JOURNAL OF MARITIME RESEARCH

Vol XVI. No. III (2019) pp 14–25

ISSN: 1697-4040, www.jmr.unican.es

Proposed Improvement on Availability of Sarawak Marine Aids to Navigations by Using FSA And Swiss Cheese Model

Ahmad Faizal Ahmad Fuad[1], Mr. Mohd Hafizi[2], Dr. Khalid Samo[3], Dr. Mohd Hairil[4], Mr. Ismail Zainol[5]

ARTICLE INFO

Article history:
Received 16 September 2019;
in revised form 20 October 2019;
accepted 7 November 2019.

Keywords:
Marine Aids to Navigation, Formal Safety Assessment, Swiss Cheese Model.

ABSTRACT

The study started with obtaining aids to navigation maintenance data year 2014 to 2016 from Marine Department Sarawak Malaysia. The data is used to determine the availability percentage of Marine Aids to Navigation (AtoN) in Sarawak according to type of equipment. The navigation buoy availability was below the standard set according to IALA and QMS. Formal Safety Assessment (FSA) was used to asses risk by unavailability of navigation buoy. Fault Tree Analysis was used to identify the root cause of failure. Swiss Cheese Model (SCM) was used to identify the management related cause at various management level. Risk control options were proposed based on findings in the FTA and SCM. The best risk control option proposed to top management was based on the five-level cost and effectiveness matrix of Cost-Benefit Analysis. Result of this research is applied to reduce the downtime of navigational buoys and would improve the safety of navigation in Sarawak waters.

1. Introduction

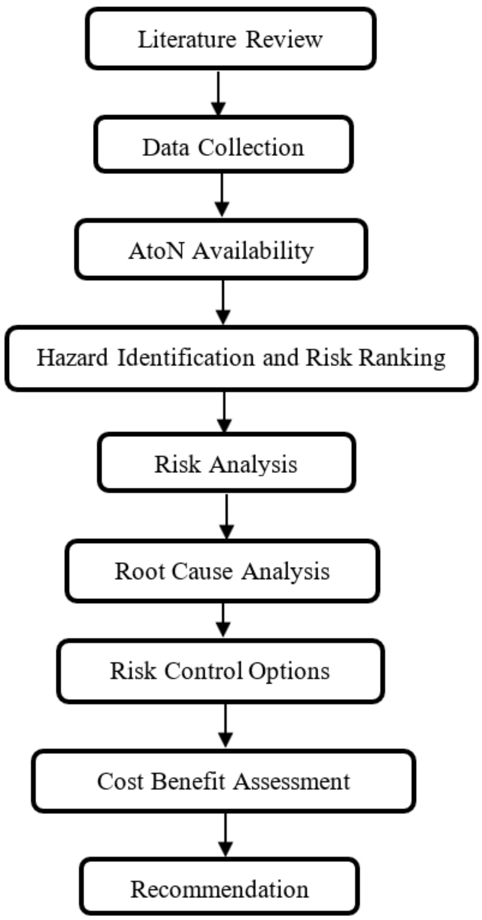
Maritime Aids to Navigation (AtoN) is defined as a device, system or service, external to vessels, designed and operated to enhance safe and efficient navigation of individual vessels and/or vessel traffic (IALA, 2016). The examples of AtoN are lighthouse, fog horn, and navigational buoy. AtoN is different with navigational aid that is defined as an instrument, device, chart, method, or such, that are carried on board to assist in the navigation of a craft (McGraw-Hill, 2003). The examples of navigational aids are radar and GPS. Marine Department Malaysia is responsible for the establishment and maintenance of AtoN in Malaysia. Sarawak Buoys and Light Board and Marine Department Malaysia Sarawak Region (SMD) is the authority responsible for AtoN in the state of Sarawak. There are three main categories of AtoN under the responsibility of SMD, namely lighthouse, beacon and navigational buoy. In order to ensure a quality service, SMD has been established the ISO Quality Management System (QMS) since year 2000 for the maintenance of AtoN in Sarawak. SMD has incorporated the IALA guideline 1077 Maintenance of Aids to Navigation into SMD ISO QMS (IALA, 2009; ISO, 2015). This action had set the objective standard for availability of AtoN, namely lighthouse 99%, beacon 98% and navigation buoys 97%. Therefore, by fulfilling the set quality objective in the ISO QMS, SMD has also complied with IALA guideline (IALA, 2013, 2014). However, the availability of navigational buoy availability from 2014 to 2016 is less than 97%. Therefore, SMD has not complied with the quality objective in ISO QMS and IALA guideline 1077 (IALA, 2009, 2013). Therefore, the objective of this study is to identify the contributing factors that caused the failure to achieve the objective and to propose the recommendation for improvements. The significance of this study is to improve the safety of navigation in Sarawak waters.

[1]Professor at Universiti Malaysia Terengganu.
[2]Professor at Universiti Malaysia Terengganu.
[3]Associate Professor at Universiti Malaysia Terengganu.
[4]Professor at Universiti Malaysia Terengganu.
[5]Professor at Universiti Kuala Lumpur. Institute of Marine Engineering Technology.

2. Research Methodology.

The overall research activity is shown in the flowchart (Figure 1). The detail explanation is stated in the following paragraphs.

Figure 1: Flowchart of overall research activity.



Source: Authors.

2.1. Literaure Review.

The literature review is conducted by focusing on relevant publication on standards and guidelines on Marine AtoN. The most relevant sources are IALA and ISO. The guidelines and standards are relevant on setting the standard on availability and quality management system of Marine AtoN. Another focus of literature review was the quality management systems for organization. The review was focus on factors that contribute to the availability of marine AtoN.

2.2. Data Collection.

Three types of data are collected for this research. The first data is the customer complaint data, the second is monthly technician report and the third is the survey data. The customer complaint data is obtained from year 2014 to 2016 for all parts of Sarawak. These data are obtained from Safety of Navigation Division, Marine Department Malaysia Sarawak Region by visiting the responsible officer. These data were collected by the division from regional office, namely east, central and west. The second data is the monthly report by technician in charge of the equipment. This report would give the result of inspection and the maintenance report of AtoN. Third type of data is the survey conducted to the technician and marine officer of the division. The survey was conducted at four stages of the Formal Safety Assessment, namely risk ranking during hazard identification, fault tree analysis, risk control option and recommendation. The survey was conducted according to Delphi method, which 2 rounds session was adequate to generate a consensus.

2.3. Data Analysis.

Two types of data analysis method were used. The first method is to determine the availability of AtoN and Risk Assessment by using Formal Safety Assessment.

2.3.1. Availability of AtoN.

Customer complaint data is categorized into four, namely lighthouse, beacon, transit/leading light, and navigation buoy. The data analysis would identify type of AtoN that does not comply with the IALA guideline and objective quality of ISO9001 quality management system of Marine Department Malaysia. Mean and frequency are the statistical method used to analyze customer complaint data, which is type of failure for each category of AtoN. The availability of each type AtoN within given period of time was calculated by using Equation 1.

$$Availability\ (percentage)\ = \frac{Total\ Down\ Time}{Total\ Time} \qquad (1)$$

However, Equation 1 was modified to calculate the availability for different type AtoN, as shown in the following equations.

$$Buoy\ Total\ Down\ Time = \sum b_i \qquad (2)$$

Where:

$$Buoy\ Total\ Time\ buoy = \sum b_n \times\ 365\ days \qquad (3)$$

b_i= buoy i downtime days in one year

Where: b_n= total number of buoys in a year

$$Buoy\ Availability\ (percentage)\ = \frac{Buoy's\ Total\ Down\ Time}{Buoy's\ Total\ Time} \qquad (4)$$

$$Beacon's\ Total\ Down\ Time = \sum c_i... \qquad (5)$$

Where: c_i= beacon i downtime days in one year.

$$Beacon\ Total\ Time = \sum c_n \times\ 365... \qquad (6)$$

Where:

c_n= total number of beacons in a year

$$Beacon\ Availability\ (percentage)\ = \frac{Beacon's\ Total\ Down\ Time}{Beacon's\ Total\ Time} \qquad (7)$$

$$Lighthouse\ Total\ Down\ Time\ = \sum l_i... \qquad (8)$$

Where:

l_i= lighthouse i downtime days in one year

$$Lighthouse\ Total\ Time = \sum l_n \times\ 365 \quad (9)$$

Where:
l_n= total number of buoys in a year

$$Lighthouse\ Availability\ (\%) = \frac{Lighthouse's\ Total\ Down\ Time}{Lighthouse's\ Total\ Time} \quad (10)$$

2.3.2. Formal Safety Assessment.

Formal Safety Assessment (FSA) is the method used to collect and analyze the data. There are five steps in FSA. The steps are as follows: hazard identification and risk ranking, risk analysis, risk control option, cost-benefit assessment, and recommendation (IMO, 2002; Kontovas, 2009). The details for each step are explained in the following sections.

2.3.2.1. Hazard Identification and risk ranking.

Hazard identification was determined from the list of AtoN's faulty, malfunctioned and damaged (Svein Kristiansen, 2005). The risk ranking of the hazards is using the frequency index and severity index. The frequency index is developed based on the frequency of malfunction occurrence from the faulty report data. The risk ranking process was conducted by the technicians of safety of navigation division by using the developed frequency index and severity index table. Results of the risk ranking was achieved by using the Delphi method (Skulmoski, Hartman, & Krah, 2007; Thangaratinam & Redman, 2005). One round of meeting was able to get an anonymous result.

2.3.2.2 Risk Analysis

Risk analysis was conducted by using fault tree analysis with logic gate. The fault tree analysis was conducted together with the senior technicians on hazard (AtoN's malfunctioned) ranked with high-risk index. The Event Tree analysis was not conducted because the result of risk index was sufficient to rank the risk level for each hazard. Fault tree analysis was conducted to determine the technical and operational root cause of the failure. However, it is less effective to determine the root cause in the perspective of management level. Therefore, Swiss cheese model is used to cover this gap and uses to determine the root cause or latent failure and active failure in the management. Swiss cheese model is an accident causation model to find the root cause of an accident in a multi-level of an organization (Perneger, 2005; Reason, 2000).

2.3.2.3 Proposed Risk Control Options

Risk control options were proposed by the technicians using the Delphi method (IMO, 2002; Powell, 2003; Skulmoski et al., 2007) The risk control options were proposed by referring to the developed FTA for each failure and the identified level in the swiss cheese model. The risk control options were recommended to reduce the frequency or downtime of the identified hazard with high-risk index. The risk control options were ranked according to its ability to reduce risk index.

2.3.2.4 Cost-Benefit Assessment (CBA)

Cost benefit assessment was conducted by using the Delphi method to the technicians. The CBA index was determined by using 5 levels of cost index and 5 levels of effectiveness index.

2.3.2.5 Recommendation

The best recommendations for risk control options were selected from the CBA process. The recommendations will be proposed to Sarawak Light Dues Board for their selection and final decision during board meeting.

3. Results and Discussion.

3.1. AtoN Avaibility.

Table 1 shows the number of AtoN in Sarawak for year 2014 and number of complaints for the particular type of AtoN. The number of beacon/transit is the highest, follow by buoy and lighthouse. Most of beacon and transit are on dry land and small number piled in river. All navigation buoys are floating on sea or rivers. The highest number of complaints received was buoy with 33, followed by beacon/transit with 27 and lighthouse with 1. Navigation buoys received highest number of complaints because it is secured to a position by a mooring system that subjects to movement all the time by currents, tides and waves. The lighthouses, beacons and transits are stationary by piling or a foundation system. Table 2 shows the complaints according to type of AtoN. Lamp malfunction is the highest complaint received followed by dim light and buoy off-position. Five complaints received on lamp not synchronized for transit light. The total downtime (days) for lighthouse, beacon/ transit and buoy are 0, 131 and 509 respectively. The availability of lighthouse, beacon/transit, and buoy for 2014 are 100%, 99.7% and 98.4% respectively (Table 3). These values are above the KPI set by IALA and objective quality in ISO.

Table 1: AtoN Complaint in 2014

No.	AtoN Type	Unit	No. of Complaint
1	Lighthouse	7	1
2	Beacon/ Transit	126	27
3	Navigation Buoy	85	33
	Total	218	61

Source: Authors.

Table 2: AtoN type and number of complaints in 2014 (nr: not relevant)

AtoNs Type	Type and Number of Complaint				
	Lamp mal function	Dim light	Lamp not synchronised	Lost/ Collapse	Off-position
Light house	0	1	nr	0	nr
Beacon	3	1	nr	2	nr
Transit	11	5	5	0	nr
Navigation Buoy	20	2	nr	2	9
Total	34	9	5	2	9

Source: Authors.

Table 4 shows the number of AtoN in Sarawak for year 2015 and number of complaints for the particular type of AtoN. The highest number of complaints received was buoy with 31, followed by beacon/transit with 21 and lighthouse with 1. Table 5 shows the type of complaint for the AtoN. Lamp malfunction is the highest complaint received followed by lost/collapse and buoy off-position. One complaint on lamp not synchronized for transit was received. The total downtime (days) for lighthouse, beacon/ transit and buoy are 12, 414 and 2425 respectively. The availability of lighthouse, beacon/transit, and buoy for 2015 are 99.5%, 99.0% and 92.2% respectively (Table 6). The buoy availability is below the KPI set by IALA and objective quality in the ISO.

Table 3: AtoN availability in 2014

No.	AtoN Type	Unit	Down time (day)	Availability	KPI
1	Lighthouse	7	0	100.00%	99%
2	Beacon/ Transit	126	131	99.7%	98%
3	Navigation Buoy	85	509	98.4%	97%

Source: Authors.

Table 4: AtoN Complaint in 2015

No	AtoN Type	Unit	No. of Complaint
1	Lighthouse	7	1
2	Beacon/ Transit	67	21
3	Buoy	81	31
	Total	218	53

Source: Authors.

Table 5: AtoN type and number of complaints in 2015 (nr: not relevant)

AtoN Type	Type and Number of Complaint				
	Lamp mal function	Dim Light	Lamp not synchronised	Lost/ Collapse	Off-position
Lighthouse	1	0	nr	0	nr
Beacon	9	1	nr	3	nr
Transit	8	0	1	0	nr
Buoy	14	0	nr	10	7
Total	32	1	1	13	7

Source: Authors.

Table 6: AtoN availability in 2015

No.	AtoNs Type	Unit	Downtime (day)	Availability	KPI
1	Lighthouse	7	3	99.9%	99%
2	Beacon/ Transit	67	470	98.1%	98%
3	Buoy	81	2189	92.6%	97%

Source: Authors.

Table 7 shows the number of AtoN in Sarawak for year 2016 and number of complaints for the particular type of AtoN. The highest number of complaints received was buoy with 18, and followed by beacon/transit with 12. Table 8 shows the number and type of complaint for the AtoN. Lost/collapse is the highest complaint received followed by lamp malfunction and buoy off-position. Two complaints received for transit lamp not synchronized. The total downtime (days) for lighthouse, beacon/ transit and buoy are 0, 287 and 1828 respectively. The availability of lighthouse, beacon/transit, and buoy for 2015 are 100%, 99.4% and 94.1% respectively (Table 9). The buoy availability is below the KPI set by IALA and objective quality in ISO.

Table 7: AtoN Complaint in 2016

No.	AtoNs Type	Unit	No. of Complaint
1	Lighthouse	7	0
2	Beacon/Transit	67	12
3	Buoy	81	18
	Total	218	30

Source: Authors.

Table 8: AtoN type and number of complaints in 2016

AToNS Type	Type and Number of Complaint				
	Lamp mal function	Dim Light	Lamp not synchronised	Lost/ Collapse	Off-position
Lighthouse	0	0	nr	0	nr
Beacon	2	0	nr	3	nr
Transit	4	1	2	0	nr
Buoy	6	0	nr	10	2
Total	12	1	2	13	2

Source: Authors.

Table 9: AtoN availability in 2016

No.	AtoNs Type	Unit	Down time (day)	Availability	KPI
1	Lighthouse	7	0	100.00%	99%
2	Beacon/ Transit	67	176	99.0%	98%
3	Buoy	81	1180	94.7%	97%

Source: Authors.

Table 10 shows the AtoN downtime and availability 2014 to 2016. The availability of lighthouse, beacon/transit, and buoy for this period are 99.9%, 99.0% and 96.1% respectively (Table 10). The buoy availability is below the KPI set by IALA and objective quality in ISO.

Table 10: AtoN availability in 2013-2016

AtoN Type	Unit	Availability			Average Avail ability (%)
		2014	2015	2016	
Lighthouse	7	100	99.9	100	99.9
Beacon/ Transit	126 (2014) / 67 (2015-16)	99.7	98.1	99	99.0
Buoy	85 (2014) / 81 (2015-2016)	98.4	92.6	94.7	96.1

Source: Authors.

3.1.1. Risk Ranking of Hazard.

The risk ranking of hazard in Table 11 hazard is according to the occurrence or frequency and severity of hazard. The frequency index and severity index are used in the calculation.

Table 11: AtoN availability in 2013-2016

No.	Identified Hazard posed by malfunctioned AtoN
1	Buoy lamp malfunction
2	Beacon lamp malfunction
3	Transit lamp malfunction
4	Lighthouse lamp malfunction
5	Buoy lamp dim
6	Beacon lamp dim
7	Transit lamp dim
8	Lighthouse lamp dim
9	Beacon collapse
10	Buoy lost
11	Buoy off-position

Source: Authors.

3.1.2. Development of Frequency Index.

The frequency of malfunction for each type of faulty is shown in Table 12 in the first column. The probability of occurrence days per year for 2014, 2015 and 2016 are shown in shown in Table 13. The last column shows the average probability of occurrence day per year. Table 14 was developed based on Table 12, it shows the probability of occurrence in days within a certain period of time. Table 14 is developed based on Table 12 and 13, which shows the frequency index for AtoNs.

Table 12: AtoN faulty probability occurrence according to type of faulty 2014-2016

AtoN Unit	Fault Type	2014	Prob. 2014	2015	Prob. 2015	2016	Prob. 2016
81	Bouy lamp malfunction	147	0.0050	385	0.0130	32	0.0011
50	Beacon lamp malfunction	34	0.0019	79	0.0043	22	0.0012
17	Transit lamp malfunction	21	0.0034	7	0.0011	8	0.0013
7	Lighthouse lamp malfunction	0	0.0000	12	0.0047	0	0.0000
81	Bouy lamp dim	1	0.0000	0	0.0000	0	0.0000
50	Beacon lamp dim	0	0.0000	4	0.0110	0	0.0000
7	Lighthouse lamp dim	5	0.0020	0	0.0000	2	0.0001
17	Transit lamp dim	0	0.0000	0	0.0000	0	0.0000
50	Beacon collapse	55	0.0030	324	0.0178	253	0.0139
81	Bouy lost	61	0.0021	1130	0.0382	1478	0.0500
81	Bouy off position	300	0.0101	910	0.0308	318	0.0108

Source: Authors.

Table 13: AtoN average faulty probability occurrence according to type of faulty 2014-2016

AtoN Unit	Fault Type	Avg.	Avg Prob.	Prob. day/ year
81	Bouy lamp malfunction	188	0.0064	2.32
50	Beacon lamp malfunction	45	0.0025	0.90
17	Transit lamp malfunction	12	0.0019	0.71
7	Lighthouse lamp malfunction	4	0.0016	0.57
81	Bouy lamp dim	0	0.0000	0.00
50	Beacon lamp dim	1	0.0037	1.33
7	Lighthouse lamp dim	2	0.0007	0.25
17	Transit lamp dim	0	0.0000	0.00
50	Beacon collapse	211	0.0115	4.21
81	Bouy lost	890	0.0301	10.98
81	Bouy off position	509	0.0172	6.29

Source: Authors.

3.1.3. Severity Index.

Severity index is applied directly from IMO as shown in Table 16.

3.1.4. Risk Ranking of Hazard.

The ranking of hazard was performed by the senior technicians. According to Table 17, the top three risk calculated are buoy lost (no.10), buoy off-position (no.11), and buoy lamp malfunction (no.1) with risk index 7, 6, and 5 respectively.

Table 14: Probability of Occurrence

Day	Probability
11.0	once a month
6.3	once in two months
4.2	once in three months
2.3	once in 6 months
1.3	once a year
0.9	once a year
0.7	once a year

Source: Authors.

Table 15: Frequency Index table for AtoN

Index	Meaning	Probability
7	Frequent	Once a week
6		Once in 2 weeks
5	Reasonably Probable	Once a month
4		Once in 3 months
3	Remote	Once in 6 months
2		Once a year
1	Extremely Remote	Once in 3 years

Source: Authors.

Table 17: Risk Ranking of Hazard

No.	Hazard	Frequency Index	Severity Index	Risk Index
1	Buoy lamp malfunction	3	2	5
2	Beacon lamp malfunction	2	1	3
3	Transit lamp malfunction	2	2	4
4	Lighthouse lamp malfunction	2	1	3
5	Buoy lamp dim	1	2	3
6	Beacon lamp dim	1	1	2
7	Transit lamp dim	1	2	3
8	Lighthouse lamp dim	1	1	2
9	Beacon collapse	4	1	5
10	Buoy lost	5	2	7
11	Buoy off-position	4	2	6

Source: Authors.

Table 16: Severity Index for AtoN

SI	Severity	Effects on Human Safety	Effects on Ship	S (Equivalent Fatalities)
1	Minor	Single or minor injuries	Local equipment damage	0,01
2	Significant	Multiple or severe injuries	Non-severe ship damage	0,1
3	Severe	Single fatality or multiple severe injuries	Severe damage	1
4	Catastrophic	Multiple fatalities	Total loss	10

Source: Authors.

3.2. Risk Assessment.

Risk assessment was conducted by using Fault Tree Analysis, which consists of top and below events linked by relevant logic gates (Deacon, Amyotte, Khan, & Mackinnon, 2013; IMO, 2002; Verma, Kumar, & Singh, 2012). Fault tree analysis was conducted on buoy lost, buoy off-position, and buoy lamp malfunction, which are the top three ranked risk indexes. The fault tree analysis is shown in Figure 2, Figure 3 and Figure 4. respectively.

Table 18: Swiss cheese analysis on broken chain event

No.	Steps	Details of Steps
1	Decision maker: Sarawak Buoys and Light Board (SBLB)	Fallible decision: • Give limited budget due to split of dues collected between SBLB and Sarawak River Board. • Most of the board members do not have a maritime background, so their contribution are limited to their knowledge and background such as finance and management and not on maritime operation.
2	Line Management: • Safety of Navigation Division • Aids to Navigation Unit (HQ) • Aids to Navigation Unit (Regional Office)	Deficiencies: • Limited record on chain age and condition; • Less priority on planning of chain replacement; • Inadequate procurement of new chain in the budget; • Limitation of budget had caused the line management to give other priorities in the budget instead of new chain.
3	Precondition:	Relevant condition, precursor of unsafe acts: • High tide; • Strong currents; • Shallow area.
4	Productive Activities:	Unsafe acts: • The deteriorated chain not replaces on time.
5	Defenses inadequate	Minor maintenance by regional only limited to inspection and maintenance of equipment above water.

Source: Authors.

3.3. Root Cause Failure.

Root cause failure is using the Swiss Cheese Model (Reason, 2000). Three results of root cause failure are shown below, namely for buoy's lost, buoy's off-position and buoy's lamp malfunctioned.

3.3.1. Buoy Lost.

The immediate events that cause buoy lost are broken chain, broken swivel, broken shackle, broken mooring eye and buoy sunk. However, among the 5 events aforementioned, broken chain has been identified in the maintenance report as the main cause for buoy lost. The highest abrasion occurred to chain within 2-3 meters from the sinker at the sea bed, which cause the thinning of the chain that eventually leads to the broken chain. Swiss cheese analysis on broken chain event in shown in Table 18.

Table 19: Swiss cheese analysis on buoy off-position

No.	Steps	Details of Steps
1	Decision maker: Sarawak Buoys and Light Board (SBLB)	Fallible decision: Most of the board members do not have a maritime background, so their contributions are limited to their knowledge and background such as finance and management and not on maritime operation.
2	Line Management: Safety of Navigation Division Aids to Navigation Unit (HQ) Aids to Navigation Unit (Regional Office)	Deficiencies: Decided to construct sinker with standard weight to be used all over Sarawak (drifted due to strong current). Decided to place the buoys at required position (dragged by vessel).
3	Precondition:	Relevant condition, precursor of unsafe acts: High tide (drifted due to strong current); Strong currents (drifted due to strong current); Shallow area (drifted due to strong current); Turning point for a vessel (dragged by vessel).
4	Productive Activities:	Unsafe acts: Strong current. (drifted due to strong current) Wrong judgement on time to turn the vessel – Human error (dragged by vessel).
5	Defenses inadequate	Sinker weight not adequate. (drifted due to strong current) Lack of experience in handling vessel in the respective area (dragged by vessel).

Source: Authors.

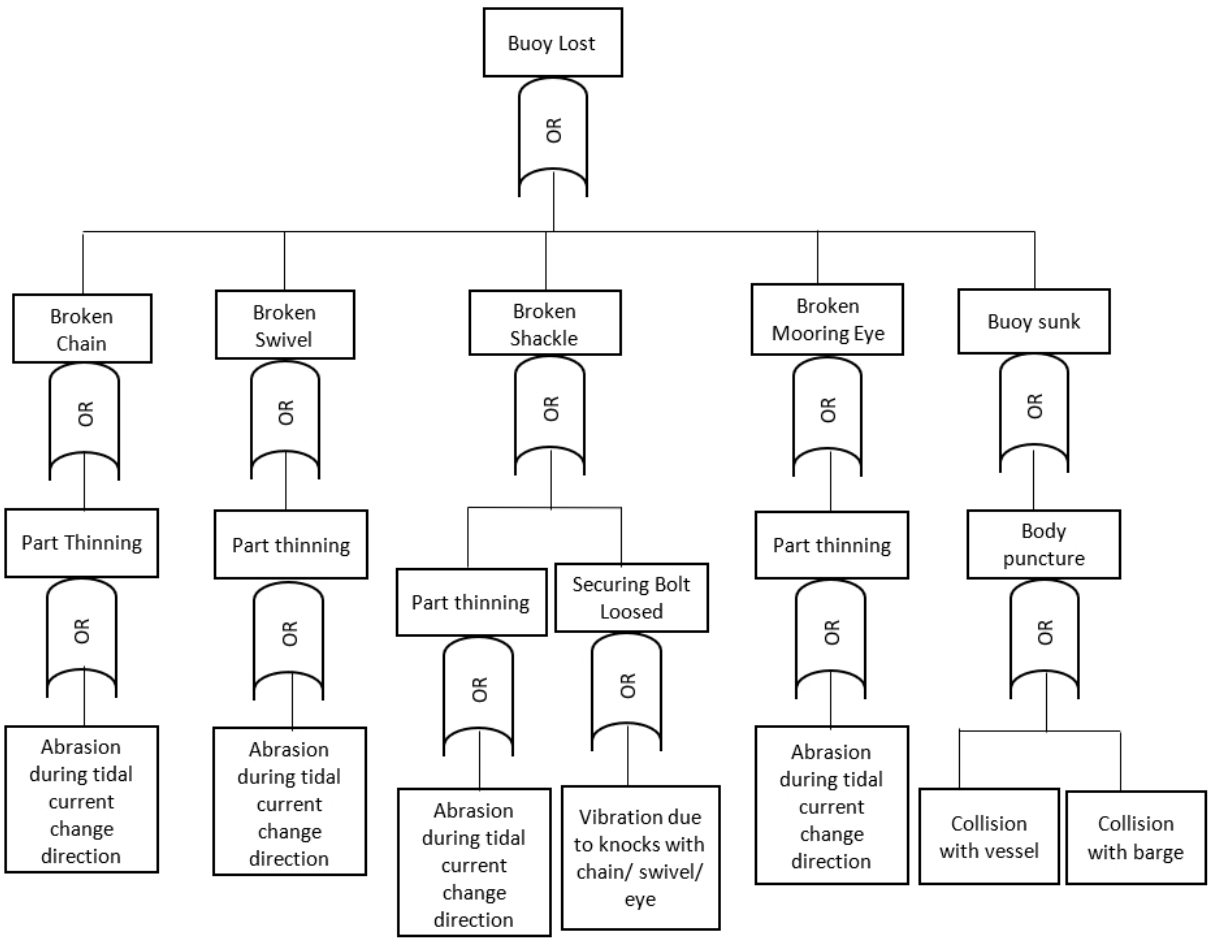
3.3.2. Buoy Off-Position.

There are two reasons for the buoy off-position. The first reason is the buoy drifted due to strong current and the second reason is the buoy is dragged by a vessel. Swiss cheese analysis on buoy off-position event in shown in Table 19.

3.3.3. Buoy Lamp Malfunctioned.

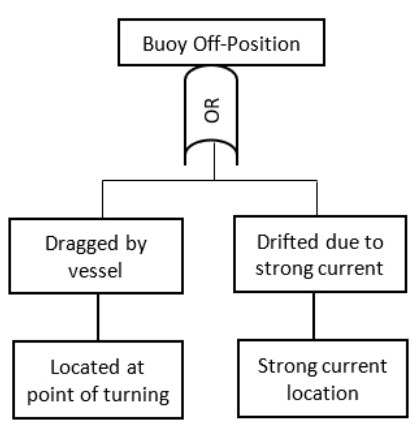
The immediate events that cause buoy lost are broken chain, broken swivel, broken shackle, broken mooring eye and buoy sunk. However, among the 5 events aforementioned, broken chain has been identified in the maintenance report as the main cause for buoy lost. The highest abrasion occurred to chain within 2-3 meters from the sinker at the sea bed, which cause the thinning of the chain that eventually leads to the broken chain. Swiss cheese analysis on broken chain event in shown in Table 18.

Figure 2: Fault Tree Analysis of Buoy Lost Eventd



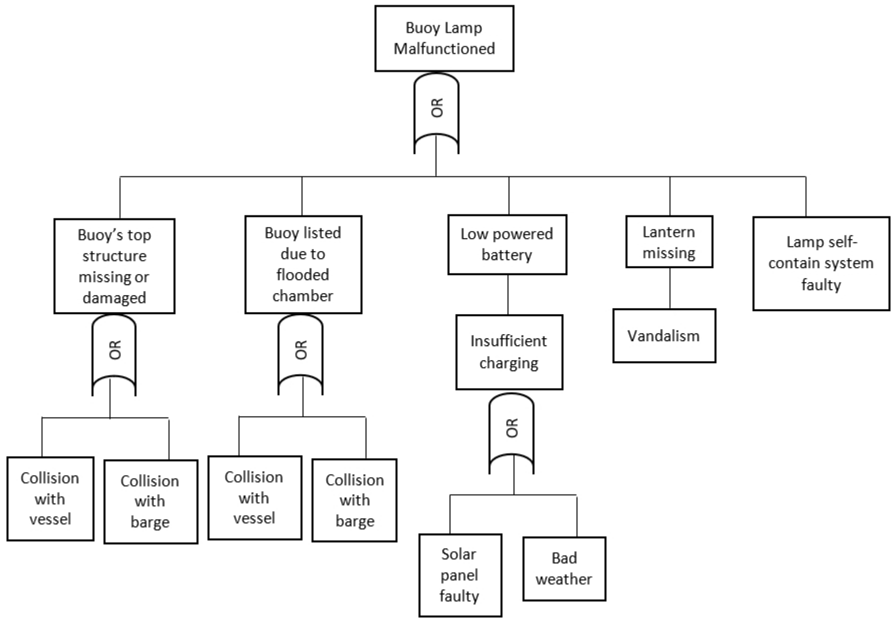
Source: Authors.

Figure 3: Fault Tree Analysis of Buoy Off-Position Event



Source: Authors.

Figure 4: Fault Tree Analysis of Buoy Lamp Malfunctioned



Source: Authors.

Table 20: Swiss cheese analysis on low powered battery

No.	Steps	Details of Steps
1	Decision maker: Sarawak Buoys and Light Board	Fallible decision: • Give limited budget due to split of budget between SBLB and SRB. • Most of the board members do not have a maritime background, so their contribution are limited to their knowledge and background such as finance and management and not on maritime operation.
2	Line Management: • Safety of Navigation Division • Aids to Navigation Unit (HQ) • Aids to Navigation Unit (Regional Office)	Deficiencies: • Limited record on solar panels condition (age, colour and efficiency); • Inadequate procurement of new solar panels; • Limitation of budget had caused the line management to purchase with limited quantity.
3	Precondition:	Relevant condition, precursor of unsafe acts: • Solar panels have been used beyond its designed life span; • Brownish colour; • Charging power out below required standard; • Insufficient good day weather for solar panel to charge the batteries.
4	Productive Activities:	Unsafe acts: The deteriorated solar panel not replace on time.
5	Defenses inadequate	The regional staff may only check the present of charging from the solar panel but may not measure the battery's power/voltage.

Source: Authors.

3.4. *Risk Control Option.*

The proposed RCO for buoy's lost as follows:

i. Prepare a proper chain record for maintenance and replacement (headquarters)

ii. Identify quantity for replacement annually, which include emergency spares.

iii. Prepare budget for the replacement a year before.

iv. Inform the board on the implication for not replace the chain on time based on records.

v. Replace the identified chain on time by replacing the whole length of the chain.

vi. Replace the worn chain only.

vii. Invert the chain from front to back and vice versa.

The proposed RCO for buoy's lamp malfunctioned as follows:

i. Prepare a proper solar panel record for maintenance and replacement (regional office)

ii. Identify quantity for replacement annually, which include emergency spares.

iii. Prepare budget for the replacement a year before.

iv. Inform the board on the implication for not replace the chain on time based on records.

v. Replace the solar panel at identified area on time.

3.5. *Cost Benefit Assessment (CBA).*

The CBA analysis to the RCO aforementioned is perform in Table 21, Table 22, Table 23 and Table 24. The analysis is using the scale for cost and effectiveness for the CBA.

Table 21: Cost Index

Cost Index	Meaning
1	Very High
2	High
3	Moderate
4	Low
5	Very Low

Source: Authors.

Table 22: Effectiveness Index

Effectiveness Index	Meaning
1	Very Low
2	Low
3	Moderate
4	High
5	Very High

Source: Authors.

Table 23: CBA Index Table for Buoy's Lost

No	RCO	CI	EI	CBA Index
1	Identify the quantity for chain replacement annually based on maintenance records, which include emergency spares.	5	2	7
2	Propose budget for chain replacement to the board based on chain's life span.	5	2	7
3	Replace the identified chain on time by replacing the whole length of the chain	2	5	7
4	Replace the worned chain only from the whole length	3	3	6

Source: Authors.

Table 24: CBA Index Table for Buoy's Lamp Malfunction

No	RCO	CI	EI	CBA Index
1	Identify the quantity for solar panels replacement annually based on maintenance records, which include emergency spares.	5	2	7
2	Propose budget for solar panels replacement to the board based on chain's life span.	5	2	7
3	Replace the identified solar panels on time	2	5	7

Source: Authors.

3.6. Recommendation for Decision Making.

3.6.1. Buoy's Lost Recommendation.

There are four recommendations for the buoy's lost due to the broken chain. Three recommendations have the same CBA rating with highest value and one recommendation of a lower value. "Replace the identified chain on time by replacing the whole length of the chain" would be the best recommendation because it would be the most effective approach although the cost is high. Recommendation "Propose budget for chain replacement to the board based on chain's life span" and "Identify the quantity for chain replacement annually based on maintenance records, which include emergency spares" have a very low cost and moderate effectiveness. Recommendation "Replace the selected length of worn out chain with reusable units." would not be recommended to the board because it is used as the last alternative by marine department in the event of no full-length chain spares is available.

3.6.2. Buoy's Lamp Lost Recommendation.

There are three recommendations for the buoy's lamp malfunction due to solar panel faulty. The CBA rating for these three are same. However, the most effective recommendation to solve the problem is "Replace the identified solar panels on time". The rest two recommendations are to support the replacement of the solar panels on time.

4. Conclusion and Recommendation.

This research is using marine aids to navigation maintenance data from 2014 to 2016. Based on the analysis on availability of each type of marine aids to navigation, marine navigation buoy's availability is below the objective quality set in the marine department's ISO quality management system and level of availability recommends by IALA.

The frequency index for the calculation of risk index was developed based on AtoN's faulty data. The risk index of the FSA method had ranked buoy's lost, buoy-off position and buoys lamp malfunction were the first, second and third respectively. Other eight type of AtoN's malfunction were ranked less.

The root cause of the top three ranked faulty had been identified by Fault tree analysis. Swiss Cheese model has been used to determine the latent failure in different level of management. Event tree analysis was not conducted because the result of the risk index is sufficient to determine the level of risk of each faulty.

Risk control option were proposed to reduce the risk of navigation buoy's availability below the quality objective. There were four risk control options recommendation for buoy's lost and three risk control options for buoy' lamp malfunction. The top recommendation for buoy's lost is "replace the identified chain on time by replacing the whole length of the chain" and for buoy's lamp malfunction is "replace the identified solar panels on time". The implementation of the top recommendations may reduce the risk of downtime of navigation buoy. These recommendations are also used as corrective actions in the ISO management review meeting. The application of FSA and Swiss Cheese model into the marine department ISO quality management system would improve the quality management system by application of risk-based decision making and root cause analysis at different management level.

For future research, other statistical and management tools can be used to the same set of data. The different analysis would yield more information for decision making.

Conclusions

Multiple observers have suggested major changes are necessary for OTI's to remain viable in future years (Johnson, 2016; Gueard and Martinez-Simon, 2012). Increased consolidation and further disintermediation of the industry to facilitate cloud based booking systems that can be done simply and easily may well occur in the near future. At this writing though, the role of ocean freight forwarders and NVOCCs is still an invaluable necessity for expediting the movement of goods from sellers to buyers. OTIs still handle a major portion of the cargo flow of international trade, hence the need for regulations and procedures to govern their activities. The need for OTIs to offer differentiated, unique, difficult to replicate services and avoid commodity type activities will be necessary to their continued growth.

What will change for OTIs is the removal of manual tracking of shipments, most phone calls and many customer interactions due to the advent of apps offering storied learning, chatbots, and decision algorithms. Block chain technology will make the documentation process far more transparent than it has been and cargo flows across the supply chain that is connected will flow more seamlessly than the sequential handoffs that are performed at present. Datasets can be easily created with the Internet of Things that will show when and where loads are that will most likely negate the need to work with individual carrier websites. New data sources with combined information, predictive data, devices and sensors will provide far more visibility to products than ever before. Tracking systems will be put in place to offer door to door pickup across the global spectrum.

One of the major challenges regarding the information revolution is security and privacy. To participate in the benefits of enhanced information exchange, firms need to modify their views and policies on information collaboration. Increased cooperative access to information may perhaps erode some minor competitive advantage of a firm; but the larger 'pie' created by increased simplification of maritime trade will far outweigh the minor losses due to revelation of some minute trade specifics. Especially in a time when prices and terms are highly competitive, we know that with sophisticated buyers, knowledge of price becomes less important, since they are all competitive; terms and service capability become the differentiators. Thus specifics of transactions and transits, revealed through access by query to large databases, will be more valuable shared than closely held.

The above technologies will transform the nature of the OTI but not replace them. Their role as the conduit of international trade from ship to rail to truck to warehouse will still require their presence and perhaps preeminence as the key channel member within the international logistics realm. The important coordination function they fill means that they cannot locate away from port areas. There will continue to be a need for OTIs to locate in clusters near ports of entry and exit, due to 'soft' factors regarding salesmanship and negotiation regarding localized services, even though the information may be available from anywhere to anywhere. Size and scale are important but an understanding of customers and coordination relationships, and a diversity of key services offered will be essential to OTIs? continued ability to survive and thrive in the 21st century. We therefore believe centers like Chicago and major sea and air port geographies will continue to be sources of innovation in the Ocean Freight Forwarding field, resulting in both new entrants and their subsequent consolidation into larger firms.

References

Deacon, T., Amyotte, P. R., Khan, F. I., & Mackinnon, S. (2013). A framework for human error analysis of offshore evacuations. SAFETY SCIENCE, 51(1), 319–327. https://doi.org/10-.1016/j.ssci.2012.07.005

IALA. (2009). IALA Guideline 1077 Maintenance of Aids to Navigation. Sa, France: IALA.

IALA. (2013). Quality Management Systems For Aids To Navigation Service Delivery.

IALA. (2014). Aids to Navigation Manual 2014. St Germain En Laye: IALA. Retrieved from http://www.iala-aism.org

IALA. (2016). IALA Dictionary.

IMO. MSC\1023-MEPC392 Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule-Making Process (2002).

ISO. (2015). ISO 9001:2015 How to use it. ISO. Geneva: ISO. https://doi.org/ISBN 978-92-67-10640-3

Kontovas, C. A. (2009). Formal Safety Assessment: a critical review. Marine Technology, 46 (1), 45-59.

McGraw-Hill. (2003). McGraw-Hill Dictionary of Scientific & Technical Terms.

Perneger, T. V. (2005). The Swiss cheese model of safety incidents: Are there holes in the metaphor? BMC Health Services Research, 5, 1–7. https://doi.org/10.1186/1472-6963-5-71

Powell, C. (2003). The Delphi technique?: myths and realities. Journal of Advance Nursing, 41(4), 376–382.

Reason, J. (2000). Human error: models and management. Bmj, 320, 768–770. https://doi.org/10.1136/bmj.320.7237.768

Skulmoski, G. J., Hartman, F. T., & Krah. (2007). The Delphi Method for Graduate Research. Journal of Information Technology Education. https://doi.org/10.1.1.151.8144

Svein Kristiansen. (2005). Maritime Transportation Safety Management and Risk. Oxford: Elsevier Butterworth-Heinemann.

Thangaratinam, S., & Redman, C. W. . (2005). The Delphi Technique. The Obstetrician & Gynaecologist, 7 (2), 120–125.

Verma, M., Kumar, A., & Singh, Y. (2012). Power System Reliability Evaluation Using Fault Tree Approach Based on Generalized Fuzzy Number. Journal of Fuzzy Set Valued Analysis, 2012, 1–13. https://doi.org/10.5899/2012/jfsva-00106