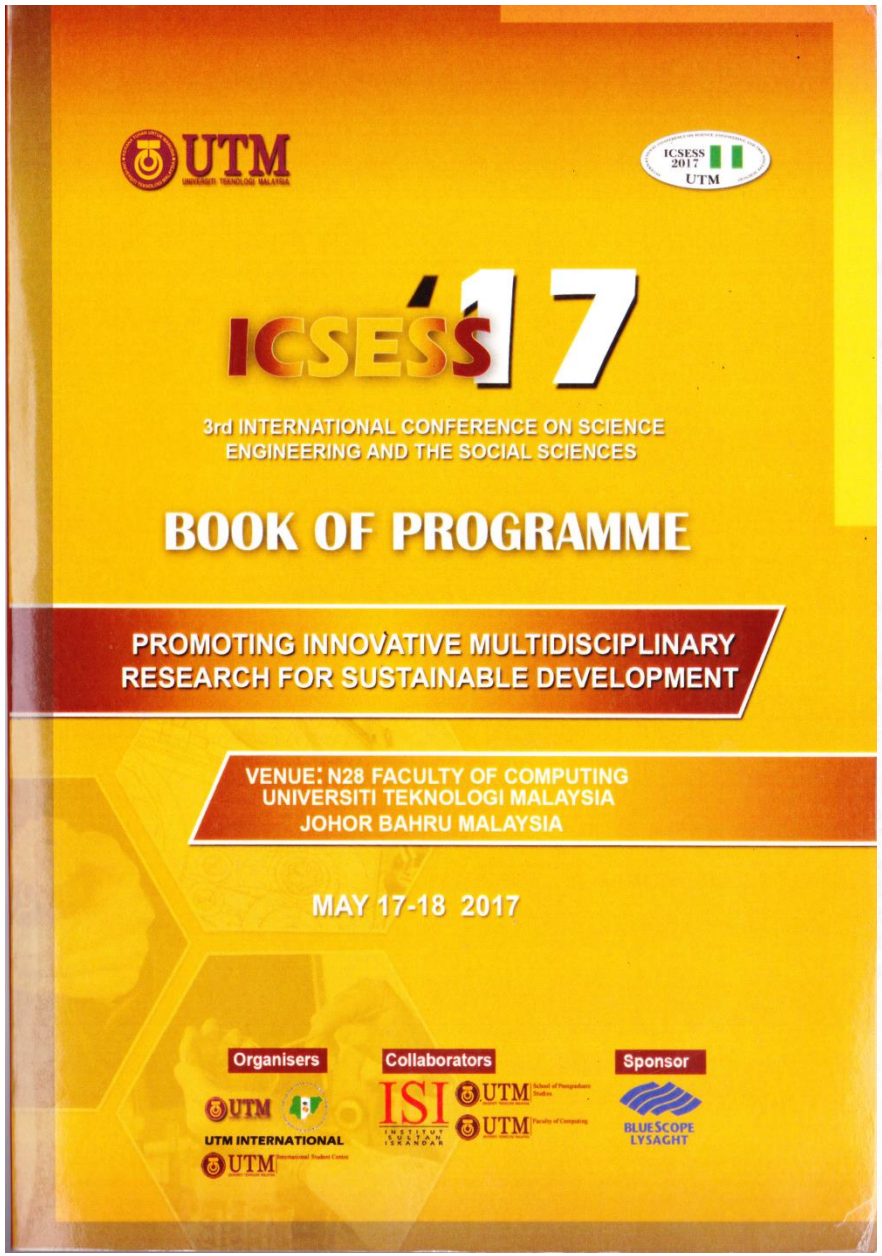

Identification of Downtime Influence Factors to Naval Ship Operational Availability for Sustainment of Naval Force

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ABSTRACT

Navies around the world aspire to improve fleet operational availability. Only navies able to mantain high operational availability can sustain deterrence and naval presence. Navies such as the Royal Australian Navy explore sustainable strategies for their existing and future fleet of vessels. The dilemma is accommodating increased design complexity, mantaining vessel classes at various locations, enduring budget restrictions, whilst achieving high operational availability targets. Studies have shown that modern navies such as the Unites States Navy continuously implemented sophisticated strategies including improved maintenance concepts, human capital development and optimized fleet response plan that provided near-term benefits, nevertheless significant short, medium and long term issues were faced associated with high ship operational tempo especially when far from home base. Increasing vessel operational availability to meet presence requirements with existing force structure increases costs and decreases crew and ship readiness in the short term, it degrades the ship material condition over medium and long term with a likely impact on the fleet's intended lifecycle. Therefore, efforts in improving availability without identifying and understanding the underlying Downtime Influence Factors (DIFs) are futile as some of these DIFs may be the root cause to the discovered short, medium and long term issues. Due to limited available data and research into naval ship DIFs, an explorative study across various engineering disciplines was carried out to generate generic naval ship DIFs through mixed-method research beginning with comprehensive literature review, followed by Focus Group Discussions and subsequently a survey with experts knowledgeable in naval ship maintenance contracts. The study revealed 50 DIFs involving human and equipment related factors as a stepping stone towards future research in quantifying and ranking the DIFs on vessels worldwide with the ultimate objective of pinpointing the exact key problem areas for prioritisation of efforts by the navies.

Keywords: Naval vessels, navy ship maintenance, operational availability, downtime Influence Factors (DIFs), Focus Group Discussions.

IDENTIFICATION OF DOWNTIME INFLUENCE FACTORS TO NAVAL SHIP OPERATIONAL AVAILABILITY FOR SUSTAINMENT OF NAVAL FORCE

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ABSTRACT

Achieving high operational availability of the fleet of naval vessels remain the target of all navies around the world. Only navies able to mantain high operational availability can sustain deterrence and naval presence. Navies such as the Royal Australian Navy explore sustainable strategies for their existing and future fleet of vessels. The dilemma is accommodating increased design complexity, mantaining vessel classes at various locations, enduring budget restrictions, whilst achieving high operational availability targets. Sophisticated strategies have been continuously implemented by modern navies such as the United States Navy through improved maintenance concepts, human capital development and optimized fleet response plan. Nevertheless, they continue to face near, medium and long term issues associated with high ship operational tempo. Increasing vessel operational availability to meet presence requirements with existing force structure increases costs and decreases crew and ship readiness in the short term, it degrades the ship material condition over medium and long term with a likely impact on the fleet's intended lifecycle. Therefore efforts in improving availability without identifying and understanding the underlying Downtime Influence Factors (DIFs) are futile as some of these DIFs may be the root cause to the discovered short, medium and long term issues. Due to limited available data and research into naval ship DIFs, an explorative study across various engineering disciplines was carried out to generate generic naval ship DIFs through mixed-method research beginning with comprehensive literature review, followed by Focus Group Discussions and subsequently a survey with experts knowledgeable in naval ship maintenance contracts. The study revealed 50 DIFs involving human and equipment related factors as a stepping stone towards future research in quantifying and ranking the DIFs on vessels worldwide with the ultimate objective of pinpointing the exact key problem areas for prioritisation of efforts by the navies.

Key words: Naval vessels, navy ship maintenance, operational availability, Downtime Influence Factors (DIFs), Focus Group Discussions.

INTRODUCTION

Navies around the world aspire to improve fleet operational availability. For instance the Royal Australian Navy (RAN) is exploring new strategies for the sustainment of existing and future naval vessels in the fleet. RAN's focus has shifted to building for sustained capabilities and availability in future to provide strategic deterrence and naval presence (1). Availability is seen as a key enabler of future sustainment. Ship availability is defined following (2) and (3) as the probability that the ship is available and capable of performing the intended function at any random point in time. Studies into modern navies such as Unites States Navy show that continuously implemented sophisticated maintenance

strategies, human capital development and optimized fleet response plan provided near-term benefits, nevertheless significant short, medium and long term issues were faced especially when far from home base. Increasing vessel operational availability to meet presence requirements increases costs and decreases crew and ship readiness in the short term, it degrades the ship material condition over medium and long term with a likely impact on the fleet's intended lifecycle (4).

Therefore efforts in improving availability without identifying and understanding the underlying Downtime Influence Factors (DIFs) are futile as some of these DIFs may be the root cause to the discovered short, medium and long term issues. Due to limited available data and research into naval ship DIFs, an explorative study across various engineering disciplines was carried out to generate generic naval ship DIFs through mixed-method research beginning with comprehensive literature review, followed by Focus Group Discussions (FGD) conducted with 30 panel experts and subsequently a survey with 30 experts knowledgeable in naval ship maintenance contracts as in Figure 1 below.

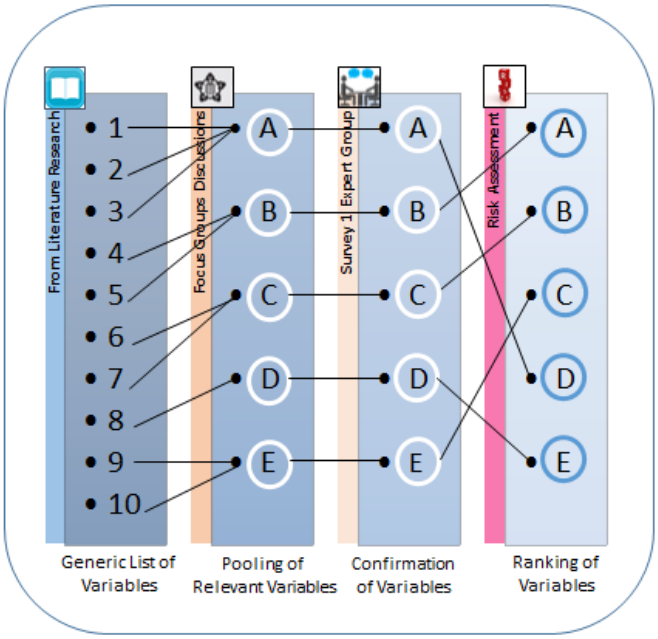

Figure 1. Method of Identifying Key Variables

MAIN RESULTS

Various literatures that have been written by multiple authors over the years on factors impacting availability of equipment, systems and plants. Nevertheless, there are only a limited number of literatures on factors impacting downtime specifically on naval ship availability. This study compiles the findings of a comprehensive review of all past literatures on downtime factors from various fields as summarized in Table 1 below.

Table 1. Downtime Factors from various fields

S/No	DIFs for Ship Operational Availability	Authors of Literatures from various Fields
1	Equipment & Systems (E&S) – Hull and Design	(5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18),(19), (20), (21), (22),(23), (24), (25),(26),(27)
2	E&S – Main Propulsion	
3	E&S – Electrical	
4	E&S – Weapon Systems incl. guns and missiles	
5	E&S – Auxiliaries	
6	E&S – Outfittings	

7	Maintenance Policy - Priority on Type of Maintenance	(10), (28) , (29), (30), (31), (32),(33), (34), (35), (36), (37), (38)
8	Awareness of Importance of Maintenance / Attitude – including hiding problems from becoming official.	(12), (39), (16), (40), (41), (42), (43), (44),(45), (46), (47), (48)
9	Maintenance Budget Allocation	(49), (10), (50), (51), (52), (18), (12), (53), (54),(55),(56), (57), (58), (59), (60), (61), (9), (49), (62), (63), (64), (65),(66), (67), (68), (25), (26), (46)
10	Information Management	(69), (70), (71), (72), (73), (74)
11	Preventive Maintenance	(10), (8), (28), (18), (75), (76), (77), (78), (79), (32),(80), (33), (73), (81), (82)
12	Corrective Maintenance	(10), (81), (83), (82), (84),(85),(86), (18), (87), (82), (50), (76), (79), (47)
13	Predictive Maintenance	(28), (10), (77), (78), (88), (82)
14	Emergency Repair & Docking	(89), (90), (91), (18), (92), (50),(93)
15	Equipment Technology / System Complexity	(10), (48), (77), (94), (95), (50), (96), (75), (87), (97),(98), (99), (100), (83), (23)
16	Scheduling Issues	(33), (50), (81),(101), (58), (102),(103),(104), (105), (106), (107), (108), (42),(109),(110),(83),(7)
17	Maintenance of Special Tools, Test Equipment	(10), (73), (12), (75),(18)
18	Availability of Facilities	(10), (12), (7) , (42), (111), (112), (24), (18), (110)
19	Spares Availability	(10), (12), (95), (8), (42), (29), (113), (114), (115), (18),(116), (117)
20	Obsolescence Issues	(10), (118), (119),(120),(121),(122),(123), (124), (125), (29), (36), (126), (127), (128), (129), (130), (131), (132), (116),(133)
21	Design and Design Change Issues	(134), (10),(12), (135), (16), (18)
22	Knowledge Management including Training, Knowledge and Skills	(136), (10), (75),(41), (59),(65), (133)
23	Availability of OEM Expert Support	(10), (41),(137),(138), (18)
24	Availability of Local vendor support	(10), (12), (139),(138), (18),(140),(141)
25	Complexity and efficiency of existing contract	(142), (137),(135), (65), (88) (25), (143)
26	Capability of Customer performing Maintenance	(10), (12), (42), (29), (144), (40), (145), (146),(147), (50), (148), (126), (149), (74), (150)
27	Morale & Attitude of Customer involved in Maintenance	(10), (12), (50), (42), (29), (144), (145),(146), (40, 147), (148), (126), (149), (74), (150)
28	Morale & Attitude of Contractor involved in Maintenance	(50), (12), (42), (41), (39),(151), (40), (150), (43),(152), (153)
29	Efficiency of Processes, Procedures and reporting structure include Finance	(136), (74), (12), (18),(10), (154), (155), (108), (152), (156), (157),(158), (159), (17, 151), (28)
30	Ship Operational/sailing schedule	(82), (81)
31	Non-Commonality of Equipment issues	(29), (9), (47)
32	Non Redundancy of Equipment	(8),(52), (29), (41),(29), (160), (154), (161)
33	High Turnover of maintenance supervisors.	(73), (162), (133)
34	High Turnover of maintainers	(163), (149), (164),(165), (44), (18),(166), (167), (73)
35	Different location of ships	(168), (18)
36	Statutory requirements	(22),(23),(138), (77),(53), (158)
37	Cashflow Shortages	(23),(138),(42),(53), (12),(7), (13),(14),(15)
38	Government Requirements and Policies (i.e. EEP, Offset etc)	(169), (170)
39	Variation Order and Contract Change	(42), (53), (62),(171), (152), (153), (155), (153), (172), (173), (174), (143), (61),(175)

40	Ageing of Equipment (Aging)	(36), (129), (47), (23), (9), (73), (60), (77), (176), (49), (65),(177), (44), (178), (179),(153), (180)
41	Force Majeure	(181),(168), (9), (138)
42	Accidents & Hazards	(182), (29),(138), (183), (184),(185),(186), (42), (106), (187), (188), (9),(73), (189), (190),(191), (126), (153), (192), (49)
43	Extraordinary Price Escalations (Spares, Consumables, Equipment)	(29, 42, 53)
44	Pilferage, Theft & Fraud & Cheat	(193),(194),(195),(196),(193),(159), (51), (197), (41),(157)
45	OLM, ILM, DLM - Overlap of maintenance duties (contractual) and impact if not performed	(198), (83),(135), (50), (12), (59),(25), (199), (200), (201),(88)
46	Contract Management across a wide range of stakeholders with conflicting interests	(178), (179), (202), (88), (53), (203), (204), (205), (206), (153), (143), (207), (208), (46), (17), (199), (209),(53), (76),(64)
47	Impact of Parallel Contracts to Schedule, Genuinity of Spares, Professionalism of Repair Team etc.	(210), (211), (212), (213)
48	Supporting of the Vessel outside of home ports (e.g. issue on mob, availability of materials etc.)	(10), (4)
49	Exogenous factors (i.e. company profit margin, administrative costs, peripheral costs, support cost)	(100), (10), (73), (42), (138), (59)
50	Exogenous factors - Contract Concept (Total Maintenance Package against segregated orders without interrelationships) & based on ecommendations	(10), (214)

Focus Group Discussion (FGD)

A FGD was conducted with an Expert Group to confirm, screen and carefully pool the identified variables into groups of relevant terms with a manageable number. 30 Expert members who were working directly on ISS Contract and other relevant organisations with sufficient working experience or knowledge in the ship maintenance field from contractor and the customer's organisations were selected to populate the variables based on their knowledge and experience. Table 2 and Table 3 list the Expert members' details based on years of working experience and job positions/designations.

Table 2. Working experience of the Expert members

Years	Percentage
0-5	5%
6-10	30%
11-20	30%
>20	35%

Table 3. Job position/designation of the Expert members

Designation	Number
Technical Executive	6
Senior Technical Executive	9
Supervisor	1
Senior Supervisor	2
Assistant Manager	1
Manager	3
Project Manager	1
Head of Division	3
Commanding Officer Navy Ships	3
Senior Navy Engineer and Contract Manager	1
Total	30

The FGD complemented the findings from over hundreds of literatures to populate the factors affecting the operational availability of ships. Table 4 contains the agreed list of 50 DIFs identified.

Table 4. The 50 groups of DIFs agreed by Expert's via Focus Group Discussions

No	DIFs for Ship Operational Availability	No	DIFs for Ship Operational Availability
1	Equipment and Systems – Hull and Design	28	Morale & Attitude of Contractor involved in Maintenance
2	Equipment and Systems – Main Propulsion		
3	Equipment and Systems – Electrical	29	Efficiency of Processes, Procedures and reporting structure include Finance
4	Equipment and Systems – Weapon Systems including guns and missiles		
		30	Ship Operational/sailing schedule
5	Equipment and Systems – Auxilliaries	31	Non-Commonality of Equipment issues
6	Equipment and Systems – Outfittings	32	Non Redundancy of Equipment
7	Maintenance Policy - Priority on Type of Maintenance	33	High Turnover of maintenance supervisors
		34	High Turnover of maintainers
8	Awareness of Importance of Maintenance / Attitude – including hiding problems from becoming official.	35	Different location of ships
		36	Statutory requirements
		37	Cashflow Shortages
9	Maintenance Budget Allocation	38	Government Requirements and Policies (i.e. EEP, Offset etc)
10	Information Management		
11	Preventive Maintenance	39	Variation Order and Contract Change
12	Corrective Maintenance	40	Ageing of Equipment (Aging)
13	Predictive Maintenance	41	Force Majeure
14	Emergency Repair & Docking	42	Accidents & Hazards
15	Equipment Technology / System Complexity	43	Extraordinary Price Escalations (Spares, Consumables, Equipment)
16	Scheduling Issues	44	Pilferage, Theft & Fraud & Cheat
17	Maintenance of Special Tools, Test Equipment	45	OLM, ILM, DLM- Overlap of maint. duties (contractual) and impact if not performed
18	Availability of Facilities	46	Contract Management across a wide range of stakeholders with conflicting interests
19	Spares Availability		
20	Obsolescence Issues	47	Impact of Parallel Contracts to Schedule, Genuinity of Spares, Professionalism of Repair Team etc.
21	Design and Design Change Issues		
22	Knowledge Management incl Training, Knowledge and Skills	48	Supporting of the Vessel outside of home ports (e.g. issue on mob, avail. of materials etc.)
23	Availability of OEM Expert support		
24	Availability of Local Vendor support	49	Exogenous factors (i.e. company profit margin, admin.costs, peripheral costs, support cost)
25	Complexity & efficiency of existing contract		
26	Capability of Customer performing Maintenance	50	Exogenous factors - Contract Concept (Total Maint. Package against segregated orders without interrelationships) & based on recommendations
27	Morale & Attitude of Customer involved in Maintenance		

*Abbreviations: [*1] OEM: Original Equipment Manufacturer, [*]EEP Economic Enhancement Program, [*3] OLM (Operational Level Maintenance), ILM (Intermediate Level Maintenance), DLM (Depot Level Maintenance)*

While the FGD served as expert validation of the generic DIFs identified by literature study, no further consensus concerning the 50 agreed DIFs was yielded.

Survey of Expert Group

This stage was designed to build the consensus among the 30 Expert members regarding the importance of each DIF towards the ship availability. A questionnaire was developed for the usage in this Mixed Method research. The questionnaire is constructed in structured questions which consisted of closed, dichotomous questions and Likert Scales.

The questions which contained the 50 DIFs produced by the FGD were brought forward to this stage for evaluation by the Expert Group of its relevancy to ship operational availability.

The experts were asked to select the DIFs that have impact on ship availability via Risk Assessment method. Qualitatively, risk is proportional to the expected losses that can be induced by a certain accident and to the likelihood of an occurrence. Greater loss and greater likelihood result in an increased overall risk (189). The best suited Risk Assessment Matrix for the study was as a 5x5 Matrix, with a five points Likert Scale on the impact of the DIFs onto the ship availability for the ISS Contract and five degrees of DIFs probability occur throughout the contract duration employed for the rating as summarised in Table 4 are inquired for each DIF selected.

Figure 2 displayed the ranking of the 50 DIFs based on results of the Risk Assessment Matrix, ranking from most severe (Rank 1) to least severe (Rank 50).

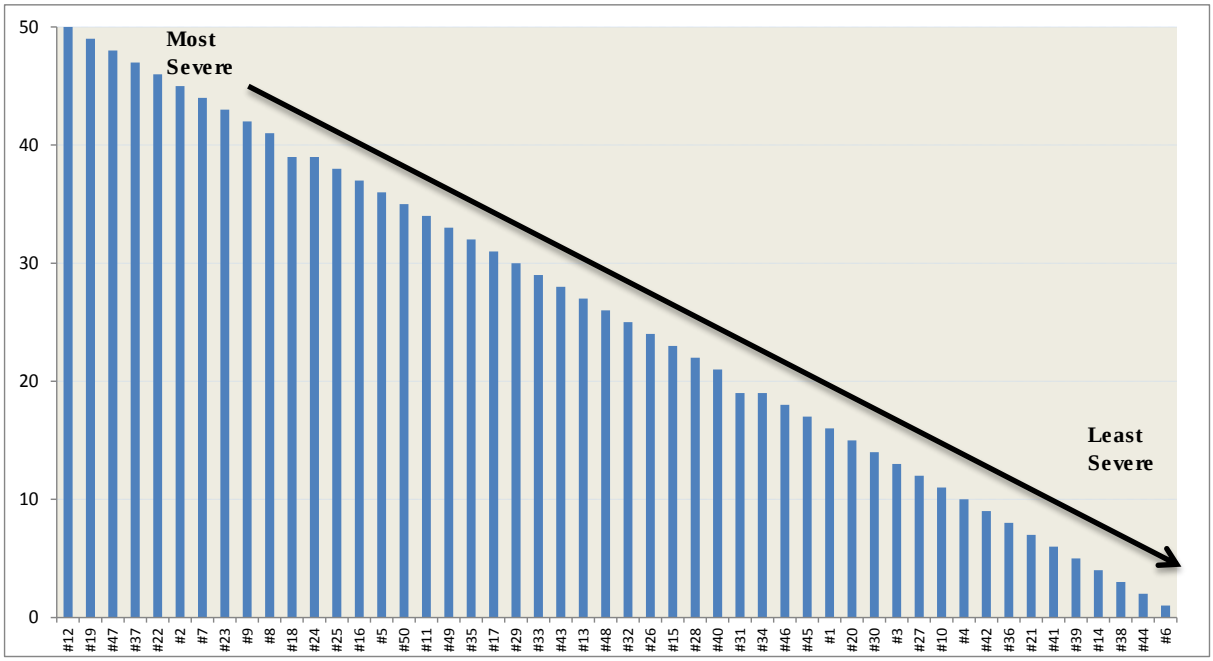

Figure 2. Ranking of DIFs from Most Severe to Least Severe

Consensus among the expert group members regarding the importance of each of the 50 DIF was achieved.

CONCLUSION

Many papers have been written previously on maintenance for math purposes only. Mathematical analysis and techniques, rather than solutions to real problems, have been central in many papers on maintenance optimization models (52).

In this study, the researcher has revealed 50 DIFs involving human and equipment related factors as a stepping stone towards future research in quantifying and ranking the DIFs on naval vessels worldwide with the ultimate objective of pinpointing the exact key problem areas for prioritisation of efforts by the navies. It is an achievement to holistically study and consolidate all factors impacting the availability of naval vessels based on real problems and issues faced by stakeholders on the ground.

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