals have been suggested as the most logical point in the supply chain to weigh boxes. With no one ascertaining if the VGM provided by the shipper is accurate or not, this study concludes that it is safer to use the port terminal.

6.3 Cost Benefit Analysis (CBA)

Following the results of the AHP-TOPSIS analysis on the most suitable CWS for the VGM implementation in chapter three, this study aims to carry out cost and benefit analysis on the best weighing systems inferred in the previous chapter. The study will reveal possible economic concerns by Port/terminal investors on weighing systems with regard to the VGM requirements. In addition to the economic feasibility study for port/terminal investors, the study will infer which of the alternatives is more beneficial for an investor in terms of monetary value while meeting the regulatory requirement.

6.3.1 CBA: Step-by-step procedure and Results

The CBA has been performed using the steps below.

Step 1: CBA begins with defining the scope of application and specifying the alternatives involved. In this study, the scope of application is, projects of port investment (check and rewrite) on container weighing systems considering four different alternatives. The alternatives to be considered are the best four of the eight container weighing systems (CWS) discussed in chapter three of this thesis. They are the Mobile Crane, Ship to Shore Cranes, Rubber tyre gantry cranes and Weighbridge.

Experts acknowledge that the weighbridge is an effective weighing system and costs £20,000.

Step 2: The next thing is to decide the "standing" which means "whose benefits and cost should be included". Although the cost and benefits affect almost all stakeholders in the supply chain such as the shippers, lines, truckers, freight forwarders etc., in this study, the CBA is conducted from the perspective of the ports/terminals as major participants involved in the SOLAS VGM as they are directly involved in port terminal investments.

In a custom market research conducted by TMR 2020, it was stated that the increasing adoption of the SOLAS VGM regulations for shipping containers is driving the growth of the CWS market during the forecasted period from 2017 to 2025. In addition to that, the growing automation across different ports and in the manufacturing areas enable the adoption of container handling equipment that is integrated with the weight measurement system. In turn, this will also be expected to create an impact in the CWS market in a positive way during the forecasted period of 2017-2025. Owing to the pandemic recession period, does this predicted forecast remain the same? Or has there been any effect on the market? Some of the leading players operating in the container weighing systems market include *Strainstall, Rice Lake Weighing Systems Incorporated, Avery Weigh-Tronix LLC, Fairbanks Scales, Incorporated, LCM Systems Ltd, Tamtronoy (Finland), Weightron Bilanciai Limited, and Mettler-Toledo International Incorporated.*

Step 3: This requires the analyst to identify the physical impact categories of the proposed options, list them as benefits or costs, and determine the measurement indicator of each effect classification.

Table 6. 3: Classification of cost and benefits

S/N	**Costs**	**Benefits**
1	Capital	Times used per day
2	Maintenance cost	Operating days
3	Running cost	Annual uses
4	Total Cost	Total benefit

Step 4: The next phase is to quantify all impacts at each time. This will be made for all four alternatives for a period of 5 years in the category of a port/terminal.

- The number of times the equipment is used per day

- The number of VGM provided per day
- The number of VGM provided per year
- With the above information, the analyst can estimate the following
- The total VGM operating cost that the port saves

Step 5: The fifth step is to monetize each impact by accrediting a value in pounds. The unit of time labour cost will be monetized. The monetary values used in the analysis were derived from port experts and weighbridge manufacturers and suppliers.

Table 6. 4: Monetary values

Yearly maintenance	256,000		Estimated yearly benefit	£699,262.00	
Capital	20,000				
Investment time (years)	5		PV (Costs)	PV (Benefits)	NPV
interest rate	5%		£1,394,346.03	£3,027,438.52	£1,633,092.49

In deriving the capital, a pert distribution was used and calculated as follows:

=@RiskPert (15000,30000,45000, Risk Static (30000))

Step 6: For a project that has an impact of five years, the benefits and costs should be aggregated. Cost and benefits happening in various timeframes inside the lifetime of the undertaking must be aggregated to get the net present value (NPV). Notwithstanding, for most people a dollar today has more worth than a dollar one year from now. A cost or benefit that occurs in a year$t$ is changed over to its "present value" by dividing it by $(1+S)^t$,where S is the social discount rate. Assume a project has a life of n years and let B_t and C_t denote the costs and benefits in year t, respectively. The present value of the benefits, $PV(B)$, and the present value of the costs, $PV(C)$, of the project are as follows:

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+S)^t}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+S)^t}$$

For a Five (5) years investment plan where: Yearly maintenance = £256000

Capital = £30000, Investment time (years), interest rate = 5%, Estimated yearly benefit = £699,262.00

$PV(C)$ = $(£256000 + £30000) + \frac{£256000}{(1+0.05)} + \frac{£256000}{(1+0.05)^2} + \frac{£256000}{(1+0.05)^3} + \frac{£256000}{(1+0.05)^4} + \frac{£256000}{(1+0.05)^5}$

= £1,394,346.03

$PV(B)$ = $\frac{£699262}{(1+0.05)} + \frac{£699262}{(1+0.05)^2} + \frac{£699262}{(1+0.05)^3} + \frac{£699262}{(1+0.05)^4} + \frac{£699262}{(1+0.05)^5}$

= £3,027,438.52

Step 7: In a project where there are more alternatives, as in the case of this study, the weighing system with the highest NPV will be selected (Boardman, Greenberg, Vining and Weimer, 2017). The NPV of each alternative weighing system equals the difference between the PV of the benefits and the PV of the cost. The rule for a single alternative project is to simply proceed with the project if its NPV is positive PV, which means the benefits surpass its costs.

$$NPV = PV(B) - PV(C) > 0$$

$$NPV = £3,027,438.52 - £1,394,346.03$$

$$NPV = £1,633,092.49$$

$$\boldsymbol{PV(B) > PV(C)}$$

Table 6. 5: Present value calculations

Time in Years	0	1	2	3	4	5	
Cost per year	£286,000.00	£243,809.52	£232,199.55	£221,142.43	£210,611.83	£200,582.70	Outflow's

Benefit per year	£699,262.00	£665,963.81	£634,251.25	£604,048.81	£575,284.58	£547,890.07	Inflows
Net PV per year		£422,154.29	£402,051.70	£382,906.38	£364,672.74	£347,307.38	Actual Benefits
PV Benefit	£1,919,092.49						
Net PV	£1,633,092.49						

Step 8: There may be significant uncertainty about both the expected impacts and the suitable monetary valuation of every unit of the impact. The analyst may likewise be unsure about the suitable social discount rate and the suitable level of standing. The reason for sensitivity analysis is to recognize and deal with the hidden uncertainties. In this work, we use Monte Carlo simulation to investigate the robustness of our results and to illustrate its use within CBA.

A Monte Carlo simulation is a procedure that creates a model of potential results by substituting a scope of values (taken from a likelihood distribution) for any uncertain factor (Vose, 2020). During the simulation, values are arbitrarily sampled from the input probability distributions and for each set of values (called an iteration) the output is determined. This is performed for multiple times and the outcome is a probability distribution of potential results, for this situation the NPV is seen in Figure 6.2. It is known from theory that a few variables follow the explicit distribution. For example, ship appearances in ports or administration times follow a Poisson distribution. Perhaps one does not have hypothetical or empirical proof that recommends a specific distribution, then it is sensible to determine a uniform distribution over the range.

If no data are accessible, expert judgment could be used. Here we use the so-called Pert distribution, for only three-point estimates, i.e., a lowest (minimum), a highest (maximum) and a most probable (mode) value, are needed (check and correct). Figure 6.4. illustrates the used distribution.

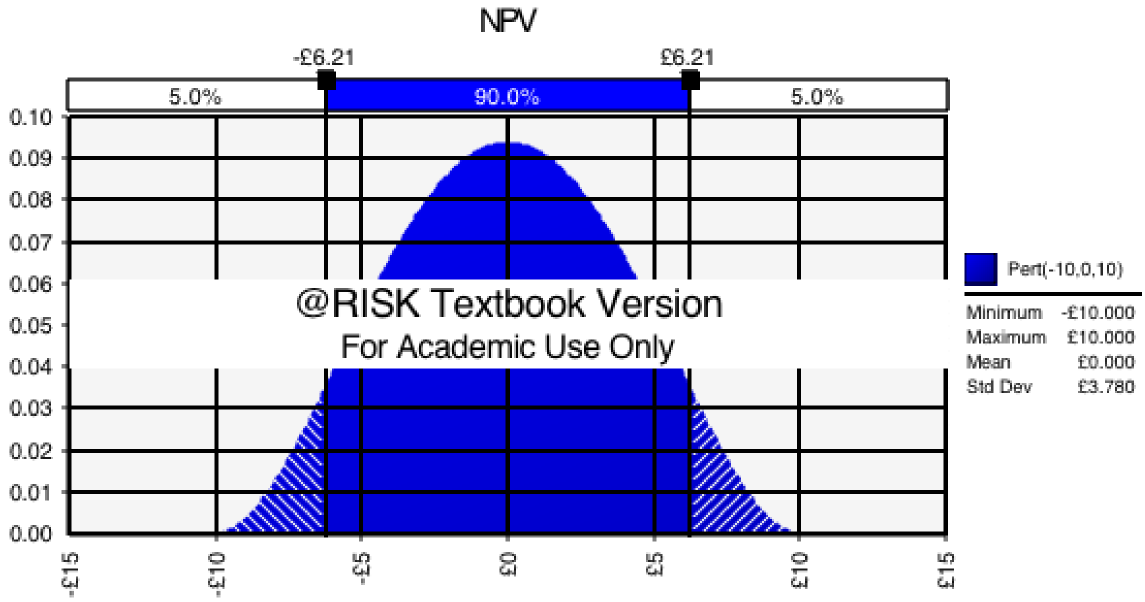

Figure 6. 4: Pert distribution - source: author

6.3.2 Discussion of CBA results and conclusion

From the analysis, investing in a weighing system is a good project because the calculation shows that this project has a positive NPV of £1,633,092. The outflows for the project were calculated for the next five years with an interest rate of 5%. This was summed up as the PV cost (£1,394,346.03) the yearly inflows were calculated and summed up as the PV benefit (£3,027,483.52). Finally, after subtracting the PV cost from the higher PV benefit, the NPV of the project is £1,633,092.49.

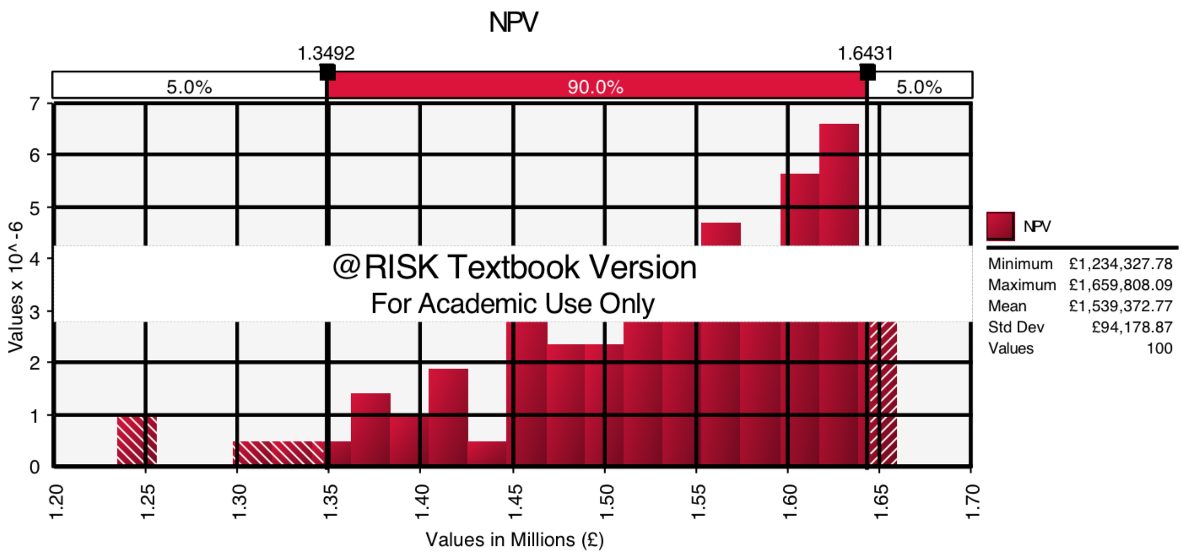

Figure 6. 5: Net present value - Source: author

Using the above parameters, a sensitivity analysis is performed using Monte Carlo simulation; see Fig. 6.6. Similar analysis can be performed by using a probability distribution function for any value we feel there is uncertainty. Based on the results, it is clear that the NPV is always positive. This means that the project should be recommended for implementation. Actually, our simulation gives a 90% probability that the NPV (benefit) will be between 1.234 and 1.539 million GBP.

Unforeseen circumstances always come up when businesses least expect, such is the case of the pandemic period. Also, are these equipments frequently used during these periods compared to before the pandemic? With ports investing a lot in weighing systems, were they really prepared for such a recession period, does this affect this investment? These are probing questions that can be considered in future work using the proposed methodology.

Chapter 7

Final Conclusions

7.1 Literature review

The literature review was focused on reviewing the context and impact of the implementation of the SOLAS VGM regulation by different sectors like different maritime stakeholders and nationalities (section 2.2). The problem of misdeclared container weight and effects such as threat to human live and damage to cargoes and vessels was reviewed. From the reviews, some researchers highlighted that the regulation is not enough to solve the problem of misdeclared weight. Generally, most of the articles reviewed were within the maritime industry and academic institutions, hence the information received provided a good foundation for further research in assessing the performance of maritime regulations.

It was discovered that different countries have adapted their own VGM guidelines as a substitute for the IMO official VGM guidelines. As a result, shipping company should review their contract to ascertain if new clauses should be added to the regulation guideline. The reason behind the amendment and the IMO guideline was also reviewed. A flow diagram showing the process of communicating VGM was created (figure 2.2)., The agreed methods of weighing (methods 1& 2) which all stakeholders must decide which method to use and who's solely responsible for the regulation was also identified through the review.

7.2 Research methodology

Upon identifying the different context and impact of the regulation, the research aims and objective was based on the findings from the review. The overall aim of this project is to assess the performance and effectiveness of the container weighing verification requirements. In other to capture the current practice of the VGM implementation in the industry, both quantitative and qualitative research techniques such as AHP, TOPSIS, BSC, Fuzzy AHP, CBA, decision trees and Monte Carlo simulation were reviewed and utilized. Data were collected through questionnaires and industrial interviews with port/terminal operators. A case study was conducted on NIMASA and a policy was constructed.

7.3 Achieving research objectives

The success of the research activity in achieving the research objectives stated in chapter 1 (section 1.3) is as follows.

- *Investigate the problem of misdeclaration of container weights and its effect on safety in the shipping industry*

This objective was achieved in chapter 2 by conducting a comprehensive literature review on the problem of misdeclared containers and how the SOLAS VGM regulation came about. This helped to understand the problem of misdeclared container weight and how it affected the shipping industry. There is scant academic literature or published materials on the issue of misdeclared container weights, so this objective helped in bridging that gap. Information was sourced from the World Shipping Council (WSC), IMO, ICHCA, maritime news article, Journal of Commerce (JOC), industry frequently asked questions, shipping companies, port, and freight companies' websites.

- *Investigate all the issues related to the container weighing verification requirements; those involved, the weighing process, weighing system, method of weighing, etc.*

This objective was achieved in chapters 2 and 4 by conducting in-depth research from industrial and academia on all the issues surrounding the container weight requirement. The regulation guidelines produced by the IMO were reviewed, a breakdown of the regulation requirements was well portrayed, a concise explanation of its terms was presented and industrial stakeholders involved were identified. Chapter 3 helped in bridging the industrial gap of ports' selection of the most suitable weighing system. This was achieved by conducting research on all approved container weighing system and applying the steps of a proposed model. Steps in developing this model were validated by seasoned industrial experts including the final choice of most suitable weighing system.

- *Investigate and assess how different stakeholders in the maritime sector are implementing the SOLAS VGM regulation*

This objective was achieved in chapters 2 and 4 by conducting a state-of-the-art review on all the industry stakeholders that are associated with VGM. From these findings, five stakeholders (shipper, port/terminal operator, freight forwarder, carrier and national authority) and their responsibilities in line with VGM regulation were as discussed in detail in chapter 4. Although the regulation stated that the shipper is responsible for providing VGM, this helped in bridging the gap of identifying all those impacted by the regulation in the industry and their roles in implementing it.

- *Demonstrate the applicability of a model that would measure the implementation performance of major stakeholders using the Nigerian Maritime Administration and Safety Agency (NIMASA) as a case study*

This objective was achieved in chapter 5 by developing a model consisting of six major steps that can be applied by all VGM concerned bodies under the IMO, to assess their implementation performance of the VGM regulation. NIMASA as an IMO member state was used as a case study to test this model as few NIMASA experts participated in the research survey. This helped in bridging the gap of having a system that can be used as a tool capable of assessing, calculating and measuring the effective implementation performance of the SOLAS VGM regulation from time to time for the maritime industry and its stakeholders.

You need to change the format of the bullet points below as it's not the same with the previous bullet points in this chapter

- Develop a methodology to conduct an economic appraisal on the regulation implementation

This objective was achieved in chapter 6 by applying a decision-making analysis and a financial analysis technique, DTS and CBA, to the shipper's decision of how to provide VGM and the port's decision of investing in CWS. A comprehensive review was conducted on the DTS and CBA techniques, values applied to these techniques were sourced from port experts and MCA-approved VGM providing companies. A sensitivity analysis was conducted to validate the results of both analyses. This helped in bridging the gap of having an analytical framework that would help port/terminal to decide if investing in a CWS is a good project or not. Also, in the aspect of providing VGM either through a 3rd party or in the terminal, a framework was developed to aid the shipper's decision.

- Identify best practices and, if any, possible ways to strengthen compliance, verification, and enforcement of the SOLAS VGM requirements

This objective was achieved in chapters 2,5 and 6 by discussing and analysing all issues related to the SOLAS VGM regulation like the selection of the most suitable

CWS; measuring the implementation performance of key participants using NIMASA as a case study, economic appraisal on the VGM financial aspects (check and correct as thus is too long for a paragraph). From these related issues, solutions were offered in each of the technical chapters (chapter 2,5,6), balanced scorecards were designed for five key participants to measure their performance and policies for NIMASA, and other national authorities were suggested in chapter 5 (section 5.5). In conclusion, the findings from each technical chapter bridged this gap.

7.4 Research contributions

At the start of this thesis registration, the initial research idea was to find a solution to the problem of misdeclared container weight. However, the SOLAS VGM regulation came on board and the research focus changed from finding a solution to the problem to assessing the effectiveness and performance of the solution (SOLAS VGM Regulation).

The research activity contributed to existing knowledge on evaluating the implementation performance of maritime regulation. It focused on assessing a newly introduced maritime regulation "SOLAS VGM Regulation". This work has investigated different aspects of the Regulation to measure the effectiveness and performance of the regulation. From the research process, four surveys and a series of interviews were conducted, and the following contributions were made.

- Container weighing system selection: From the AHP-TOPSIS analysis conducted in chapter 4, the most suitable container weighing system was identified among eight choices of alternatives. This finding would guide industry stakeholders like port managements and freight companies in investing in the right choice of weighing scale and highlights different criteria they should consider. Five selection criteria such as cost, accuracy, technical properties, safety and reliability were identified through literature and expert judgement.

- Design of Balanced Scorecards for five stakeholders: Although the regulation clearly states that it is the responsibility of the shipper to provide the VGM, this research has identified other key industry stakeholders that are more concerned and affected by the regulation. In chapter 4, Balanced Scorecards were developed for these key industry stakeholders: shippers, port/terminal operators, carriers, freight forwarders and national maritime authority. These stakeholders, when measuring their implementation performance of any future IMO regulation can apply the scorecard.

- NIMASA VGM total rate of performance: Also, in chapter 5, a case study was conducted on one of the key stakeholder's national maritime authorities (NIMASA) using the proposed BSC-FAHP model to derive its total rate of performance. Hence, scorecards were designed for NIMASA key departments. NIMASA was used as a case study because it is the strategic and regulatory body governing the maritime sector of Nigeria. The designed scorecards were created and validated through the survey collected from NIMASA officials situated at three main offices in Nigeria. These scorecards can be employed by other IMO member states to measure their implementation performance of the SOLAS VGM regulation or future regulations issued by other national IMO member state. Through the acquired rate of performance, some policies were suggested in section 5.4.

  One significant conclusion from the case study is that it may take some years to ascertain if a regulation has achieved its aim. This is because not all IMO member states can immediately adapt to the changes caused by the introduction of a regulation. While the regulation may affect the practices of most maritime entities, it could also be a burden to a particular stakeholder and result in further expenses.

- Economic appraisal on VGM implementation: In chapter 6, two analyses were conducted using DTs and CBA. The results show that it is preferable for a shipper to provide VGM through the port/terminal because it is safer. It was also found that investing in CWS is a good project for the port/terminal to embark on.

To that extend, not only the objectives have been met but we have achieved to contribute to the literature in the following. First, this thesis, to our knowledge, is among the very few theses that address this topical issue. We offer a structured way to guide port operators and users in selecting suitable equipment for the measuring the weight of containers through an AHP-based approach, and some insights on the relevant economic decisions. In addition, we present a framework to evaluate the implementation of the VGM regulation and an application to the Nigerian industry. This is a novel application which can help increase the performance of this regulation (and can also be extended to cover others) by helping the regulator to focus on areas that need more attention.

7.5 Limitations of the research

One major limitation identified during the research is the challenge in gathering data; most participants did not want to disclose much information. In chapter 4 a model that can be used by all VGM concerned bodies under the IMO was proposed. Five surveys were created and disseminated to different organisations like the European Shipping Council (ESC), Global Shippers Forum (GSF), International Cargo Handling Coordination Association (ICHCA), Tt Club, freight and shipping companies, ports (DP world Southampton, Peel Ports group, Port of Felixstowe. Maritime authorities like the MCA, NIMASA, Australian Maritime Safety Authority (AMSA), South African Maritime Safety Authority (SAMSA) were also contacted.

However, one maritime authority was used as a case study due to the challenge and constraint experienced when collecting data. It was quite difficult finding the direct email details of most potential experts from their companies, who appear to be knowledgeable in the field owing to their experience and positions. The name of these potential experts was sourced from LinkedIn and other company handles. Some of the experts were not familiar with the questionnaire format and needed further explanation before providing answers, whilst others never responded.

7.6 Future research

In this chapter, we have summarized the research contributions and how the objectives of this work have been achieved. In the technical chapters, we have presented the relevant work carried out throughout the years of the study and the main findings. At the same time, several limitations of the proposed methods have been identified. In addition, we discussed the key findings and offered several policies and managerial insights. These form our suggestions for future work. Below, we summarised the key points.

Chapter 4

Our first area of research is related to the selection of a suitable container weighing system that will meet the needs of the port and VGM providers without undermining the requirements of the SOLAS VGM Regulation.

We argued that in practice, the best solution will be decided by a small number of decision-members, e.g., the terminal management teams; the number of experts used will be low, in our opinion between 3 and 7 (check and rewrite). A group decision making exercise though means there is a need to aggregate the different opinions. We noticed that the opinion of the experts might not be consistent (low CR value), and this might happen for the aggregated opinion. We should note that in cases where there is not much consensus among the experts, the decision makers should be asked to adjust their judgments to obtain more consistent input during the pairwise comparisons. In addition, a direct assignment of weight – thus eliminating the need to use the AHP method altogether- could be considered as an alternative. More research is therefore needed related to the aggregation of expert opinion and maybe comparing our proposed method with one where weights are obtained by direct assignment.

Note that our sensitivity analysis revealed that none of the changes in the weight of each criterion changed the final ranks of the systems analysed. Obviously, these results depend on the criteria and the parameters used, however this might imply that some systems are by far superior and therefore our proposal to directly assign the weights (and thus eliminate the need to perform the AHP step) might be practicable.

Chapter 5

We have presented the methodology behind a model to measure the implementation performance of the VGM regulation. We proposed the use of the Balanced Scorecard (BSC) method and the Fuzzy AHP (FAHP) technique to help evaluate each of the key industry stakeholders' performance using several different perspectives and measures (performance indicators).

First, we should highlight that although we approached many experts, in this case governmental employees, we received fewer responses than expected. One main issue identified is the substantial amount of work that was needed to complete the questionnaire; perhaps a more systematic way (and an online tool) should be used. In addition, they found the pairwise comparisons difficult to comprehend; see also our comment below on the high CR ratios. One way to overcome this is to get the responses during an organised group meeting, where further assistance could be provided, or to try another approach such as directly assigning weights. This coupled with a thorough sensitivity analysis will be able to provide stable results.

Furthermore, as per our comments above, we want to highlight the issue of the inconsistency of the real opinion of the experts, as evidenced by the high CR ratios; similar issues have been experienced in the selection of the CWS. We have decided not to alter their opinion in order to obtain more acceptable values as we wanted to capture the real opinion of the experts.

We should point out here that there is much work on the judgement scales and the consistency tests that can be used; see the excellent work of Franek and Kresta (2014) for a discussion. According to their work, there is literature which suggests accepting matrices even when the consistency ratios are high, as they ratios given by Saaty are too tight. Different scales can be used, for example, it is shown that the" higher the variance of the scale, the bigger the consistency index" (Franek and Kresta, 2014). In future work, different scales (such as the root square, the logarithmic etc) could be investigated.

Our main conclusion is that more research is needed also in the direction of perhaps assigning weights directly or using a more guided process when obtaining the expert opinion. These would probably alleviate the issues; the first option will actually eliminate the issue.

Various studies (Fletcher & Smith, 2004; Rickards, 2007) have criticized the Balanced Scorecard (BSC), presenting a number of limitations such as BSC applies many variables which creates complex optimization problems. Moreover, Banker, Potter, & Srinivasan, (2000) argue that a BSC lacks a standardized baseline or benchmark to compare performance. We also agree with Rickards, (2007) that this approach is not based on a concrete mathematical model or a weighting scheme. In addition, Banker et al., (2004); Neves & Lourenco, (2008) argue that the BSC does not have a comprehensive index to review the interaction between measures of performance. These can all be addressed.

We feel also that future research related to the performance evaluation of the VGM regulations should try, first, to incorporate as many stakeholders as possible and, secondly, to try to establish which performance is acceptable. The latter is related to the 'performance' goal that needs to be achieved. An important conclusion from the case study is that the SOLAS VGM regulation is satisfactorily implemented by the departments at a total performance rate of 6.554 in the Nigerian maritime industry even though they were faced with some challenges of meeting all the requirements during the regulatory process. What is the value that we should have expected? Is 5 or 6 (which are obviously acceptable performances) good enough? Or should we have expected a 7 or an 8? (don't write a sentence when you're obviously trying to write a question).

In addition, more emphasis could be placed on determining how ratings (and performance) for individual aspects and measures can be increased as this will provide NIMASA with recommendation on how to improve their performance.

Another interesting conclusion that can be drawn from the study is that the designed system can be used as a tool capable of assessing, calculating and measuring the effective implementation performance over time. Further research could be performed on how this could work.

Chapter 6

It is clear that there are numerous uses of the methods described. We have noticed, as expected, that the results heavily depend on the inputs. Is it easy though to predict how many times the equipment will be used per year, especially if we are talking about a lifetime of 10 or more years? And how easy is it to obtain the costs and benefits for future cashflows? There is clearly a need to obtain more accurate data and to further investigate the use of Monte Carlo simulation to help deal with the relevant uncertainties.

In addition, future work could incorporate other considerations especially related to externalities such as to take the environmental aspect into account. Placing a monetary value for instance on emissions and considering this into the cost benefit analysis could help evaluate investments such as in CWS but also considering the emissions produced. Doing so, there is no need for a multicriteria analysis approach as all costs and benefits can be monetized.

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APPENDIX A

Perspectives and measures

The first step is to obtain generic measures from the initially suggested measures of Kaplan and Norton and modify their definitions to fit into the stakeholder objectives as it concerns the SOLAS VGM requirements for its effective implementation in the maritime industry. The initial measures, which are appropriately modified for their applications in the shipping industry, are suggested in Table A.1.

The second step is to determine their measurement quantity (what we could also refer to as key performance indicators) that would be a guide to select the specific measures. The concept of quantifying measure is that each performance measure of the scorecards should be clearly identified with a measurement quantity that would be utilized as indicators for proper evaluation of that measure under it perspective goal for that stakeholder. Examples of such measurement quantities are money, hours, human errors etc. It is interesting to note that the measurement quantity for internal business perspective should cover two fundamental elements; the time needed to get appropriate job done and the cost of the job.

The third step is to ascertain the perspectives and measures that can assess the costs and the benefits of the implementation of the regulation for each selected department. The general principle of designing perspectives and measures of the scorecards is to provide notable items, which are in line with objectives of the organization, in such a way that the items are capable of serving as a guide for any division within the organization to effectively implement the goals. Similarly, in order to measure effective implementation performance rate; a list of significant items which are in line with the requirements of SOLAS VGM regulation that also reveals the cost and benefits of implementing the regulation for each of the three key NIMASA department were used to design the perspectives and measures for each of them. The list comprises essential functions of the regulation as required by IMO such as implementation procedure, availability of resources, cost assessment, risk assessment and performance monitoring.

Furthermore, it is important to stress that the inventor of the BSC (Kaplan and Norton 1996a, b) advised that an organization should use moderate number of measures that can be controlled. That a manager in an organization can operate with not more than twenty-five measures to help him keep track of the goal**.** The same approach was followed in this research to every department scorecard.

In Table A.1. below, a list of suggested generic measures for all the perspectives, modified definitions of the measures and their measurement quantity for the assessment of implementation performance of the SOLAS VGM regulation is displayed.

Table A.1 Suggested Generic Measures and measurement quantities for the implementation of the SOLAS VGM regulation – Adapted from Karahalios (2009)

Generic Measure	**Measure**	**Measurement Quantity**
Financial Perspective		
Profit	Rise in revenues from administrations and product	Quantity of new revenues
Revenue	Grow existing income	Quantity of revenues
Cost	Lessen both direct and indirect cost	Total of cost reduction
Use of Assets	Maintain cash flow to a minimum	Total of cash expended
Customer Perspective		

Productivity	Grow administrations and services	Total of new output
Competitiveness	Grow commercial advantage	Number of new customers
Quality	Grow the nature of administration and services	Quantity of management deficiencies
Reputation	Grow organization image	Number of claims
Learning & Growth Perspective		
Human Capital	Minimize the need to hire employees with high skills, talent and knowledge	Amount of new vacancies required to fulfil new
Information capital	Minimize the need to adopt new information systems, networks and technology infrastructure.	Amount of new IT integration
Organization Capital	Improve a company's culture, its leadership how aligned its people are with its strategic goals, and employee's ability to share knowledge.	Amount of human errors
Innovation	Increases the ability of people to produce new practices.	Quantity of new practices adopted by the organization
Internal BusinessPerspective		
Risk analysis	Diminish the labour expected to carry out a risk evaluation of the potential challenges that a recently presented regulation can cause during its execution.	Money/hours
Planning	Lessen the labour expected to plan an suitably documented strategy with detailed steps regarding the execution of a regulation, including correspondence and response plans	Money/hours

Training	Diminish the labour expected for creating awareness and educating those involved.	Money/hours
Review	Lessen the labour expected to confirm the good implementation of new planning including monitoring, supervision, review and inputs.	Money/hours

The third is to determine the link between the four different perspectives for a stakeholder and their measures. Before addressing the main performance measures, it is important to present the best order of arrangement by which the suggested BSC perspectives and the measures should be used in such a way that the framework would address the internal and external business practices of a stakeholder while implementing the regulation. Figure A.1 is a graph that represents the main direction of the system revealing the links between the various perspectives and their respective measures. Each of the main performance measures under the objectives of a perspective was assumed to be a number of small triangles when added together builds up to form a bigger triangle of each perspective. Consequently, the perspectives also add up to produce an overall biggest triangle for a stakeholder in the regulatory process such that the larger the base of the triangle the more stable the system would be for a stakeholder to meet the desired goal.

By beginning from the bottom to the top as indicated by the arrow, the first perspective at Tier 1 is the Learn & growth that comprises all the past organization knowledge, data systems (human resources and information technology). This means that the existing knowledge which stands for improvement should result in an effective information management system that is able to monitor all the activities of a stockholder by the IMO. Tier 2 is the internal business perspective which reveals the procedures to implement the SOLAS VGM regulation. Tier 3 which is the customer perspective highlights the outcome of implementing the regulation in business practices. For instance, there would be an increase in customer satisfaction if the regulation supports more production and better quality which would, in turn, increase competitiveness and finally improves the reputation of that stakeholder. Tier 4 is the monetary perspective; it shows the achievements or losses of a stakeholder company from implementing the regulation in terms of economic value. An increase or losses from existing assets value depends on cost reduction and profit as it is the profit of a company that will contribute to the future survival of that company.

It is remarkable to note that the process will begin again from tier 1 at the end of tier 4. This is because the profit made by a company from implementing the regulation would be invested to creating knowledge and experience that was attained through the previous procedure. In addition, the establishment would gain innovation for further growth by applying the knowledge from past experience on the next process while implementing the regulation.

Finally, the specific measures are determined in order to reveal the cost and benefits for a participant while implementing the regulation. They are reviewed in detail at the preceding sections on this chapter as it requires proper attention because experts would depend on them for pairwise comparison as well as using them for measurement parameters in this study.

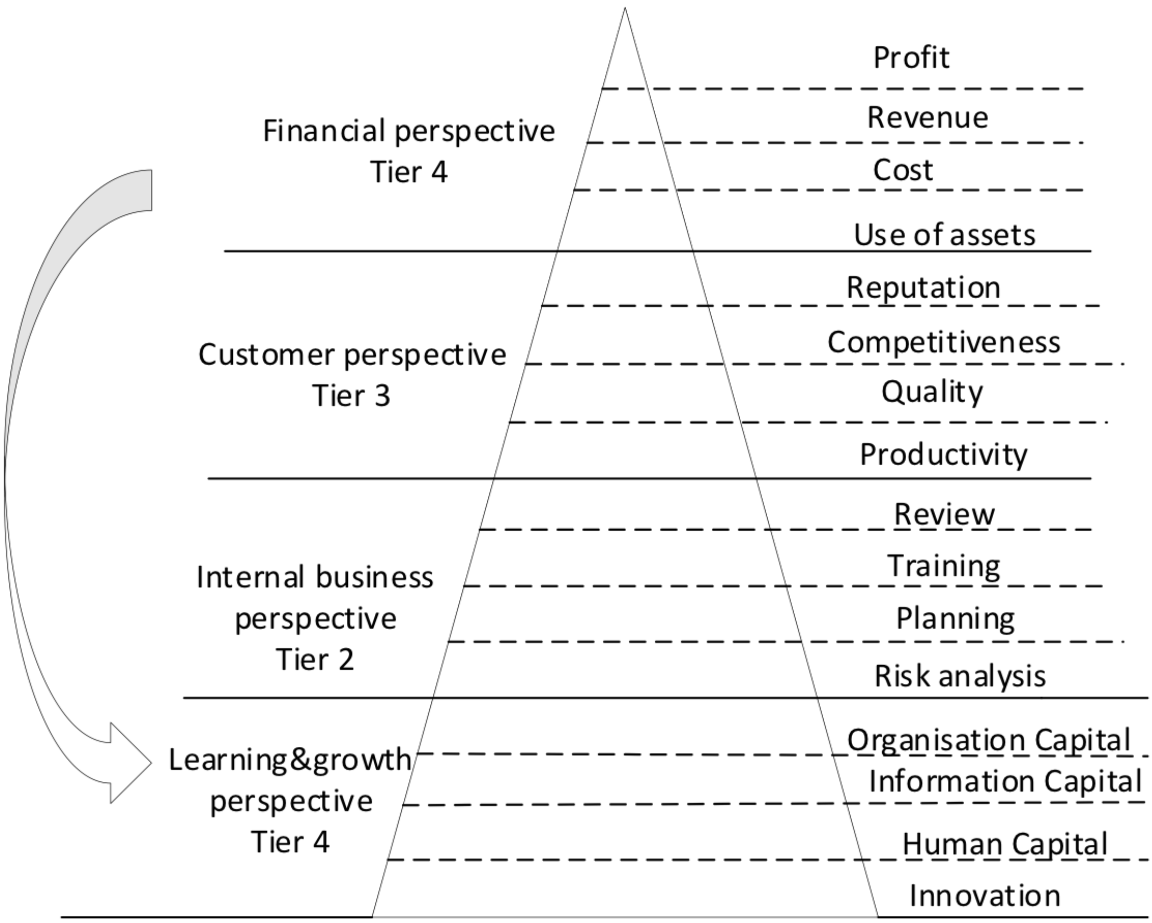


Figure A.1 The connection of each perspective and measures
Source: Karahalios, 2011

APPENDIX B

Questionnaire for port/terminal operators related to the VGM regulation

Dear Sir/Madam,

A PhD research at Liverpool Logistics, Offshore and Marine (LOOM) Research Institute is currently being carried out on "Assessing the effectiveness and Performance of the SOLAS Verified Gross Mass Regulation", under the supervision of Dr Christos Kontovas (xxx@ljmu.ac.uk). The subject has become a hot topic in the maritime industry due to the series of accidents that occurred as results of misdeclared container weight.

The overall goal of this research is to assess the effectiveness of the container weighting verification requirements. The compliance of shippers, including the selection of the appropriate weighting equipment, as well as the enforcement by the national authorities will be at the centre stage of our investigation. In light of the above aim, a specific model is developed in order to achieve a part of the aforementioned aim. A requirement for this study is to employ experts' judgement in determining the weights of each parameter of the model in order to prioritise them for an advanced computational analysis.

Thus, this study set out to provide an organised method for collecting experts' opinions in order to select the best suitable weighing system that can lead to the enhancement of safety and sustainability of the container weighing machineries and transportation systems.

In order to improve the quality and relevance of the research, the researcher would greatly appreciate your views by completing the following questionnaire and return using the email address given below. Please note that the completion of this questionnaire takes about 10 minutes of your time; your feedback will greatly enhance the research development and contribute to the industry wise opinion. Finally, the information provided and your identity will be treated with confidentiality. For further questions or enquiries about the study, please do not hesitate to contact the researcher.

Thank you. **Ugedi Preye Jennifa**

"I have read the information sheet provided and I am happy to participate. I understand that by completing and returning this questionnaire I am consenting to be part of this research study and for my data to be used as described in the information sheet provided"

The questionnaire includes three parts. Part 1 consist of some general required information. Part 2 includes two groups: Group A (Criteria), and Group B (Sub-criteria). An example for Part 2 is given after Part 1 to illustrate how the questionnaires should be filled. Part 3 introduces another research technique and illustrations are given at the start.

PART 1

GENERAL QUESTIONS

1. Please provide your work experience (***please tick the appropriate box***).
   - □ 1-5 years
   - □ 6-10 years
   - □ 11-30 years
   - □ Over 30 years

2. Please provide your industry position in the appropriate box.
   - □ Vice-president or above
   - □ Manager/Assistant manager
   - □ Director
   - □ Sales representative
   - □ Other: ______________

3. Please provide your highest academic qualification
   - □ PhD
   - □ Master
   - □ Bachelor
   - □ High School or equivalent
   - □ Other______________

4. How much does your company charge for weighing containers, and why?

5. What type of weighing instrument do you have installed? Why the particular choice of equipment?

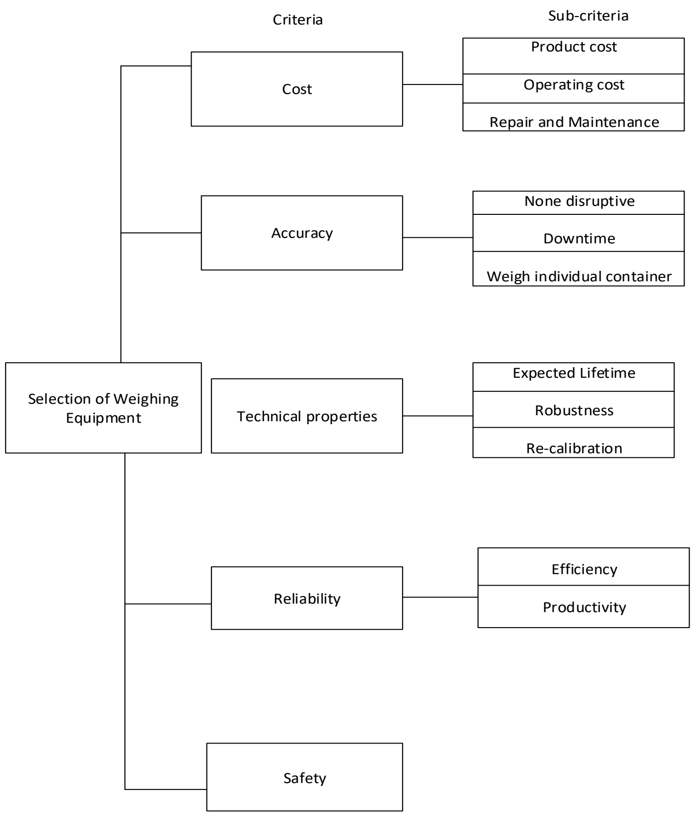
6. Please give an estimation of the following cost with regards to the weighing system

Installation cost =
Operation and maintenance cost =
Other associated cost =

7. Please provide any other comment:

Part 2 - Introduction

The primary goal of this study is to select the best and highly recommendable weighing equipment by comparing the listed criteria. The criteria and sub-criteria listed in the figure below are the parameters that need to be investigated and evaluated using “*pair-wise comparison*” techniques.



- *Equipment cost includes Product cost, operating cost, and cost related to repair and maintenance of equipment*
- *Equipment accuracy is the degree to which the result of the weight verified by the equipment’s, calculation, or specification conforms to the correct value or a standard, it includes None disruption to terminal work flow, downtime* (a period during which an *equipment* or *machine* is not functional or cannot work is referred to as the equipment downtime) and if the equipment can weigh individual container
- *Equipment technical characteristics includes equipment expected lifetime, robustness and re-calibration*
- *Equipment reliability can be described as the probability that an equipment system will operate at a specified performance level for a specific period, it includes equipment efficiency and productivity*
- *Equipment safety is the condition of equipment being protected from or being unlikely to cause danger, risk, or injury during operation.*

To proceed with the "*pair-wise comparison*" technique, an expert need to have a good knowledge of the qualitative descriptors or linguistic scales used for measurement in this study as represented in Table 1. The table describes the numerical assessment together with the linguistic meaning of each number.

Table 1: Ratio scale for pair-wise comparison - Importance

Numbers	**Strength of importance in Linguistic scales or qualitative descriptors**
1	Equally Important
3	Moderately Important
5	Strongly Important
7	Very strongly important
9	Extremely Important
2,4,6,8	Intermediate value of Importance

With reference to this, an expert is required to give a judgement to all question based on his/her experience and expertise. The judgement process must be focus on how to achieve the goal of each section. To do so, you are required to tick (x) as the rate of importance or priority of each criteria and sub-criteria in the given column. For instance:

<u>Example</u>

Part 1: Group A: If you think the first criterion **'Cost'** is strongly More important when buying a car than the second criterion **'Color'**, then please tick as follows:

	which parameter do you think is more important? Increasing ← → importance Increasing importance																	
Parameter	Extreme importance	(8)	Very strong	(6)	Strong	(4)	Moderate	(2)	Equally	(2)	Moderate importance	(4)	Strong	(6)	Very strong	(8)	Extreme importance	Parameter
Cost					x													Colour

*NB: Please remember to **<u>mark only one number on either the left or right side</u>** of the scale of importance or just the middle of the scale, which is equal importance. Intermediate values are also acceptable, e.g., Tick 6 is you feel that Cost is strongly to very strongly more important that Colour when buying a car.*

Group A (Main Criteria)

Which parameter do you think is more important? Please mark in the table

Increasing importance ← → Increasing importance

Parameters	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate importance **(3)**	**(2)**	Equally Important **(1)**	**(2)**	Moderate importance **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance **(9)**	**Parameters**
Cost																		Accuracy
Cost																		Technical characteristics
Cost																		Reliability
Cost																		Safety
Accuracy																		Technical characteristics
Accuracy																		Reliability
Accuracy																		Safety
Technical characteristics																		Reliability
Technical characteristics																		Safety
Reliability																		Safety

Remember the main criteria in the selection of a weighing equipment are:

- **Cost**: includes Product cost, operating cost, and cost related to repair and maintenance of equipment

- **Accuracy**: the degree to which the result of the weight verified by the equipment's, calculation, or specification conforms to the correct value or a standard, it includes None disruption to terminal work flow, downtime (a period during which an *equipment* or *machine* is not functional or cannot work is referred to as the equipment downtime) and if the equipment can weigh individual container
- **Technical characteristics**: e.g., equipment expected lifetime, robustness and re-calibration
- **Reliability**: probability that an equipment system will operate at a specified performance level for a specific period, it includes equipment efficiency and productivity
- **Safety**: the condition of equipment being protected from or being unlikely to cause danger, risk, or injury during operation.

Group B: Sub-criterion COST
Which parameter do you think is more important? (Please mark in the table)

Increasing importance ← → Increasing importance

Parameters	Extreme importance (9)	**(8)**	Very strong (7)	**(6)**	Strong (5)	**(4)**	Moderate (3)	**(2)**	Equally important	**(2)**	Moderate (3)	**(4)**	Strong (5)	**(6)**	Very strong (7)	**(8)**	Extreme	**Parameters**
Product cost																		Operating cost
Product cost																		Repair/ maintenance
Operating cost																		Repair/maintenance

Group B: Sub-criterion **ACCURACY**

Which parameter do you think is more important? (Please mark in the table)

Increasing importance ← → Increasing importance

Parameters	Extreme importance	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate **(3)**	**(2)**	Equally	**(2)**	Moderate **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme	**Parameters**
None disruptive																		Downtime
None disruptive																		Weigh individual container
Downtime																		Weigh individual container

Group B: Sub-criterion – **TECHNICAL PROPERTIES/CHARACTERISTICS**

Which parameter do you think is more important? (Please mark in the table)

Increasing importance ← → Increasing importance

Parameters	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate **(3)**	**(2)**	Equally	**(2)**	Moderate **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance **(9)**	**Parameters**
Expected lifetime																		Robust-ness
Expected lifetime																		Re-calibration
Robust-ness																		Re-calibration

Group B: Sub-criteria

In-group B, which parameter do you think is more important. (Please mark in the table)

Increasing importance ← → Increasing importance

Parameter	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate **(3)**	**(2)**	Equally important **(1)**	**(2)**	Moderate **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance **(9)**	**Parameter**
Efficiency																		Produ ctivity

Part 3

Introduction

In this section, the decision alternatives and evaluation criteria listed in Table 3.1 are the parameters that need to be considered and evaluated using "*fuzzy Linguistic variables scale*" techniques.

Table 3.1**:** List of Decision Alternatives and Evaluation Criteria

Decision Alternatives	**Evaluation Criteria**
1. Weighbridges 2. Load cells on ship to shore cranes 3. Load cells on RTGs 4. Weighing systems on Mobile harbour cranes 5. Weighing systems on reach stackers 6. Load cells on straddle carriers 7. Weighing systems on container forklifts FLTs 8. Load sensing systems using spreader twist lock	1. Equipment cost 2. Equipment accuracy 3. Equipment technical characteristics 4. Equipment reliability 5. Equipment Safety

Table 3.2: Fuzzy Linguistic Variables and Corresponding Scales

5 Linguistic Variables	**Corresponding Scale**
Very Low	(0, 0, 0.1, 0.2)
Low	(0.1, 0.25, 0.25, 0.4)
Medium	(0.3, 0.5, 0.5, 0.7)
High	(0.6, 0.75, 0.75, 0.9)
Very High	(0.8, 0.9, 1, 1)

with reference to Table 3.2, an expert is required to give a possible judgement to all question based on his/her experience and expertise in the container weighing systems. The judgement process has to be focus on how to achieve the goal of each decision alternative with respect to the evaluation criteria. To do so, please enter only one out of the five linguistic variables against each of the decision alternatives with respect to the evaluation criteria in the given column. For instance, see Table 3.3 below

EVALUATION CRITERIA	**EXAMPLE DECISION ALTERNATIVES**			
	Weighbridges	Load cells on ship to shore cranes	Load cells on RTGs	Weighing systems on mobile harbour crane
Cost	VH			
Accuracy	VL			
Technical characteristics	M		*Example*	
Reliability	L			
Safety	H			

VH = Very High, VL = Very Low, M = Medium, L = Low, H = High.

In the above example the expert believes that Weighbridges have a Very high (VH) cost, very low (VL) accuracy, medium (M) technical characteristics, low (L) reliability, and high (H) safety.

Please note that these judgements are subjective and should be made for each alternative having in mind that each criterion has to be evaluated compared to what they consider as the minimum and maximum characteristics.

PLEASE FILL THE TABLES BELOW - Main Question

Use the five linguistics variables very low VL, low L, medium M, high H, and very high VH to fill in the empty all cells corresponding to each of the decision alternatives and the criteria.

EVALUATION CRITERIA	DECISION ALTERNATIVES			
	Weighbridges	Load cells on ship to shore cranes	Load cells on RTGs	Weighing systems on mobile harbour crane
Cost				
Accuracy				
Technical characteristics				
Reliability				
Safety				

EVALUATION CRITERIA	DECISION ALTERNATIVES			
	Weighing systems on reach stackers	Load cells on straddle carriers	Weighing systems on container Fork lifts	Load sensing systems using spreader twist lock
Cost				
Accuracy				
Technical characteristics				
Reliability				
Safety				

Please fill all empty cells using the linguistic terms L, VL, M, H, VH

APPENDIX C

NIMASA questionnaire development for all departments

The opinions of experts from the three selected departments would be required to justify the rationality of all the selected measures and effectively evaluate the VGM regulation in the industry. As a result, various books and guidelines were reviewed for the construction of a conventional AHP questionnaire. The three basic requirements that was revealed are: the survey should be appropriately designed for the level of participants such that the questions would be easy for them to understand (Houtkoop-Steenstra 2000). The questionnaires should be developed in different sections in such a way that each section would be targeting a part of the research objectives (Frazer and Lawley 2001). A part of the questionnaire should include some personal details of participants (to be kept confidential) such as education and age as it may reveal different school of thought for the study (Bradburn and Sudman 1979).

Five set of questionnaires were designed for all the three different departments. Because each department is having its own BSC as presented on the hierarchical structure above in figure… Each of the questioners is divided into six different sections; each section is addressing a part of the research methodology.

Section 1- The first section includes general questions containing personal details of the experts participating on the survey such as academic qualification, industrial position, years of experience etc. Using these, the weight of experts can be ascertained.

Section 2 –The second section comprises a table of pairwise comparison on the three different departments whereby experts should indicate which department is more important than another. This would be used to determine the weight of each department as it would reveal the burden and level of responsibility for all the departments in the regulatory process.

Section 3- The third section comprises a table of pairwise comparison on the four different perspectives under a department whereby experts should indicate how much a perspective is more important than another in a pair. This would be used to determine the weight of each perspective as it would reveal the burden and level of responsibility for all the perspectives under their respective department in the regulatory process.

Section 4- The fourth section comprises a table of pairwise comparison on the four different measures under a perspective whereby experts should indicate how much a measure is more important than another in a pair. This would be used to determine the weight of each measure as it would reveal the burden and level of responsibility for all the measures under their respective perspectives in the regulatory process.

Section 5- The fifth section contains a table for scoring the measures with respect to implementation performance of the VGM regulation from a scale of 0-10. This would be used to evaluate the total performance rate of the regulation in the three key departments.

Section 6- Eventually the last part of the questionnaires is asking for comments with regard to the questionnaires.

A copy of questioners meant for maritime labour service departments is shown below.

Maritime labour service survey

Dear Sir/Madam,

The IMO has introduced many conventions, codes, resolutions and circulars collectively known as "Maritime Regulations". These regulations have been promoted as the worldwide uniform regulatory regime encouraging and aiming at the reduction or elimination of maritime disasters, accidents and pollution. However, there is some concern that the implementation of every maritime regulation may create difficulties and costs for the industry participants.

A research project at Liverpool John Moores University is currently being carried out with regard to the evaluation of the SOLAS Verified gross mass (VGM) regulations. This research will hopefully succeed in highlighting potential difficulties that industry participants face with the VGM regulations. NIMASA is the maritime agency controlling the maritime sector of Nigeria and also a member of the International Maritime Organisation (IMO). The aim of this research is to assess the implementation performance of the SOLAS VGM regulation with regard to the costs and benefits of implementing the regulation in Nigeria. This would be achieved by designing a tool that would measure the current rate of performance of the regulation. This tool would be beneficial to NIMASA and other participants in the maritime industry in monitoring the regulation implementation.

Following a thorough review of literature, three main Divisions representing the organisational structure of NIMASA have been identified. These three Divisions are Maritime labour service, Maritime Safety and Seafarers Standard, Marine environment management. Furthermore, a set of measures have been identified in order to evaluate the performance of each Division. This research needs to determine the effect of the SOLAS VGM regulation implementation on each of these Divisions and their measures. Thus, this survey sets out to provide an organized method for collecting views and information pertaining not only to the implementation issues of the SOLAS VGM regulation, but also to the performance of the SOLAS VGM regulation.

I should be most grateful if I could ask you to spare some of your very valuable time to complete the accompanying questionnaire, and then to e-mail or post it to myself at the address as shown above. Your vital feedback will greatly benefit and contribute in the formulation of an industry wide opinion. I can assure you that the confidentiality of your response will be honoured and respected.

Yours sincerely

Preye Ugedi

Liverpool Logistics Offshore and Marine Research Institute (LOOM)

PART 1

GENERAL QUESTIONS

1. Name: ____________

2. Age: 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55+ ☐

3. Branch Name ______________

4. Please tick your position or state your equivalent department position in the space provided, as it corresponds to your own department

- ☐ Executive Director
- ☐ Director
- ☐ Assistant director
- ☐ Chief maritime safety officer ______________
- ☐ Principal maritime safety officer ______________
- ☐ Senior Maritime safety officer ______________
- ☐ Maritime safety officer ______________
- ☐ Other: ______________

5. Please provide your industry experience (please tick the appropriate box).

- ☐ Below 3 years
- ☐ 3-9 years
- ☐ 10 – 19 years
- ☐ 20 – 29 years
- ☐ Other

6. Please provide your highest academic qualification

- ☐ PhD

- ☐ Master
- ☐ Bachelor
- ☐ HND or equivalent
- ☐ High School or equivalent
- ☐ Other_____________

Section 1

To proceed with the "pair-wise comparison" technique, an expert need to have a good knowledge of the qualitative descriptors or linguistic scales used for measurement in this study as represented in Tables 1. The tables describe the numerical assessment together with the linguistic meaning of each number.

Table 1: Ratio scale for pair-wise comparison - Important

Numbers	Strength of importance in Linguistic scales or qualitative descriptors
1	Equally Important
3	Moderately Important
5	Strongly Important
7	Very strongly important
9	Extremely Important
2,4,6,8	Intermediate value of Important

With reference to this, an expert is required to give a judgement to all question based on his/her experience and expertise. The judgement process has to be focus on how to achieve the goal of each section. To do so, you are required to tick (x) as the rate of importance or priority of each criteria and sub-criteria in the given column. For instance:

__Example__ Part 1: Group A: If you think, the first criterion '**Cost'** is strongly more important when buying a car than the second criterion '**Color'**, then please tick as follows:

	which parameter do you think is more important Increasing ← → importance Increasing importance	

Parameter	Extreme importance(9)	(8)	Very strong (7)	(6)	Strong importance (5)	(4)	Moderate importance (3)	(2)	Equally important (1)	(2)	Moderate importance (3)	(4)	Strong importance (5)	(6)	Very strong (7)	(8)	Extreme importance (9)	Parameter
Cost					x													Colour

NB: Please remember to ***mark only one number on either the left or right side*** *of the scale of importance or just the middle of the scale, which is equal importance.*

Intermediate values are also acceptable, e.g., Tick 6 is you feel that Cost is strongly to very strongly more important that Colour when buying a car.

a. In an initial study, three departments of NIMASA were identified concerning SOLAS VGM Regulation. In your opinion, please tick the more important department of each pairwise comparison in the SOLAS VGM regulatory implementation process. By using the linguistic terms, as they appear in table 1 above, please indicate how more important the department that you chose in each pairwise comparison is.

Group A (Criteria)

Which department do you think is more important in the enforcement of SOLAS VGM regulation? Please mark in the table

Increasing importance ← → Increasing importance

Departments	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate importance **(3)**	**(2)**	Equal **(1)**	**(2)**	Moderate importance **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance **(9)**	**Departments**
Maritime labour Service																		Maritime Safety and Seafarers standard
Maritime labour Service																		Marine Environment Management
Maritime Safety and																		Marine Environment Management

Seafarers Standard																		

b. In the same study, four perspectives regarding regulation performance were identified for each department of the shipping industry. In your opinion, please tick the more important perspective of every pairwise comparison for the department. By using the linguistic terms, as they appear in Question 1 of Section B, please indicate how more important a perspective from each pairwise comparison is.

- Financial Perspective: Is the cost and profits that would result from the implementation of a regulation.
- Customer perspective: Is the satisfaction of a stakeholder's customer as an outcome of the implementation.
- Learning and growth Perspective: Is the resources that are required to implement a regulation.
- Internal Business Perspective: Is the procedure that should be followed to implement a regulation.

(Maritime Labour Service Perspectives)
Which perspective do you think is more important in the implementation of the SOLAS VGM regulation? Please mark in the table

Increasing importance ← → Increasing importance

Perspective	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate importance **(3)**	**(2)**	Equal **(1)**	**(2)**	Moderate importance**(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance**(9)**	**Perspective**
Financial																		Customer
Financial																		Internal Business

Financial																		Learning and growth
Customer																		Internal Business
Customer																		Learning and growth
Internal Business																		Learning and growth

c. Using the definitions of measures below, please carry out a comparison of the measures as it concerns each perspective.

Financial Perspective: Is the cost and profits that would result from the implementation of a regulation. It consists of the following.

- Profit - Increase profit from regulating the implementation of new safety standards through VGM requirements in relation to the provision of maritime labour in Nigeria.
- Revenue - Increase revenue from existing cost of inspection due to risk of mis-declared weights to ensure maritime labour employers compliance to maintain safety.
- Cost - Reduce administration costs.
- Use of Assets - Minimize the need for immediate cash expenditure to meet regulations requirements.

Financial Perspective

Which measure do you think is more important? Please mark in the table

Increasing importance ← → Increasing importance

Measures	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate importance **(3)**	**(2)**	Equal **(1)**	**(2)**	Moderate importance**(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance**(9)**	**Measures**
Profit																		Revenue
Profit																		Cost
Profit																		Use of Assets

Revenue																		Cost
Revenue																		Use of Assets
Cost																		Use of Assets

The Customer perspective Is the satisfaction of a stakeholder's customer as an outcome of the implementation. It consists of the following;

- Productivity - Achieve IMO standard of implementation as member state.
- Competitiveness - High-level playing field in the maritime industry.
- Quality - Increase quality of regulation enforcement and compliance
- Reputation - Increase reputation and credibility

Customer perspectives

Which measure do you think is more important? Please mark in the table

Increasing importance ← → Increasing importance

Measures	Extreme importance (9)	**(8)**	Very strong (7)	**(6)**	Strong (5)	**(4)**	Moderate importance (3)	**(2)**	Equal (1)	**(2)**	Moderate importance (3)	**(4)**	Strong (5)	**(6)**	Very strong (7)	**(8)**	Extreme importance (9)	**Measures**
Productivity																		Competitiveness
Productivity																		Quality
Productivity																		Reputation
Competitiveness																		Quality
Competitiveness																		Reputation
Quality																		Reputation

The Internal Business Perspective Is the procedure that should be followed to implement a regulation and it consist of the following.

- Risk analysis - Minimize efforts to carry out risk assessment for the VGM regulation.
- Planning - Minimize efforts to develop plans to implement the VGM regulation.
- Training - Minimize efforts to provide training regarding implementation of the VGM regulation.
- Review - Minimize efforts to review the internal business process

Internal business Perspectives

Which measure do you think is more important? Please mark in the table

Increasing importance ← → Increasing importance

Measures	Extreme importance (9)	(8)	Very strong (7)	(6)	Strong (5)	(4)	Moderate importance (3)	(2)	Equal (1)	(2)	Moderate importance(3)	(4)	Strong (5)	(6)	Very strong (7)	(8)	Extreme importance (9)	Measures
Risk Analysis																		Planning
Risk Analysis																		Training
Risk Analysis																		Review
Planning																		Training
Planning																		Review
Training																		Review

Learning and growth Perspective Is the resources that are required to implement a regulation. It consists of the following.

- Human capital- Reduce the need to hire additionally employees
- Information capital - Reduce the need to purchase additionally IT applications

- Organisational capital - Reduce number of misdeclared container incidents.
- Innovation - Introduce new shipping standards

Learning & growth Perspectives

Which measure do you think is more important? Please mark in the table

Increasing importance ← → Increasing importance

Measures	Extreme importance **(9)**	**(8)**	Very strong **(7)**	**(6)**	Strong **(5)**	**(4)**	Moderate importance **(3)**	**(2)**	Equal **(1)**	**(2)**	Moderate importance **(3)**	**(4)**	Strong **(5)**	**(6)**	Very strong **(7)**	**(8)**	Extreme importance **(9)**	**Measures**
Human Capital																		Information Capital
Human Capital																		Organisation Capital
Human Capital																		Innovation
Information Capital																		Organisation Capital
Information Capital																		Innovation
Organisation Capital																		Innovation

Section 2: Performance score of the Stakeholder Measures.

Each identified perspective is described and defined by four measures. Please tick the performance rate of each measure by using values from 1-10.

Performance Intensity	Performance score
Very high performance	9-10
High performance	7-8
Medium performance	4-6
Low performance	2-3
Very Low performance	0-1

Maritime Labour Service											
Perspective	**Measures**	**Rate**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Financial	Increase revenue from regulating the implementation of new safety standards through VGM requirements in relation to the provision of maritime labour in Nigeria.										
	Increase revenue from existing cost of inspection due to risk of mis-declared weights to ensure maritime labour employers compliance in order to maintain safety.										
	Reduce administration costs.										
	Minimize the need for immediate cash expenditure to meet regulations requirements.										
Customer	Achieve IMO standard of implementation as member state.										
	High-level playing field in the maritime industry.										
	Increase quality of regulation enforcement and compliance										
	Increase reputation and credibility										
Learning and growth	Reduce the need to hire additionally employees										
	Reduce the need to purchase additionally IT applications										
	Reduce number of misdeclared container incidents.										
	Introduce new shipping standards										
Internal business	Minimize efforts to carry out risk assessment for the VGM regulation.										
	Minimize efforts to develop plans to implement the VGM regulation.										
	Minimize efforts to provide training regarding implementation of the VGM regulation.										
	Minimize efforts to review the internal business process										

d. Comments. If you have any general comments on regulation performance evaluation or about this questionnaire, please feel free to suggest in the space below.

APPENDIX D

CBA Questionnaire

As mentioned at the start, the focus of this survey is to collect data that will be used in conducting a cost-benefit CBA analysis. Providing the requested information under cost and benefits sections is really needed in conducting this analysis.

The aim of the CBA is to identify the pros and cons of any intended project. CBA aid social decision-making and to make it more realistic. In general, the cost components consist of the initial or capital cost, and operating cost for the case of application, maintenance cost is also inclusive e.tc. The benefit part is more complicated, it focuses on the advantages of the project.

Please give the following information as it relates to your port container weighing system:

Table 1 – Cost
What type of container weighing system (CWS) do you have in your port? =
Cost of purchase/installation =
Yearly cost of Maintenance =
Running Cost Per time =
Running Cost Per year =
Total annual cost =
Annuity =

Table 2 – Benefits
Investment time =
Interest rate =
Times Used per day =
Operating days =
Annual uses =
Weighing charges =

APPENDIX E

Decision tree questionnaire

PART 1

Expert details (Optional)

1. Name: ______________
2. Company Name: ______________
3. Please what position are you in the company? ______________
4. Please tick your years of experience.

☐ 1-5 years
☐ 6-10 years
☐ 11-30 years
☐ Over 30 years

5. Please tick your highest academic qualification

☐ PhD
☐ Master
☐ Bachelor
☐ High School or equivalent
☐ Other_____________

PART 2

The shipper is responsible for providing a VGM to the carrier. A shipper may contract out the packing and the determination of the VGM of a container. The verified gross mass should be as accurate (+ or – 5%). This can be done by either using Method 1 or 2;

Method 1: Weighing the packed and sealed container. Using weighbridges, or lifting equipment fitted with load cells, or other appropriate weighing equipment to determine the verified gross mass (VGM) of a loaded container.

Method 2: Involves a summation of the weight of the cargo, weight of pallets, dunnage (items used to secure the cargo etc.), and the tare weight of the container.

With the above definitions please provide the possible answers for the following questions.

1. If providing the VGM in-house (shipper) what is the probability of the shipper using method 1 over method 2 other?
   ☐ 50% - 50%
   ☐ 80% - 20%
   ☐ 75% - 25%
   ☐ 60% - 40%
   ☐ 15% - 85%
   ☐ Other ______________

2. If providing the VGM through a third-party what is the probability of the shipper using method 1 over method 2?
   ☐ 50% - 50%
   ☐ 80% - 20%
   ☐ 75% - 25%
   ☐ 60% - 40%

☐ 15% - 85%
☐ Other ______________

3. How much does it cost a shipper to provide VGM in-house (himself) using method 1? ______________

4. How much does it cost a shipper to provide VGM in-house using method 2? ______________

5. How much does it cost a shipper to provide VGM through a third-party using method 1? ______________

6. How much does it cost a shipper to provide VGM through a third-party using method 2? ______________

PART 3

Shipper (in-house)
Please score or write down the appropriate answer **with the understanding that the shipper decides to provide VGM Himself (in-house)**

When using Method 1		**When using Method 2**
1.	What is the probability of getting an accurate VGM? ______________ ☐50% ☐75% ☐25% ☐80% ☐95%	What is the probability of getting an accurate VGM? ______________ ☐50% ☐75% ☐25% ☐80%☐95%
2.	What happens in the event of an in-accurate VGM? ______________	What happens in the event of an in-accurate VGM? ______________
3.	If there was an additional charge, how much would it cost? ______________	If there was an additional charge, how much would it cost? ______________
4.	If the VGM is in-accurate and it resulted to container rejection/fine, how much would it cost the shipper? ______________	If the VGM is in-accurate and it resulted to container rejection/fine, how much would it cost the shipper? ______________
5.	What is the probability of the mis-declared container being rejected or incurring a fine? ______________	What is the probability of the mis-declared container being rejected or incurring a fine? ______________

	☐50% ☐75% ☐25% ☐80%☐95%	☐50% ☐75% ☐25% ☐80%☐95%

Third-Party

Please score or write down the appropriate answer **with the understanding that the shipper decides to provide VGM by contracting a third-party**

	When using Method 1	**When using Method 2**
1.	What is the probability of getting an accurate VGM? _____________ ☐50% ☐75% ☐25% ☐80%	What is the probability of getting an accurate VGM? _____________ ☐50% ☐75% ☐25% ☐80%
2.	What happens in the event of an in-accurate VGM? _____________	What happens in the event of an in-accurate VGM? _____________
3.	If there was an additional charge, how much would it cost? _____________	If there was an additional charge, how much would it cost? _____________
4.	If the VGM is in-accurate and it resulted to container rejection/fine, how much would it cost the shipper? _____________	If the VGM is in-accurate and it resulted to container rejection/fine, how much would it cost the shipper? _____________
5.	What is the probability of the mis-declared container being rejected or incurring a fine? _____________ ☐50% ☐75% ☐25% ☐80%	What is the probability of the mis-declared container being rejected or incurring a fine? _____________ ☐50% ☐75% ☐25% ☐80%

Assuming the shipper choose to use SOLAS method 2, please provide the appropriate answers to the following questions.

What is the probability of getting an accurate VGM?

What happens in the event of an in-accurate VGM?

If there was an additional charge, how much would it cost?

If the VGM is in-accurate and it resulted to container rejection/fine, how much would it cost the shipper?

What is the probability of the mis-declared container being rejected or incurring a fine?

APPENDIX F

Evaluation of the NIMASA departments

With the help of data provided by experts in the second section of the survey, which comprises a table of pairwise comparison for the three different department; the TFNs of Figure 4.3 In addition, table 5.7 are used to fill in the pairwise comparison matrix for the three departments as shown in below in table F.1 (matrix is symmetric)

Table F. 1: Detailed pairwise comparison table for participants

STAKEHOLDER	Maritime Labour			Maritime Safety			Marine Environment		
Maritime Labour Service	1	1	1	8	9	9	8	9	9
	1	1	1	8	9	9	7	8	9
	1	1	1	8	9	9	7	8	8
	1	1	1	8	9	9	7	8	9
	1	1	1	1/7	1/6	1/5	1/4	1/3	½
	1	1	1	1/6	1/5	1/4	1/4	1/3	½
	1	1	1	1/7	1/6	1/5	1/4	1/3	½
	1	1	1	1	1	1	8	9	9
	1	1	1	8	9	9	4	5	6
	1	1	1	1/8	1/7	1/6	1/4	1/3	½
	1	1	1	1/4	1/3	1/2	1/4	1/3	½
	1	1	1	1/7	1/6	1/5	1/5	1/4	1/3
	1	1	1	1/9	1/9	1/8	1/4	1/3	½
	1	1	1	1/9	1/9	1/8	1/4	1/3	½
Maritime Safety and Seafarers Standard	1/9	1/9	1/8	1	1	1	8	9	9
	1/9	1/9	1/8	1	1	1	7	8	9
	1/9	1/9	1/8	1	1	1	6	7	8
	1/9	1/9	1/8	1	1	1	7	8	9
	5	6	7	1	1	1	5	6	7

	4	5	6	1	1	1	4	5	6
	5	6	7	1	1	1	5	6	7
	1	1	1	1	1	1	8	9	9
	1/9	1/9	1/8	1	1	1	2	3	4
	6	7	8	1	1	1	6	7	8
	2	3	4	1	1	1	8	9	9
	5	6	7	1	1	1	5	6	7
	8	9	9	1	1	1	8	9	9
	8	9	9	1	1	1	8	9	9
Marine Environment Management	1/9	1/9	1/8	1/9	1/9	1/8	1	1	1
	1/9	1/8	1/7	1/9	1/8	1/7	1	1	1
	1/8	1/8	1/7	1/8	1/7	1/6	1	1	1
	1/9	1/8	1/7	1/9	1/8	1/7	1	1	1
	2	3	4	1/7	1/6	1/5	1	1	1
	2	3	4	1/6	1/5	1/4	1	1	1
	2	3	4	1/7	1/6	1/5	1	1	1
	1/9	1/9	1/8	1/9	1/9	1/8	1	1	1
	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1
	2	3	4	1/8	1/7	1/6	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1
	3	4	5	1/7	1/6	1/5	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1

STAKEHOLDER	Maritime Labour			Maritime Safety			Marine Environment		
	1	1	1	8	9	9	8	9	9

Maritime Labour Service	1	1	1	8	9	9	7	8	9
	1	1	1	8	9	9	7	8	8
	1	1	1	8	9	9	7	8	9
	1	1	1	1/7	1/6	1/5	1/4	1/3	1/2
	1	1	1	1/6	1/5	1/4	1/4	1/3	1/2
	1	1	1	1/7	1/6	1/5	1/4	1/3	1/2
	1	1	1	1	1	1	8	9	9
	1	1	1	8	9	9	4	5	6
	1	1	1	1/8	1/7	1/6	1/4	1/3	1/2
	1	1	1	1/4	1/3	1/2	1/4	1/3	1/2
	1	1	1	1/7	1/6	1/5	1/5	1/4	1/3
	1	1	1	1/9	1/9	1/8	1/4	1/3	1/2
	1	1	1	1/9	1/9	1/8	1/4	1/3	1/2
maritime Safety and Seafarers Standard	1/9	1/9	1/8	1	1	1	8	9	9
	1/9	1/9	1/8	1	1	1	7	8	9
	1/9	1/9	1/8	1	1	1	6	7	8
	1/9	1/9	1/8	1	1	1	7	8	9
	5	6	7	1	1	1	5	6	7
	4	5	6	1	1	1	4	5	6
	5	6	7	1	1	1	5	6	7
	1	1	1	1	1	1	8	9	9
	1/9	1/9	1/8	1	1	1	2	3	4
	6	7	8	1	1	1	6	7	8
	2	3	4	1	1	1	8	9	9
	5	6	7	1	1	1	5	6	7
	8	9	9	1	1	1	8	9	9
	8	9	9	1	1	1	8	9	9

Marine Environment Management	1/9	1/9	1/8	1/9	1/9	1/8	1	1	1
	1/9	1/8	1/7	1/9	1/8	1/7	1	1	1
	1/8	1/8	1/7	1/8	1/7	1/6	1	1	1
	1/9	1/8	1/7	1/9	1/8	1/7	1	1	1
	2	3	4	1/7	1/6	1/5	1	1	1
	2	3	4	1/6	1/5	1/4	1	1	1
	2	3	4	1/7	1/6	1/5	1	1	1
	1/9	1/9	1/8	1/9	1/9	1/8	1	1	1
	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1
	2	3	4	1/8	1/7	1/6	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1
	3	4	5	1/7	1/6	1/5	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1
	2	3	4	1/9	1/9	1/8	1	1	1

Hence, table F.1 above is further presented in the table below

Table F. 2: Detailed pairwise comparison table for participants

STAKEHOLDER	Maritime Labour			Maritime Safety			Marine Environment		
Maritime Labour Service	1	1	1	8.000	9.000	9.000	8.000	9.000	9.000
	1	1	1	8.000	9.000	9.000	7.000	8.000	9.000
	1	1	1	8.000	9.000	9.000	7.000	8.000	8.000
	1	1	1	8.000	9.000	9.000	7.000	8.000	9.000
	1	1	1	0.143	0.167	0.200	0.250	0.333	0.500
	1	1	1	0.167	0.200	0.250	0.250	0.333	0.500
	1	1	1	0.143	0.167	0.200	0.250	0.333	0.500
	1	1	1	1.000	1.000	1.000	8.000	9.000	9.000
	1	1	1	8.000	9.000	9.000	4.000	5.000	6.000
	1	1	1	0.125	0.143	0.167	0.250	0.333	0.500
	1	1	1	0.250	0.333	0.500	0.250	0.333	0.500
	1	1	1	0.143	0.167	0.200	0.200	0.250	0.333

	1	1	1	0.111	0.111	0.125	0.250	0.333	0.500
	1	1	1	0.111	0.111	0.125	0.250	0.333	0.500
maritime Safety and Seafarers Standard	0.111	0.111	0.125	1	1	1	8.000	9.000	9.000
	0.111	0.111	0.125	1	1	1	7.000	8.000	9.000
	0.111	0.111	0.125	1	1	1	6.000	7.000	8.000
	0.111	0.111	0.125	1	1	1	7.000	8.000	9.000
	5.000	6.000	7.000	1	1	1	5.000	6.000	7.000
	4.000	5.000	6.000	1	1	1	4.000	5.000	6.000
	5.000	6.000	7.000	1	1	1	5.000	6.000	7.000
	1.000	1.000	1.000	1	1	1	8.000	9.000	9.000
	0.111	0.111	0.125	1	1	1	2.000	3.000	4.000
	6.000	7.000	8.000	1	1	1	6.000	7.000	8.000
	2.000	3.000	4.000	1	1	1	8.000	9.000	9.000
	5.000	6.000	7.000	1	1	1	5.000	6.000	7.000
	8.000	9.000	9.000	1	1	1	8.000	9.000	9.000
	8.000	9.000	9.000	1	1	1	8.000	9.000	9.000
Marine Environment Management	0.111	0.111	0.125	0.111	0.111	0.125	1	1	1
	0.111	0.125	0.143	0.111	0.125	0.143	1	1	1
	0.125	0.125	0.143	0.125	0.143	0.167	1	1	1
	0.111	0.125	0.143	0.111	0.125	0.143	1	1	1
	2.000	3.000	4.000	0.143	0.167	0.200	1	1	1
	2.000	3.000	4.000	0.167	0.200	0.250	1	1	1
	2.000	3.000	4.000	0.143	0.167	0.200	1	1	1
	0.111	0.111	0.125	0.111	0.111	0.125	1	1	1
	0.167	0.200	0.250	0.250	0.333	0.500	1	1	1
	2.000	3.000	4.000	0.125	0.143	0.167	1	1	1
	2.000	3.000	4.000	0.111	0.111	0.125	1	1	1
	3.000	4.000	5.000	0.143	0.167	0.200	1	1	1
	2.000	3.000	4.000	0.111	0.111	0.125	1	1	1
	2.000	3.000	4.000	0.111	0.111	0.125	1	1	1

The logical systematic concessions between the three opinions can be determined by calculating their average as shown below.

$$E_{\tilde{m}_x} = \frac{\sum_{i=1}^{r} E_i}{r}$$

$$= \left\{\frac{8+8+8+8+0.143+0.167+0.143+1+8+0.125+0.250+0.143+0.111+0.111}{14}\right\}$$

$$= 3.014$$

Table F. 3: Showing fuzzy decision matrix for participants

Stakeholder	Maritime Labour Service	Maritime Safety and Seafarer's Standard	Marine Environment Management
Maritime Labour Service	1,1,1	3.014,3.386,3.412	3.068,3.542,3.845
Maritime safety management	3.183,3.754,4.188	1,1,1	6.214,7.214,7.857
Marine environment management	1.267,1.843,2.423	0.134,0.152,0.185	1,1,1

The fuzzy numbers of the matrix for the participants are defuzzified to find the crisp numbers of the TFNs by using Equation 9, which would effectively give the actual elements of the decision matrix as illustrated with the pairwise comparison of Maritime labour and Maritime safety below:

$$M_{Crisp} = \frac{(b+a+c)}{3} = \frac{3.014 + 3.386 + 3.412}{3} = 3.270$$

The defuzzication results from the fuzzy matrix of the participants are shown in Table F.4 below.

Table F. 4: Showing defuzzified decision matrix for participants

Department	MLS	MSS	MEM
MLS	1.000	3.270	3.485
MSS	3.708	1.000	7.095
MEM	1.844	0.157	1.000

From the defuzzified decision matrix for departments shown in Table F.4 above λ_{max} is calculated by using Equation 5 as 6.405 and the RI value is 0.58.

Therefore, the CI and CR values for the above decision matrix are calculated.

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{6.405 - 3}{3-1}$$

$$CR = \frac{CI}{RI} = \frac{1.703}{0.58} = 2.94$$

The departments are ranked in terms of their weighting in the regulatory process and the results are shown in Table 5.4. An example of calculation for the weight of the MLS is shown below:

$$w_{Dp} = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} akj}$$

Where $n = Number\ of\ departments = 3$

Table F.6 shows the relevant weight of each department, which indicates their relative importance in the implementation process, according to the experts.

Table F.6: Showing the weight of participants

STAKEHOLDER	Weight	Rank
Maritime Labour Service	0.397	2
Maritime Safety and Seafarers Standard	0.468	1
Marine Environment Management	0.134	3