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DEMYSTIFYING SHIP OPERATIONAL AVAILABILITY – AN ALTERNATIVE APPROACH FOR THE MAINTENANCE OF NAVAL VESSELS

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Abstract

Asset availability improvement has been the focus of many studies by various industries for a few decades now, and the defence industry is no exception. To date, there exists no simple and inexpensive high availability solution for the complex naval ships consisting of many interdependent systems and subsystems working in parallel. Any given approach must strike a balance between true needs and economics, an ever-increasing decision-making burden to stakeholders. Nevertheless, there are many ways to approach the problem. In the past, availability has been viewed as complex mathematical calculations and estimates involving defective equipment. The applied approach has not been fully understood nor appealing to most practitioners as well as the majority of stakeholders who continuously complain about the gap between theory and practice. This paper aims to demystify the complex naval ship availability issue, simplified for easy understanding of operators, maintainers and logisticians as well as other stakeholders involved in the maintenance of naval vessels. The step-by-step approach begins with the identification of severe factors involving both human and machinery affecting downtime of naval vessels culminating into the generation of an availability-oriented model, summarized to a simple four-step approach to availability improvement. Practitioners are now able to appreciate their individual contribution towards improving ship availability.

Keywords: 4-steps availability improvement, Demystifying ship availability, Downtime influence factors (DIFs); Human and equipment factors; Severe DIFs.

1. Introduction

Asset availability optimisation concepts have been introduced and studied at length and in depth in a multitude of industries for a few decades now. For industrial organisation, high asset availability has traditionally been linked to higher profits, for the defence sectors high availability was viewed as a required performance measure or a targeted Operational Availability (Ao) [1]. In recent years, however, government agencies worldwide are increasingly subjected to higher risk compliance with a reducing defence budget. This is also the case for most navies that have to strike a balance to satisfy the various stakeholder requirements. Some navies have pioneered innovative concepts such as contracting for availability as a means to delegate some of the burdens to their contractors, such as the Royal Navy in the UK [2] and Italian/French Navy through the FREMM Program [3]. As studied by Hamilton [4], other navies such as Australia are studying how to achieve the optimum Preventive Maintenance requirements to mitigate technical risks to an acceptable level, comply with regulations and policy and provide an acceptable level of Ao at the lowest Life Cycle Cost.

The Royal Malaysian Navy (RMN) [5], alike its counterparts worldwide also strives to achieve high Ship Availability within a set budget, whilst achieving its vision of becoming a World Class Navy. Nevertheless, even those established navies such as United States Navy (USN), Dutch Navy, Royal Navy UK, Australian Navy have not been able yet to formulate a strategy that can be applied neither to their own fleet nor universally to improve availability whilst regulatory or/ and quality or/and cost performance measurements are being imposed. In simple terms, there appears to be no generic “best-suited methodology”. This is mostly due to the fact that naval vessels are complex assets and have to be viewed as a system with highly interlinked relationships. According to Siel [6], the term System of Systems (SoS) is used by the US Navy Research, Development and Acquisition in an Engineering Guidebook to describe an integrated force package of interoperable systems acting as a single system to achieve a mission.

In accordance with Reliability Analysis Centre [7], Operational Availability is not just a function of design but also of maintenance policy, the logistics system and other supportability factors. It can be improved by improving the design, improving the support, or both. As availability is a measure of maintenance performance [8] any effort resulting in an increase of ship operational availability is commendable [9]. Na et al. [10] derived with the key concept of the presented research is that availability can be simply expressed as uptime and can be formulated as “One minus Downtime”. Basically, the lower the downtime, the higher the availability.

Efforts in improving availability and implementing various independent strategies without identifying and understanding the underlying Downtime Influence Factors (DIFs) could be futile as some of these DIFs may be the root cause to the resulting short, medium and long-term issues. Due to limited available data and research into naval ship DIFs, a literature review across various engineering disciplines on factors affecting Downtime and Operational Availability was carried out by the authors. The focus of the research is based around the RMN Patrol Vessels (PVs) that are currently being maintained through the In-Service Support (ISS) Contract between the Government of

Malaysia (GoM) and Boustead Naval Shipyard [11]. The ISS Contract covers Maintenance Services, Spare Parts, Training and Computer Support System of Systems for Maintenance. Refer to Fig. 1 to view a display of the RMN PV in operation and firing exercise performed under the PV ISS Contract.

This paper represents the latest instantiation of a series of evolving work by the authors attempting to improve the methods and techniques used by various stakeholders worldwide in their attempt in improving their operational availability figures in general, with an immediate application to naval surface combatants. The main contributions include the consolidation of a multitude of DIFs related to human and equipment from various fields of research, the ranking of DIFs to identify the most troublesome factors and determination of DIFs that could be improved even with budget constraints for purposes of improving ship operational availability.

The successful application of multiple rounds of Delphi Methodology with Snowballing Technique has provided the necessary verification, validity, accuracy and rigorousness of the study. The post-survey expert validation by another set of top management experts also provided additional evaluation, validation and reconfirmation of the results. This provides the necessary credibility of the research towards fulfilling the research objectives.

Fig. 1. RMN PV in operation and firing exercise.

2. Research Aim and Research Objectives

The aim of the complete 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. The research aim could be achieved by fulfilling the research objectives as follows:

- Simplifying the ship availability issue for a better understanding of practitioners (maintainers and logisticians) in appreciating their individual contribution towards improving ship availability.
- Determining the factors impacting naval ship availability from a holistic perspective involving equipment and human factors and ranking the most severe factors.
- Determining the possibility of improving ship availability when faced with budget constraints.
- Proving the reliability, accuracy and validity of the rigorous multiple rounds of Delphi combined with a Focus Group Discussion on this exploratory study.

- Re-confirmation of the results following additional evaluation and validation through post-survey top management expert validation.

The research would bridge the knowledge gap concerning human and equipment related factors impacting ship availability. The model shall provide 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. It helps to demystify the complex naval issue of improving the vessel and overall fleet Operational Availability (Ao) 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 Ao. 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 a 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 combinations of factors affecting naval ship availability. More research opportunities with international collaboration would be expected. 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 a 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.

3. Methodological Approach to Research

3.1. Gap between theory and practice

Based on Dekker [12] findings, many papers have been written for math purposes only. Mathematical analysis and techniques, rather than solutions to real problems, have been central to many papers in maintenance optimization models. However, the mathematical results are not appealing to practitioners. Dekker [12] continued by stating that it is astonishing how little attention is paid either to make results worthwhile or understandable to practitioners or to justify models on real problems or to consider data problems. The authors further agree with Dekker that companies are not interested in publication and that many good ideas have been developed in industry, but only a small amount has appeared in scientific literature.

3.2. Determination of downtime influence factors impacting ship availability

The identification of research variables begins with a thorough Literature Review (LR) of over 700 literatures concerning downtime elements that affects the availability of naval vessels, and downtime of equipment and systems from various fields of research, which include Oil & Gas, Construction, Nuclear, Aviation and Aerospace, Business Intelligence, Mining and Energy. Subsequently a further literature review was conducted in determining other relevant data to the study from various stakeholders including copies of the ISS Contract, historical records of vessel condition, home base of vessel (location), vessel operations area, mission schedule, availability of maintenance support facilities, availability of spares support, logistical support, infrastructure, availability of Original Equipment Manufacturers (OEM) and specialists, availability of special tools and test equipment, funding approval period, budget and cash flow status and management organization structure, etc.

All pertinent information relevant to the scope of the current ISS Contract includes Planned Maintenance or Preventive Maintenance (PM), Corrective Maintenance (CM), provision of spares, computer support, engineering support, training and Integrated Logistics Support (ILS) were collected.

Other relevant information beyond the ISS contract but relevant during the implementation of ISS activities such as the RMN Administrative Order for the execution of ISS, was also collected for study.

The generic list of variables consisted of close to 100 variables, some of which, were believed by the researcher to be similar in meaning and interpretation. In order to reduce the list and pool into a more manageable number of groups with relevant terms for better understanding for future stages, a Focus Group Discussion (FGD) was conducted. A pre-requisite (pre-selection criteria) for the variables to be considered as possible factors by the FGD were as follows:

- Relevancy towards impacting downtime (therefore availability).
- Have been mentioned multiple times by various authors globally, and especially if continuously appearing over time.
- Similar definitions could be grouped into a familiar term for the FGD.

The FGD generated a list of 50 possible factors, which was subsequently confirmed by a panel of 30 ISS experts and 5 top management experts confirmed with a 100% consensus the list of 50 factors termed as Downtime Influence Factors (DIFs).

Figure 2 depicts a subset of the Delphi process with the participants [13]. A 7-Stage Modified Sequential Delphi approach into identifying the DIFs for the RMN ISS for PV was carried out as summarised in Fig. 2. The objective was to discover and better understand the unavailability causes and to highlight as well as to prioritize the areas of improvement.

A panel of 30 professionals directly involved in naval ship maintenance was selected and their expert opinion was sought via various questionnaires. In a subsequent stage, five top management experts as proposed via Snowballing technique in earlier rounds were used to validate and confirm the total.

Subsequent to the seven-stage Delphi as shown in Fig. 3, a post-validation survey with five industrial leaders was carried out to validate the findings as per Fig. 4.

(a) (b)

Fig. 2. Experts participating in brainstorming and FGD during Delphi rounds (a) the PV ISS maintenance organisation, (b) the RMN officers [13].

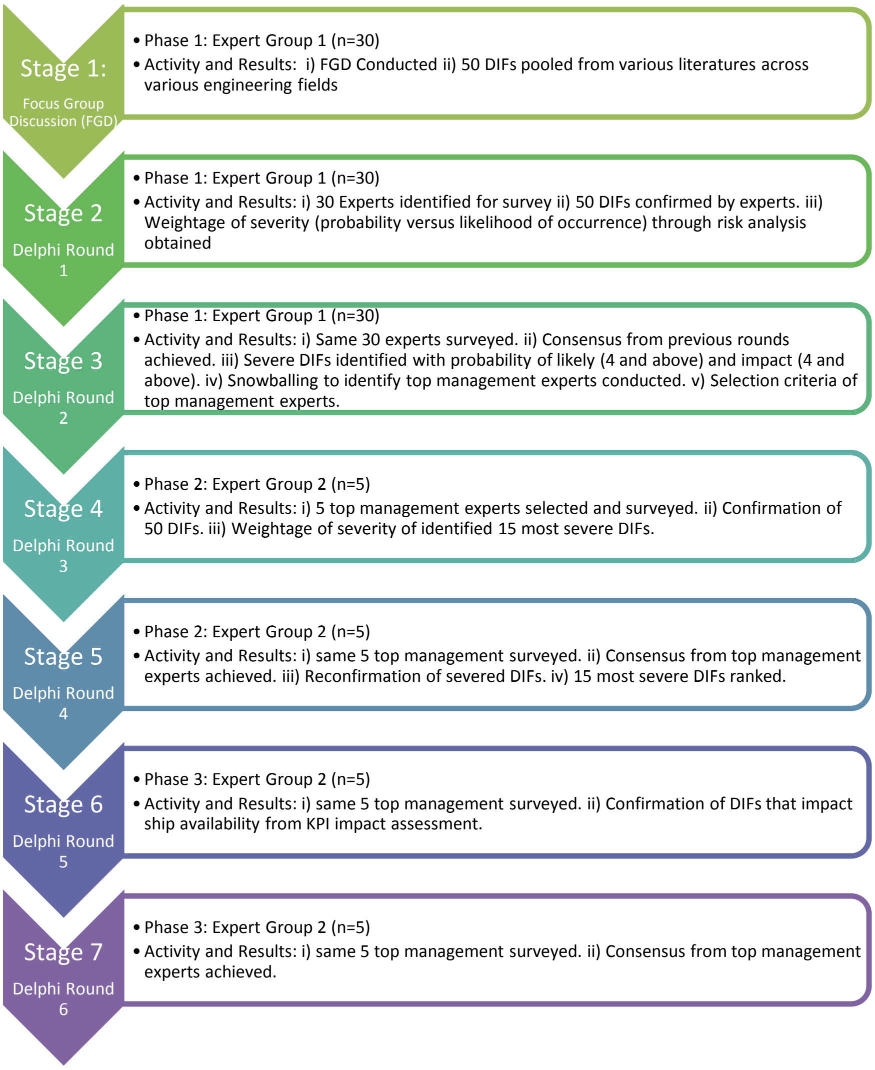

Fig. 3. The seven stages of the Delphi study.

Fig. 4. Research steps.

Table 1 summarises the 50 categories of DIFs as supported by literature and pooled by the FGD, confirmed by the 30 experts and 5 top management experts. The ranking of DIFs as identified by the experts from most Severe (Rank 1) to Least Severe (Rank 50) is displayed in Table 2. The ranking mechanism is explained in subsection 2.3. For ease of reference, the 15 most severe DIFs are highlighted in "light blue" in Table 1.

Another purpose of Table 1 is to provide easy access to various authors who may have studied a combination of a few DIFs in their publications, for the benefit of other researchers worldwide.

Table 1. 50 DIFs confirmed by 30 experts and 5 top management experts.

Serial no.	DIFs for ship operational availability	Authors of literature from various fields	Expert confirmed	Rank by expert
1	Equipment and systems – Hull and design	[3, 14-22].	Yes	35
2	Equipment and systems – Main propulsion		Yes	6
3	Equipment and systems – Electrical		Yes	38
4	Equipment and systems – Weapon systems including guns and missiles		Yes	41
5	Equipment and systems – Auxiliaries		Yes	15
6	Equipment and systems – Outfittings		Yes	50
7	Maintenance policy - Priority on type of maintenance	[3, 7, 15, 16, 19, 23-25] .	Yes	7
8	Awareness of importance of maintenance/attitude-including hiding problems from becoming official.	[18, 26, 27-30]	Yes	10
9	Maintenance budget allocation	[3, 12, 14, 15, 19, 25, 26, 31-34]	Yes	9
10	Information management	[12, 18, 26, 31, 33, 35, 36]	Yes	40
11	Preventive maintenance	[3, 17-19, 37-39].	Yes	17
12	Corrective maintenance	[3, 19, 33, 40-46]	Yes	1
13	Predictive maintenance	[3, 18, 19, 38, 47, 48]	Yes	24
14	Emergency repair and docking	[19, 33, 49, 50]	Yes	47
15	Equipment technology/system complexity	[3, 19, 33, 35, 38, 51, 52]	Yes	28
16	Scheduling issues	[12, 19, 32, 33, 37, 38, 41, 43, 44, 51, 53, 54].	Yes	14
17	Special tools, test equipment maintenance.	[3, 19, 26, 55-58]	Yes	20
18	Availability of facilities	[3, 17, 19, 26, 32, 41, 44, 51, 53, 58-60]	Yes	11
19	Spares availability	[3, 17, 19, 26, 31, 32, 38, 40, 44, 53, 58, 59, 61, 62]	Yes	2
20	Obsolescence issues	[3, 25, 32, 40, 63-65]	Yes	36

Serial no.	DIFs for ship operational availability	Authors of literature from various fields	Expert confirmed	Rank by expert
21	Design and design change issues	[3, 12, 17, 18, 20, 66, 67]	Yes	44
22	Knowledge management including training, knowledge and skills	[3, 16, 18, 19, 26, 32, 33, 47, 66, 68-70]	Yes	5
23	Availability of OEM expert support	[3, 19, 39, 40].	Yes	8
24	Availability of local vendor support	[3, 19, 26, 39, 71, 72]	Yes	12
25	Complexity and efficiency of existing contract	[56, 59, 69, 73-76]	Yes	13
26	Capability of customer performing maintenance	[3, 26, 29, 33, 40, 53, 58, 77-79]	Yes	27
27	Morale and attitude of customer involved in maintenance		Yes	39
28	Morale and attitude of contractor involved in maintenance	[18, 26, 27, 29, 33, 53, 80, 81]	Yes	29
29	Efficiency of processes, procedures and reporting structure include finance	[3, 18, 26, 31, 48, 58, 67, 78, 82, 83]	Yes	21
30	Ship operational/sailing schedule	[43, 84-86]	Yes	37
31	Non-commonality of Equipment issues	[40, 45]	Yes	31
32	Non-redundancy of equipment	[12, 17, 38, 40, 69, 80, 85, 87]	Yes	26
33	High Turnover of maintenance supervisors.	[19, 88, 89]	Yes	22
34	High turnover of maintainers		Yes	32
35	Different location of ships	[11, 19, 90, 91]	Yes	19
36	Statutory requirements	[78, 92]	Yes	43
37	Cashflow shortages	[14-16 , 53, 92]	Yes	4
38	Government requirements and policies (i.e., offset, etc.).	[77, 93-96]	Yes	48
39	Variation order and contract change	[53, 76, 92, 93, 97, 98]	Yes	46
40	Ageing/aging of equipment	[25, 28, 74, 83, 99, 100]	Yes	30
41	Force majeure	[11].	Yes	45
42	Accidents and hazards	[25, 53, 77, 101-103]	Yes	42
43	Extraordinary price escalations (spares, consumables, equipment)	[53, 92]	Yes	23
44	Pilferage, theft, fraud and cheat	[104-108]	Yes	49
45	OLM, ILM, DLM - Overlap of maintenance duties (contractual) and impact if not performed	[33, 35, 54, 59, 68, 74, 109, 110]	Yes	34
46	Contract management across a wide range of stakeholders with conflicting interests	[30, 35, 41, 54, 74, 76, 92, 107, 111, 112]	Yes	33
47	impact of parallel contracts to schedule, genuinity of spares, professionalism of repair team, etc.	[113, 114]	Yes	3
48	Supporting of the vessel outside of home ports (i.e., issue on mob, availability of materials, etc.)	[3, 90, 91]	Yes	25
49	Exogenous factors (i.e., company profit margin, administrative costs, peripheral costs, support cost)	[3, 53, 68, 115]	Yes	18
50	Exogenous factors - contract concept (total maintenance package against segregated orders without interrelationships) and based on recommendations	[2, 3]	Yes	16

3.3. Ranking of downtime influence factors

The simplified conceptual diagram in Fig. 5 portrays the relationship between Uptime and Downtime (and availability) as well as the various DIFs that make up the Downtime, for the benefit of all levels of stakeholders. The circles represent DIFs of various type and sizes, and the grey background represents the Uptime or availability. The authors have proven through the conceptual diagram that any removal or reduction of size to any DIFs shall result in an increase in availability.

Ranking of DIFs utilizes risk assessment methodology in order to identify DIFs that have the most impact to ship availability. A 5-point Likert Scale as per Table 2 containing the "Impact of the DIFs to Ship Ao" versus the "Probability of the DIF's occurrence" was provided to the experts to select their scoring of the severity of each DIF.

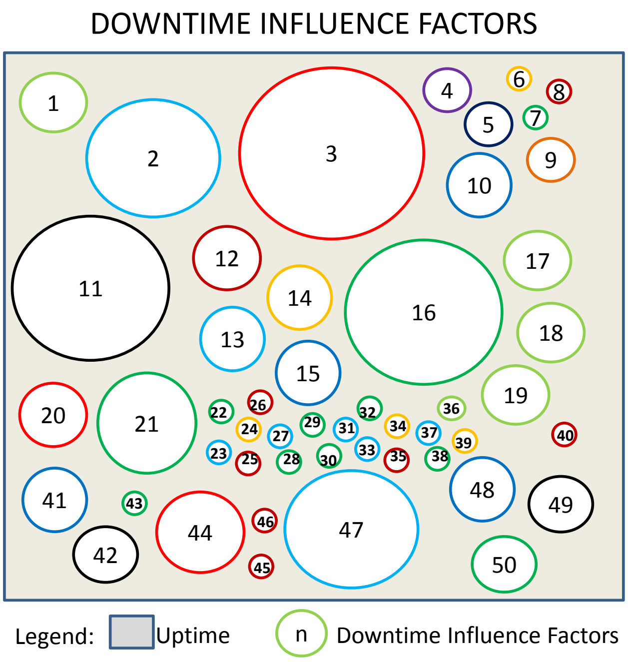

Fig. 5. Conceptual diagram of the 50 DIFs.

Table 2. Impact vs. probability, 5-point Likert scale.

Impact vs. probability (Risk-Analysis Matrix)			
DIF's impact onto ship availability		**Probability of DIF's occurrence**	
Description	**Rating**	**Description**	**Rating**
Extreme	5	**Almost certain**	5
High	4	**Likely**	4
Medium	3	**Possible**	3
Low	2	**Unlikely**	2
Negligible	1	**Rare**	1

DIFs were classified as severe if the experts assigned them as “High Impact and above” and “Likely and above” to occur resulting in a scoring of “16 and above”. Based on results of Risk Analysis, 15 DIFs were found to be severe by top management experts as highlighted in Table 1. An illustration of the derived 15 Severe DIFs impacting RMN Ship Operational Availability and the resulting reduced size of DIFs (improved availability) is reflected in Fig. 6.

Wahid et al. [116] presented the size of the sphere for each of the 15 Severe DIFs is proportionate to their Severity Index (SI). The higher the index, the bigger the sphere and the more severe the DIF.

For example, focusing attention and efforts on the most severe DIF, which is “corrective maintenance” in order to reduce the size of this DIF, would result in a sizeable overall improvement in Uptime. Wahid et al. [13] commented that the SI was then expanded into an Availability-oriented Contract Management Control and Monitoring System (ConCaMS). A display of a screen of the ConCaMS is as per Fig. 7.

Unlike current common practise whereby no comparison is made, the new availability-oriented model (ConCAMS) allows the targeted Ao to be continuously compared with actual Ao. The shortfall in days of downtime is automatically calculated and segregated in accordance to the various severe DIFs categories identified from the research.

This become specific pointers on problem areas for all stakeholders to improve and provides transparency on accountability, which reduces the ‘blaming game’ between various organizations involved in the ISS contract.

Stakeholders at every level would have better appreciation of their contribution towards availability, besides having “close to real time” feedback on availability figures based on their individual actions. The ConCaMS could also be used internationally as a tool or mechanism to compare contract performance of various contracts, with desired availability targets.

It could be used as-is or customized by the customers enhancing it to be suitable with their own organizations. Overall organization performance in operations and business are expected to improve with the utilization of the model developed from this research.

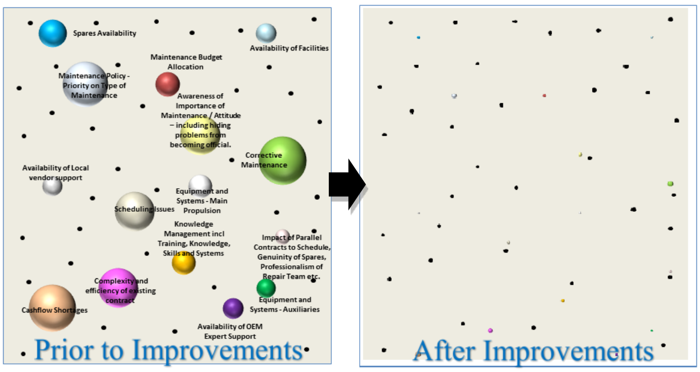

Fig. 6. Example of reduction of severe DIFs.

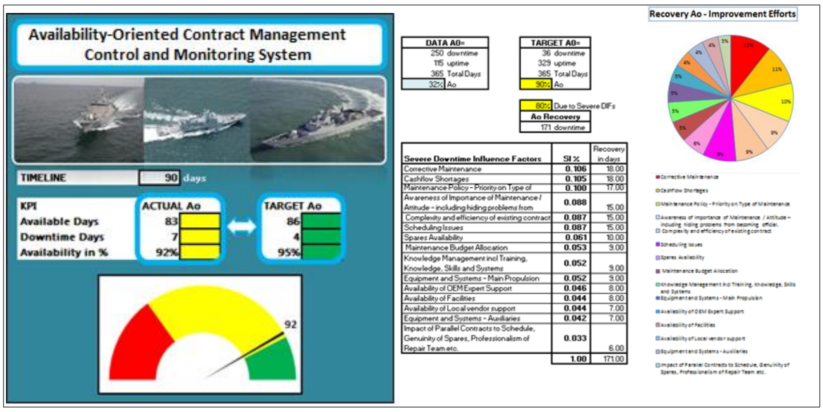

Fig. 7. Example of reduction of severe DIFs.

3.4. Post-survey validation

In a final step, an evaluation and validation process of the proposed model (ConCaMS) took place by means of an independent set of Industrialist leaders. The participants were selected from Shipyards, RMN and Malaysian Maritime Enforcement Agency (MMEA) Top Management based on their most recent and remarkable contributions to the maritime and defence industry in Malaysia, categorically recognizing them not only as leaders but also as subject-matter experts. A total of five experts was selected, two representing the RMN, 1 representing MMEA and 2 representing commercial shipyards. The demography of the panellists is described in Table 3.

Based on the results the questionnaires, consistent with the methodology applied by Ramasamy [117], following explanation of the complete research and demonstration of the developed model, the panel of post-survey validation experts have agreed with 92% concurrence of the research questions in Table 4.

A selection of additional remarks by the post-survey experts are listed as follows:

- Two experts mentioned that the model and method was good, two experts mentioned that the method was exciting. One expert mentioned that this is a new approach compared to the current conventional method of availability calculations.
- One expert mentioned that the methodology was able to determine factors that contributed to either low or high operational availability.
- One expert found that the findings of 15 severe DIFs would easily facilitate the RMN in identifying Key Performance Indicators, which will assist in the measurement of overall preparedness. One expert stated that this will assist in identifying the root causes affecting the fleet readiness, as the current Urgent Defect reporting is very subjective and easily manipulated.
- Two experts recommended the model and method to be implemented for the MMEA for the new Offshore Patrol Vessel (OPV) and the New Generation Patrol Crafts (NGPC) projects, 1 expert recommended for implementation for monitoring vessel availability for the whole fleet. One expert suggested for the study to be used in the improvement of ISS contract clauses.

- One expert stated that in his many years of working experience, he has never seen anyone study or introduce a model, which is very related to his job.

Table 3. Demography of post survey validation experts.

Details	**Panel of Post Survey Validation Experts (PSE)**				
	PSE 1	**PSE 2**	**PSE 3**	**PSE 4**	**PSE 5**
Designation	First Admiral	Executive Director	CEO/ Managing Director	Rear Admiral	Rear Admiral
Organization	RMN	Shipyard	Shipyard	RMN	MMEA
Job function	Head of Engineering	As above	As above	Chief of Strategic Management	Director of Maritime Safety and Surveillance
Working experience	28 years	24 years	42 years	34 years	40 years

Table 4. List of research questions towards achieving research objectives.

Research Question (RQ)	
RQ1a	What are the human and equipment related Downtime Influence Factors (DIFs) affecting 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”?
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?
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?
RQ5a	How can the developed model assist the various organisations in their ultimate effort for improving the ship availability?
RQ5b	How can the model assist Contract Managers in managing their contracts better?
RQ5c	How can the model assist policymakers, maintainers and logisticians, as well as other stakeholders to contribute better in improving ship availability?
RQ5d	How can the model and associated research finding specifically benefit other navies implementing ISS contract, and generally benefit other engineering industries as well?

4. Recommended 4-Steps Availability Improvement

Following the various graphical illustrations and introduction of a new simple perspective on the relationship between DIFs and Availability described above, the authors hereby summarize the simplified approach through the introduction of the four steps to improve availability as described in Fig. 8.

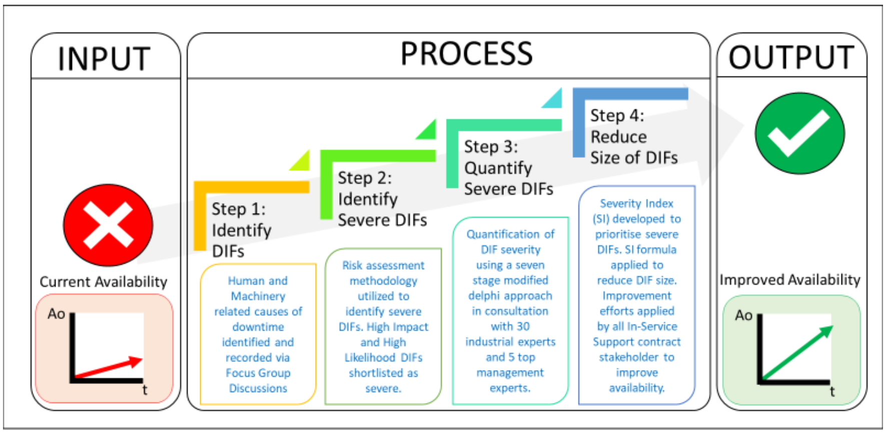

Fig. 8. Availability improvement in four steps.

5. Results and Discussion

Complex Systems could reasonably be replicated or simulated in a controlled environment, i.e., in the laboratory with an ascertained INPUT and OUTPUT. However, in open systems environment, it becomes extremely complicated to manage. This is especially true for dynamic systems like naval ships whereby many systems operate simultaneously with interdependencies in series and in parallel as well as redundancies, on a floating and moving platform. There has not been any model successfully developed and proven to resolve the issues involving complex assets such as the naval vessels, simply because if there has been any breakthrough, it would have been published and shared globally to be implemented. To date, models and simulations remain on small equipment and systems with many presumed conditions and assumptions, which have not reached a stage to be implemented on complex systems.

The proposed 4-Steps Availability Improvement philosophy focuses on a systematic reduction of DIFs based on severe or priority DIFs. The authors embarked on a journey to broaden the horizon on available knowledge by progressively evolving from the exhaustive screening of more than 700 literatures to identify the DIFs, until the introduction of a simplified “bite-size” approach for practitioners and stakeholders in general. From the extensive research, the authors have not found any previously-discovered “one-size fits all solution” towards this complex naval ship availability issue.

Nevertheless, it is evident on the valuable contribution of the authors in guiding stakeholders to place the appropriate efforts on tackling the identified DIFs with the aim of improving Naval Ship Availability. However, due to the time, resources and financial constraint involved in this exploratory but highly specialized research in naval ship maintenance, which has spanned over 5 years, and in order for the results to remain current for the partial fulfilment of the Doctorate in Mechanical Engineering, the authors have concluded this exploratory research by evidently paving the way for more focused future research in all of the areas covered by the 50 DIFs individually and combined, including the 15 identified Severe DIFs.

The authors have embarked on the journey of bridging the knowledge gap between academics and practise, with the hope that the published study would benefit all, academics and practitioners alike. Most importantly, the ultimate goal of the researcher who has been involved close to 20 years in naval shipbuilding, operations and ISS contract was to demystify the complex naval ship availability issue imagined by ground level practitioners as either pure mathematical algorithms or just daily component defects, and to shift their understanding that there are many factors impacting ship availability but everybody could play their part in improving some DIF, which will ultimately result in the improvement of the ship availability.

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