# SHIP AVAILABILITY ORIENTED CONTRACT MANAGEMENT MODEL FOR IN-SERVICE SUPPORT CONTRACTS OF NAVAL VESSELS

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# SHIP AVAILABILITY ORIENTED CONTRACT MANAGEMENT MODEL FOR IN-SERVICE SUPPORT CONTRACTS OF NAVAL VESSELS

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**DEDICATION**

*To Allah (SWT), my beloved Prophet Muhammad Rasulullah (PBUH), my mother and father, my wife and children.*

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# ABSTRACT

The rapid development of the ship building and ship repair industry in recent years has transformed the way organizations perceive the future industry growth. Greater growth of naval technology is clearly noticed as well. Disappointingly, the worldwide phenomenon reflects that availability of naval vessels remained lower than expected. The Royal Malaysian Navy (RMN) vessels currently maintained under in-service support (ISS) contracts suffer the same fate, despite continuous yearly effort to improve the ships' availabilities. The complexity of naval ship itself and its ever-changing roles and mission makes the situation more complex. Previous studies remained focused mostly on availability calculations and availability modelling of few factors only. There has not been any holistic study on all human and equipment factors impacting availability. The research aim is to demystify the complex naval ship availability issue by developing a decision-making model in improving ship operational availability of naval vessels under the ISS contract. Besides introducing a simplified view to the complex naval issue, this multiple-staged mixed-method sequential Delphi exploratory research has determined and ranked various downtime influence factors (DIFs) viewed holistically from both human and equipment perspectives, as well as determining the DIFs impact from the contract and project management perspectives. A panel of 30 experts and five top management experts in ISS contract in Malaysia participated in the research. 50 DIFs were identified, and a severity index (SI) was developed for each of the determined 15 severe DIFs. The developed SI highlights that almost 45% of the downtime causes are due to the top five severe DIFs with corrective maintenance (SI 0.142) ranked first, spares availability (SI 0.082) ranked second, cash flow shortages (SI 0.078), ranked third maintenance budget allocation ranked fourth (SI 0.075) and knowledge management including training and skills (SI 0.070) ranked fifth. In this study, an availability-oriented model has been developed to assist policymakers in decision making and for maintainers and logisticians in appreciating their individual contribution to improve availability. Contract managers are provided with a tool to better manage the contract at 'close to real time' with identified prioritization on severe issues added with recovery recommendation to improve the ongoing availability situation. The simple approach and model are more appealing to practitioners unlike previously where complex mathematical results and algorithms were made available. An interesting finding is that availability could be improved even with budget constraints.

# ABSTRAK

Perkembangan pesat pembinaan kapal dan industri pembaikan kapal pada tahun-tahun kebelakangan ini telah mengubah persepsi masyarakat terhadap pertumbuhan industri masa depan. Kemajuan teknologi tentera laut juga lebih jelas kelihatan. Walau bagaimanapun, fenomena sedunia menunjukkan kesiapsiagaan kapal tentera laut kekal rendah daripada sasaran. Kapal Tentera Laut Diraja Malaysia (TLDM) yang disenggara di bawah Kontrak Sokongan dalam Perkhidmatan (ISS) mengalami nasib yang sama, walaupun terdapat usaha berterusan untuk meningkatkan kesiapsiagaan kapal. Kapal tentera laut yang rumit ditambah dengan peranan dan misi yang sentiasa berubah menjadikan keadaan lebih kompleks. Kajian terdahulu kerap tertumpu pada pengiraan tahap kesiapsiagaan dan penyediaan model yang melibatkan beberapa faktor sahaja. Tiada sebarang kajian holistik merangkumi faktor-faktor manusia dan peralatan dilaksanakan secara meluas. Matlamat penyelidikan ini adalah untuk mempermudah konsep kesiapsiagaan bersama sebuah model yang berkeupayaan menyokong proses membuat keputusan bagi meningkatkan kesiapsiagaan kapal di bawah ISS. Selain memudahkan pemahaman konsep kesiapsiagaan, penyelidikan jenis penerokaan menggunakan metodologi campuran melibatkan kumpulan fokus serta beberapa fasa Delphi yang berturutan ini berjaya menentukan dan mengukur faktor yang mempengaruhi ketidakaktifan kapal (DIF) dilihat secara holistik daripada perspektif manusia dan peralatan, serta impak DIF dari perspektif pengurusan kontrak dan projek. Panel pakar seramai 30 orang dan lima pakar pengurusan tertinggi organisasi ISS di Malaysia telah terlibat. 50 DIF telah dikenalpasti, dan Indeks Keparahan telah ditentukan bagi setiap 15 DIF utama. Indeks Keparahan (SI) mendapati hampir 45% ketidakaktifan kapal berpunca daripada lima DIF utama iaitu senggaraan baikpulih (SI 0.142) di tempat pertama, kesediaan alatganti (SI 0.082) di tempat kedua, masalah aliran tunai (SI 0.078) ketiga, kekurangan bajet (SI 0.075) keempat dan pengurusan pengetahuan termasuk latihan dan kemahiran (SI 0.070) di tempat kelima. Hasilnya, model berorientasikan kesiapsiagaan telah dibangunkan bagi membantu pembuat dasar membuat keputusan, serta penyelenggara dan anggota logistik dalam menghargai sumbangan masing-masing bagi meningkatkan kesiapsiagaan kapal. Pengurus Kontrak kini disediakan suatu alat bantuan mengurus, mengawal dan memantau kontrak dengan lebih efektif pada 'hampir masa sebenar' dengan keutamaan diberi pada DIF-DIF kritikal bersama cadangan kiraan pemulihan bagi kesiapsiagaan selanjutnya. Pendekatan dan model ini terbukti lebih mudah serta menarik kepada para pengamal berbanding sebelum ini di mana mereka hanya diperuntukkan dengan keputusan dan algoritma matematik yang kompleks. Satu penemuan menarik adalah bahawa kesiapsiagan kapal masih boleh ditingkatkan tanpa penambahan bajet.

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| | | |
|---|---|---|
| AAW | - | Anti-Air Warfare |
| ABC | - | Availability-Based Contract |
| Am | - | Mission Availability |
| Ao | - | Operational Availability |
| ASW | - | Anti-Submarine Warfare |
| ASuW | - | Anti-Surface Warfare |
| At | - | Technical Availability |
| AMT | - | Advanced Manufacturing Technologies |
| ANOVA | - | Analysis of Variance |
| BN | - | Boustead Naval Shipyard Sdn Bhd |
| BNT | - | BHIC Navaltech Sdn Bhd |
| BHIC | - | Boustead Heavy Industries Corporation Berhad |
| CBM | - | Condition Based Maintenance |
| CBS | - | Contract Build Specifications |
| CfA | - | Contracting for Availability |
| CM | - | Corrective Maintenance |
| COM | - | Class Output Management |
| ConCaMS | - | Contract Management Control and Monitoring System |
| CV | - | Coefficient of Variation |
| DLM | - | Depot Level Maintenance |
| DIF | - | Downtime Influence Factor |
| DSA | - | Defence Services Asia |
| EEP | - | Economic Enhancement Programme |
| EW | - | Electronic Warfare |
| FGD | - | Focus Group Discussions |
| FinAT | - | Final Acceptance Trial |
| FMEA | | Failure Modes and Effects Analysis |
| FREMM | - | Fregate Europe Multimissione |
| FTV | - | Fast Troop Vessels |
| GAO | - | Government Accountability Office |

| | | |
|---|---|---|
| GOM | - | Government of Malaysia |
| ICT | - | Information Communication Technology |
| ILM | - | Intermediate Level Maintenance |
| ILS | - | Integrated Logistics Support |
| ISS | - | In-Service Support |
| LCC | - | Life Cycle Cost |
| LCS | - | Littoral Combat Ships |
| LFT | - | Live Firing Trials |
| LTI | - | Loss Time due to Injury |
| MM | - | Maintenance Management |
| MMEA | - | Malaysian Maritime Enforcement Agency |
| MTTB | - | Meantime to Breakdown |
| MTTR | - | Meantime to Repair |
| OEE | - | Overall Equipment Effectiveness |
| OEM | - | Original Equipment Manufacturer |
| OLM | - | Onboard Level Maintenance |
| PBC | - | Performance-based Contract |
| PdM | - | Predictive Maintenance |
| PHM | - | Prognostics and Health Management |
| PM | - | Preventive Maintenance |
| PMI | - | Project Management Institute |
| PV | - | Patrol Vessel |
| RA | - | Research Aim |
| RAN | - | Royal Australian Navy |
| RCM | - | Reliability-Centred Maintenance |
| RI | - | Remaining Items |
| RFP | - | Request for Proposal |
| RFQ | - | Request for Quotation |
| RMN | - | Royal Malaysian Navy |
| RN | - | Royal Navy |
| RO | - | Research Objectives |
| ROVA | - | Return of Vessel Availability |
| RQ | - | Research Questions |

| | | |
|---|---|---|
| SAR | - | Search and Rescue |
| SAT | - | Sea Acceptance Trial |
| SI | - | Severity Index |
| SLEP | - | Ship Life Extension Programme |
| SoS | - | System of Systems |
| SPSS | - | Statistical Package for the Social Sciences |
| STW | - | Setting to Work |
| SWBS | - | Ship Work Breakdown Structure |
| TGS | - | Temporary Global Support |
| TOC | - | Total Cost of Ownership |
| TOF | - | Task Order Forms |
| TPM | - | Total Productive Maintenance |
| UK | - | United Kingdom |
| USA | - | United States of America |
| USAF | - | United States Air force |
| USN | - | United States Navy |
| WOS | - | Weightage of Severity |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Security challenges facing Malaysia have evolved with the ever-growing new and emerging technologies. The Malaysia National Defence Policy (MOD Malaysia, 2018) states clearly that the Malaysian Armed Forces (MAF) has to be flexible, mobile and possess a high degree of readiness. This requires the MAF organizational structure and strategic assets to be built and consistently maintained enabling it to always be ready to address all threats simultaneously. However, these threats with varying degrees of criticality, have not compelled the government of Malaysia (GOM) to substantially increase its expenditure in defence. Prudent spending measures result in most new defence programmes shelved or deferred for the time being (Guan, 2016). This results in an inevitable increase in the criticality of maintaining operational availability of existing defence assets including naval vessels.

Ship operational availability is described as the number of days the warships are available for operational tasking in a year (GAO, 2015c). The duration a naval vessel is able to remain in an area of operations reveals the sustainability and deterrence of the naval vessel (GAO, 2015c). In contrast to merchant ships, naval vessels which possess different set of functions, complex design characteristics (Dell'Isola and Vendittelli, 2015, Submarine Institute of Australia, 2017) and a variety of military roles (Directorate of Maritime Strategy Canada, 2001, Royal Navy Canada, 2012) and concept of operations, are equipped with a greatly different set of systems and equipment onboard to suit its war, combat and battle management capabilities. Naval warships are also equally demanded for many other missions during peace and conflict other than war. The navy's military operations other than war (MOOTW) includes search and rescue, disaster relief, surveillance and control of the country's territory and approaches, peace support operations and many more (Directorate of Maritime Strategy Canada, 2001). Therefore operational availability of naval ships or warships is a complex problem (Dell'Isola and Vendittelli, 2015, Ng *et al.*, 2009).

Availability is also a measure of maintenance performance (Parida and Kumar, 2009). For many decades, maintenance was regarded as an unavoidable part of the production function and difficult to manage. Maintenance was initially considered as 'necessary rework' and was not paid too much attention. In fact, quite often in most organizations, maintenance is considered a burden, sometimes considered a needless cost, sometimes given the least priority in time, resources and budget. Dekker (1996) pointed that there was minimal focus given to maintenance due to the difficulty to relate its contribution to company profits, therefore often seen as a cost function only. Swanson (2001) explained that traditionally, many companies approach to maintenance was to react, activities would only be carried out because machinery had to be fixed as it had stopped working.

Ship maintenance was not well structured or organized in comparison with other industrial entities which observed that huge savings may be made when carrying out proper maintenance tasks (Leger and Iung, 2012). There have been several cases which had proven that a proper maintenance strategy could have saved the organization or the industry millions of dollars, but most of them involved the more glamorous industries such as aviation and oil and gas sectors (Parida and Kumar, 2009, United Nations, 1993). Ship maintenance was previously considered as tasks needed to be performed on daily basis as part of operation, a mere necessity to keep the ship going in order to fulfil its mission of travelling from point A to point B. The maintenance activities were done mainly based on the experience of the chief engineer and his crew, or instruction of the ship captain for the range of equipment onboard the vessels.

In Malaysia, the Royal Malaysian Navy (RMN) has been managing a fleet of naval vessels for the last 80 years, and there are various types of vessels in the fleet including fast attack crafts, transport ships, frigates, corvettes, tugs, and the latest batch of six patrol vessels (PVs) of MEKO 100 RMN design. These PVs were commissioned into the RMN from 2006 and maintained through the in-service support (ISS) contract between the government of Malaysia (GOM) and Boustead Naval Shipyard Sdn Bhd (BN Shipyard). Even though three separate ISS contracts have been implemented on three classes of navy ships over a period of three years each, the RMN continued to face great challenges to meet its targeted operational availability of its fleet of naval vessels. This obstacle is common to most navies worldwide including United States Navy (Marais *et al.*, 2013), Italian and French Navy (Dell'Isola and Vendittelli, 2015), Korean Navy (Paik, 2014) and Royal Netherlands Navy (van Donkelaar, 2017).

This is a result of having insufficient holistic study and concentrated effort in improving ship availability. As a result, the RMN PV ISS contracts continued to use legacy clauses that have not been formulated to meet its prime objectives in accordance to the National Defence Policy but seemed to have enough coverage to allow the contract to be implemented for purposes of maintaining the vessels. It has not been structured to meet a certain availability or productivity or reliability target, or to minimize contract risks, or to optimize maintenance activities, neither to follow certain crucial policies or philosophies of maintenance.

## 1.2 Organizational Challenges

BN Shipyard has been the leading shipyard in Malaysia for the repair of naval ships since its corporatization in 1991 and subsequently its privatization from being the government-owned Naval Dockyard Sdn Bhd in 1995. On shipbuilding, the shipyard had successfully completed mega-projects such as the shipbuilding of six PVs awarded in 1998, resulting with the award of the new and sophisticated littoral combat ship (LCS) contract for six vessels in 2014. On ship repair, the shipyard has continued to perform RMN vessels repair work year after year.

Nevertheless, similar to problems faced by other shipyards worldwide, the performance of BN Shipyard over the last decade has shown large areas for improvement especially in reducing extended delays in ship repair work and mitigating human-related issues. Even as the leader of naval repair and newbuilding works, BN Shipyard continued to face difficulties in maintaining profitability and on several occasions posted losses. Many reasons and excuses were given by the staffs and significant efforts were implemented by the shipyard top management to try curb these problems (Shamaun, 2017).

Irrespective of these management efforts, the 'blaming game' continued to occur between shipyard departments, between shipyard and the end-customer RMN, and between shipyard and vendors. The situation seemed similar to the explanation by Karube *et al.* (2009) that low organisational cohesiveness creates unnecessary conflict; thereby, dissipating managers' effectiveness towards meeting objectives through efficient coordination and communication. On many occasions, staffs were paying too much attention to the customer, at the expense of company's profitability and failure to abide by the internal procedures. Frequently procedures were bypassed as the staffs believed that "the end justifies the mean", delivering the ships is most important.

Similarly, the PV ISS organization suffered the same fate, as the organization was originally derived from a department of BN Shipyard which was later formed as a sister-company called BHIC Navaltech Sdn Bhd (BNT). The PV ISS contract was officially signed between the GOM and BN Shipyard, but the implementation was subcontracted out to BNT in 2011 for a period of three years. This was the first time a major ISS contract was awarded to the newly formed organization, with the aim of maximizing the ships' operational availability as part of the RMN fleet readiness. The PV ISS contract was subsequently renewed for a further 3-year term in 2014 with negligible improvement in the scope and clauses.

Many more issues surfaced beyond the above-mentioned organisational related problems, mostly due to insufficient knowledge and experience of the ISS concept by both contracting parties. The new ISS contract awarded to this newly-formed organization created additional issues including but not limited to maintenance philosophy, priority of work, budget appropriateness, effectiveness of processes, sufficiency of scope, inability to meet availability targets, design and engineering issues and also government policies and procedures. Accountability problems are rampant between stakeholders; 1) internal stakeholders, the various subsidiaries of the large Boustead Heavy Industries Corporation (BHIC) group of companies as well as externally, and 2) between the various companies and the various customers especially with the multiple departments of the RMN.

The tendency remained that stakeholders prefer to work in clusters, such as the finance department prefer to work with financial background personnel within the organization and with the supply branch of the RMN whilst similarly the engineering personnel are comfortable to work closely with the Engineering Branch of the RMN. The top management including the project managers of the BHIC group would deal mostly with the executive branch of the RMN who would normally be the top management and policy makers. This inevitably creates a discord whenever there is a project or contract management issue, whereby the clustered groups of stakeholders would defend their cluster and throw the blame to other clusters creating accountability issues whenever there is any question of non-performance.

This dysfunctional behaviour between stakeholders, often also driven by personalities, has been described in detail in a thesis by Shamaun (2017) called *Management of Resistance to change using lean principles in transforming a shipyard operation*. Shamaun (2017) also pointed out that on certain cases in the shipyard, because of the busied environment and hurried pace of a programme, projects were poorly managed resulting in project control and monitoring became cumbersome ending up with confusion and dispute between parties. Similarly, for the PV ISS contract, the overlapping areas of duty between engineering, finance and project management clusters create grey areas of accountability as there currently exist no mechanism to segregate the responsibility and contribution of each cluster of personnel to the success of the project. BNT as the ISS contractor shares the concern of Kwak and Smith (2009) that the issue of lack of accountability especially regarding department of defence (DoD) officials who openly place full responsibility on contractors therefore relieving themselves of pressure, and having the underlying assumption that large projects would not be cancelled despite poor project performance.

At the ground level on the ISS project, some random or selective data has been collected previously on naval ship maintenance and repair, but without specific objectives or guidelines, with questionable quality and considerable number of gaps resulting in very seldom been analysed. The consequential effect is the reduced motivation or mindset of the staffs to continue collecting data (GAO, 2014b) as they believe it would continue to be a waste of time as the data will remain not be analysed for maintenance decision making and no benefit would come out of it. This is similar to the findings of Jardine (1996) that it is common that data seems to be plentiful, may not be at the expected quality, nevertheless data analysis is fundamental in optimizing decision making in maintenance but decision policies based on incorrect information may not just be useless but also harmful. As the researcher was formerly involved during the design, shipbuilding and subsequently the ISS phase of the PV vessels, this has spurred the researcher to embark on this current research to study not only to improve on the current PV ISS contract issues but also to meet the targeted operational availability. Any successful improvement shall naturally spill over and benefit the remaining fleet awaiting to be awarded with new ISS contracts in future. This research is termed by Jardine (1996) as an *industry driven applied research* which is motivated by the practical need, the research problems arise directly from the industrial organizations, and the research will definitely bring benefits to the organizations involved.

## 1.3 Problem Statement

All navies in the world aspire to improve the operational availability of their fleet. Most navies such as the United States (US) Navy (Marais *et al.*, 2013), Korean Navy (Paik, 2014) and RMN (RMN, 2011b) have specific operational availability targets, but still remains a problem to be achieved. It remains a question as to why availability is still lower than expected.

Naval vessel or warship in itself as an asset is inherently complex, and the operational availability of warship is also a complex problem (Dell'Isola and Vendittelli, 2015). Therefore, improving ship availability or operational availability of naval vessel further magnifies the complexity of the problem making it "complexly complicated". Ship availability is defined by Inozu (1996) and Blanchard and Fabrycky (1998) as the probability that the ship is available and capable of performing the intended function at any random point of time. Hou Na *et al.* (2012) described availability as "uptime" which can be formulated as one minus downtime or known as unavailability, with the resulting mathematical implication that the more unavailability or "downtime", the lesser the availability achieved. Furthermore, there is a long list of human and equipment-related downtime influence factors affecting ship availability that are intertwined, ambiguous and uncertain, with uncertain significance and weightage. A few researchers have attempted to study individual factors such as Sandborn (2013) and Moon (2010) but none have been able to consolidate them comprehensively. It is hardly found that literature has attempted to consolidate factors involving human and equipment combined into one study involving ships due to the complexity.

Without simplifying the notion of naval availability, maintainers and support staffs remain confused and continue to be in "fire-fighting" mode trying to solve daily issues without any guidance on priority (Swanson, 2001). Improvement efforts could not be placed precisely, as the root cause of downtime from human and equipment related factors have not been identified. This negative effect is magnified due to the limited data being populated and analysed to date with these objectives in mind, as a result of poor awareness and understanding on most stakeholders towards the importance of this issue at hand. The complexity of naval ship maintenance activities coupled with the limited literatures available to date on factors having negative influence on ship availability has created a seemingly impossible task to improve the current situation faced by the contract managers in the implementation of the ISS contract. To date, there exists no model or mechanism to assist the contract managers in managing the contract efficiently in meeting all contractual obligations at the targeted availability figures. Moreover, the model should be simple and practical, able to be understood by all levels of stakeholders in meeting targeted availability and able to assist contract managers to control and monitor the contract better. It is a documented fact that ship crews tend to change rapidly therefore a simpler model allows knowledge in processes to be retained easier as they are rarely trained in maintenance management (Wang et al., 2010).

## 1.4 Research Aim and Objectives

The aim of this research is to demystify the complex naval ship availability issue through the development of a contract management model in improving naval ship operational availability especially for the ISS contract. The research aims to bridge the knowledge gap concerning human and equipment related factors impacting ship availability. This model provides the linkage between human and equipment related factors holistically impacting naval ship availability that has to date been mostly tackled separately by policymakers, maintainers and logisticians as well as researchers who own conflicting goals and objectives (Davis, 2014). After all, according to Wang et.al (2010) the shipboard personnel are already overburdened being operators as well as maintainers, who would not appreciate long and complex methodologies for maintenance.

The outcomes of the model and the process would benefit every stakeholder. It helps to demystify the complex naval issue of improving the vessel and overall fleet operational availability faced by all levels of stakeholders. The step by step approach assists the policymakers to have a better grasp hence be able to make better decisions concerning all factors affecting the naval ship operational availability. Contract managers would have an efficient and handy tool to continuously track, manage and control the contract better with the necessary feedback and recovery information enabling faster decision making. Maintainers, storekeepers, trainers and all other stakeholders would have better appreciation of the tasks at hand with a clearer view of their individual contribution towards improving the navy's availability figures. Resources would therefore be ensured to be put to the best use.

Researchers on naval ships worldwide would have a holistic understanding of the entire cloud surrounding the complex naval availability issue, dissected to 'bite-size' for easy comprehension in order to participate in further research on individual or multiple combination of factors affecting naval ship availability. This would trigger more opportunities for international collaboration. The developed tool could be used internationally as a mechanism to compare contract performance, and project analysts would have a better systematic system for evaluation of contract or project. The outcome of the research would benefit other engineering fields in general that have continuously attempted to improve the productivity and availability of their assets.

The research aim could be achieved by meeting the following research objectives:

i) To determine the downtime influence factors (DIFs) to naval ship availability.

ii) To develop the DIF's impact matrix on contract and project management elements of the "iron triangle of cost, time, quality and scope".

iii) To develop the severity index as the mathematical algorithm to the model

iv) To develop a "ship availability oriented model" for ISS contract

## 1.5 Research Questions

Understanding the aspiration of all navies in the world to improve the operational availability of their fleet and handicapped with ongoing confusion and desperation due to the complexity issue above, the researcher emphasized that a list of critical research questions is necessary to be answered in this research. The research questions (RQ) are as in Table 1.1.

Table 1.1 Research questions through research objectives

| ***Research aim:*** ***The aim of this research is to demystify the complex naval ship availability issue through the development of a decision-making model in improving naval ship operational availability especially for the in-service support (ISS) contract. It could be achieved by meeting the following research objectives (RO) through the research questions (RQ):*** | | | |
|---|---|---|---|
| **Code** | **Research Question (RQ)** | **Code** | **Research Objective (RO)** |
| **RQ1a** | What are the human and equipment related downtime influence factors (DIFs) affecting ship availability? | **RO1** | To determine the downtime influence factors (DIFs) to naval ship availability. |
| **RQ1b** | How can the DIFs affecting ship availability be-ranked and prioritized? | | |
| **RQ2a** | How do the DIFs impact the contract and project management elements of the "iron triangle of cost, time, quality and scope"? | **RO2** | To develop the DIF's impact matrix on contract and project management elements of the "iron triangle of cost, time, quality and scope". |
| **RQ2b** | Is it possible to improve ship operational availability by improving DIFs? | | |
| **RQ2c** | What areas can be improved when faced with budget constraints, if RQ2b is positive? | | |
| **RQ3** | Is it possible to develop an index based on ranking of the DIFs to indicate the severity of the DIFs? | **RO3** | To develop the severity index as the mathematical algorithm to the model |
| **RQ4** | Is it possible to develop a new model to assist stakeholders to better understand the availability concept and assist contract managers to monitor and control the contract better? | **RO4** | To develop a "ship availability-oriented model" for ISS contract |

## 1.6 Scopes of the Study

The current research is constrained to the ISS contract for the maintenance of the PVs in Malaysia, which have been implemented by BN Shipyard through BHIC Naval Tech Sdn Bhd since June 2011 for 3-year terms. This is the approved and available full contract on maintenance of naval vessels for the researcher to conduct the research.

It is also crucial to point out that for purposes of this study, the scope is constrained to 'operational ships' in the fleet based on the scope of the contract (RMN, 2011b). Extended downtime for ships undergoing major refurbishment or refit is not included in the ISS contract and therefore not included in the study. This is especially important as the availability figure would evidently be significantly reduced or down to zero in cases of ship refit and major refurbishment such as ship life extension programme (SLEP). Nevertheless, these cases are not part of the study as they are implemented under separate refit or SLEP contracts, which is beyond the scope and provisions of the ISS contract. In accordance to Storch et. al (2007), basic actions carried out during maintenance that are significant during a ship's service life includes planned maintenance (dry dock and non-dry dock), unscheduled repairs and conversion or modernisation.

For ISS contract in Malaysia, the scope of research is limited to planned maintenance (non-drydock) and unscheduled repairs only, but with an additional category of emergency docking (unplanned drydock). The panellists involved in this Delphi study would be limited to experts of naval ship maintenance who are familiar with the clauses of the ISS contract, familiar with the day-in and day-out routines of the ISS contract, as well as navy key personnel who are directly involved and benefitting from the implementation of the ISS contract. The panelists would combine the necessary background in human and related equipment factors. The contract has only been implemented for two terms, therefore the number of qualified experts is also limited. The model developed for the ISS contract in Malaysia may need to be adjusted appropriately by other ISS organisations worldwide to cater for other types of ships and contract provisions depending on their individual scope of ISS contract.

## 1.7 Significance of Study

To date, during the naval ship ISS maintenance contract preparation and negotiation stage, neither the RMN nor the subcontractor is aware of any mechanism or model to simulate possible outcomes of the ISS contract to be signed. As a result, the ISS contracts continue to be awarded based on legacy contract terms and clauses. There has been no improvement due to the lack of studies being carried out on improving the contract clauses as well as the contract clauses' relevancy towards the dictated ship availability.

The snowballing effect as a result of ineffective contract formulation impacts the contract manager threefold, a weak contract to be implemented resulting in the brewing and subsequent surfacing of a magnitude of issues that could have been avoided, inability for the assets to be managed with high availability, and the non-existence of a model or mechanism to assist the contract manager in managing the contract efficiently. This negative effect is magnified due to the limited data being populated and analysed to date with these objectives in mind, as a result of poor awareness and understanding on most stakeholders towards the importance of this issue at hand. The complexity of naval ship maintenance activities coupled with the limited literatures available to date on factors having negative influence on ship availability has created a seemingly impossible task to improve the current situation faced by the contract managers in the implementation of the ISS contract.

The step by step approach in this research would provide all stakeholders with a clearer and simplified view to recover from the seemingly-hopeless situation. Similar to the manner applied by Wang *et al.* (2010), the overall concept is to locate the most troublesome areas and concentrate resources on them. The approach begins with the identification of the range of DIFs that influence naval ship availability, concentration on the severe or critical DIFs using risk analysis, identification of the severe DIFs' impact to cost, budget, schedule and scope of the contract and finally the development of a mathematical algorithm that provides the opportunity to produce a ship availability-oriented contract management model for naval vessels that would provide a solution to systematically tackle the issues mentioned above. Given the targeted operational availability and the actual operational availability, the availability-oriented contract management model shall be capable of pinpointing the downtime in number of days lost for each of the severe DIFs and would be able to calculate the recovery operational availability in order to be back on track. The same applies when combined for the squadron operational availability at various locations, or even for the maximizing of fleet operational availability (Nguyen, 2017).

Besides the obvious transparency benefits to the maintainers and logisticians, the contract managers would have a tool to not only control and manage the existing contract better but also to be used during contract closure as well as improvement in new contract formulation utilizing the developed model. Top management and policymakers would have a tool to decide on whether the fleet has not been optimized or whether more vessels are required to be purchased to meet the operational needs of the nation. The result of the research shall also offer significant contribution to the body of knowledge as there currently exists restricted discussions and limited literatures on the downtime factors related to the naval ship maintenance impacting availability.

Stambaugh and Barry (2014) stated that for a ship valued at USD500million and a 30-year target service life, losses would amount to approximately USD50,000 per day if the ship was not able to operate. This shall be an indicative value to the RMN of potential losses due to unavailability caused by downtime. Therefore, the overall improvement achieved in increasing RMN ship availability from the efforts of all levels of stakeholders could save the GOM millions of Ringgit which could be better spent elsewhere.

## 1.8 Operational Definitions

The following are the key operational definitions referred to throughout the various chapters of the thesis.

i. *Availability:* the probability that the asset is available and capable of performing the intended function at any random point of time.

ii. *Complexity:* The state or quality of being intricate or complicated.

iii. *ConCaMS: An 'availability-oriented' model/system* designated Contract Management Control and Monitoring System.

iv. *Delphi Technique or Method:* A renowned method for eliciting and synthesizing expert opinion. The original intent of Delphi was as a forecasting technique, designed to predict the likelihood of future events using expert judgment in the military. It is primarily concerned with making the best you can of a less than perfect kind of information. The Delphi method is a flexible research technique that has been successfully implemented in many areas of study. It is well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon. The Delphi technique works especially well when the goal is to improve our understanding of problems, opportunities, solutions, or to develop forecast. The technique has since been widely accepted throughout the world in many industry sectors including healthcare, defence, business, education, information technology, transportation and engineering. It allows researchers to maintain significant control over bias in a well-structured academically rigorous process using the judgment of qualified experts.

v. *Downtime:* time during which production is stopped especially during setup for an operation or when making repairs. Also referred to as inactive time. For this study, any time period that the asset or equipment or system is unavailable or not operational.

vi. *Downtime Influence Factors (DIFs):* Root cause of various downtime viewed holistically from equipment-related and human related factors.

vii. *In Service Support (ISS):* Performance of programme management, logistics services, and engineering that are required in order for an asset to operate properly and perform required functions throughout its lifecycle. However, the scope and duration of ISS contract varies between assets of various countries.

viii. *Iron Triangle:* A project management triangle also called the triple constraint and Project Triangle) is a model of the constraints of project management. Also referred to as the triple constraint or flexibility matrix, is a way to reconcile the key factors of scope, schedule, and cost as competing constraints on any project. The International Project Management Association (IPMA, 2006), in its *IPMA Competence Baseline* 2006 states that project success relates strictly to project management success as the ability to deliver the project's product in scope, time, cost, and quality. Display of an “iron triangle” in Figure 1.1.

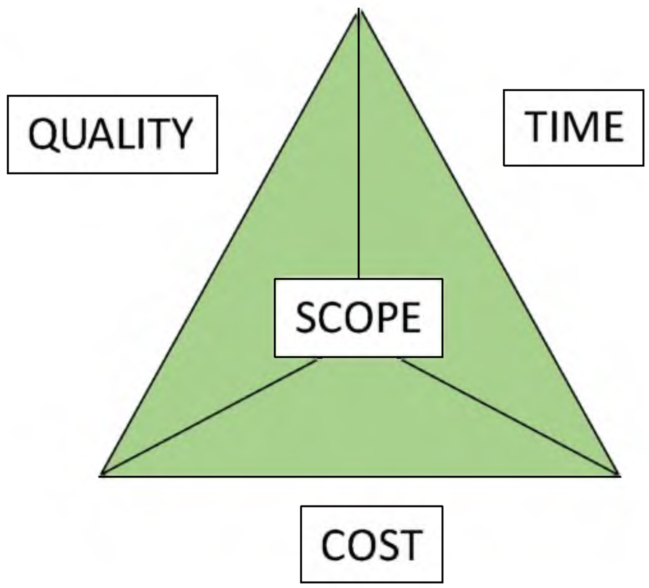


Figure 1.1 Project Management Iron Triangle (IPMA, 2006)

ix. *Maintenance:* British Standards Institution, BS3811 Glossary of maintenance terms in Terotechnology, BSI, London, 1984 defines maintenance as the combination of all technical and associated administrative actions intended to retain an item or system in, or restore it to, a state in which it can perform its required function.

x. *Mission Availability: Mission availabilit*y of naval ships reflects the number of days they are available for performing its mission tasking in a year

xi. *Operational Availability:* Operational availability (Ao) of naval vessels is a measure to reflect the number of days the ships are available for operational tasking in a year. Also reflected as the number of days the ships are able to spend in an area of operations.

xii. *Unavailability: The opposite to Availability.* The probability that the asset is unavailable and incapable of performing the intended function at any random point of time.

xiii. *Uptime*: Time during which production is in operation. Also referred to as active time. For this study, any time period that the asset or equipment or system is available or operational.

## 1.9 Thesis Organization

This thesis elaborates on the work undertaken in the research project and comprises of five chapters. Chapter 1 introduces the research project by providing the general background to the research, organizational challenges, problem statement, research aim and objectives, research questions, scope of study, significance of the research and operational definitions.

Chapter 2 provides an extensive literature review concerning the definition of maintenance, the significance of maintenance strategy and the relationship between the shipbuilding contracts with the ISS contract. This is followed by the categories of the maintenance activities concerning naval vessels, impact of design on maintenance, fleet-wide maintenance requirements and the impact of maintenance strategies to performance, availability and cost.

The chapter continues with the explanation on the concept of contracting for availability, spares and logistical support affecting maintenance and the consolidation of many factors and variables impacting the operational availability of a system and the implementation of effective maintenance strategies. Subsequently the review of studies on contract management philosophy, best practices, project management concepts, military versus conventional methodologies of contract management, similarities and differences between project management and contract management philosophies, past efforts in attempting to improve contract management practices, as well as other relevant literatures concerning the research subject. This chapter describes the various available research philosophies, methodologies and techniques to address research problems.

Chapter 3 fully describes the research methodology. Charts are provided to show the flow of works. Descriptions on the strategic selection of research variables via critical literature review provide leads to the preliminary model. The method of generating the generic DIFs and the strategic selection of the severe DIFs via survey and focus group discussion, which serve as the main method of data collection, is detailed out. The statistical method used to develop the DIF severity index describes the basic principle adopted in developing the formula to calculate ship availability. The chapter closes with description of methods for the development of the final ISS contract management model and its dashboard.

Chapter 4 discusses the results obtained and highlights their salient features. The first result is the simplification of the operational availability concept. The second result is the list of severe DIFs established. The third result is the formula developed to calculate the DIF severity index. The fourth result is the development of a ship availability- oriented contract management model. The fifth and final result is on the evaluation and validation of the model.

Chapter 5 concludes this research followed by explanation of the innovative contributions, areas of application and the limitations of the research. The chapter ends by highlighting several recommendations for further studies and concluding remarks.

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