The ISPS Code as a component of onboard resources in Bayesian analysis

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Abstract

Nowadays, the influence of resources on safety and security at sea is one of the most critical elements of the existing management system. The already enormous regulatory workload on crew under ISM Code, STCW, SOLAS and MARPOL has now increased due to ISPS Code requirements. This again puts more stress on human and organisational factors in general, and deck officers' attention and performance in particular. The importance of human resources can be well reflected in a model, but is difficult to reveal through statistics. Since Bayesian networks naturally represent causal chains, that is, cause-effect relationships between parent and child nodes, we can supply evidence of past events, and then run the Bayesian network to see what the most likely future outcomes will be. Their strength is that they are robust if missing some part of the information, and will make the best possible prediction with whatever information is present. Therefore they were used for modelling crew resources. The modelling proves an overload on crew members, and shows the limited resources on board ship. To ensure efficiency of ISPS Code procedures, extra training is required which should be incorporated into the general curriculum of MET institutions. More attention to security issues should be paid on the part of Port Facilities. ISPS Code related inspections should consider the availability of manpower on board to ensure efficient performance.
Keywords: ISM Code, ISPS Code, crew resources, Bayesian networks.

1 Introduction

Nowadays, the influence of resources on safety and security at sea is one of the most critical elements of the existing management system. Ship officers are responsible for planning, communication, navigation, ship handling and many other routines, including procedures under the ISPS Code. To enhance safety and security at sea we must ensure that the right people are in the right place at the right time to counteract a possible intrusion. With the introduction of the ISPS Code, the "Principles of Safe Manning" were challenged to consider how additional shipboard security duties may contribute to crew member fatigue and thus might create a hazard to the continuous safe navigation of the world's merchant fleet.

The shipping industry already constrained by SOLAS, STCW, MARPOL, ISM Code and ISPS Code requirements, is also constantly exposed to extremely tight commercial pressure to minimize the operational costs. Additional security measures under the ISPS Code resulted in a so-called "ISPS Code charge" which varies from 5 to 9 € per cargo unit.

To cope with competitors, shipping companies have to resort to measures aimed at cost reduction. Very often this leads to lower wages for crew, resulting in lower competence and reduced numbers of crew, or longer contracts. The number of seafarers trained in developed countries is constantly decreasing. Unpopularity of seafaring as a profession may lead to a lack of professionally qualified staff. On the other hand a lack of clarity in expectations for each position may confuse the post holder and might lead to under-preparedness. This situation might be aggravated by faster promotions. It is often claimed that the new generation of seafarers is less experienced. Sometimes it takes only 2 years for a junior officer to become Chief Mate. Navigation and ship handling are no longer an art, it is an occupation associated with long periods of isolation from shore.

Multinational crews are common nowadays. Anecdotal evidence shows that cases where the Chief Officer was of Polish nationality, the 2nd and 3d Officers were of Russian nationality, ratings were of PR Chinese nationality are not at all exceptional. This loosens the ties between the Shipping Company and the crew member on board the company ships. Different languages, different cultures, as well as different wages and contract duration do not encourage cooperation, safety or security. In addition we would argue, that often crews are being recruited from developing countries which have no tradition of a "safety culture".

At the same time ship traffic is increasing every year, becoming more and more intensive. To ensure fast turn-around, the time a ship is staying in the port is decreasing mostly due to the introduction of modern cargo handling technology. In some countries crew members experience to have shore leave because of ISPS Code requirements.

All this leads to a violation of STCW 95 and ILO Convention No. 180 requirements, resulting in excessive fatigue, decreasing level of safety and security. The impact of manning levels on the implementation of ISPS Code as well as on the implementation of many other regulations is a legitimate matter of concern of the IMO, National Maritime Administrations and ship managers. Attempts to rectify these deficiencies lead to tightening of inspections, increased bureaucracy and resulted in a so-called "paper-safety" culture. This term denotes safety on paper but not in reality due to lack of resources. The ISM Code was initially introduced to solve some of these problems. Unfortunately it does not seem to be effective in many companies. Numerous and tedious inspections will again put more stress on already exhausted crews in general, and deck officers in particular.

It is obvious that the "Principles of Safe Manning" should require a security component and that this regulation – if it is to achieve its desired result – may be asking too much of many of the already overloaded shipboard personnel.

An already enormous regulatory workload of crew under ISM Code, STCW, SOLAS and MARPOL was increased due to ISPS Code requirements. Together with reduced numbers of crew, this situation might endanger safety and security at sea. It begs the question: Do we have enough resources to provide for additional security measures according to level 2 or 3?

The main challenge of this research is to develop a model showing the impact of the ISPS Code on workload and crew performance. Such an impact on crew workload should not be considered separately from all of the other duties of the ship's crew. A limited number of crew members, often only the barest necessity to meet the requirements for rest hours specified by the above mentioned conventions (STCW and ILO 180) demands a systematic approach to an analysis of the impact the ISPS Code has had on shipboard organization. Such an analysis is especially necessary in the case of ships employed in short -sea navigation and at Maritime Security Level 2 and 3. One of the mathematic tools, which could be used for solving this problem, is Bayesian Network (BN).

1.1 Bayesian network

As all work onboard is performed by the crew with no additional support available, it is inexpedient to address issues of ISPS Code compliance, ISM Code compliance or watch keeping at sea and in port separately. The resource model must take into account both individual duties and the whole task. Risk modelling is an essential part of the Formal Safety Assessment (FSA) methodology. There are two ways to quantify risk, through a priori statistics and through models.

The disadvantage of using traditional statistics is that statistics only represent the past, and cannot take into account recent developments or new requirements. Risk modelling is the proactive approach, whereby risks are assessed before the accident takes place.

This is at variance with maritime history, where regulations are often adopted only after catastrophic accidents have been analysed. The importance of human resources can be well reflected in a model, however, difficult to reveal through statistics. Since Bayesian nets naturally represent causal chains, that is, cause-effect relationships between parent and child nodes, we can supply evidence of past events, and then run the Bayesian network to see what the most likely future outcomes will be. Their strength is that they are robust if missing some part of information, and will make the best possible prediction with whatever information is present; therefore they were used for crew resources modelling. HUGIN is the Bayesian network tool used in the research reported in this paper.

2 Main part

2.1 ISPS Code history

In essence, the ISPS Code takes the approach that ensuring the security of ships and port facilities is basically a risk management activity and that to determine what security measures are appropriate, an assessment of the risks must be made in each particular case. Hazard identification (HAZID) is a method used to systematically go through a system or an operation with the aim to identify and discuss hazardous elements/conditions. One of the objectives of this paper was to identify all-important hazards regarding lack of available resources on board ships influencing both security and safety. This hazard identification forms the basis for a formal safety assessment (FSA), consisting of the following steps:

hazard identification, risk analysis, Risk Control Options (RCO), recommendations for decision-making.

The purpose of the ISPS Code is to provide a standardized, consistent framework for evaluating risk, enabling governments to offset changes in threat with changes in vulnerability for ships and port facilities. Because each ship (or class of ship) and each port facility present different risks, the method in which they meet the specific requirements of this Code should be determined and eventually approved by the Administration or Contracting Government, as the case may be. In order to communicate the threat at a port facility or for a ship, the Contracting Government sets the appropriate security level. Security levels 1, 2, and 3 correspond to normal, medium, and high threat situations, respectively. The security level creates a link between the ship and the port facility, since it triggers the implementation of appropriate security measures for the ship and for the port facility.

2.2 Model description

Figure 1 gives a brief overview of the risk model developed by Bayesian network for resources. Resources in this study were defined as available human manpower on board the vessel. Various experts and data sources were used to ensure a solid foundation for the dependencies and figures entered into the model. An extensive survey among seafarers was held to serve as a base for modelling. A questionnaire "Sufficiency of resources for performing conventional duties" with more than 86 questions was developed within the framework of this research. More than 150 people took part in this survey, all of them were Masters, Chief Officers or OOW.

An Object-Oriented Bayesian network (OOBN) is a network that, in addition to the usual nodes, contains instance nodes. An instance node is a node representing an instance of another network. In other words, an instance node represents a subnet. Of course, the network of which instances exist in other networks can itself contain instance nodes, whereby an object-oriented network can be viewed as a hierarchical description (or model) of a problem domain.

In this model we took into account only ship resources as the crew component is the most fragile and exposed in the security scheme. All other components of the model were fixed. It consists of the following instance nodes (subnets) (Figure 1) shown as rectangles as opposed to original nodes shown as ellipses.

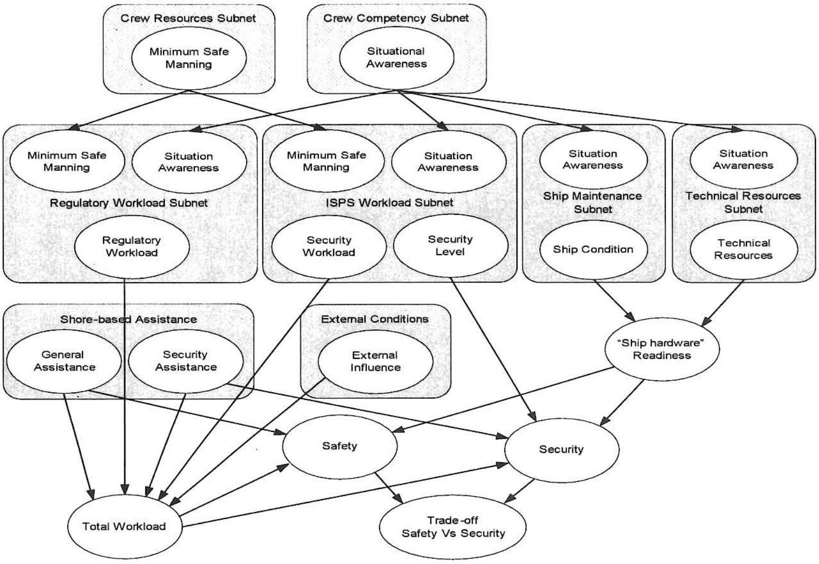

Figure 1: Bayesian crew resource model.

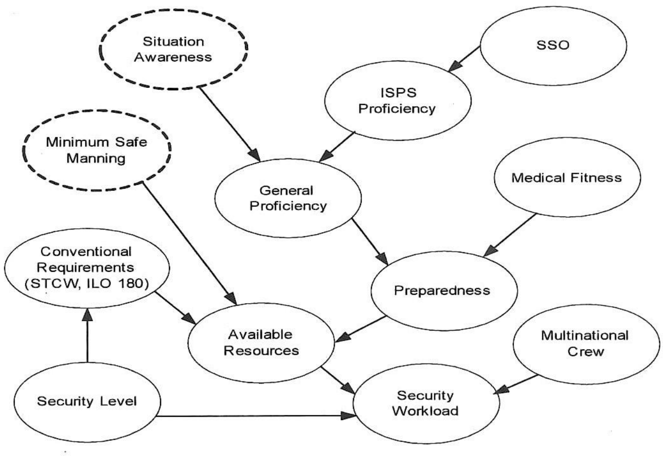

Figure 2: ISPS Code workload subnet.

The most valuable output from a model is not the overall risk level that is predicted by the model, but the structure itself and all the contributing factors that enable an understanding of the failure mechanisms. It thus gives a quantified result whenever one of the input parameters is altered. In other words, each node could be identified as a Risk Control Measure (RCM), and their influence on safety and security could be monitored.

The ISPS Code workload subnet consists of the following nodes:

• **SSO**

The node indicates the experience of the Ship Security Officer, his proficiency in security training and other security procedures. Every node is a vector with several states, e.g. $\text{vector} = \begin{pmatrix} \text{State 1} \\ \text{State 2} \end{pmatrix}$, here it is a vector with two states: - Experienced, - Non-experienced.

It could be written as $\text{SSO} = \begin{pmatrix} \text{Experienced} \\ \text{Non} - \text{experienced} \end{pmatrix}$

The probabilities in this node are based on statistics/expert data, derived from SSO training courses.

• **ISPS Code proficiency**

The node describes the crew proficiency in ISPS Code procedures. States: - Standard, - Low. The probability for this node is derived from expert data, based on results of security training programs held at Makarov Training Centre.

• **Situation awareness**

This node is an output node of Crew Competency subnet. This node shows results for professional crew competency based on the following factors:
sea experience, ship and trading area familiarization, professional competency, additional training, company's policy for non-compulsory training, tendency to hire cheaper (less qualified) crew, company's training budget.
States: - Aware, - Not aware. The probability input is derived from Crew Competency subnet.

• **General proficiency**

This node joins the nodes "ISPS Code proficiency" and "Situation awareness" and describes whether the crew member has a standard or a low (sub-standard) level of general skills. States: - Standard, - Low

• **Medical Fitness**

This node describes the physical and mental condition of the crew member, and indicates whether the crew member is fit to perform assigned duties and has 3 states:
- Fit, - Impaired, - Unfit

• **Preparedness**

This node is dependent on the nodes "General Proficiency" and "Medical Fitness". States: - Prepared, - Not Prepared. It is assumed that if the crew member is unfit, it is 100% not prepared for ISPS Code procedures; but if the crew member is impaired its preparedness is reduced by 20%. It is stated that crew member with standard level of skills are often less tolerant to minor health problems.

• **Minimum Safe Manning**

This node is an output node of Human Resources subnet.

• **Security Level**

This node describes crew workload depending on Maritime Security Level as compared to normal operation of the ship. States: - Level 1, - Level 2, - Level 3. It is supposed that within Level 1 additional workload because of ISPS Code procedures amounts to 5-10%, within level 2 -30% and within level 3 – up to 45-50% as compared to normal ship operation.

• **Conventional requirements (STCW, ILO-180)**

The node denotes standards described in STCW and ILO-180 conventions regarding rest and working hours. States: - Conventional, i.e. meeting the above mentioned requirements, - Insufficient, i.e. compromising the above mentioned requirements.

• **Available resources**

This node is made in order to gather the nodes for "Conventional requirements", "Minimum safe manning" and "Preparedness" into one. This approach is a software trick to reduce the amount of probability input. If the number of arrows onto the subsequent node is reduced, the size and the complexity of the conditional probability tables (CPTs) is also reduced. It describes whether we have available resources depending on the above nodes. States: - Available, - Not available.

• **Multinational crews**

The node shows dependence of crew cooperation in case of security threat or other emergency. States: - Multi-national crew, - Mono national crew.

• **Security workload**

This node is the output node for this subnet. It means that data from this subnet will be summarized in this node and sent to other Bayesian networks for further processing. It shows whether we have normal or high security workload. This node is dependent on maritime security level node, available resources node and crew nationality node. States: - Normal, - High. The probability input is derived from questionnaire and expert data.

The results obtained with the model are not contradictory to common sense. This proves that the model is adequate to the process researched. Basically, the model was developed for an analysis of tendency (conceptual model) and not with the aim of getting accurate figures. Therefore the model may have some limitations including those inherent in Bayesian networks:

1. An imperfect model due to an imperfect understanding of the domain, an incomplete knowledge of the state of the domain at the time where a given task is to be performed, a randomness in the mechanisms governing the behaviour of the domain, or a combination of these. We hope this imperfectness is minimized because the research team consists of professionals.
2. An incompleteness of the model due to some missing nodes (auxiliary nodes, which are not important in our opinion or nodes with insufficient data record tracking). For example, the node of education level was not taken into account simply because there was no data available on dependency of education grade.
3. The great redundancy of the model leads to low a sensitivity of the output results. This is a signal to introduce "weighting" of nodes.
4. A priori data were used for modelling. This data was based on experts' opinions derived from a questionnaire survey held among 150 deck officers of different qualifications. A frequency interpretation assessment was used

instead of probabilistic approach due to an insufficiency of data available. This approach is acceptable for practical analysis.

2.3 Model analysis

Figure 3A shows the trade-off between safety and security depending on maritime security level.

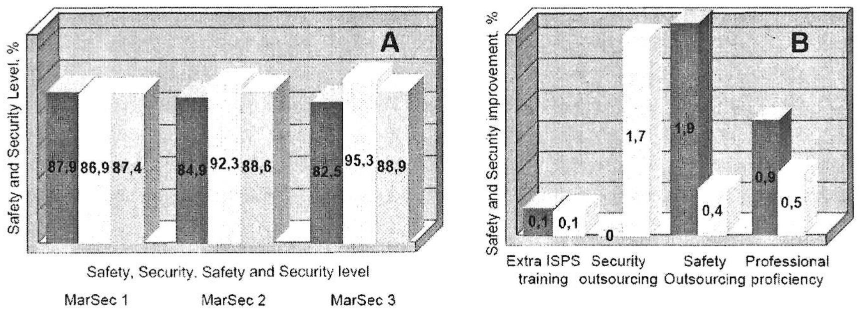

Figure 3: A. Trade-off: Safety vs. Security. B. RCO Rating.

The results show that when changing security level from 1 to 2 we still have some small gap because the total level of safety and security changes positively by 1% (from 87% to 88%). But that gap is not as great as required by level 2 where as we can see the safety level reduces to 86, and at level 3 where the summary level is practically the same as at level 2. This means that we have insufficient resources; to increase security we have to compromise safety which is absolutely unacceptable.

Figure 3B shows the safety and security level changes depending on selected RCO, so-called RCO rating based on modelling results. As can be seen from the graph, a delegation of some duties ashore yields positive results. Also, a distinct connection between safety and security is seen. With a decrease in total workload we obtain an improvement both in safety and security, as the crew member has more time to deal with shipboard routines.

Apart from technical RCO there could be RCM aimed at Human Element. The main element of this group, which is called Crew Resources RCO (CR RCO), is to enhance crew performance via additional training and additional personnel. Crew Resources RCO includes the following RCM (nodes):

Safety culture - The introduction of a safety culture on board ships should be a long term goal for any shipping company, as this not only enhances safety and security but also reduces the risk of overall negligence and poor maintenance at rather low cost. Moreover it gives a good motivation for crew members to take an active part in the SMS on board ship.

Simulator training - The training as required by the STCW Convention is the minimum, and it is further argued that improved navigator training would have a positive effect on the safety and security level of the vessel. An example of an improved navigator training is advanced ship manoeuvring, including training of crisis situations which can only be done safely in simulators.

The second RCO group deals with shore-based activities. The main idea of this group is to facilitate ship board routines either remotely via special services such as chart updating service ashore or directly, by the port facility to take the main part of the security workload during the ship's stay in port.

Figure 4 shows changes in security level depending on the implementation the level of selected RCM connected with shore-based activities.

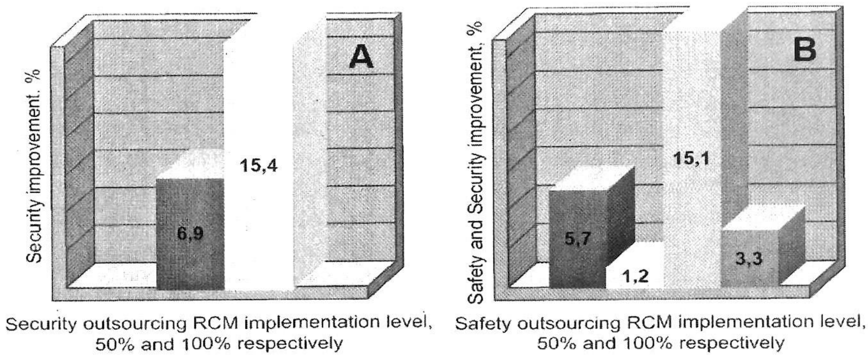

Figure 4: Security and safety outsourcing RCM.

It can be seen that outsourcing of security duties to port facilities (Figure 4A) greatly enhances security on board as port facilities are less limited in their resources. It could be that outsourcing of some ship routines to shore management (Figure 4B) enhances both safety and security as it makes more time available for performing other duties.

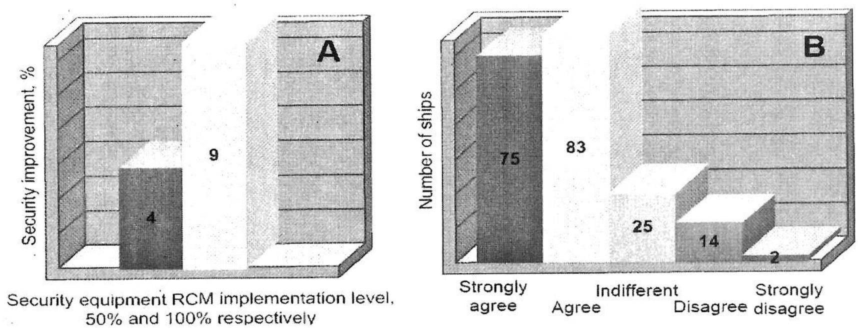

Figure 5: A. Security equipment B. ISPS Code does overload.

The third RCO group deals with technical measures aimed at reducing workload through an automation of shipboard operations, for example the installation of certified security equipment such as gangway alarm or intruder alarm. Figure 5A shows changes in security level depending on the implementation of such security equipment.

3 Conclusions

Nowadays it is hardly possible, that we could find one or two new effective measures which allow us to considerably raise the level of safety and security, therefore only a complex system of such measures could produce tangible results. The ship's crew is limited in number as well as in resources. To cope with their numerous duties, officers should be more competent to be able to do more things within allocated time. For example, to keep ship's charts folios updated an experienced Navigation Officer needs less time than his less experienced colleague. With an unchanged crew size any increase in workload implies the need for a higher competency of crew members to be able to complete their duties in time. The better the education of an individual, the better is the situation awareness. In other words here we have direct link between ISPS Code and MET.

Crew competency is the measure of ship safety and security. The number of crew depends on its qualification within reasonable limits. It is common to duplicate equipment to increase its redundancy but the same principle should be employed for crew resources too. To enable a level playing field for shipping companies, the number of less competent crew should be increased on board as compared to well-educated and trained crew.

When comparing our results with other reports we could note consistency in results shown on Figure 5B taken from "Questionnaire findings on experience on ISPS Code implementation from crew/vessel point of view" by Tim Charalambous.

Another finding of this research is the necessity to build a single unified ISM-ISPS Code System, Security and Safety Management System (SSMS), as all of security and safety aspects of ship's operation should be checked and monitored simultaneously, not separately as it is currently done. Presently too much stress is put on the ship's crew, to address security issues. Having much more resources available, undoubtedly, port facilities should be more involved.

Outsourcing of security duties to port facilities is one of the ways out to reduce crew workload without compromising safety and security.

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