SESSION 7: Transportation security, emergency management and Technologies

议程七：交通安全、应急管理及技术

危险情况下海上交通系统的行程安排

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【摘要】在海底运河航行的船只的安全问题越来越受到关注，因为它可能造成船只的碰撞，巨大的人员伤亡以及环境污染。为了避免危险情况的发生，船只交通就必须由一个监督员来控制。这个监督员控制船只的航行，并且禁止船只在即将发生危险的情况下的通行。这个监督员可以是一个处理交通规则的人，也可以是一台基于交通指示灯系统的电脑。

在海运公司的现实管理中，管理阶层经常使用各种各样的手段来处理风险性交通事务。在这篇文章中，我们提供 GA 和最优化技术来处理船只运行的安全问题。GA 为通过海底运河的船只寻找最优化的行程，从而避免要通过同一个海底运河的船只之间的冲突。必须满足以下条件：船只不能相互碰撞、互通工作安排、可行性、避免僵局和检查资源的能力，由于船只的数量以及系统复杂性的增加，更加凸显了交通控制系统的重要性。优先一致性保证了在同一时间穿过通过同一个海底运河的无僵局的行程安排。这种方法通过了海上交通系统研究案例的测试。在解决问题时定义了 GA 的染色体解码和基因操作。我们发现 GA 女能给我们提供优秀的解决方案。

【关键词】海上交通管制，项目调度，安全，资源冲突，遗传算法

PROJECT SCHEDULING IN MARITIME TRAFFIC SYSTEM UNDER RISK

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Keywords

maritime traffic control, project scheduling, safety, resource conflict, genetic algorithm

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Abstract

The safety of vessels moving through the marine canal has been increasingly concerned because it may cause ship collisions, great losses in human life and environment pollution. To avoid dangerous situation, the vessels' traffic has to be controlled by a supervisor. The supervisor monitors vessels moving and forbids only the moving in the case of immediate dangerous situation in dense traffic. The supervisor can be a man who is responsible for traffic regulation or a computer based traffic lights system. In both cases, the supervisor must apply an appropriate control method.

In real management of shipping companies, the managers often use various methods for risk traffic management. In this paper we propose genetic algorithm (GA), as well as a post-optimization technique, for vessel traffic control addressing safety issues. GA is applied to seek optimal schedule of vessels which have to pass through the canal system controlling conflict between two vessels for the same canal. The following requirements have to be satisfied:

- Vessels must not crash with each other
- Interfacing with job-allocation
- Flexibility
- Deadlock avoidance and checking resource capacity.

As the number of vessels, and thereby the complexity of the system, increases the need for traffic control system also grows. It is shown that the priority consistency guarantees deadlock-free schedules for vessels to cross the same area at the same time. The method is tested by using Matlab on the case study example of marine traffic system. Chromosome coding and genetic operators of GA are defined during the problem solving. We found that GA produces good solutions.

1. Introduction

Safety and security are constant concerns of maritime navigation, especially when considering the constant growth of maritime traffic around the world, and constant decrease of crews on decks.

In this paper potential risks in vessels moving through marine canals are analyzed. Many of those channels are narrow, forcing vessels into close and sometimes dangerous proximity. The risks may be posed by narrow and shallow waterway geometry, blind bends, sharp turns, tide and river stage fluctuations, powerful and sometimes unpredictable currents and the forces of hydrodynamic interaction. Additional risks may be posed by cross-channel and converging traffic patterns, bridges that are unsafely designed or negligently operated and frequent dredging, fishing and barge fleeting operations in some areas [Allen, 2009]. The possible values of the risks are in the span from small and big vessel damages up to the loss of the vessel or human life. It is known that financing of shipping company investments is very risky job and that ships cost millions of dollars. Those big investments need investment decisions made by experts. The same approach should be accepted by ship-owners and they can control the risks by different methods, in order to prevent future risks or to minimize possible costs.

In order to properly proceed during crisis situations in narrow canals, we need to properly approach the risks of representing the unpredictable danger that develops during some of maritime activities, with the possibility of occurrence of events with bad consequences.

So, it is very important to manage the risks in those waters through measures that include both services and regulatory requirements.

Because the canal traffic system and its risks are directly connected with project aims, it should be able to find a balance between navigational safety and economy at the same time. This means that the conflict and deadlock avoidance decision mechanism adopted can not only keep relevant danger assessments navigation, but can also consider allocation limited resources to the tasks and determines the sequence of vessel's moving through canal so that performance criteria are optimized. Genetic algorithm is adopted to find a safety-critical recommendation for canal conflict avoidance from an economic viewpoint, through simulating the biological evolution model. Previous research results prove their usefulness as a tool to solve global optimization problems [Gudelj, 2008], [Gudelj, 2009].

2. Risk management for narrow canals

Although this article is focused on manage the risks in canals, that risk must be viewed in the larger context of risk management for the Marine Transportation System. With the continued development of the shipping industry, ships have grown larger, become more specialized and capable of operating at faster speeds. The marine traffic environment has become more complicated and the density of shipping traffic has become greater. The navigation problems are more challenging in canals because many of canals are narrow. So collisions, allisions or stranding accidents are increasing in frequency, even though auxiliary ship collision avoidance equipment is widely used at present.

These accidents may cause human, environmental and financial loss. Collisions in canals threaten not only the vessels, crews, passengers and cargoes involved; they might also pollute or obstruct the canal, perhaps closing a vital waterway to other marine traffic. At the same time, provident maritime risk managers would caution against overlooking the non-collision risks posed by vessel navigation in restricted waters in our examination of collision prevention rules. Allisions—essentially, collisions by vessels with fixed objects—and groundings also pose grave risks. In an investigation into reasons for collision accidents it was found that over 80% are caused by human factors [Allen, 2009]. There are two ways to solve the problem of these human factors: Firstly, to strengthen the technical training and management of crews, to improve the quality of judging the level of potential danger.

Cost, complexity, impracticality and potential risk preclude carrying out field experimentation and evaluation of large-scale traffic management strategies. Computer simulations provide an efficient, ‘safe’ and versatile tool for such analyses, allowing a large number of strategies to be tested, under a variety of conditions. However, the degree of realism in representing actual network and traffic conditions is critical in simulation based evaluation.

Risk assessment is a systematic approach to risk identification, analysis and management. Risk identification begins with an identification of the hazards posed by a particular activity. Risk management analysts then select and implement appropriate risk elimination and reduction measures. Marine risk management incorporates both internal measures undertaken by the party engaged in the activity creating the risk and external measures by others. Internal risk management measures can be voluntary or required by law. The nautical rules of the road fall into the category of required internal risk management measures, the violation of which can lead to penalties and civil liability.

A canal system is artificially made vessel passage which is used to connect two rivers, lakes, seas or oceans. Such system, for example, enables the connection of two water surfaces that have different levels of water. The vessels, passing through the canal system in opposite directions use various resources (canals, locks, basins). Some of these resources are non-shared (resource that can be occupied by the vessels moving in only one direction), and others are shared resources (resources that can be occupied by the vessels moving in the different directions). The number of vessels in the resources is limited as a rule. Some of these states can be undesirable (in some cases even dangerous). To avoid these forbidden states such as conflicts the vessels' traffic is controlled by supervisor.

Recognizing conflict waterways are indispensible component of the Marine Transportation System. Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia seeks to manage the risks in maritime operations in those waters through measures that include both services and regulatory requirements. This has led to the installation of visual aids to navigation, like buoys and lighthouses; the development of automated monitoring systems such as the Automatic Identification System, Long Range Identification Tracking and the Electronic Chart Display and Information System (ECDIS) as a support of electronic mapping services. However, officers on the watch and monitoring authorities still require the development of advanced decision-aid solutions and analyses integrated within intelligent Vessel Traffic Control Systems (VTCS).

Such solutions aim at solving of one main issue of maritime activities, that is, providing vessel traffic control effectiveness and safety to address the following needs in terms of maritime safety, navigation effectiveness, environmental and ecological protection, coastal and shelf infrastructure :

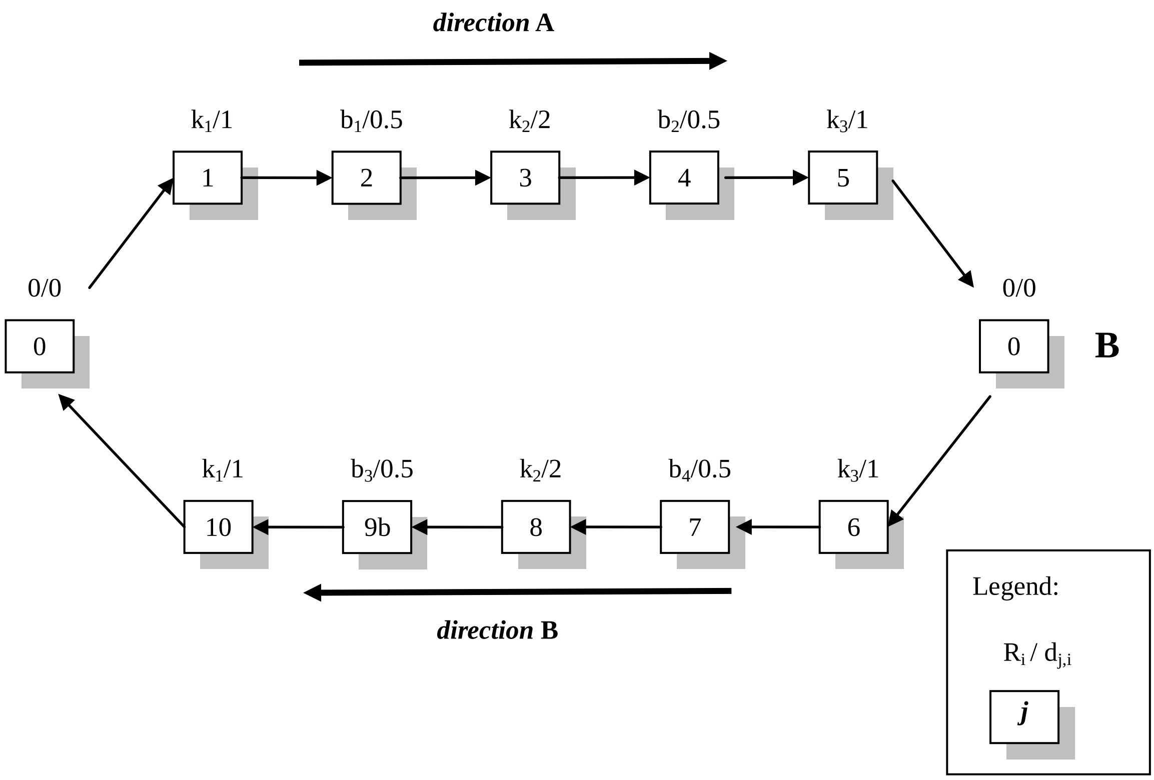
- Vessel traffic can be very high in specific areas thus increasing the risk of accident;
- Pirates activities;
- Terrorist’s threats;
- Risk of accidents in ports and coastal areas.

3. An example

This problem can be looked as the resource constrained project scheduling problem. The vessels, passing through the canal system in opposite directions use various resources (canals, locks, basins). Some of these resources are non-shared (basins that can be occupied by the vessels moving in only one direction), and others are shared resources (canals that can be occupied by the vessels moving in the different directions). The number of vessels in the resources (resource capacity) is limited as a rule.

Figure 1 gives project example of moving 10 vessels in direction A, and 10 vessels in direction B at the same time. Let $K = \{k_1, k_2, k_3\}$ denotes set of canals and $B = \{b_1, b_2, b_3, b_4\}$ denotes set of four basins. Both canals and basins represent set of seven resource types $R = \{R_i \mid R_{i=1...3} \in K, R_{i=4,...,7} \in B\}$. The vessels in both directions share canals. Basins are designed only for one direction and for waiting for the availability of next canal. Canals’ capacity is 1 vessel, basins’ capacity is 2 vessels.

Figure 1: Project traffic example



The vessels which wait on the left end of the traffic system have to pass to the right in the direction of A, and vessels on the right side have to pass to the left in the direction of B. A vessel can move through the canals using own propulsion, or by hauling vehicles which are situated at the sides of the canal. A vessel in direction A must perform following activities: passing through the canal k_1, waiting in the basin b_1; passing through the canal k_2; waiting in the basin b_2 and passing through the canal k_3. A vessel in direction B must pass next resources k_3, b_4, k_2, b_4 and k_1 in that order [Kezic, 2009].

The activities are interrelated by two kinds of constraints:

(1) The precedence constraints, which force activity *j* to be scheduled after all predecessor activities are completed.

(2) Performing the activities require resources with limited capacities.

While being processed, activity ***j*** requires resource type $R_i \in R$ during every time instant of its duration $d_{j,i}$. If a particular resource is occupied, and there are vessels waiting to use them, then these vessels wait for the availability of the occupied resource at the exit of the resource where they are at a particular time. When the resource becomes available, it is occupied by awaiting vessels.

The consequence of sharing and limited number of resources is the existence of resource conflict, because of the deficient of resources. Actually, in our traffic system canal are shared resources and when more than one vessel request to pass through the same canal at the same time, the resource conflict is inevitable.

In this paper, we assumed that all the resources can be prepared well before the start of each activity, so the preparation for resources will not delay the start of each activity. However, if one canal is shared by two actions j_1 and j_2, and j_1 is being implemented and the resource is occupied by j_1, j_2 must wait until j_1 is finished and the canal have been released.

Resource conflict will influence the efficiency of traffic canal system. The rule FIRST IN FIRST OUT it is not the best solutions every time. So, in this work as the main method to prevent conflict in canal traffic system is priority strategy. The vessel with higher priority has higher priority of resource allocation. If two vessels have the same priority, the conflict may be solved by some other strategy, such waiting time strategy. This strategy may be used in the computer system which controls traffic lights at the entrance into resource in directions A and B.

4. Methodology

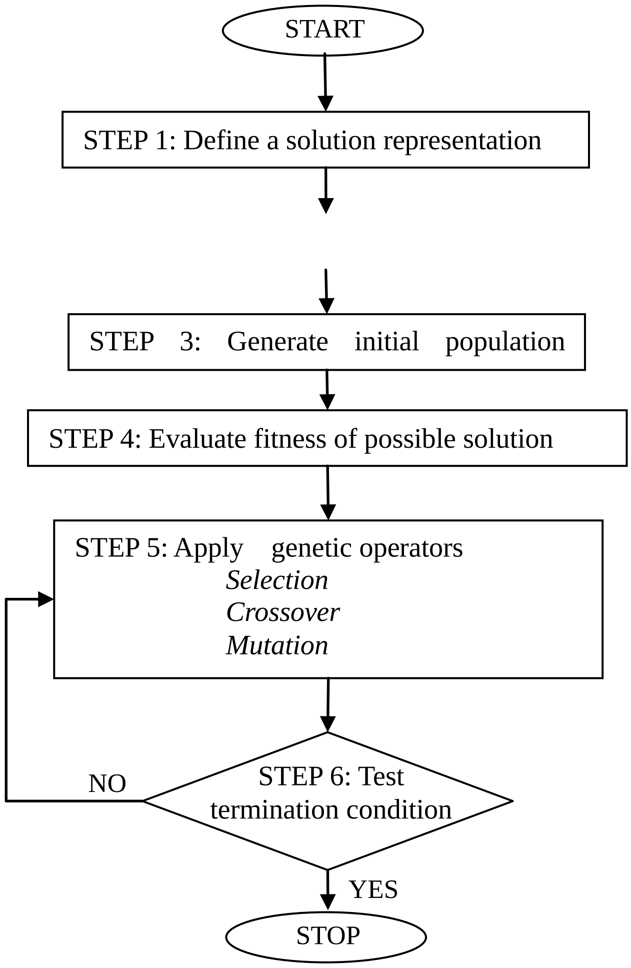
Successful project realization is linked to detailed and flexible project planning. Thereby, a multitude of restrictions and requirements has to be considered to find practicable and efficient execution solutions. All requirements including the assignment of resources and their capacities have to be considerate.

In this work we use Genetic Algorithm as search tool for optimal schedule without conflicts. The simplified procedure of GA consists of following steps; (1) Define a solution representation, (2) Define set variables, fitness functions, and constraints, (3) Generate initial population, (4) Evaluate fitness of possible solution, (5) Apply genetic operators, and (6) Test termination conditions. Figure 2 shows the simplified GA procedure.

It is assumed that a potential solution to a problem may be represented as a set of parameters. These parameters, known as genes, are joined together to form a string of values (chromosome). Each chromosome is referred to as an individual. Figure 3 shows chromosome representation for a solution for our example. It is encoded as a vector of random keys.

Using random distribution, each chromosome is made of *n*=10 genes, where *n* is the number of activities. Genes are used to determine a priority assigned to each activity. First five genes are referred to activities which are performed while vessels pass in direction A. The rest five genes are referred to passing in direction B.

Figure 2: Simplified Flowchart of genetic algorithm



igure 3: GA representation of solution

$$chromosome = \left(\underbrace{gene_1, gene_2, \ldots, gene_{10}}_{priories} \right)$$

In our GA procedure, for priority decoding expression priority, we use the term LLP_j / LCP [GONÇALVES, 2005], where LLP_j is the longest length path from the beginning of activity *j* to the end of the project and *LCP* is length along the path of the whole project. It is clear that $0 < LLP_j / LCP \leq 1$. The priorities of activities are assigned to each feasible activity based on its impact on the remaining actions of the project. Thus is enabled that the two actions no have the same priority.

A fitness function assigns a figure of merit to each encoded solution and it depends on its chromosome. Primary requirements can be rated by considering solution effectiveness in reducing the risk of resource conflicts with regard their conformity with international and national rules and regulations and cost-effectiveness.

Actually, the objective is to find an optimal sequence of incoming vessels through the canal systems, which will reduce the waiting times due to blocking resources. This will result in overall minimization of project duration and fitness value for our problem is total project finish time.

During the execution of the algorithm, parents must be selected for reproduction, and recombined to generate offspring. Given a current population, we perform the following three steps to obtain the next generation: selection, crossover and mutation.

The selection and crossover operators determine which parents will have offspring, and how genetic material is exchanged between the parents to create those offspring. Mutation it allows for alteration of genetic material.

5. Computational experiments

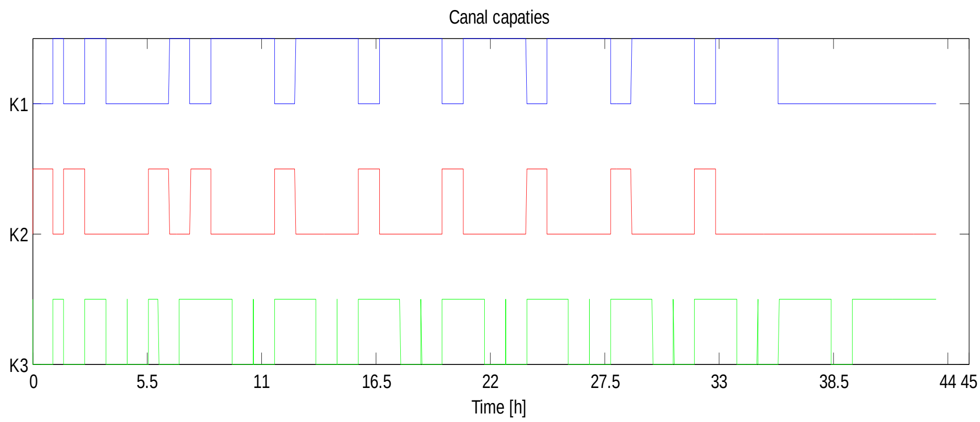
All experiments were run on PC with Pentium 4-M 2.20 Mhz under Windows. The designed scheduling procedure with Genetic Algorithm software is developed in the Matlab software package.

For reproduction new solutions, an elitist selection is used and next GA parameters:

Population size = 10 samples
Crossover probability = 0.700
Mutation probability = 0.005
Termination criteria = 20 generations (or) a satisfactory predefined minimum value for the objective function, whichever occurs first.

After 20 generations the algorithm finished and the results showed that the last vessel left the canal system after 43.44 hours. From figure 4 it is possible to see there is no conflict in canal sharing. In every time point through each canal passes ether one vessel or none. Thus the constraint for limited resource capacity is satisfied.

Figure 4: Results with no resource conflict



6. Conclusion

The article shows how GA can be used as tool which controls the traffic lights system in the marine canal system. Thus it is possible control resource conflicts and finds the best solution considering some criterions (waiting time, finish time…). To avoid conflict, priority strategy is used and parameterized genes which ensure there are no two resources with the same priority. The method is tested by using Matlab on the case study example of marine traffic system.

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Author biography

Anita Gudelj was born in Split, Croatia (1970). She received her B.S. degree in mathematics and computer science (1993) from University of Split, Faculty of Mathematics. Since 2006 she is a senior lecture at the Maritime Faculty University of Split. Also, she received the M.Sc degree in information science from Faculty of Organization and Informatics, Varaždin, Croatia (2000). Her postgraduate research was "Design and Implementation of Temporal Database". Her research interests include database design, genetic algorithms and Petri nets. Her main activity is focused on performance modeling of automated transportation systems, vehicle dynamics and control, and optimization. She is the author and co-author of several research papers in these areas. She is also a member of several national and international societies (e.g. IEEE, INTERNATIONALSTARS…).

Maja Krčum was born in Split, Croatia (1958). She was graduated from the Faculty of Electrical, Mechanical Engineering and Naval Architecture, University of Split on March 1981. She received a graduate degree (M.Sc.) at the Faculty of Electrical Engineering, University of Zagreb in 1996. Her master's thesis was entitled “Simulation on Model of Shipboard Electrical System”. In 1997, she was appointed Head of Department, also working as a tutor and counsellor. Now, she is quality manager at the Faculty. She was participated in a number of both national and international conferences where her papers and lectures were generally acknowledged as an active and valuable contribution towards the development of her profession. Her primary interest lies in the field of shipboard propulsion systems, with a special emphasis on electrical propulsion and its numerous applications (simulation methods). She is also a member of several national and international societies (e.g. IEEE, TIEMS, KOREMA…)

Predrag Krčum was born in Mostar, Bosna and Hercegovina (1953). He was graduated from the Faculty of Electrical, Mechanical Engineering and Naval Architecture, University of Split (1982). He worked as expert assistant in PTT – Split, as director of manufactory “Obuća” –Split, and since 2005 he is a lecture at the University Centre for Polytechnic Study – Split. His primary research interest lies in the field of automatic control of hidraulicsand pneumatics propulsion and also in some system for education students.

民用航空系统的安全挑战
警惕和正念作为安全屏障

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【摘要】在 911 之后欧洲安全法规的改变一直是争议的问题，批评与赞美都有。本文的主要论点是，目前的航空安全制度在执行层面上有着不可预见的后果。实际用的是聘用规则。造成这些后果的原因是没有注重实践和缺乏用户的理解。结果是降低了警惕和警觉性，因为该条例的实施是有经验的。构建民用航空安全的内容是保护乘客、航空公司和航空业的安全，避免受非法行为侵害，如恐怖行动，以损害航空系统为目的行动等。

在机场内和周围的人身安全制度已由欧盟强制制定。较"隐形"防护墙之一是警觉与安全工作的人的警觉性。

警惕使人们能够处理他们的工作情况，而不同于仅仅法规，法令或指令可以做的。因而这对整体安全也是非常重要的。本文的实证论据是通过对 3 个挪威机场的安全公司，机场管理部门的员工和操作公司等的访谈和调查得出的。通过连接到 Weick 的高可靠性组织经验数据，本文旨在说明安全规则如何在事实上抑制警惕而不是促进它。

【关键词】安全；航空；警惕；高效组织

SECURITY CHALLENG ES IN THE CIVIL AVIATION SYSTEM

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Keywords

Security, Civil Aviation, Mindfulness, High Reliability Organisations

Abstract

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The main argument in this paper is that the current aviation security regime seems to have unforeseen consequences at the implementation level where people have to apply the regulations. These consequences are caused by a vastly detailed regulatory framework that is not primarily concerned with local involvement and user understandings. This results in practices where mindfulness is reduced. This is because the regulations are experienced as detached from meaning and that there is little room for involvement for the employees who have to comply with it.

Security in civil aviation is constructed to secure passengers, airlines and the aviation industry from unlawful acts, as terrorism, aimed at harming the aviation system. The physical security walls that have been created within and around the airports are dictated by the European Union's (EU) security regulations mandatory for all countries in the EU as well as the European Free Trade Association countries (EFTA). One of the more 'invisible' protective walls is the vigilance or alertness of people working with security at the airports. This vigilance and alertness together with several other concerns are parts of what constitutes an organisation's collective mindfulness. According to Weick, Sutcliffe, and Obstfeld, the organisation's ability to act mindfully will influence both its reliability and resilience in complex, high-risk operations.

This paper's empirical argument is based on interviews and participant observation from four Norwegian airports including security providing companies, airport administration employees, and handling companies. By connecting empirical data to the concept of mindfulness in High Reliability Organisations, the paper aims at discussing how the current security regulations may in fact inhibit mindfulness and not promote it.

Introduction

This paper looks at the connection between airport security as a High Reliability Organisation (HRO) and the concept of mindfulness (E. J. Langer, 1989, p. 82; E. J. Langer & Moldoveanu, 2000; Weick, Sutcliffe, & Obstfeld, 1999). Given that the ability to operate mindfully is a condition of being a HRO, this paper argues that airport security does not fulfil the demands to be an effectively running HRO. Although there is a will in the civil aviation system to achieve mindfulness, there are structural hindrances, as the design of the regulatory regime that inhibits the organisation's ability to act accordingly. In this paper this claim is seen through a trade-off perspective where lack of resonance and meaning and the difficulty of involvement and individual actions are obstacles in becoming a mindful organisation.

The attacks on the World Trade Centre and other targets 9/11, 2001 demonstrated the vulnerability of the civil aviation to intentional attacks. Decisions had to be made rapidly to strengthen security systems as the need of more trustworthy and robust airport security became painfully evident. In Europe, the EU developed into the authority that managed this on behalf of the European continent. These processes of regulatory development have later been described in terms of secrecy, rapidity, and reactivity; secrecy to avoid terrorists from knowing the system, rapidity and reactivity to avoid attackers repeating the same actions again.

Aviation is easily connected to the High Reliability thinking as the consequences of errors in this sector can cumulate into large-scale accidents. One of the main benefits of studying High Reliability Organisations is that it provides a "unique window into organizational effectiveness under trying conditions"(Weick, et al., 1999, p. 81). This may give insights and knowledge about why some organisations are more resilient or robust to accidents than others. The typical organisations that have been examined in the High Reliability literature are air traffic control and nuclear power plants where accidents are seen as 'unwanted incidents' caused by technical or human errors. In the civil aviation setting it becomes more complicated as the threats to aviation are a mix between 'unwanted' and 'wanted' incidents; unwanted by most, but wanted by a few who intentionally seek to harm aviation through attacks. Therefore, in the civil aviation context the term security is used distinct from safety, where security is defined as the avoidance of intended happenings as terrorism, and safety is defined as the avoidance of unintended happenings as plane crashes. The 'unwanted' incidents are regulated through the safety system while the 'wanted' or 'intentional' incidents are regulated through the security system.

It is, nevertheless, the institutional characteristics of the civil aviation security system that delineates it under the category of High Reliability Organisations (Fredrickson & LaPorte, 2002). HROs are a compound group of organisations but have in common that they deal with complex tasks where there are little possibilities for learning through errors as the consequences may be too severe. In security, an error may cause incidents like the 9/11-attacks where there later was found that it had been several simultaneous errors that made the attacks possible. Airport security in an organisational perspective is also more difficult to delineate as it involves many organisations simultaneously where security is only one of more tasks that the different organisations perform. The security system is therefore defined here as the system of various organisations that operate at different levels in order to uphold and maintain a pre-decided standard of security.

The Norwegian Civil Aviation System

In Europe, all EU-members are obliged to implement the regulations appointed by the EU, including regulations of aviation security. Norway as a non-member is obliged through the European Economic Agreement (EEA) for European Free Trade Organisation countries (EFTA) to follow the regulations that are found to be relevant. In practice, this implies that Norway has the same regulatory demands as any other EU country. The EU regulations are developed at EU-level where all changes are put to vote before they are implemented. This means that after voting, the new regulation is non-negotiable at national and local levels.

When a regulation arrives in Norway, it is first received by the Department of Transportation who immediately sends it to the Civil Aviation Authority (CAA) which is the department’s executive agency. The CAA then translates the text and distributes them to the affected agents. This would mainly mean Avinor, which is the governmental-owned limited company who runs most of the Norwegian airports (46). Avinor then distributes it to affected parties at the airport; which normally is the security companies and handling companies. All new legislation is delivered with a time-frame. Both the CAA and Avinor are subject to inspections where it is the duty of the CAA to control that the airports are implementing and maintaining security satisfactorily while it is the inspection organ of the EFTA, the EFTA Surveillance Authority (ESA) who has the duty to control that the CAA is doing their job adequately. If the conditions are found to be unsatisfactory, the airport will be obliged to improve. If the condition is too unsatisfactory, the airport will receive the label of being ‘unclean’. In practice this implies that every airport that are not approved according to the EU regulation together with the countries that are outside of the union are labelled ‘unclean airports’ or ‘third countries’ and all passengers arriving from these origins will have to go through a new security clearance at arrival. This is very serious both for the affected airports but also for all airports receiving passengers from the unclean ones because it involves very much extra work to get rid of the label together with logistical challenges which again are very costly. This is consequently something that the airports work very hard to avoid.

There are more than 50 airports in Norway. Avinor runs 46 of these while the rest are privately operated commercial airports. Avinor categorises the airports into ‘large’, ‘medium’, and ‘small’. The largest airport in Norway employs 12.000 people and had in 2009 a throughput of 17 million passengers. The smallest airport employs 14 people and had in 2009 a throughput of 4700 passengers (www.avinor.no). 29 of the airports fall under the category of small airports and the aviation in Norway demonstrates a fine balance between regional politics and commercial concerns. A consequence of this diversity is also challenges in the implementation of the regulatory framework. In principle, the small airports should uphold the same level of security as any other large airport in Norway or in the EU. This is part of the one-stop-security profile of European civil aviation where passengers who travel within the EU should undergo only one single security check. This means that all airports no matter how small must have equipment and personnel to perform security checks on all passengers and employees at the airport.

Theory

Risk Trade-offs

The problem of risk reducing measures is that it always entails some kind of trade-offs. By combating one type of risk or ‘target risk’ (Graham & Wiener, 1995) ‘countervailing risks’ can increase. Graham and Wiener use the example of the treatment of headaches to exemplify this. “In order to reduce a target risk (headache), you decide on an intervention (aspirin), but thereby induce a set of countervailing risks (stomach pain, ulcers, Reye's syndrome)" (1995, pp. 2-3). In time it is possible to arrive at better options and then encounter a 'risk-superior' alternative that in the headache example could be another pain reliever which does not induce the same risks. This, of course, will rely on the fact that the countervailing risks are registered and taken into account.

In the case of security for civil aviation, the same principle applies. Even though it is impossible to outline exactly the process of tradeoffs that has been done in the development of security regulations, it is no secret that the current system is constructed around a detailed, centralised, and secretive model. Some of the greatest advantages of a centralised system are the possibility of coordination (of implementation processes), control (one standard one control), the lack of variance between airports and countries (as far as possible), and secrecy (that does not demand the openness that other industries and organisations have). These traits make it far more conceivable to actually control security in a large and complex area at the same time, as is the case of Europe. However, a natural question would be to ask what has been traded off in return for this system. Is the system for example compatible with being an HRO or further, is it compatible with being a mindful HRO.

<u>High Reliability Organisations and Mindfulness</u>

The High Reliability literature has gone through many turns after LaPorte's initial contribution of the High Reliability Theory in 1982. It has especially been discussed up against Perrow's Normal Accident Theory, which was also published in the very same book (Sills, Wolf, & Shelanski, 1982). The main point behind this literature was to investigate organisations that aspired to be failure free and reliable and initially finding out what separated the good HRO's from the bad ones. Several case studies were conducted in error intolerant systems as air traffic control, aircraft carrier operations, and nuclear power plants (Fredrickson & LaPorte, 2002). However, as the similarities between HRO's had been distinguished, the differences began to appear (Rijpma, 2003). It was evident that many processes within organisations were not similar and could not be and subsequently it also appeared more studies that compared HROs with non-HROs, or "normal organisations". Some also criticised this dichotomy between HRO and non-HROs and called for a more integrated approach to the study of organisations (Scott, 1994) In a response to this call, Weick, Sutcliffe, and Obstfeld (1999) argue that the value of the HRO approach is that they provide a "window on a distinctive set of processes that foster effectiveness under trying conditions" (Weick, et al., 1999, p. 82). This means that as opposed to other organisations, in HROs there are little or no room for trying and failing in the search of error-free procedures. Nuclear power plants and air traffic control systems are examples of such organisations where the consequences of errors can be catastrophic and would imply, to varying extents, long term costs both human and economically.

The main task for a HRO is to successfully detect errors before they occur. Weick and Sutcliffe asserts that the focus on the cognitive processes as important factors in high reliability functioning has been inadequate (Weick, et al., 1999). They employ the concept of mindfulness to describe the "enriched awareness induced by the distinctive concerns of HROs with potentials for catastrophe that facilitates the construction, discovery, and correction of unexpected events capable of escalation" (1999, p. 88). The ability to act 'mindfully' will facilitate the detection and correction of things that can cumulate into having a catastrophic outcome.

Mindfulness, according to Weick and Sutcliffe (1999) consists of some separate concerns that are tied together by "their joint capability to induce a rich awareness of discriminatory detail and a capacity for action" (1999, p. 88). These concerns are a) Preoccupation with failure, b) Reluctance to simplify, c) Sensitivity to operations, d) Commitment to resilience, e) Underspecification of Structures (ibid).

Weick and Sutcliffe build their understanding of the concept of mindfulness on, among others, the work of Langer (E. J. Langer, 1997) who describes mindfulness as a process of drawing 'novel distinctions'. By doing this we keep ourselves situated in the present. Her main point is that by relying on already drawn distinctions and categories, we become more unaware of the context around us and also our own actions (E. J. Langer & Moldoveanu, 2000). This can then lead to what she labels 'mindless behaviour' where rules and routines are more likely to govern our actions regardless of the circumstances. As Langer explains "Mindlessness can show up as the direct cause of human error in complex situations, of prejudice and stereotyping, and of the sensation of alternating between anxiety and boredom that characterises many lives" (2000, p. 6). Tasks that are mechanically carried out by people working as for example telephone operators, checkout clerks, and airline personnel may often lead to personnel sleepwalking through the work day. The effect of increased mindfulness has been demonstrated through studies done among workers and managers in the business world (Langer et al., 1988 in Langer, 2000), Education (ibid), and elderly populations through issues of aging and control (E. Langer, Hatem, Joss, & Howell, 1989). These studies showed that mindful treatments had great effect especially considering creativity, learning, and attention (Langer, 2000). But, as Weick and Sutcliffe (1999) point out, the state of collective mindfulness in HROs is not only an issue of "the way in which scarce attention is displayed" (March & Heath, 1994, p. 10). Therefore it is not only about how much attention it is possible to store up but also about the quality of this attention. It is also about how people use this attention, what they choose to do with what they notice. Derived from this, if people's possibility to act upon what they notice is limited, it is not long before their "'useless' observations of those hazards are also ignored or denied, and errors cumulate unnoticed" (Weick, et al., 1999, p. 90). Following this, the possibility of achieving a state of mindfulness will depend on the possibilities people have for action. Limited action and few possibilities for activating cognitive processes results in a state of mindlessness or situations where people act on 'autopilot' (Weick, et al., 1999).

Method

The methodology chosen for this research has followed an exploratory, qualitative strategy with main focus on extensive ethnographic fieldwork including participant observation and interviews. This strategy was found to be the most applicable since the main aim of the study was to chart possible effects and consequences at a more practical level. By using the term practical level, this describes the level where people are influenced by the security regulations in their work life and have to employ it or operate according to it in their work routines. One of the most apparent reasons for choosing this strategy was the nature of the research question. As the study aimed at exploring the theme of security in the context of civil aviation and this way getting a detailed view of the topic, a case study was particularly useful.
At the beginning of the study a pilot fieldwork was conducted at a Norwegian airport (Stavanger) to develop a guide for studying security at airports. As there are many different groups working at the airport, it was important that a selection was made among these groups. All groups in an airport have to relate to security in one or more ways, but through the criteria of contact surface with security, four groups were in the end selected. These were the airport management (Avinor) working with security related tasks, security companies, airport police, and handling companies. Within these groups, fieldwork was conducted among people spanning from leaders down to frontline staff (e.g. luggage handlers, gate personnel, security officers). The same groups were represented (where applicable) at the four different airports where fieldwork was conducted. These four airports represented respectively large (Oslo airport), medium (Stavanger airport), and small airports (Båtsfjord and Berlevåg airports), as this is the delimitation in Norwegian civil aviation system. The fieldwork consisted of participating in as many activities as possible. As an example, the researcher was present in the security control several weeks following different shifts at different time of the day, additionally participating at the security guards' patrol shift and shifts at the checkpoints at restricted areas controlling vehicles, personnel, and cargo. Similar arrangements were made among the other groups. Fieldwork at the management and middle management level mainly consisted of semi-structured interviewing and meeting participation.

Results

Security regulations, before and after 9/11, can be described as belonging to two different regulatory practices. The EU regulatory regime has developed from being relatively open and adjustable to becoming a very complex and detail-oriented system regulated in a top-down style (Olsvik & Engen, Forthcomming). Regardless of level (leader to front line), all airport workers interviewed perceived that the possibility for individual action were much more limited now than it had been. This could be regarding the possibilities of making decisions at the actual level where situations took place or in using available expertise from within their own organisation.

What appeared to be a common denominator among the airport employees was a general attitude toward the body of rules and regulations as being complicated, burdensome, and sometimes difficult to understand. Notwithstanding their perception of the system as quite cumbersome, it was simultaneously considered necessary. In one form or another, all informants considered security as a necessity. How the system was realised, however, was the subject of various and different opinions. In general, many perceived the system as an inhibiting factor for doing their job. In what follows, the findings are organised through the two categories of *lack of resonance and meaning* and *difficulty of involvement and individual action*.

<u>Lack of resonance and meaning</u>

What became rapidly clear during the fieldwork was that much of the regulations that employees are submitted to comply with did not resonate well. To say that they did not make sense or that they did not give any meaning is unclear or hazy because regulations are normally so detailed and explanatory that it should be no difficulty in understanding how one should employ them. However, what seemed to be the problem was to understand *why* one should do it. A typical issue was with the control of people and vehicles between restricted areas at airside carried out by the security company. The regulation concerning the control of a vehicle explained how one should examine the vehicle; as for example looking behind the sun visor, controlling the glove compartment and looking under the car seat. However, what was expressed by the security guards was a sort of bewilderment over the priorities of these controls. Why check the sun visor for explosives, when cargo and mail that was inside the vehicle was not subject for control (as these items had the status of cleared cargo). The security guards also explained that the leaders themselves did not seem to be able to explain why the rules were like this. One of the leaders that were interviewed explained that "*this is what the ESA* [EFTA's surveillance agency] *has decided to be good enough. They have themselves approved that this system is good enough and we can't go around and double check their assessments. This is both an economical and time consuming activity that leads to nothing as we have no power do change it either*".

It was also expressed that there was given little information as to *why* the routines were constructed as they were. The interviewees expressed that even when they asked they did not seem to get clear answers as to the *why* of the routines and practices. This was also something typical for the information flow. When new routines arrived (not counting the larger changes as exchanging complete regulations), these were printed and placed at a board in the guardroom without further explications.

Nevertheless, the meaning aspect was not reserved for frontline staff alone. Also leaders and supervisors reported that new regulations did not necessarily give much meaning and that this made it harder to motivate their employees to comply with them. One of the companies' leader explained that "*the responsibility of the leaders is to motivate the employees to do what they should according to the regulations. But when there are obvious things that make no sense, I think the leaders lose their credibility toward the employees."* And he continued by asserting that *"it all comes down to motivation. The new regulations arrive with no explanation of the assessments that formed the basis for it. This makes it very hard for us [leaders] to pass on the meaning of it to our employees*." One possibility in these situations was to contact the Civil Aviation Authority to clarify the regulations, but as this was a time consuming activity it was normally a better solution to simply implement the new regulation. As employees often asked for the why of the routines, leaders also commented that it was hard to not have an actual answer to them, but that they had to front an attitude where they "have to do as they are told" and that it "just had to be done". This was also an undesirable situation for leaders and supervisors because they find themselves under different constraints simultaneously where they are obliged to front the regulation and defend it even though they sometimes find it hard to defend. The problem, according to one of the senior supervisors, was the design of the regulatory framework. "*What is missing is the possibility to adapt the regulations to the organisations. It is [the regulatory framework] not at all elaborated with the organisations in mind*."

A recurrent question that I asked the employees was how they perceived that this way of organising affected them. The answers followed mainly two directions where the first one was an apparent plain acceptance; that it was merely a part of the job. The second direction was a more resigned acceptance. A security guard working at one of the checkpoints explained that "*They [the security company] doesn't pay you to think. The best thing to do is to do your job without thinking, unless you'll go crazy*". Comments like this was not uncommon, and to me it became a way of describing a situation where it was both hard to understand the reasons behind the action they had to perform, but also connected to the perception that the possibilities for individual action was limited.

Difficulty of involvement and individual action.

The difficulty of involvement was something that was displayed at all levels at the airport. At the lower levels this was expressed by an experience of receiving little information. Through interviews it became evident that the security guards rarely felt that they were involved in information processes concerning new rules and regulations. This resulted in experiences where information had not reached them and they could experience that team leaders corrected them for not following the latest updated regulation. To an extent, the information also seemed to be reserved for the leaders and middle leaders. This resulted in the experience that information is not for everybody and that at lower levels one is left out of the loop. At the security company level this could also be elucidated through the fact that the employees did not have an e-mail address through work, and it was also explained that they did not have all e-mail addresses (the private ones) so information was not sent by e-mail. Additionally, the employees did not have an appropriate place for receiving mail. This meant that information to a large extent was given through posters posted at the board in the lunch rooms or the guard cabins. This is not to say that no info was given, but there were no routines to guarantee that everyone had the possibility to receive the same information. Instead, information was given at the beginning of the shifts (a shift can consist of 5 persons or more at the larger airports). Considering that there are up to 700 employees at the security company, depending on size, there is no possibility that all the different shifts will receive the same amount and kind of information. This is then dependant of the amount of information the team leaders have themselves and also the ability the team leaders have of conveying relevant information to the guards.

At the higher levels the difficulty of involvement was expressed as a balancing between time pressure and regulation that arrive without explanations. The time pressure leads to a possibility for repercussions because there is always a time limit for implementation of regulations. The worst case scenario is that during inspections of the CAA or ESA, deficiency or absence of routines may lead to the airport becoming ‘unclean’. This means that priorities have to be made, and as has been expressed throughout the fieldwork the priority of implementing new regulation within the time limit has always precedence over a more “pedagogic” implementation where focus are more directed at bettering people’s understanding of the regulations. The possibility for the leaders to be involved in an adaptation of the regulations was in practice close to non-existing and this was also expressed by a few leaders to be a direct hindrance for good leadership.

Individual action also means handling strategies in cases of uncertainty. If there are arenas for handling different scenarios, this also means that the individual to some extent has a possibility of individual action. If the same person experiences that even though these arenas exist in theory but not necessarily in practice, the individual action arena narrows down. Typical situations where individual action was feasible were in situations where different handling strategies were available. These could typically be that it was possible to do more than what was necessary. As all employees learn through their training program, security is everybody’s responsibility. One of the airside workers explained how he, when he was new, had stopped one of the cleaning staff asking to see her ID-card. “*It’s a long time since I’ve received that much scolding* [laughing]. *But I reported her to the security company, but they used half an hour to send someone, and I was not going to hold her there, so she was gone long before they came.* […] *No ‘thank yous’* [...] *It’s going to be a long time till I’ll be bothered to do something like that again*.” This incident was not unique and one of the leaders expressed that “[…] *earlier, security was everyone’s business. But now there is one company who is in charge of it all and that means in practice that the rest of us have become disqualified.*

Security guards similarly reported that it was not necessarily rewarded to “walk the extra mile”. What seemed to be common in situations like these was the perception that reporting could lead to different outcomes, ranging from praise to mockery. It involved a certain risk to ask questions and report. When asked how the guards coped with this, the answers differed much. For some it was no option to not ask for assistance, and some also reported that they had seen co-workers omit asking questions and looked the other way, others again felt that they were experienced enough to make the decisions themselves, this way avoiding the situation altogether.

Discussion

The success of a security system, as opposed to other systems, is close to impossible to measure (Schneier, 2003). Aviation Safety, on the other hand, which concerns itself with securing aviation against all unintended harm, can be measured against the fact of whether or not there has been any plane crashes or other incidents. As this is not the case for aviation security, the ensuring of a resilient security system has to be made without the clear evidence that is generated from varied experience. This implies that there is no way of saying that the current regime is the *only* way to solve the necessity of security that the civil aviation system needs.

In an article from 2002, LaPorte and Frederickson claim that "commercial air passenger security is part of a unique class of institutional characteristics and decision-theoretic challenges that are collectively described as High Reliability Organizations" (Frederickson & LaPorte, 2002, p. 33). By claiming that commercial aviation security falls under the category of HROs, the next task would be to look at the necessary steps of being *good* HROs. For Weick and Sutcliffe it is the concept of mindfulness that can separate 'good' and bad' HROs. As initially described, mindfulness entails several concerns that together form the possibility of being highly reliable. A preoccupation with failure (a) implies that in an organisation where the possibility of trial and errors is limited, there is a will to learn by the errors that are available. This way it will encourage routines where people report errors because of the learning potential in them (Weick, et al., 1999). The reluctance to simplify interpretations (b) is a way to avoid complacency and situations where people are socialised into ignoring the same things. "Simplifications […] allow anomalies to accumulate, intuitions to be disregarded, and undesired consequences to grow more serious" (Weick, et al., 1999, p. 94). Sensitivity to operations (c) lies close to the concept of "situational awareness" that forestalls errors to cumulate. A commitment to resilience (d) makes an organisation not only able to "bounce back from errors"(Weick, et al., 1999, p. 100), but also able to cope with unexpected events when they happen. They prepare for unavoidable surprises. Lastly, the underspecification of structures (e) points to the case where orderly systems sometimes amplify errors. There lies a paradox there because the orderly systems that are made to avoid errors sometimes seem to cause them (Weick, et al., 1999). A way to avoid this may be through loosening the hierarchical decision structure and let the decisions follow the problem. "To loosen the filter of hierarchy […] makes people […] pay more attention to inputs in the moment, they are more sensitive to their time of arrival, and processes are more influenced by temporal connections" (Weick, et al., 1999, p. 104).

Seeing the findings presented above in relation to Weick and Sutcliffe's concerns that form mindfulness, there are some immediate points that spring out. Lack of meaning is experienced by the airport employees regardless of levels. This is especially induced by a time limit which makes implementation more important than the method this implementation is carried out by. A consequence of this may be that simplifications of processes may occur because anomalies will be harder to notice. The attitude that there is no point in asking questions or that you are 'not paid to think' is not encouraging to either the sensitivity to operations or a reluctance to simplify interpretations. Following Weick, Sutcliffe, and Obstfeld's (1999) claim that the possibility of achieving a state of mindfulness will depend on the possibilities people have for individual action, the 'autopilot' and mindlessness may be expected to be present in a system like this.

Following Langer's reasoning that when people are set to do tasks that are mechanically carried out, it often leads to personnel sleepwalking through the work day. This transfers well to many statements made by the airport workers. The assertion made by the security guard saying that "the best thing to do is to do your job without thinking" certainly demonstrates a tendency toward mindlessness. The notion of 'walking the extra mile' as a hazardous and tiring activity also point to a direction of passivity instead of proactivity. This does not lead to the concern of a preoccupation with errors. What one can miss out on because of this is a possibility to learn through them.

The regulatory system, as mentioned above, is constructed around a top-down style where the level of details is so high that there shall be no variation between airports in the implementation. This makes it hard for people to have a possibility for involvement or individual action. This stands in contrast with the underspecification of errors where the aim is to loosen the hierarchy.

Conclusion

Because of the intentionality trait in the attacks to civil aviation, the regulatory framework has developed differently than regulations in safety related areas. The initial question as to what has been traded off in choosing this approach is hard to pinpoint, but it possible to assume that some of the experiences outlined by airport personnel can be explained by the design of the regulatory system. This is especially obvious when looking at the time limit on the implementation of regulations where the trade-offs become quite visible. That regulations are fixed after they are put to vote makes it hard to make changes when they are first implemented and thus evaluated in a context. The level of details also inhibits much of the room for individual action and may also cause mindlessness. There are no perfect HROs, and the effort to become a mindful HRO should probably be seen as an ideal that the organisation may strive toward, particularly organisations that are especially vulnerable to errors and accidents. This is also so for airport security, but what seems to be the greatest inhibitor for the organisation of security to approach mindfulness is a very hierarchical structure and a regulatory framework that stands in contrast to the concerns that constitute mindfulness. A very interesting question is whether a loosening of the hierarchy automatically would lead to bad security or whether it would lead to different security.

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春节期间中国两个火车站的拥挤现象

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【摘要】春节期间有超过十亿人在不同城市间游走。火车是行程超过一千公里人们的主要交通工具之一。2006 年纪录显示，在春运高峰期间，总载客量达 1.49 亿人。郑州这个交通枢纽站，在 2006 年曾因暴雪于 1 月 19 日车展拥挤乘客超过 6 万人。其他的火车站也因此受到影响。拿北京西站为例，有十万乘客因郑州暴雪而受困车站。这些现象都是安全警告信号。文中对因郑州暴雪导致的火车严重晚点进行了陈述。因此受到影响的其他主要火车站，尤其是北京西站的情况也有阐述。新闻报道了采取的应急措施并受到广泛讨论。通过与过去几年春节旅游数据及类似案例数据的比较和事故背景、原因分析，对应急措施的实施进行了研究。通过对拥挤事件控制的总结，得出有关问题的经验教训。为处理类似事件提供防范措施的建议。

【关键词】拥挤控制；应急响应；火车站

CROWDING AT TWO RAILWAY STATIONS IN CHINA DURING THE SPRING FESTIVAL

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Keywords

Crowd control, emergency response, railway station

Abstract

Over one billion people travel around different parts of China during the Spring Festival. Railway is one of the key transportation means for traveling up to several thousand kilometres. A total railway passenger load of 149 million during the peak season was recorded in 2006. A key railway station, Zhengzhou, was crowded with over 60,000 passengers on 19 January, 2006 due to heavy snowfall. Several other major railway stations were then affected. Taking the Beijing West Station as an example, 100,000 passengers crowded at the station area in that evening. All these give a warning signal on the possible safety problems. In this paper, the serious transport delay at Zhengzhou Railway Station due to heavy snowfall on that day was described. The effects on other major railway stations, particularly the Beijing West Station, were outlined. Emergency actions taken as reported in the news were also discussed. By comparing with the travel data during the Spring Festival in the past years and with another similar case, the background and causes of the incident, and the emergency measures implemented were investigated. Lessons learnt from problems encountered in crowd control from this incident were summarized. Preventative measures for dealing with similar incidents are proposed.

1. Introduction

Traditionally, Spring Festival is the most important festival in China. There are at least seven days of holidays for all organizations. Family members prefer to meet and have celebrations. Over 140 million 'peasant labours' and 20 million college students staying outside would return to their hometowns. Permanent residents in cities (domicile control still practising in China) would travel to visit relatives, friends or enjoy their long holidays in tourist areas. Traveling during the Spring Festival holidays will give heavy traffic loadings. Passengers used to travel around different cities within 40 days, 15 days before and 25 days after the Lunar New Year. In the past ten years, the total number of passengers during this period was recorded to be over 1.3 billion each year, about the total population of the Mainland.

The total passenger load [1] during the spring travel period in the past 13 years is shown in Table 1. Distribution of daily passenger flow in these 40 days is uneven. A travel peak would be resulted when peak flows of two or three groups of travelers overlap.

Table 1: Total passenger load (Economic Operation Bureau, 2006; International Finance, 2004; Wikipedia, 2007) during the spring travel period in the past 13 years

Year	Total passenger load (in 100 million)
1994	12.2
1995	14.28
1996	16.2
1997	17.4
1998	18.2
1999	14.4
2000	16.16
2001	16.6
2002	17.4
2003	18.19
2004	18.9
2005	19.5

2006	20.54

Past records showed that highway traffic took about 91% of the total passenger load, railways 7%, water transport and airlines less than 2%. The passenger loading distribution for these means of transportation during the spring travel period in the last five years are shown in Table 2.

Table 2: Passenger load (Economic Operation Bureau, 2006; Wikipedia, 2007) of different means of transportation during the spring travel period in the last 5 years

Year	Passenger load (in 100 million)				
	Total	Railways	Highways	Water transport	Airlines
2003	18.19	1.3	16.65	0.24	0.09
2004	18.9	1.37	17.17	0.26	0.11
2005	19.5	1.4	17.7	0.28	0.12
2006	20.54	1.49	18.77	0.28	0.18

Although only 7% of the passengers used railway during the spring travel period, it plays a unique role. In terms of price, speed and safety, railway is the first choice of transportation for peasant labours and college students with a long trip. The total length of the operating railways in the Mainland is only 75,000 km. The averaged value is 5.6 cm per person, about the length of a cigarette, lying outside the list of the world top 100 [2]. However, the total passenger load of railways in 2005 in Mainland China was 603.456 billion person-kilometer, being at the top of the world [3]. Having 149 million passengers traveling in 40 days means that the railway system would have double or even triple the normal loading. In addition, the railway also has to transport important goods such as coal, oil and food for the country. The transportation capacity of railways is inadequate for such a huge loading of passengers.

At the start of the spring travel peak on 19 January 2006 in Mainland China, Zhengzhou Railway Station, one of the key stations, was paralyzed by heavy snowfall as reported by the local and overseas media [4-6]. Over 60,000 passengers crowded at the station as in Fig. 1. Several other major railway stations in the country were then affected. The Beijing West Station was affected most with over 100,000 passengers crowded inside in the evening on 19 January as in Fig. 2. Such crowded stations have potential safety problems.

Figure 1: Passengers outside the Zhengzhou Station

Figure 2: Passengers at the north square outside the Beijing West Station

The railway system in Mainland China is shown in Fig. 3. There are eight key railway lines operating at the moment, five running north-south and three east-west. Jing-Guang Line is the central axis of the railway, connecting through Huabei, Huazhong and Huanan. It is the largest north-south trunk line with the highest carrying capacity. The Longhai Line is the most important east-west line [7].

Cities such as Beijing, Zhengzhou, Shanghai, Guangzhou, Wuhan, Chengdu, Xi'an, Harbin, Shenyang and Lanzhou with two or more lines become the railway hubs. Beijing is the terminal station for three north-south lines (Jing-Guang, Jing-Hu, Jing-Jiu) and one east-west line (Jing-Bao). Zhengzhou, located at the intersection of Jing-Guang Line and Longhai Line, is the heart of the railway network. These lines and hub cities are the key parts during the spring travel period. Their operation would directly affect the smooth transportation of passengers.

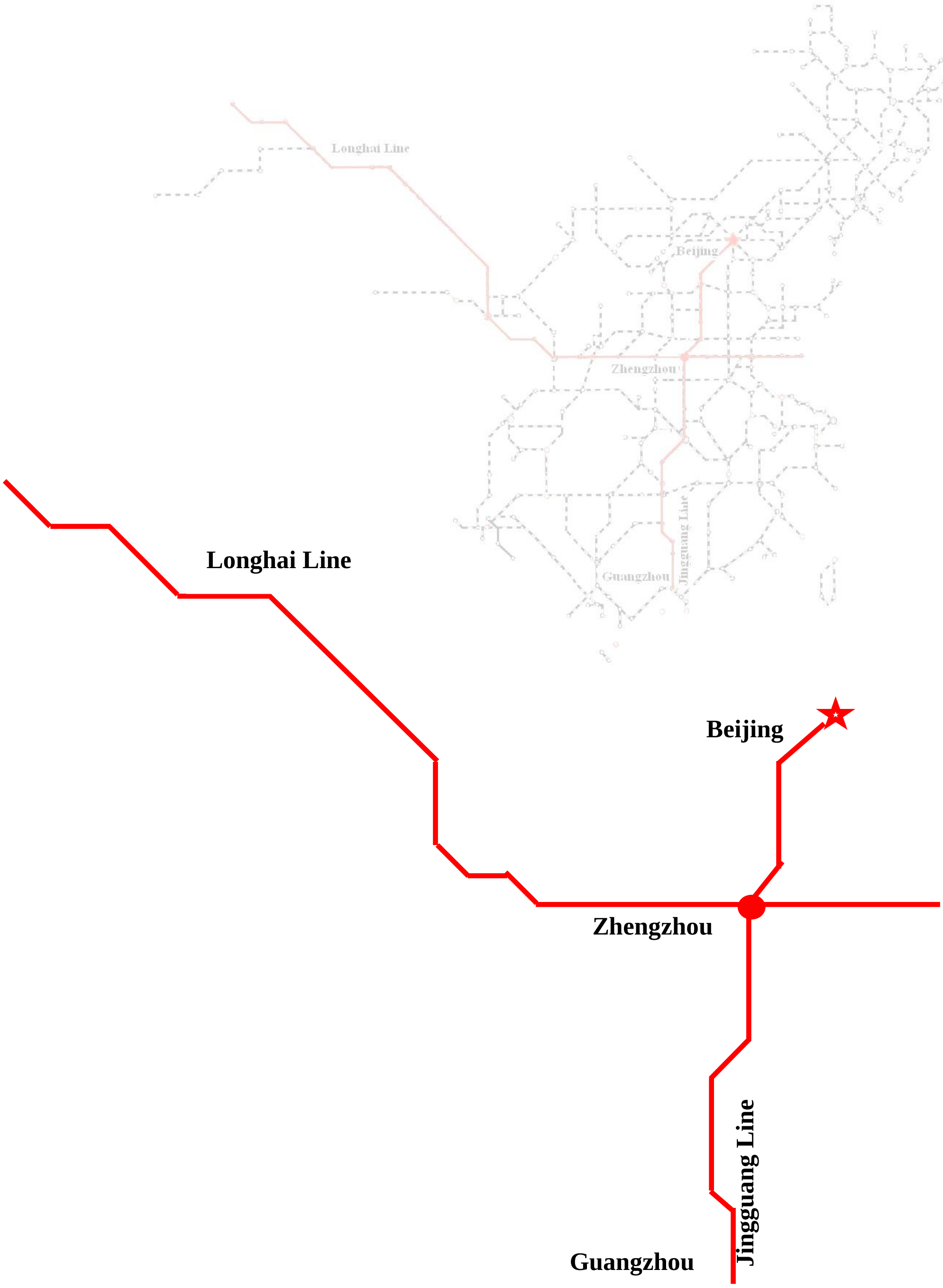

Figure 3: Railway system in China

2. The Zhengzhou Incident

The spring travel season in 2006 started on 14 January. The first travel peak was estimated by the railway authority to be on 20 January. Starting from about 6:00 am on 18 January, snow began to fall in large areas of China. Medium to heavy snow was reported in Zhengzhou and Wuhan; small snow or rain with snow in

Shanghai, Xi'an, Ji'nan, Lanzhou, Guangzhou and Urumqi. Heavy snow kept on falling in Zhengzhou until nighttime on 19 January, resulting in over 15 cm snow on ground [8-11].

All the main highways were closed due to heavy snow on 18 January. Traffic at the north-south trunk roads passing through Zhengzhou was heavily congested. All the flights scheduled to take off at the Zhengzhou Xinzheng Airport between 17:30 on 18 January to 21:00 on 19 January (28 hours) were cancelled. As a result, many passengers turned to railways.

Railway switches were frozen due to the heavy snowfall. Almost all the trains departing from or passing through Zhengzhou Station were delayed. Many trains were delayed for more than 8 hours and some were even stopped. As reported [12], passengers accumulated quickly at the Zhengzhou Railway Station from 5:00 pm to 7:00 pm on 19 January. Over 60,000 passengers were held up at the station at 6:00 pm as in Fig. 1. Although all the 11 waiting halls in the station were opened, spaces were still inadequate. After clearing up the tracks through great effort by the railway authority, all delayed trains finally began to arrive at Zhengzhou Station since midnight on 19 January. Those trains then departed accordingly.

Longhai Line and Jing-Guang Line were under snow on 19 January. As Zhengzhou Station was at the intersection point of these two lines, the jamming effect spread out quickly to other stations.

In the evening on 19 January, all the trains of the Jing-Guang Line passing through Wuhan were delayed. Trains arrived late at stations of Zhuzhou and Hengyang in Hunan province. Passengers crowded at the stations of the Jing-Guang Line and Longhai Line due to train delays. On 19 January, over 4000 passengers were held up at the Xi'an Station of the Longhai Line. There, part of the station terminal such as the fast food restaurants were changed to temporary waiting areas. In the afternoon on 20 January, over 10,000 passengers were waiting at Chengdu Station. That station had to transfer money from the bank for ticket refunding. Up to seven refund counters were opened, note that there was only one such counter in normal days. In Shanghai, over 15,000 passengers were held up on 19 January. The peak value was 35,000 passengers; ticket selling was stopped. In Guangzhou, 11 trains were delayed and about 10,000 passengers held up on 19 January.

Beijing West Station, the terminal station of the Jing-Guang Line, was seriously affected. It was predicted that the first travel peak day would be on 19 January 2006, with about 130,000 passengers departing. At 10:30 am on 19 January, information from Zhengzhou, Henan and the weather observatory confirmed that trains on the Jing-Guang Line were disrupted. Snow fell heavily in Henan and so trains at the Beijing Station could not leave as scheduled. At noon, over 10 trains were delayed, with some delayed for more than 10 hours. All the 13 waiting halls at Beijing West Station were opened, being the first time happened in recent years. There were only 500 seats at each waiting hall, but observed to have over 1,500 passengers. Many passengers were crowded at the corridors, the south and north squares outside the station and the footbridges nearby. At about 12:00 pm on 19 January, passengers accumulated at the waiting hall on the 2nd floor of the station. As more trains were delayed, more passengers were crowded at the station area. The peak crowd loading reached 140,000, including about 30,000 passengers waiting to board as in Fig. 2. At 11:00 pm on 19 January, 12 trains arrived late and the departure of 20 trains were delayed. At about 0:00 am on 20 January, Zhengzhou Section of the Jing-Guang Line resumed train service. At 0:40 am, the first south-bound train of Jing-Guang Line on that day departed from Beijing West Station, the crowd was gradually relieved. From 0:00 am to 6:00 am, nine more trains were put into service to carry the 20,000 passengers stayed at the station. A total of 20 passenger trains had departed from the station in that six hours. At 10:40 am, the train from Beijing to Chongqing departed. At that time, train service basically resumed normal with all delayed trains due to heavy snowfall departed.

After taking emergency actions for two days on 20 and 21 January, the railway traffic in Mainland China basically resumed normal on 22 January.

3. Response of the Authority in Emergency

Three levels of emergency warning signals dealing with peak passenger flow were planned at the Beijing West Station:

- Yellow warning with over 120,000 passengers to be departed on a single day:

  Only those passengers holding valid tickets for trains departing on that day are allowed to enter the station;

- Orange warning with over 130,000 passengers to be departed on a single day:

  Only those passengers holding valid tickets for trains departing within 6 hours are allowed to enter the station;

- Red warning with over 140,000 passengers to be departed on a single day or under other special situations:

  Selling of tickets would be stopped and only those passengers holding valid tickets for trains departing within 6 hours are allowed to enter the station.

At 11:00 am on 19 January, red warning scheme was launched at the Beijing West Station. The information was immediately broadcast through the traffic radio to the public. The following actions were taken afterward:

- **Directing the waiting passengers**

At the Beijing West Station, passengers waiting for seriously delayed trains were directed to the waiting hall at the 2nd underground level. At one to two hours before the arrival of the trains, some platforms were opened earlier for the passengers at the waiting halls. Senior management and staff of the Beijing Bureau of Railways were on duty with the assistance of police. Vice-Minister of the Ministry of Railway and Deputy Mayor of Beijing arrived at the station at about 4:00 pm on 19 January to command. Relevant authorities including the Beijing Municipal Emergency Office, West Station Regional Management Committee, Municipal Transport Committee, Public Security Bureau, Traffic Management Bureau worked closely together. About 1100 policemen and 300 soldiers from Tianjin, Shijiazhuang and Dezhou were assigned to keep order. This was the first time with so many policemen since the opening of the West Station. The Ministry of Railway, Beijing Municipal Government and Beijing Bureau of Railways formed a joint command centre at the West Station. At 8:30 pm on 19 January, the passengers were directed to the south square by 10 police cars. The big restaurant on the 3rd floor and the large conference room on the 2nd floor of the nearby Beijing Railway Hotel were used as temporary waiting halls for the passengers.

At Zhengzhou Station, two Vice-Governors of Henan Province arrived in the evening on 19 January to direct work. Emergency measures were implemented by the Spring Travel Office. All the waiting halls inside the station were opened and the plaza outside was used to house the waiting passengers. Passengers were queued up for boarding. With the help of the regional government, over 1000 policemen were positioned at the Zhengzhou, Luoyang, Kaifeng and Anyang stations.

- **Increasing the traffic flow**

At the Beijing West Station, technicians were instructed to complete the inspection and maintenance works of all the arrived trains at the platform within 25 minutes. The trains would then depart immediately. Nine more trains were operated in the evening on 19 January to clear up the crowd faster. Tickets were sold earlier to relieve the pressure of waiting passengers. More buses and taxis were called to the station to pick up the passengers just arrived.

In Zhengzhou, the two major telecommunications companies were requested by the Authority in Henan Province to send out messages in the evening on 19 January, informing citizens that trains at Zhengzhou Railway Station would be delayed, and some even stopped. Passengers were recommended to leave the waiting hall and station square and change for other means of transportation. Additional eight trains were departed to carry the passengers. More trains from Zhengzhou to Xinyang and from Zhengzhou to

Nanyang were temporarily operated to carry the short-distance passengers. The transport authorities in the entire province backed up the Zhengzhou Railway Authority. Starting from 20 January, all passengers holding valid tickets were not required to pay extra fees when traveling on long-distance buses. All losses would be credited to the account of the transport authorities.

Passengers holding tickets of the delayed trains would be fully refunded, no need to pay the 20% handling charge. Passengers might choose to change to travel at another time and on a different train. On 19 January 2006, 12 refund counters were operated at the Beijing West Station.

- **Clearing up the tracks**

On 19 January 2006, several thousand railway staff were organized by the Zhengzhou Bureau of Railways to clear up the snow on the tracks and 'defrost' the frozen railway switches. Zhengzhou Section of the Jing-Guang Line resumed service at 0:00 am on 20 January 2006.

With the above actions, the problems due to holding up large numbers of passengers at railway stations were solved. Not even a single injury was reported. Based on the above descriptions of the incident, actions taken by the authorities, background information on spring travel and the railway system in Mainland China, causes for this incident are analyzed. Results will be applied to solve similar incidents.

4. Causes of the Incident

Serious consequences can easily be resulted in the above incident in densely crowded stations. The Zhengzhou Station is at the centre of the railway network, being the intersection of the two main north-south and east-west railway lines, Jing-Guang Line and Longhai Line. Over 315 trains would be departing, arriving or passing through this station everyday during the spring travel period; a train would arrive, depart or pass through the station every 4 to 5 minutes on average. The shortest interval is less than 3 minutes at the daily peak hours. If this station cannot operate normally, transportation of the entire railway system for the long-distance passengers would be affected. During the spring travel period, 104 of the 258 trains departing, arriving or passing through Beijing West Station would travel through Zhengzhou everyday. Any disturbance at the Zhengzhou Station would affect the Beijing West Station as demonstrated.

Beijing West Station used to be a key station in the past spring travel seasons. On the days around 19 January, the daily crowd flow at the Beijing West Station was over 300,000. If the West Station cannot operate normally, passengers would be definitely held up. Several incidents happened before at the Jing-Guang Line. For example, a railway train ran off the track in the Hunan Hengyang Section at 21:00 on 25 September 2000. The Jing-Guang Railway Line was suspended for over 50 hours. Normal service was not resumed until the morning on 28 September 2000 [13]. As that case was not happened in the peak travel season, trains normally passing through the Jing-Guang Line were diverted to other lines. Although the train service of Jing-Guang Line was suspended for a much longer time than in this incident, the consequences were not so significant.

The primary cause for this incident was due to the heavy snowfall. If only the railway system was suspended, passengers could still be diverted to expressways and airlines. For this case, the entire traffic system in Zhengzhou was suspended due to the heavy snowfall. No alternative traffic means was available as the airport and highways were closed. Large crowd waited outside the stations.

On the other hand, trains jammed at the Beijing and Zhengzhou stations could only be cleared up when the Jing-Guang Line resumed normal. During the spring travel season, most of the tickets would be sold up. The waiting passengers were unlikely to cancel their travel plans. They kept on waiting all the time at the stations until the Jing-Guang Line operated.

Response of the authorities is another factor. Normally, bad weather would not affect the railway system significantly, far less than on roads and airlines. It is difficult for the Railway Authority to work out appropriate preventive actions beforehand as Zhengzhou did not have bad weather record affecting railway traffic. Practising actions against such big scenarios would not be welcome by the public. This is similar to performance-based design for fire safety. A very low value of design fire (say 2 MW) used to be proposed in big halls by consultants, even criticizing that the government worried too much to have a big fire! On 18 January 2006, heavy snowfall started to fall suddenly in Henan Province. Snowstorm warning and frozen roads yellow warning signals were issued four times by the regional observatory. Trains were already delayed at Zhengzhou and Beijing West stations. Emergency warning scheme at Beijing West Station was only activated until 19 January. However, experience was gained in handling this incident. Another heavy snowfall occurred about two weeks later from 2 to 6 February 2006, also within the same spring travel season. Since the railway authority had experience and watched the rapid changes in weather conditions with well-planned preventive measures, transportation was not seriously affected [14]. Therefore, safety awareness and adequate planning are the key points to avoid adverse effects.

Dissemination of message was not adequate in the whole process. Information exchange among parties such as bureaus of the Chinese railway systems, large railway stations, local government and the public was not fast enough. Note that there are 18 railway bureaus in China after ‘reengineering’ in March 2005. There are three points to note:

i. The total operating mileage of the Zhengzhou Railway Bureau decreased from 6600 km to 2400 km. Without quick information exchange, it is difficult to prevent unexpected incidents. Note that the spring travel in early 2006 was the time after ‘reengineering’. It is difficult for the Zhengzhou Bureau to handle big unexpected incidents [15,16].

ii. Large railway stations such as Zhengzhou Station and Beijing West Station are operated by the railway department and the local government collaboratively. When serious incident happens, the corresponding branches of the railway system and the local government must report to supervisor first, before taking necessary responsive actions [17]. Taking the Beijing West Station as an example, the incident at Zhenzhou happened at 10 am. However, formal collaboration between the railway system and the local government started 6 hours later at 4:00 pm.

iii. With limited information exchange between the railway system and the public, it was difficult to announce effectively that a red warning scheme was hoisted at the Beijing West Station. Message could only be broadcast through the traffic radio [9]. Audience of the traffic radio broadcast were limited to those traveling on private cars and taxis. Very few peasant labours or students went to the railway stations by such vehicles. A better way is to disseminate information repeatedly through more channels including television and mobile phone messages. Passengers can then get the latest train information conveniently. This would help to reduce the crowd loading at the station. Finally, Zhengzhou Station announced through the cellular phone networks at night of 19 January. However, the station area had already been crowded with passengers. Open, fast and wide coverage channels were not available to broadcast train information around the Beijing West Station or Zhengzhou Station. People waiting at the square outside could not obtain the latest information, which imposed more pressure on crowd management at the stations.

5. Conclusion

In the incident of holding up 160,000 people at the Beijing and Zhengzhou Railway Stations due to heavy snowfall, the government had demonstrated its capability in crisis management and crowd control. The problems were eventually solved successfully. It was difficult for the Authority to work out emergency plan before this issue happened in Zhenzhou. Such bad weather was not reported since there was railway system in China. Obviously, the incident would be prevented if there was planning. Requesting too much would get more criticisms, and using too many resources. Information exchange between different parties and the public is another point. The incident would be easier to handle if there is better information exchange.

If this crisis developed very fast that leaving no time for the government to react, the consequences could be disastrous. An example is the crowd gathering at the Miyun Park in Beijing during the Spring Festival in early 2004 [18]. 37 people were killed within just a few minutes. Besides, the occupant loading at Beijing West Station and Zhengzhou Station were very high at that time. There was no room to relieve the passenger crowd. The only way was to send more staff and policemen for keeping better order. Therefore, it was only a passive approach to crowd control.

Fortunately, the government has recognized the limitations of the passive emergency warning scheme for handling emergency incidents. Therefore, much effort was put to promote the rationale of emergency management. If the relevant authorities can conduct comprehensive risk assessment in advance, similar incidents would not happen again. This incident had identified a major problem on communication [19]. The government is now fully aware of the importance of disseminating information in handling similar events.

Through analyzing the above incident, the two key factors to prevent similar incidents are enhancing information flow and cooperation among different departments; and effective crowd control.

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关于基于 MAS 的信息系统间相互操作的协同机制的研究

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【摘要】本文在信息系统间的相互操作中引入了多级代理系统(MAS)的概念,定义了信息系统间相互操作中多种代理的建构与功能，并阐述了相互操作的机制。在此基础上，本文研究了基于 MAS 的互操作过程的运作。

【关键词】信息系统 配合运作 MAS; 协作技巧 ; 协作进程

RESEARCH ON THE COOPERATION MECHANISM OF INFORMATION SYSTEM INTEROPERATION BASED ON MAS

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Key words

information system; interoperation; MAS; cooperation mechanism; cooperation process

Abstract

In this paper, the concept of multi-Agent System (MAS) is brought into interoperation among information systems, the construction and function of kinds of Agents in the interoperation between information systems is defined, and cooperation mechanism is presented. Based on these, the cooperation process of interoperation based on MAS is researched.

Introduction

With the continuous improvement of informatization and in-depth application of information system, more and more departments are no longer satisfied with the information sharing and business cooperation among them, and have begun to put forward to information resources sharing cross domains. As the core technology of achieving the cooperation and information sharing between different information systems, the interoperation gradually catches people's attention. Currently, plenty of research on interoperation has been done and a series of technology and methods have been proposed. However, for the different development parts, being lack of standards and specifications, and the complexity and diversity, the realization of interoperation among the large-scale and distributed information systems becomes very difficult.

Therefore, in this paper, the concept of multi-Agent has been brought into the interoperation platform, using the autonomy, flexibility, adaptability, asynchronism of multi-Agent system, taking the needs of information system interoperation as guide, specific to the feature of interoperation, firstly, the construction and function of the Agents used in the process of interoperation is defined. Secondly, the communication, mission distribution and other mechanism is researched, and based on these, the cooperation process of interoperation is researched in order to direct the achievement of the interoperation between information systems.

Theory and Method

Definition of Agent's Construction and Function

Agent is a kind of program or computational entity which is in a particular environment and can run flexibly and autonomously in this environment [1~3]. It can perceive the environment and achieve a set of goals of designers and users. In this paper, interactive Agent is the function module within the interoperation platform, According to the different function in the interoperation, four types of Agent have been defined:

(1) Interactive *Agent***:** *CA= {I, K, A, C, L, AL}* [2, 4]

Interactive Agent is the bridge that connects the user (the information systems taking part in interoperation) and the interoperation platform. On one hand, it achieves the transmitting of missions and results between user and interoperation platform, on the other hand, the identification of user`s identity, character and permissions can be achieved by interactive Agent. So, interactive Agent has both knowledge of user and interoperation platform, it consists of six parts:

① I: Interface

It provides visual interface to users that they can communicate with the interoperation platform intuitively and conveniently.

②K: Knowledge base

It contains the information of users and message, K= {identity base, character base, right base, format base, manifestations base, historical record base}.

③ A: Analysis and treatment module

This module is the core of the Agent, in this module, corresponding information and algorithms are been invoked to deal with the request that users proposed.

④ C: Communication module

This module is mainly responsible for the task of communicating with other Agents, in this paper, it mainly communicate with system Agent (It will be introduced later in).

⑤L: Learning module

Agent is a series of hardware or program that has the ability of studying independently. After achieving a mission, it can compare the process with other similar missions and find the differences among them and record the process into the knowledge base by learning module. In this way, Agent can upgrade their ability continuously.

⑥AL: Algorithms base,

It contains the algorithms that can be used in the process of executing missions. AL= {decryption algorithm, unpacking algorithm}.

The logical structure is shown in Fig 1.

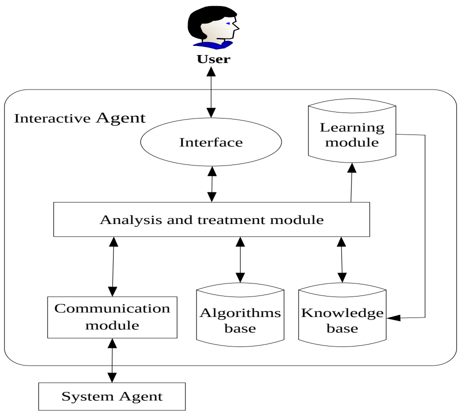

Fig 1 logical structure of interactive Agent

(2) *Managing* Agent*: MA={C, A, L, K, AL, AD}* [2, 4]

The function of managing Agent is exhibited with the planning and adhocery of the mission, as well as the control and supervision of other Agents. It also consists of six parts:

①C: Communication module

This module is the same as interactive Agent, the only difference is that it communicates with system Agent and executive Agent.

②A: Analysis and treatment module

This module is the same as interactive Agents, the only difference are the methods that invoke the information and algorithms.

③L: Learning module

This module is the same as interactive Agent's.

④K: Knowledge base

In this Agent, K= {agent model base, mission knowledge base, coordination and control knowledge base, relationship base, adhocery base, historical record base}.

⑤AL: Algorithms base

In this Agent, AL= {mission decomposition algorithm, capacity assessment algorithm, mission dynamic distribution algorithm, group establishment algorithm}

⑥AD: Adhocery module

In this module, the final computing results will be used to make a decision and form the output.

The structure of managing Agent is shown in Fig 2.

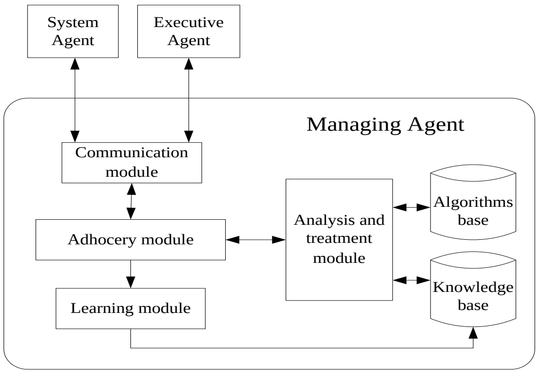

Fig 2 logical structure of managing Agent

(3) System Agent: SA={C, A, L, K, AL, AD}

System Agent realizes the management of the managing Agent; it is the key to the cooperation of multi-mission. One interoperation platform can have many multi-managing Agents, but only can have one System Agent. Missions are accepted from interactive Agent by System Agent and distributed to managing Agents. When the conflicts among missions appear, system Agent will deal with them at a certain mechanism. The structure of system Agent is the same as managing Agent, as shown in Fig 3. The differences between them lie in the algorithms and knowledge base. In this Agent, AL= {access control algorithm, mission assessment algorithm, redundancy control algorithm}. K= {mission base, classification rule base, relationship base, historical record base}

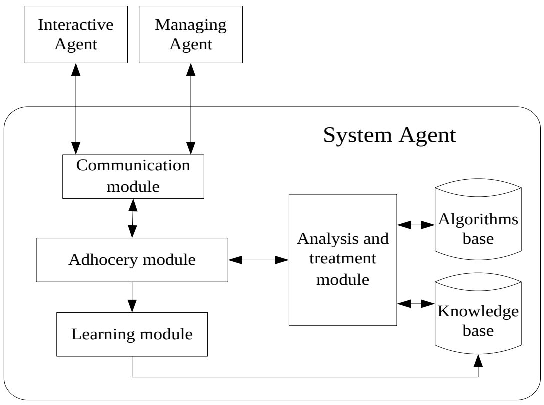

Fig 3 logical structure of system Agent

(4) Executive Agent: EA

Executive Agent is a kind of Agent, which cannot affected by the domain and with a general-purpose for mission. It is the executor of the mission. The structure of executive Agent is the same as managing Agent, as shown in Fig 4.

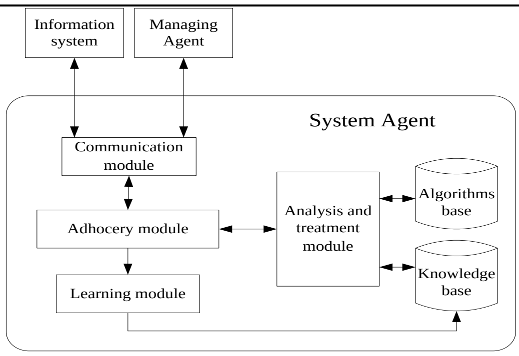

Fig 4 logical structure of executive Agent

According to the different function, executive Agent also contains many types, the differences among them lie in the algorithms and knowledge base. In this paper, executive Agent consists of seven types.

①Semantic parsing Agent [5~6]

Semantic parsing Agent executes semantic matching and conversion. The former is to match the keywords to the semantic rules base. The latter is to convert the nature of mission and set up subquery to the data source of server-side.

In semantic parsing Agent, AL (algorithms base) = {semantic matching base, semantic conversion base}, K (knowledge base) = {semantic rules base, mission base, rule base}.

②Searching and locating Agent [7~8]

Searching and locating Agent is used to find the location of data source. Through establishing searching matrix, using breadth-first, depth-first and hybrid searching algorithm, the searching aim can be executed by searching and locating Agent.

In searching and locating Agent, AL (algorithms base) = {depth-first searching algorithm, breadth-first searching algorithm, hybrid searching algorithm}, K (knowledge base) = {index base, mission base, rule base}.

③Access control Agent [9]

If the number of users exceeds the capability of server-side, access control Agent will control the access by the order of user`s priority.

In access control Agent, AL (algorithms base) = {load quantization algorithms, user-priority quantization algorithms}, K (knowledge base) = {load capability base, load balancing base, trust base, mission base, rule base}.

④Result integration Agent

During the process of interoperation, the integration of final mission result is achieved by result integration Agent, in other words, it can integrate all resource that been researched.

In result integration Agent, AL (algorithms base) = {result integration algorithms}, K (knowledge base) = {mission base, rule base}.

⑤Data mapping Agent [10]

By means of some mapping mechanism, the function of data mapping between heterogeneous databases is realized by data mapping Agent. The mission result will be mapped into the form that can be identified by users.

In data mapping Agent, AL (algorithms base) = {data mapping algorithms}, K (knowledge base) = {mission base, rule base}.

⑥Feedback Agent

The task of delivering results is done by feedback Agent.

In feedback Agent, AL (algorithms base) = {push algorithms, pop algorithms}, K (knowledge base) = {delivery memory base, result relation base, mission base, rule base}.

⑦Trust managing Agent [11]

Trust managing Agent is used to realize the dynamic management of user`s trust.

In feedback Agent, AL (algorithms base) = {trust calculation algorithms, comprehensive evaluation algorithms of dynamic trust}, K (knowledge base) = {dynamic trust base, relation base, mission base, rule base}.

Cooperation Mechanism for Interoperation of Information Systems

Cooperation mechanism is the description of the principle that all the Agents follow to cooperate with each other. In this paper, the cooperation mechanism is presented from aspects of communication, mission distribution, results delivery and safety control, in order to direct the achievement of interoperation.

(1) Communication mechanism [2~3]

The communication of the Agent is the basis of interaction between Agents. In this paper, the communication of the Agent is realized by the method based on the blackboard, in other words, a public workspace will be provided, where the Agents exchange information by the way that write and view information, as shown in Fig 5.

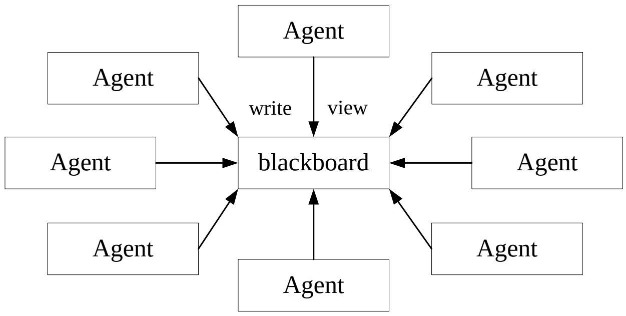

Fig 5 communication mechanism based on the blackboard

All the Agents can visit the blackboard, write or view according information. The format of the information is shown in Fig 6.

Identifier	Source Agent logo	License	Lifecycle	Content of the message

Fig 6 the format of the information

Identifier: The serial number of this message;

Source Agent logo: The identification of the Agent that creates the message (each Agent can only have the unique identification);

License: The delimitation of the Agents which can view this message;

Lifecycle: The delimitation of the time during which this message can be kept in the blackboard;

Content of the message: The concrete content of this message.

(2) Mission distribution mechanism [12]

The method based on contract net has been used here to achieve dynamic distribution of the mission. The process is shown below.

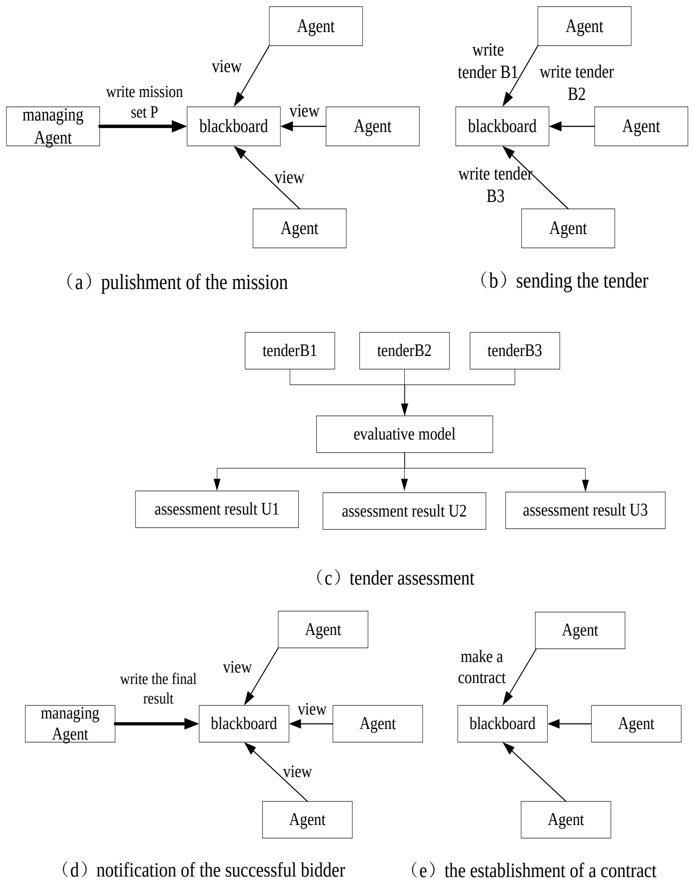

Fig 7 the process of distribution

Step1： Managing Agent writes set P into the blackboard. The set P is called mission set, P= {Xi}, in Which Xi=（N, A, T, C）, N is the code of the mission, A is the set of Agents which can carry out the mission, T is the generated time of the mission and C is the content of the mission.

Step2： Each Agent views the mission information from the blackboard and writes the tender Bi after judging their own capacity. Bi={R, C, Q, F}, R (restriction) is the time constraint, C (cost) is the cost for achieving the mission, Q (quality) is the quality of the result, F (free) is the working state of the Agent.

Step3： Assess the tenders according to the assessment model, choose one Agent as the successful bidder based on the assessment result Ui.

Step4： The managing Agent will publish the final result and the contract of the mission into the blackboard.

Step5： The successful bidder publishes the contract that it filled, which means a contract has been made.

(3) Coordination control mechanism

Redundant activities and control of the conflict in the coordination process can be realized through the development of coordination control mechanism, which contains the redundancy control mechanism, mandatory relationship control mechanism, Non-mandatory relationship control mechanism.

①Redundancy control mechanism

Step1： Finding the redundancy activities

Definition: P, Q, R are different mission sets.

```
P=(x1, x2…xm)
Q=(y1, y2...yn)
R= (z1, z2...zk)
 (int i,j,k=0
For ( i=1; i<=m; i++)
 (For (j=1; j<=n; j++)
If xi=yj
zk=xi
k++)
)
```

Set R is the set of redundancy activities.

Step2：Capacity assessment of the executive Agent

For the redundancy mission, the managing Agent will assess the capacity of the executive Agent in each mission, and find the optimal solution. Then the mission will be finished by this Agent.

Step3：Other Agents which have the same mission will make a delivery commitment to the optimal solution, waiting this Agent for finishing the mission and deliver the final result.

②mandatory relationship control mechanism

There is a mandatory relationship in the whole coordination process. For example, enable (x1, x2), only in the situation x1 is accomplished, x2 can be carried out. In this paper, the mandatory relationship is controlled by managing Agent, according to the mandatory relationship set contained in the knowledge base.

③Non-mandatory relationship control mechanism

When multiple mission requests are existed, for the reason that the capability of the interoperation platform is limited and the efficiency of the mission should be ensured, the order for executing the concurrent missions must be controlled.

In this paper, the level of the mission has been classified according to the real-time requirement of the information and the trust of the user. When the simultaneous mission requests occur, mission with a higher level can be firstly executed.

(4) Results Delivery mechanism

The mechanism provides that if the delivery commitment has been established, the mission view can be exchanged and the results of the missions can be delivered. This mechanism mainly be used by system Agent.

(5) Authorization control mechanism

This mechanism can realize the access control of users with different level. It is a flexible and scalable mechanism, which mainly based on the security level of information content, authentication of user`s identity and the calculation of user`s trust.

The mechanism consists of three aspects: information management, character and function management and identity authentication, as shown in Fig 8.

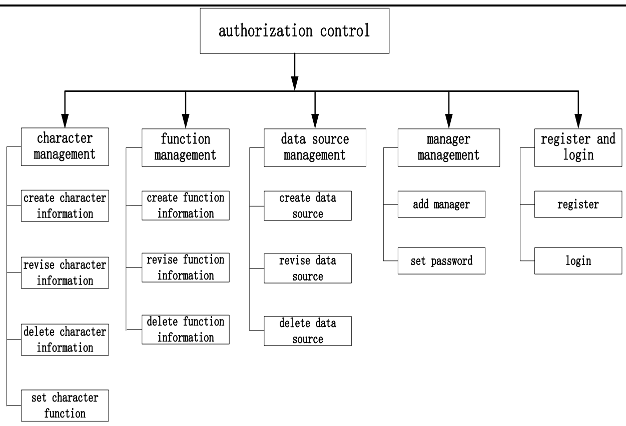

Fig 8 authorization control of interoperation

The process of interoperation is shown as Fig 9, it mainly contains 11 steps:

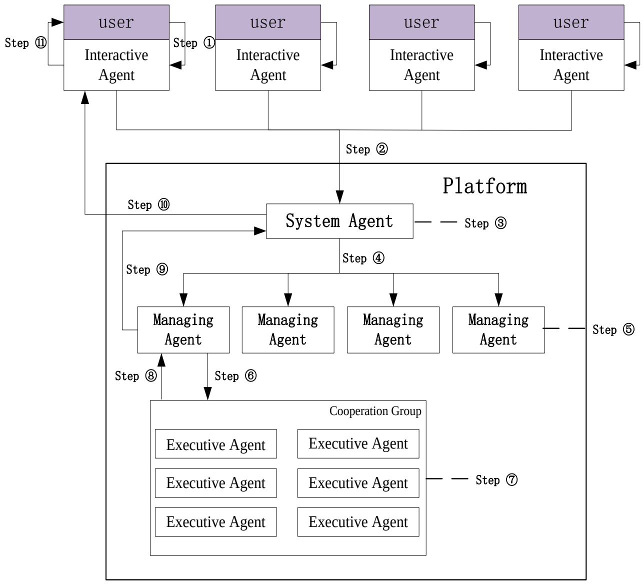

Fig 9 the process of interoperation

Results

Step ①: The users send the mission requests to the interactive Agent through the operation interface;

Step ②: The interactive Agent judges the user's role and verifies the identity of the user. If the verify fails, the interactive Agent will send the rejecting message to the user. If the verify is successful, the interactive Agent will send the request to the system Agent;

Step ③: The system Agent establishes the mission according to the mission request and the redundancy control mechanism;

Step ④: The system Agent distributes the mission to the managing Agent randomly. Then it will make a record of the mission and the serial number of the managing Agent that undertakes the mission;

Step ⑤: The managing Agent decomposes the mission and then a planning for achieving the mission will be made. A cooperation group will be established to manage the executive Agents that execute the mission together.

Step ⑥: The managing Agent distributes the decomposed mission to the executive Agent according to the mission distribution mechanism and the executive Agents that have signed the contract with the managing Agent will be added in the cooperation group;

Step ⑦: The executive Agents accomplish the mission according to the contract and make records of the mission;

Step ⑧: The final result of the mission will be delivered to the managing Agent;

Step ⑨: The managing Agent sends the result to the system Agent, and then, the cooperation group will be dissolved;

Step ⑩: The system Agent sends the result to the interactive Agent;

Step ⑪: The interactive Agent sends the result to the user through the operation interface, which means that the mission is over.

Discussion

In this paper, the key technology of the Information Systems interoperation is combined with the Agents: various types of Agents used in the process of interoperation have been defined. The application of the Mechanism has the following advantages:

Even if a great amount of information systems have participated in the interoperability, new systems that want to join in the interoperation can easily be put in by the way of installing interactive Agent and registering;

The process of interoperation can be expressed in the form of Agents and missions, the accomplishment of the missions are unitarily managed by a managing Agent, and all managing Agents are managed by unique system Agent. In this way the process of the interoperation shows a clear logic;

The optimized distribution of the missions can be realized by the dynamic distribution mechanism based on the contract net;

Certainly, with the continuous improvement of the computer technology, there must be a growth in the types and number of information systems that participate in the interoperation, which will leads to the result that the function of the interoperation platform will to enriched. In other words, the demand for performance and function will be increased, and more and more Agents with different function will be defined. How to solve the problem that the definition of new Agents and the large load of the Managing Agent caused by the great number of information systems interoperation has became the focus of the research.

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瑞士卢维茨堡火车隧道的应急管理研究

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systransis Ltd.，瑞士

【摘要】新建成的穿越瑞士阿尔卑斯山的单轨通道要求有针对紧急状况的新颖和精密的处理方案以及由 AdmiRail-AF 提供的基于铁路交通管理系统(TTC)的优化。TTC 在通道安全的全面保障上扮演着重要的角色。在此方面新 TTC 的重要特性包括设备监控，列车动作监控，警报处理以及使用 ETCS 倒车模式离开通道的列车自动逃生系统。TTC 的另一项重要特性是铁道交通的优化。通过对司机建议大大低于最高时速的最优速度，TTC 首先几乎完全避免了通道内列车的停顿，并因此增加了通道的整体安全性能。其次，该举措同时赢得了可观的时间和能量并因此对（司机的）稳定操作起到作用。

【关键词】Lötschberg Base Tunnel；火车操控中心；疏散；应急管理

EMERGENCY MANAGEMENT IN THE Swiss LÖTSCHBERG BASE RAILWAY TUNNEL

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Keywords

Lötschberg Base Tunnel, Train Control Centre, Evacuation, Emergency Management

Abstract

A long single-track line in a newly built tunnel through the Swiss Alps requires novel and sophisticated solutions for the handling of emergency situations and optimisation, which are provided by the Train Traffic Control system (TTC), AdmiRail®-AF. The TTC plays an important role in the provision of the overall safety for the tunnel. Important features of the novel TTC in this respect include the supervision of equipment, the supervision of train movement, the handling of alarms and the automatic evacuation of all trains out of the tunnel using ETCS reversing mode. Another important feature of the TTC is the optimization of train traffic. By proposing optimal speed – potentially well below the maximal one – to the driver the TTC firstly avoids almost all standstill cases of trains inside the tunnel and thus increases the overall safety of the tunnel, and secondly – not less important – it can gain a substantial amount of time and energy and hence it contributes to a stable operation.

Introduction

The new Lötschberg base tunnel (LBT) through the Swiss Alps is in operation since December 2007. The tunnel, which leads from Frutigen (Canton Bern) to Visp (Canton Valais), is 34.6 km long (see

Figure **1**). To reduce costs, it had been decided to equip the north half of the tunnel with a single-track line only. The tunnel is a high-speed line with a maximum speed of 250 km/h; therefore, cab-signalling is mandatory. The system supplied by Thales Rail Signalling Solutions is a radio-based system without line-side signals that is 100% compliant to the European Train Control System (ETCS) level-2 specifications (see [1] for details).

In Swiss mainline railways, the train traffic control and dispatching in regular operation is highly automated by means of Train Traffic Control systems (TTCs). Clearly, the expectations regarding traffic density and punctuality require at least the same degree of automation for the newly built tunnel. Hence the new TTC system forms an integral part of the signalling and train control equipment of the tunnel. The TTC system is supplied by Thales, while the software development had been subcontracted to systransis Ltd.

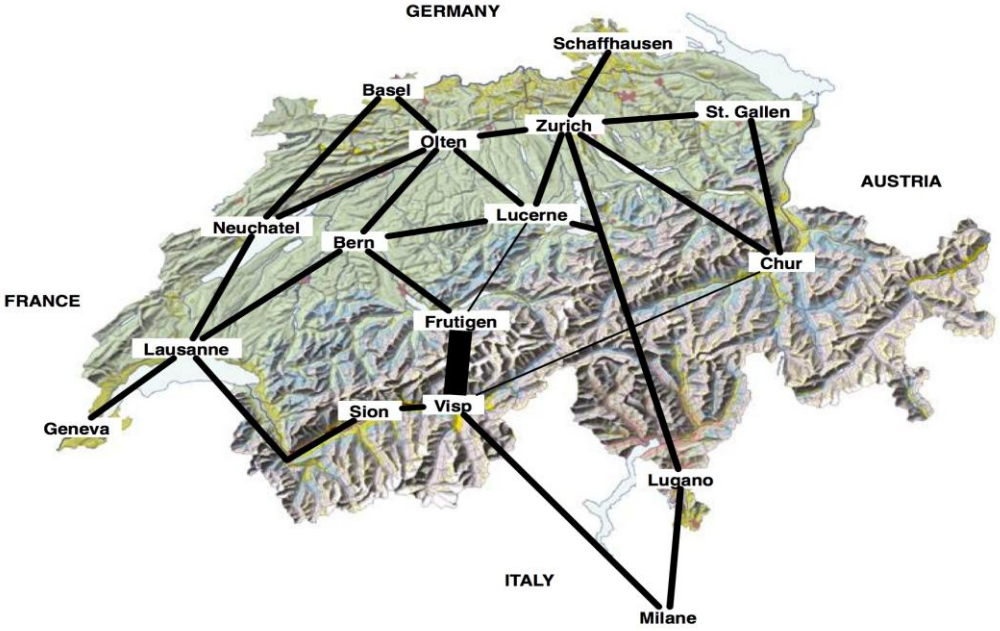

Figure 1: Location of the Lötschberg base tunnel (LBT) between Frutigen and Visp in Switzerland

As mentioned above, almost 20 km of the tunnel consist of a single-track line. Due to these specifics of the track layout, several new functional and integrative requirements were addressed in the design of new TTC. Innovative measures regarding the automatic dispatching of the trains and the control of their optimal speed were required [3].

In order to increase stability of operation and capacity, the TTC must provide automatic support for traffic optimisation and assistance to the dispatcher for the handling of critical events and alarm situations. The expected features of the TTC regarding the traffic control can be summarised as follows:

1. Provide stable, predictable traffic patterns according to the given scheduling plan.
2. In case of irregularities, minimize the exit delays, minimize stopping of trains in the tunnel, and optimize the speed of trains involved in conflicts in order to gain time.
3. Supervise equipment and train movements, such that potentially dangerous situations are identified as early as possible.
4. In case of emergencies, compute a scheduling plan, which shall lead all trains out of the tunnel as quickly and safely as possible.

The implementation of these demanding expectations asked for novel means. To our knowledge, this is the first system in a mainline rail system which makes use of the accurate odometry data provided by an European Train Control System (ETCS) [2] on Level-2 (radio-based control). The TTC receives train positions and speeds every 6 seconds from the ETCS Radio Block Centre (RBC). The TTC can influence the trains by transmitting a “Recommended Speed” through free-text messages of the ETCS, which are displayed on the onboard unit of the locomotive.

The novel tunnel required new procedures for emergency handling and the new technology imposes adaptations to the existing standard procedures. The contribution of systransis Ltd. was to develop, specify, in tight cooperation with the customer and the authorities, the new procedures and technical features supporting them, and implement them in the TTC.

During implementation of this novel TTC, it turned out that the challenges despite simple track topology are very substantial. The main challenge did not so much lie in the algorithmic aspects but much more in the integration of online data from many different heterogeneous and asynchronous sources and the overcoming of all possible cases of degradation of this highly complex system.

The following sections will explain the mechanisms for supervising train movement, and tunnel equipment. Then an emergency situation is shown, where the TTC is computing a new scheduling plan using reversal of train. And finally the underlying mechanisms for providing stable traffic patterns using speed optimisation are explained.

Principles of the Train Traffic Control System

In general, relatively little is known about feasible automatic approaches solving the aforementioned expectations in the context of an arbitrary railway network. The reason for the lack of practical application is manifold. One reason is that any optimisation in railway is not practically solvable in reasonable time, as the solution space is extremely large for an arbitrary topology, additionally the optimisation criteria is often unclear and generally difficult to formalise. Thanks to the simple track topology, however, semi-automatic solutions seemed promising and proofed feasible.

To implement the required functionality, the following principles are applied:

1. In general, the TTC dispatches the trains exactly – along the paths, according to the times, in the order – as specified by the scheduling plan. In other words, no automatic, unpredictable changes to the plan will be made, even in case of major delays.
2. The number of train routes automatically requested by the TTC fits the train properties. Fast trains or trains with bad brake characteristics tend to need more routes than slow trains or trains with very good brakes. Requesting too few routes must be avoided, as the train may unnecessarily be forced below the currently possible maximum speed. Requesting too many routes may lead to an overly long movement authority. Unexpected events or alarms may necessitate the shortening of a movement authority in the latter case, which in turn may lead to emergency brake applications – highly undesirable in such a long tunnel.

3. The TTC computes a forecast of passing times of each train. Based on these predictions the TTC detects conflicts, i.e., it observes the fact that one train will obstruct a second train, because the first train will release a certain track element too late, and hence the second train cannot travel according the currently defined scheduling plan. For those trains involved in conflicts, the TTC computes an optimal speed curve, which may be well below the maximal one. The optimal speed is then transmitted to the driver.

4. The TCC supervises many states of tunnel equipment elements (e.g. Battery operation mode of some critical equipment, fire detection sensors, etc.) As soon as such element's state is changing into an unexpected state the TTC reports this event to the operator in form of warnings or alarm proposals depending on the severity of the unexpected event.

5. The TCC supervises the train movement. E.g. as soon as the observed speed of a train falls outside of the tolerated band, or when some expected events, such as route reservation or route releasing don't occur within supervised time interval, the TCC issues a warning or an alarm to the operator.

Supervision and Alarm Handling

The length of the tunnel, as well as the long single-track section, results in a series of complex questions regarding the safety of operations, particularly in the case of critical events, such as fires. The overall safety concept allocates the TTC a substantial range of responsibility in the area of supervision of equipment and trains, as well as in the alarm handling. The considered objects include a vast amount of tunnel equipment which is not directly related to railway safety in the classical sense, such as fire alarms, pressure sensors, mountain water flow meters, various types of doors, etc. In order to facilitate communications between the TTC and this type of equipment, an interface to the tunnel control system (TCS) has been designed, which focuses on those data and commands relevant for the railway operation.

The list of equipment taken into account for supervising and alarming is quite long. It includes:

- Sections of the high voltage train power supply
- Optional neutral section of the high voltage train power supply
- Tunnel doors, that are orthogonal to tracks and close off sections of the tunnel for maintenance
- Sliding doors (see Figure 2), that close off equipment cabinets and places of safety
- The interlockings and objects controlled by it (e.g. position of switches, connection to interlocking, etc.)
- The RBC and its controlled objects (e.g. trains, temporary speed restrictions, etc.)
- The TCS and objects controlled by it (e.g. Smoke- and Fire detection, Battery-operation of critical elements, etc.)

Supervision of expected states

A vast amount of discussion between suppliers, operators and the authorities, and went into clarifying and specifying the automatic reactions with which the TTC should respond to unexpected state changes. As an example, suppose that some maintenance personnel working in an equipment cabinet operated the handle of the sliding door depicted in Figure 2. The TCS will report the new state of the sliding door (as "Door unlocked") to the TTC. The TTC immediately issues a warning to the operator and installs temporary speed restrictions of 40 km/h along the "unlocked Door". The operator can now decide whether to escalate the warning into an alarm maybe after contacting and talking to the maintenance personnel on-site.

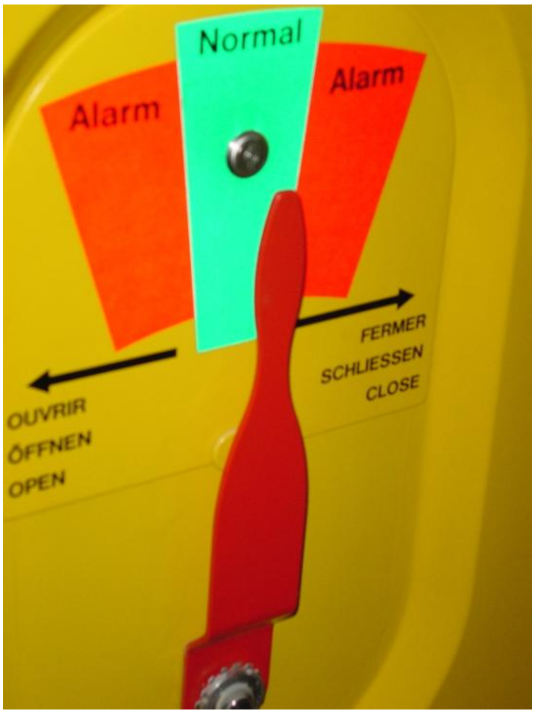

Figure 2: Example of tunnel equipment taken into account for alarming by TTC: lock of sliding doors closing off equipment and places of safety

Supervision of Trains

Special attention is given to the supervision of trains in two respects.

Permission to enter tunnel: Firstly, the TTC has to give each train an explicit permission to enter the tunnel automatically – the TTC checks the plausibility of train data reported by several data sources. In the regular state, the entrances to the tunnel are closed off by direction-dependent interdictions, which are implemented in the interlockings but controllable by the TTC. These interdictions prevent the interlocking from automatically setting regular train routes in one direction only. In other words, this direction-dependent interdiction controls the entrance such that trains may not enter the tunnel automatically but can leave the tunnel. A direction-dependent interdiction at a tunnel entrance is only temporarily removed if all of the following conditions are met:

- According to the scheduling plan, a train is supposed to enter by this track and the train is close enough to the tunnel.
- The train is reported to be connected to the RBC and hence capable of using an ETCS Level-2 line.
- This train has passed a train data consistency check, which includes the comparison of data provided by the OBU and by the nation-wide train data supplying system.
- The train will not cause a deadlock in the tunnel.
- There is no alarm situation.

The direction-dependent interdiction is put back as soon as the commissioning of the train route at the entrance is observed by the TTC. In this manner, the entrance is immediately blocked for subsequent trains.

Again, the TTC reports by means of immediate control of the interdictions at the tunnel entry and by warnings to the dispatcher, that some train data reported from surrounding systems inhibit further smooth operations, and it is up to the operator in charge to take appropriate measures.

Speed Supervision: Secondly, the TTC supervises a speed for each train in the tunnel in order to detect trains with technical problems in an early stage. There is a long list of rules, which identify suspicious train movement, amongst which the following:

- When a train falls below a minimal speed
- When a train stops too far away from its end of authority
- When a train fails to accelerate if allowed to do so, an alarm is issued for this train.

The rules are designed in a relatively flexible manner to prevent false alarms and to take into account the differences in the driver behaviour. As an example see Figure 3: As soon as a train leaves the area of tolerated speeds, the TTC starts a timer. The TTC escalates the reporting depending on how long the train's speed violates the "band of tolerated speeds": First, by a message to the driver and operator, then by a warning to the operator and finally by an alarm proposal to the operator. Again, the TTC issues some immediate reactions, such that the operator wins some time for his/her decision-making. After all, the dispatcher in charge has different possibilities to tackle the situation reaching from "ignoring the warning" up to "declaring Alarm in the tunnel".

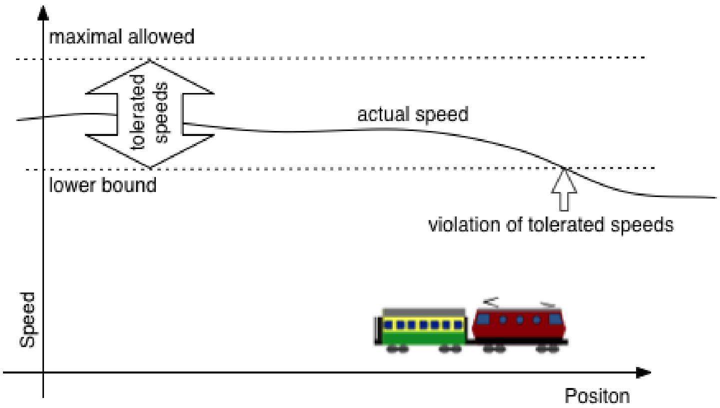

Figure 3: Speed supervision of each train

Classification of Alarms

In general, the TTC recognises degraded states of each object. The specification of degraded modes depends on the type of equipment. For instance, interlockings are supervised to ensure that a regular exchange of heartbeat is possible and that train routes can be commissioned and are released in time. It has to be stated that in addition certain objects are supervised by the interlockings directly, such as open tunnel doors. In this manner hazards that may cause direct danger to train traffic are excluded with SIL-4.

Aberrations from the normal state are reported to the dispatcher. There are several levels of severity:

1. **Alarm Serious Event:** Imminent danger for persons in the tunnel, clear tunnel as fast as possible
2. **Alarm Non-serious Event:** No imminent danger for persons in tunnel, but longer disruption of service has to be expected. Not all trains may be able to clear tunnel forward in a regular way.
3. **Alarm Technical:** No danger, trains can leave tunnel in a regular manner.
4. **Warning:** No immediate impact on train operation.

There is a well-defined allocation of degraded equipment states to alarm categories. In any case, in order not to overly reduce the availability of the tunnel to regular operations, the dispatcher has to confirm the issuing of any alarm. The same principle applies to reactions to state changes and revocations of alarms.

Automatic Reactions to Alarms

Depending on the level of the alarm there is a well-defined set of automatic standard reactions. These include:

- Reporting the alarm to the TCS, which will forward it to the authorities

- Closing of the tunnel for any further automatic train entrance
- Closing off affected areas (problem zones)
- Not extending existing allocated routes for trains heading towards problem zones
- After the dispatcher's decision: Computing and automatically executing a new scheduling plan to clear the tunnel from trains as fast as possible.

  This last automatic reaction is quite revolutionary indeed. It includes the use of the ETCS Reverse Mode. The algorithm, which computes the new scheduling plan, decides for each train whether it shall be cleared forwards or backwards. Hereby certain priority rules apply. The goal of this concept is to remove every train from the tunnel within the time within which the equipment is generally considered to be fire resistant.

Additionally, depending on the cause for warnings or for an alarm, there are particular automatic reactions pertaining to the peculiar situation, such the setting of speed restrictions in case of unlocked sliding doors as explained above.

Rescheduling in Severe Emergencies

In case of an emergency situation, it is the goal to safely guide all trains out of the tunnel. A single impassable track, which is in the single-track section of the tunnel and ahead of a train already prevents the forward-evacuation of at least this train. Therefore, the automatic evacuation must be able to evacuate trains by using the ETCS reversing mode.

In case of an emergency, the dispatcher manually defines either a fixed region of the tunnel as the “problem zone” or a specific train as the “alarm train”. As an alternative, the TCS can report an alarm state. The dispatcher can initiate the evacuation, without the need of prior alarm definition.

Rescheduling in case of a tunnel evacuation is structured into the following phases, which are detailed in the following sections:

1. Keep trains away from the problem zone (where possible)
2. Transform the current operational schedule into an evacuation schedule, which must ensure specific conditions for the evacuation
3. Guide trains out of the tunnel according to the evacuation schedule

Keep trains away from the problem zone

This goal is achieved by ceasing to request routes for trains that are heading against the problem zone. As a consequence, such trains are stopped by the OBU at their End of Authority. In addition, direction-dependent interdictions prevent trains outside of the tunnel from entering the controlled area and thereby further increasing the risk potential of the situation.

Transformation of the operational schedule into an evacuation schedule

The algorithms classify trains as follows:

1. Trains, which can be evacuated in forward direction.
2. Trains, which must be reversed.
3. Trains, which cannot be evacuated.

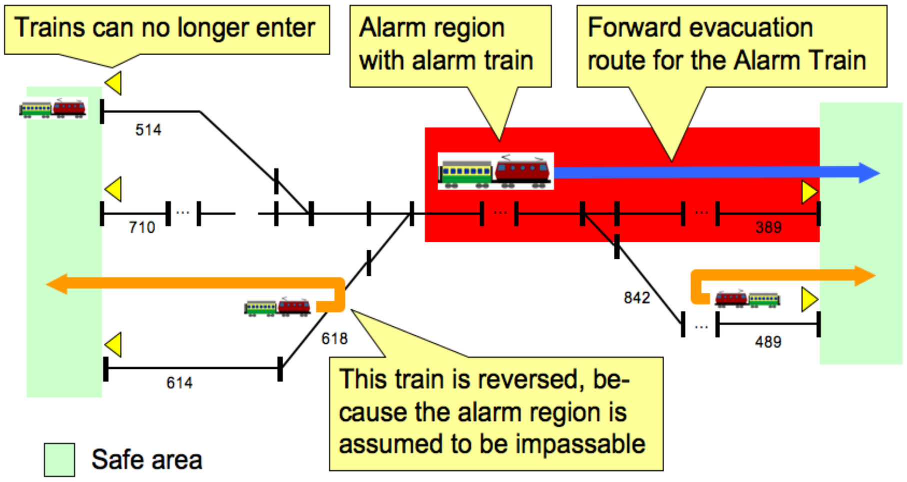

Figure 4: Example of an evacuation schedule in the case in which the alarm train is on the single track line.

Although the train schedule is deadlock-free in regular situations, the occurrence of an impassable problem zone might immediately cause a deadlock within the tunnel. Hence there are indeed worst cases in which a train cannot be evacuated at all. In this case there are rescue-road accesses by which passengers still could be evacuated.

The decisions on how to evacuate trains are made as follows:

1. The alarm train, if there is one, is always evacuated in forward direction (in addition, it is evacuated as the last train).
2. Trains cannot be evacuated through an "impassable" section. A section is "impassable" in the following cases:

a. There is an active interdiction or a direction-dependent interdiction (by selectively adding/removing interdictions/direction-dependent interdictions, the train dispatcher can directly influence the generated evacuation schedule)

b. A problem zone covers the section

c. The alarm train covers the section

3. A train can be evacuated in forward direction if there is a path from its current location and the tunnel exit in forward direction without any problem zone on it (including the potential problem zone caused by the alarm train, if any). It is assumed that all trains lying ahead of the train under consideration – including the one train having no further trains in front of itself – can be evacuated in forward direction, thereby subsequently freeing a path for their succeeding train.
4. The same principle also applies for the possibility of reverse evacuation.
5. Forward evacuation is always preferred if it is feasible.
6. Additional rules ensure e.g. that no train passes a problem zone in the opposite tunnel tube later than a specific delay after the start of the tunnel evacuation.

As soon as the evacuation direction of each train is determined, the details of the evacuation schedule are computed. Later on, there are no attempts to adapt it to possible new evolvements of the situation. Yet, the dispatcher can always adapt it manually.

Guiding trains out of the tunnel according to the evacuation schedule

The system ensures, as far as possible, that the alarm train always has a secured headway to drive at speed 80 km/h. For trains that are evacuated forward, forward evacuation routes are requested. Trains, are planned for reversal, are stopped by not prolonging their End of Authority. As soon as the train comes to standstill, reversing routes are requested for it and the driver is requested to confirm the reversing mode on his DMI. With a maximum of 80 km/h, he can then drive “backwards” out of the tunnel. As soon as the train reaches the tunnel borders, the neighbouring TTC requests reversing routes according to a set of pre-defined evacuation paths.

In case of an evacuation (and in some other degraded situations), the following information is transmitted to engine drivers:

1. As the train moves, the position of emergency stopping locations (where people could be evacuated by rescue-roads) is periodically announced to the engine driver via the DMI.
2. Engine drivers in the geographic area around the tunnel are informed via GSM-R voice, that there is a serious problem in the tunnel.

By this procedure shown above, it is expected to provide a strategy to master each situation with some standardised means.

Conclusion

An overview of the rescheduling strategies in regular and emergency operation of the Lötschberg Base Tunnel was given. Although its track layout is quite simple, it still turns out to be very challenging to provide a stable real-time optimisation, which is capable of coping with all issues caused by potential shortcomings of the underlying online-data. The system is, however, in regular operation since December 2007 and proofs its capability of taking decisions and optimising train speeds daily, thereby contributing to an increase of capacity and stability on the overall system.

In an additional set of novel functionality, AdmiRail®-AF, the Lötschberg TTC, implements many functions for alleviating the management of incidents of higher severity. In this area, as usual, the fine line between providing the required level of safety and availability had to be approached as best as possible. In extended discussions and testing scenarios, those equipment failures had to be identified which require immediate automatic action in train operation, and those excluded which are not immediately relevant and would unnecessarily restrict the availability. The quintessential principle is that the automatic responses of the system should initiate the obvious immediate actions, thereby giving some time to the dispatcher in charge for analysing the situation and react appropriately. Let's hope, that many of these functions will never be needed in real emergency situations. However, the managed incidents in numerous testing exercises, that have been conducted, proofed the feasibility and usefulness of the applied principles.

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Author Biography

Dr. Erwin Achermann, born 1968 finished his PhD at ETH in 2002. He works for systransis Ltd. since 2004, mainly in the development of the TTC software.

Dr. Markus Montigel, born 1961 finished his PhD at ETH in 1994. He was a professor at the University of New Orleans. He has extensive expertise in the fields of railway and safety applications. He is the CEO and founder of systransis Ltd.

全国路网管理与应急处置中心奥运期间路况信息保障服务

汤筠筠

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【摘要】21 世纪以来,伴随着全球工业化进程,在经济快速发展的同时,重大公共事件处置对路况信息的需求日益凸现，在 2008 年 8 月的北京奥运会中，奥运快速通道路况信息在确保奥运会运输及安全保障中发挥了重要作用。本文针对此次重大事件，详细介绍全国路网管理与应急处置中心路况信息保障服务的情况，并讨论其存在的问题及处置建议。

【关键词】路网管理；应急；路况信息保障

TRAFFIC INFORMATION SAFEGUARDS SERVICES PROVIDED BY NATIONAL HIGHWAY NETWORK MANAGEMENT AND EMERGENCY CENTRE DURING BEIJING OLYMPIC GAMES

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Keywords

Highway network management; Emergency; Traffic information safeguards

Abstract

From the 21st century, accompanying with global industrialization, and rapid development of economy, the demand for traffic information has keep rising in the course of treating major public events. During the Beijing Olympic Games in August 2008, the traffic information of “Olympic rapid highways” played an important role in ensuring safe transport in Olympic Games. Aiming at this event, this paper details on the situation of traffic information safeguards services of National Highway Network Management and Emergency Centre in China, and discusses the existing problems and dealing suggestions of the centre.

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Sections

For research papers, sections should include: Introduction, Theory and Method, Results, and Discussion.

For best practice papers, sections should include: Introduction, Thesis, Sources of information, Findings and Discussion.

Introduction

Chinese highway network that expressway mileage totaled 53,000 kilometers during 2008 played an whole and irreplaceable role to the national economy and social development. So far as Beijing Olympic Games was concerned, it was important to ensure the highway transportation, and provide prompt and effective traffic information for all social sectors. These were both important emergency management means to ensure the national highway network operating in an orderly, coordinated and highly efficient way, and played major roles in holding the Olympic Games successfully. Therefore, taking Beijing Olympic Games for instance, this paper introduces traffic information safeguards services for major public events provided by National Highway Network Management and Emergency Centre(NHNMEC) in China.

Beijing Olympic Games in 2008

During Beijing Olympic Games, for improving and fostering emergency mechanism of major public events, Ministry of Transport(MOT) opened 12 “Olympic rapid highways” with a total length of about 1400 km via 6 provinces and cities, and set up “Olympic special passageways” at toll stations along the 12 highways in order that Olympic vehicles had priority over other traffic, and passed without obstructions. To prepare for traffic information safeguards services for Olympic Games, and improve the monitoring and warning for ‘Olympic rapid highways’ and the dissemination of traveling information, NHNMEC established emergency duty system of major public events from August 7 in 2008, and arranged staff to be on duty for 24 hours. From then on, NHNMEC began a 44-day Olympic emergency services, which provided especially traffic information of ‘Olympic rapid highways’ in Beijing, Shanghai, Qingdao, Shenyang and other Olympic cities for MOT, guaranteed ‘Olympic rapid highways’ unblocked, dealt rapidly with unexpected events. Traffic information safeguards services during Olympic Games include:

Operate ‘Olympic rapid highways’ video monitoring system

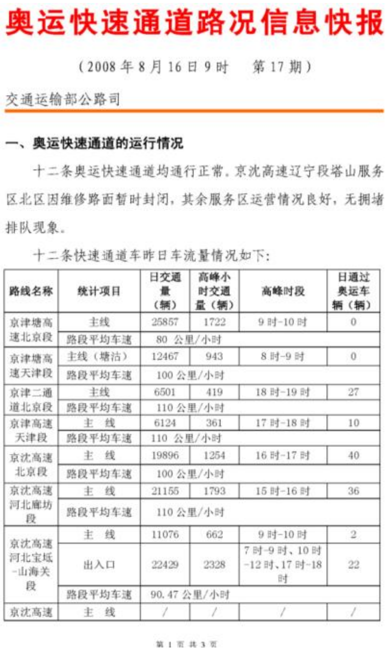
During Beijing Olympic Games, NHNMEC could view real-time traffic information of Beijing Transport Committee, Shanghai Municipal Engineering Administration, and Shandong Traffic Communication Information Center, and accomplish to monitor the operating status of ‘Olympic rapid highways’. Besides, the centre also could show the real-time video of Jingshen expressway, Jingshun highway, two long-distance bus stations in Beijing, and GPS information service system in Shandong, which accomplish to show the conditions of traffic information, security check and Olympic service vehicles.

Tab 1. Traffic information of Jingjintang expressway during Olympic Games

Make traffic information express newspapers of ‘Olympic rapid highways’

Up to September 20 in 2008, NHNMEC completed 76 traffic information express newspapers of 'Olympic rapid highways', which included traffic conditions of 12 'Olympic rapid highways' and national road 112, service areas, traffic control in 24 hours, daily traffic of every highway, peak hour flow, peak time, and Olympic vehicles of a day. MOT submitted promptly traffic information express newspapers of 'Olympic rapid highways' to the State Council twice a day in order that the higher organizations knew rapidly the traffic information of 'Olympic rapid highways' and made emergency decision for unexpected events in time.

Tab 2. Traffic information express newspapers of 'Olympic rapid highways'



奥运快速通道路况信息快报

（2008 年 8 月 16 日 9 时　第 17 期）

交通运输部公路司

一、奥运快速通道的运行情况

十二条奥运快速通道均通行正常。京沈高速辽宁段塔山服务区北区因维修路面暂时封闭，其余服务区运营情况良好，无拥堵排队现象。

十二条快速通道车昨日车流量情况如下：

路线名称	统计项目	日交通量（辆）	高峰小时交通量（辆）	高峰时段	日通过奥运车辆（辆）
京津塘高速北京段	主线	25857	1722	9 时-10 时	0
	路段平均车速	80 公里/小时			
京津塘高速天津段	主线（塘沽）	12467	943	8 时-9 时	0
	路段平均车速	100 公里/小时			
京津二通道北京段	主线	6501	419	18 时-19 时	27
	路段平均车速	110 公里/小时			
京津高速天津段	主　线	6124	361	17 时-18 时	10
	路段平均车速	110 公里/小时			
京沈高速北京段	主　线	19896	1254	16 时-17 时	40
	路段平均车速	100 公里/小时			
京沈高速河北廊坊段	主　线	21155	1793	15 时-16 时	36
	路段平均车速	110 公里/小时			
京沈高速河北宝坻-山海关段	主　线	11076	662	9 时-10 时	2
	出入口	22429	2328	7 时-9 时、10 时-12 时、17 时-18 时	22
	路段平均车速	90.47 公里/小时			
京沈高速	主　线	/	/	/	/

第 1 页 共 3 页

Traffic information service system of 'Olympic rapid highways'

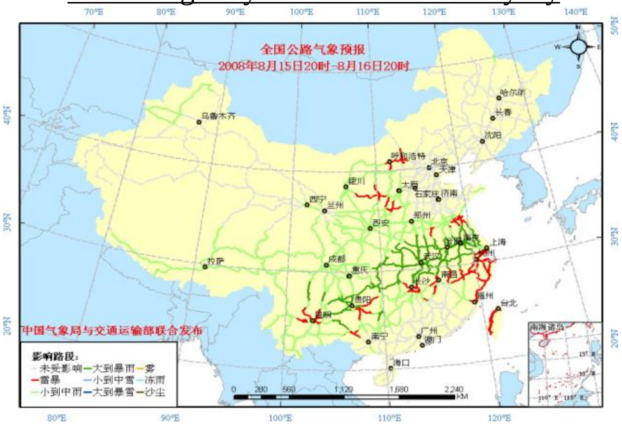
To protect public safe traveling and transporting during Olympic Games, NHNMEC opened traffic information service system of 'Olympic rapid highways' for 24 hour service, which issued dynamically traffic conditions of 12 "Olympic rapid highways" on the government web. In addition, the government web also includes the existing traffic information submitting system of national trunk highways and highway weather forecast and warning system, and issues timely traffic traveling service information, which all make the public to learn the traffic conditions of 'Olympic rapid highways' and national trunk highways more convenient.

Tab 3. Traffic information service system of 'Olympic rapid highways'

Highway weather forcast

During Olympic Games, NHNMEC further strengthened cooperation with meteorological fields, which were to develop highway weather forcasting consultation and warning joint issuing mechanism, and issue highway weather information timely, in order to do traffic information safeguards services well.

Tab 4. Highway weather forcast everyday



Existing problems and dealing suggestions

Now, the Beijing Olympic Games have been held for a year, and NHNMEC has successfully developed China Highway information service, traffic information management system, highway weather forecast and warning system, highway database and electronic map system and highway video system. Among them, highway video system has been connected to 16 provinces and cities, which realizes primarily the functions of monitoring the dynamic operation of national highway network and emergency consultation.

The next stage, NHNMEC will speed up to upload the highway video, acquire dynamic data of highway network, construct synthetical management information platform, and integrat with existing operating system, which will form synthetical information platform to deal with the daily management, contingencies, as well as travel services of the highway network, and realize data docking and resource sharing with the provincial platform.

Improve transportation emergency preplan system and operational mechanism

Nowadays, transportation emergency preplan system is lack of some special preplans to unexpected events, public events, etc. At the same time, the system has no concrete measures and strong operability. This paper proposes to establish a coordination agency composed of transportation, police, meteorology, army and medical care, which is responsible for unified arrangements, command rescue, post-disaster reconstruction work and drawing up supportive instructions for disposing unexpected public events to national highway network.

Speed up the advancement of the construction of NHNMEC, and enhance emergency capabilities for transportation

Nowadays, NHNMEC doesn't accomplish the purpose of sharing information and network management. Thus, the centre should achieve capabilities as follows: strengthen data monitoring, forcasting and warning, information report and announcement, and emergency command and control; construct information transmission and data management mechanism, and match Management Methods and measures of highway network management and emergency disposal; make technical standards and rules of sharing information and data exchange of national highways.

Establish a unified national highway service window

It is important to establish a unified national highway service window for external propaganda, public consultation and transportation management. To make use of the information from highway network management platform, NHNMEC issues the traffic information by means of newspaper, mobile phone text messages, VMS, radio and Television. The functions and contents of government web should be further optimized, and the service field of it should be also broadened accordingly.

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火车站乘客应急疏散时间研究

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中国铁道科学研究院

【摘要】在中国，火车站作为一个大型的公共场所，聚集了数以千计的旅客并拥有复杂的逃生路径。同时因为存放了大量包裹使得火灾变得相当危险，基于此原因，研究人类逃生时间拥有理论与实践的共同意义。根据站内的火灾逃生路径，我们在分析了大量国内外文献的基础上建立了静态和动态的网络流模型。我们计算了各种逃生策略和旅客数量条件下的逃生时间并得出相应结论，本文将为车站应急预案的制定提供充分信息。

【关键词】火车站；应急疏散；网络流动模型

STUDY ON PASSENGER'S EMERGENCY EVACUATION TIME IN RAILWAY STATION

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China Academy of Railway Science, China[5]

Keywords

Railway station; Emergency Evacuation; network flow model

Abstract

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Railway station is a large public place in china, accumulated with thousands of passengers and having complex evacuation routes. It is every dangerous in case of fire because there are so many baggage. So, there are theoretical and practical significance to study the human emergency evacuation time. Based on the evacuation flow routes inside the station, we established the static and dynamic network flow models through analysis amount of literatures home and abroad. Then we calculated the evacuation time at different evacuation strategies and different number of passengers and got relate conclusions. This study can provide useful information for making station emergency plan.

Introduction

Railway station is a crowded place, large amount of passengers gathered here, especially in the Spring Festival or the Golden Weeks. Besides that, there are a large amount of luggage bags and most of them are flammable. They will cause heavy casualties and huge property losses in case of fire. We can develop effective emergency plan through studying emergency evacuation time (Bao Lukun, Bao Jingjing, 2008).

This paper is organized as follows. we studies the literature at home and abroad and analysis their application scope in Section 2; then we established the static and dynamic network flow model based on a common station in Section 3; in section 4, we simulated the emergency evacuation time using different model at different conditions and got the corresponding results. In the last Section, we introduce some issues related to section 4 and draw some conclusions.

Literature Review

Fire emergency evacuation total time includes fire detection time, passengers' pre-action time and the evacuation time. It is hard to calculate fire detection and passengers' pre-action time because they are influenced by alarm equipments' performance and passengers' behavior. So, this paper we only calculate the passengers' evacuation time (Fan Weicheng, Sun Jinhua, Lu Shouxiang, 2004).

At home and abroad, these literatures mainly focused on developing model and the use of computer simulation for large-scale public places emergency evacuation. The evacuation model can be divided into two types: the macro model and micro model.

In micro-models, the building was divided into many smaller grids to definite the individual's location, and every person occupies a small grid at any time. The person can only move from one grid to its neighbouring grids (Xu Gao, 2003; Cecelia Wright Brown., 2005; Pan Zhong,Wang ChangPo,Xie Buying.,2006). Micro-models are good at describing individual's behavior and trajectories during the emergency evacuation, and it's have high accuracy in calculating passengers' emergency evacuation time. But, it is difficult to find the evacuation bottlenecks because micro-models cannot simulate congestions. Besides that, it is time consuming to calculate emergency evacuation time for large public places due to the large amount of grids.

However, passengers' evacuation can be seen as network flow in Macro-Models. Network flow model is a mathematical model based on graph theories. It does not take into account the passengers' behavior. The places accumulated with large amounts of passengers can be seen as source codes, the exit can be described as destination nodes and the corridors can be described as arcs (Wang Zheng,Liu Mao.,2006; Stoko Mamada, Kazuhisa Makino, Takashi Takabatake, Satoru Fujishige.,2003). Macro-Models are good at description of passengers' evacuation over time. It has high efficiency calculating the evacuation time for large place.

Theory and Method

As network flow models are applicable for large public place, especially for the buildings having complex passageways. In this paper, we calculate passenger's evacuation time using static and dynamic network flow modes.

Based on network flow models, the waiting rooms, halls can be seen as sources nodes which having capacity limit, the aisle, corridors can be seen as arcs and the exits can be seen as destination nodes. All destination nodes can be connected as an artificial node; this node is the final destination. As the waiting rooms and corridors have max capacity, so the passenger number must less than their max capacity in any time. Each arc has a time property which represents passengers' evacuation time from the two nodes connected by this arc. Besides that, an arc has a max capacity which represents the max passengers can evacuate through this arc in a fixed time. Of course, the max capacity and the time property may be different over time. Therefore, the passenger emergency evacuation problem can be described as a multi-source and a single destination network flow problem.

Fig.1 is the plane diagram of a station, according to passengers' emergency evacuation route; the evacuation problem can be described as network flow mode that is shown in Fig. 2.

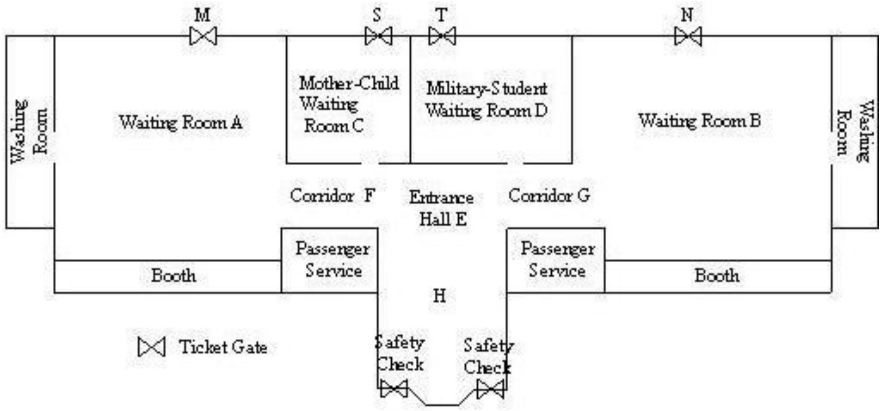

Fig. 1. Common station's plane diagram

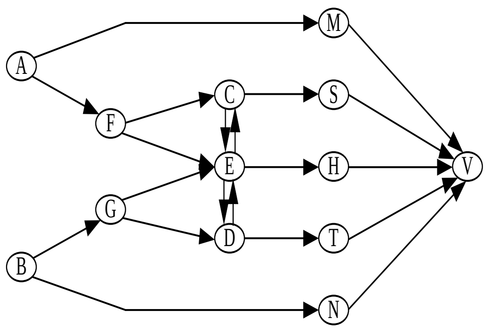

Fig. 2. Emergency evacuation network flow diagram

As can be seen from Fig.2, passengers at waiting room *A* can go through the ticket gate *M* directly evacuated to the safe area *V*, or they can evacuate to the hall *E* through corridor *F* and then arrive to safe area *V*. If the hall *E* has high density, passengers at waiting room *A* can also get into mother-child waiting room *C* through corridor *F* and than evacuated to safety area *V* through ticket gate *S*. Mother-child waiting room *C*, military-students waiting room *D* and the hall *E* can flow with each other if there are density imbalances. Where *V* is the artificial node represents a safety place outside the station house.

Static Network Model: Suppose the network $G = (N, A)$ is a static network, *N* is the collection of nodes and *A* is the collection of arcs. Among them $N=(S, D)$, *D* represents the destination node and *S* represents the nodes except for the destination node *D*. Each node has a maximum capacity of C_i and an initial number of people I_i. *T* is the total time of all passengers evacuated to safety areas. Each arc (i, j) has a time propertyλ_{ij} and a max evacuate capacity u_{ij}. λ_{ij} represents the evacuate time from node *i* to node *j* and this arc can evacuate the maximum passengers is u_{ij} in a given timeλ_{ij}. Mathematically described as follows:

$$Minimize \quad T \qquad (1)$$

$$st \begin{cases} \sum_{t=0}^{T} \sum_{m} x_{mi} + I_i = \sum_{t=0}^{T} \sum_{n} x_{in} \qquad \forall i \in S & (2) \\ \sum_{i \in S} I_i = \sum_{t=0}^{T} \sum_{j \in S} x_{jD} & (3) \\ \sum_{j} x_{ji}(t) + y_i(t) \le C_i & (4) \\ 0 \le x_{ij}(t) \le u_{ij} \qquad \forall (i, j) \in A & (5) \end{cases}$$

Variables $x_{ij}(t)$ represent the amount of passengers on the arc (i, j) at time *t* and $y_i(t)$ represent the amount of passengers at node *i* at time *t*; where equation (2) explains the flow conservation at no destination nodes; equation (3) shows that the total network flow conservation; formula (4) guarantee the node max capacity constraints at any time; formula (5) ensure the arc max capacity flow restrictions at any time.

Dynamic Network Model: There are many shortcomings using the static network flow model to simulate passenger emergency evacuation in the station fire emergency evacuation. In static network flow model, the maximum capacity of nodes and arcs is not change over time. But, in reality, those properties changed over the evacuation process. For example, the maximum capacity of halls will be decreased as the smoke spread to the halls. Besides that, the evacuation speed will be affected too. Therefore, it is necessary to improve the static network flow model to dynamic network flow model for a better describing the evacuation process.

Suppose the network $G=(N, A)$ is a dynamic network, *N* is the collection of nodes and *A* is the collection of arcs. Among them $N=(S, D)$, *D* behalf of the evacuation destination and *S* represents the nodes except for the destination node. Each node has a dynamic maximum capacity of $C_i(t)$ and an initial number of people I_i. *T* is the total time of all passengers evacuated to safety areas. Each arc (i, j) has a dynamic time propertyλ_{ij} and a dynamic max evacuate capacity $u_{ij}(t)$. λ_{ij} represents the evacuate time from node *i* to node *j* and this arc can evacuate the maximum passengers is $u_{ij}(t)$ at time *t*. Mathematically described as follows:

$$Minimize \quad T \qquad (6)$$

$$st \begin{cases} \sum_{t=0}^{T} \sum_{j \in S} x_{ji}(t) + I_i = \sum_{t=0}^{T} \sum_{j \in S} x_{ij}(t) & \forall i \in S \qquad (7) \\ \sum_{i \in S} I_i = \sum_{t=0}^{T} \sum_{j \in s} x_{jD} & \qquad (8) \\ y_i(t) \le C_i(t) & \forall t \in T \qquad (9) \\ 0 \le x_{ij}(t) \le u_{ij}(t) & \forall (i, j) \in A \quad \forall t \in T \qquad (10) \end{cases}$$

Variables $x_{ij}(t)$ represent the amount of passengers on the arc (i, j) at time t and $y_i(t)$ represent the amount of passengers in node i at time t; where equation (7) explains the flow conservation at no destination nodes; equation (8) shows that the total network flow conservation; formula (9) guarantee the node max capacity constraints at any time; formula (10) ensure the arc max capacity flow restrictions at any time.

Simulation Results

Based on the models on section 3, all the passengers evacuated to the safety area is a fastest network flow problem. It can be described as all the passengers at the non destination nodes flow to the destination node the sooner the better with the capacity constraints of nodes and arcs. It is time consuming to solve this problem using conventional method. In this paper, we calculate the approximate emergency evacuation time using computer simulation. The simulation is over until all passengers at non-destination nodes evacuated to the destination node. Following, we give out the simulating results only omitting the properties of nodes and arcs because of page limit.

Simulating Using Different Evacuation Strategies: Strategy A: in the evacuation process, we close the entrance of mother-child waiting room C and military-students waiting room D to prohibit the passengers' free flow at mother-child waiting room, military-students waiting room and the hall, that is to say passengers at nodes C, D and E cannot flow from one place to another freely. Strategy B: in the evacuation process, the entrances of mother-child waiting room C and military-students waiting room D is always opened, that is to say passengers at C, D and E can flow freely based on the passengers' densities.

At the condition of every node and arc have the same property; using static network flow model, we get the "evacuation time - evacuated passenger" curves Fig 3 and Fig 4. Where the evacuation time at Evacuation strategy A is 432s and evacuation strategy B is 324s.

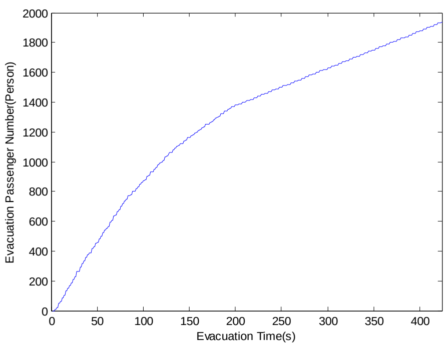

Fig. 3. evacuation time-evacuated

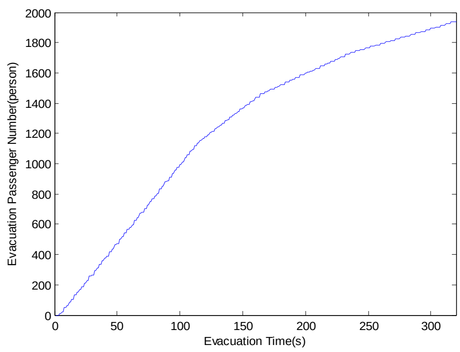

Fig. 4. evacuation time-evacuated

passenger of strategy A passenger of strategy B

From Fig. 3 and Fig. 4 we can see that strategy A's evacuation time is longer than the strategy B. This is mainly because we prohibit the passenger's free flow at node C, D and E through closing the entrance of C and D. The evacuation routes that passenger can select is decreased even if there are density differences at C, D and E, so the evacuation time increased significantly.

Simulating Using Different Models: We got the "evacuation time - evacuated passenger" curves fig 5 and fig 6 using static and dynamic network flow models. At the condition of every node and arc having the same properties, where the evacuation time of static network flow model is 324s and the dynamic network flow model is 400s.

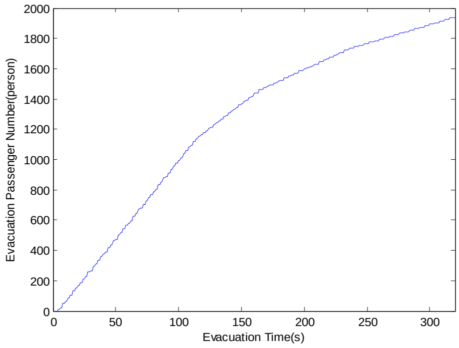

Fig. 5. evacuation time-evacuated passenger of static network flow model

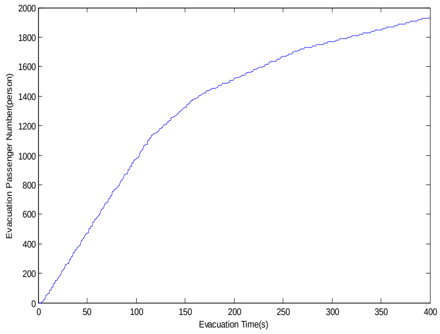

Fig.6. evacuation time-evacuated passenger of dynamic network flow model

From Fig. 5 and Fig. 6, we can see the evacuation time using dynamic network flow mode is longer than the static network flow model. This shows that the dynamic network model describes the smoke spread. The node and arc's property is changed over time, so passenger's evacuation speed is influenced too.

Simulating at Different Initial States: In order to study the effect to evacuation time at different passengers' numbers, we set two scenarios: Scenario A and Scenario B. In Scenario A, every node's initial passenger number is two times of scenario B. Nodes and arcs' other properties are the same. Using dynamic network flow model, we get the "evacuation time- evacuated passenger" curves as Fig.7 and Fig.8. Where scenarios A's evacuation time is 400s, scenario B's evacuation time is 174s.

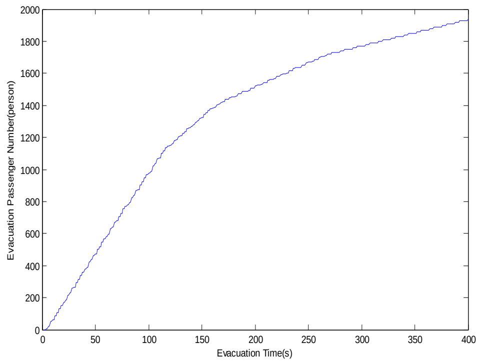

Fig. 7. evacuation time-evacuated passenger of Scenario A

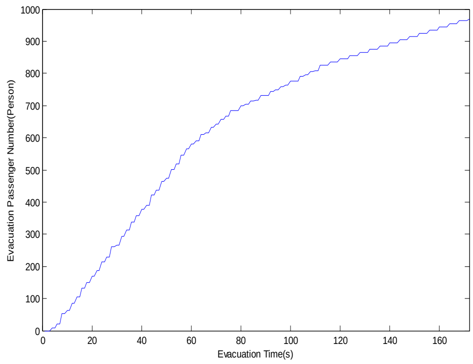

Fig. 8. evacuation time-evacuated passenger of Scenario B

From Fig.7 and Fig. 8, we can see that scenario C's evacuation time is two times more than scenario D's evacuation time. This shows that the station's evacuation ability is decreased with the increase of smoke over time.

Discussions

In this paper, we calculate the evacuation time through computer simulation using different models, different strategies and different scenarios. However, passenger's evacuation process is a complicated behavior; many factors need to be concern, such as the interaction between passengers. So there are many work need to do for future study.

Based on the simulation results on section 4, we can see that emergency evacuation time will be significantly decreased if passengers have more evacuation route and the evacuation speed will decrease over time as the smoke spread.

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基于事故理论的城市轨道交通风险评价模型研究

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【摘要】本文分析了城市轨道交通事故，结合我国其他行业事故分类的基础上，确定城市轨道交通事故分类标准，即重大事故、大事故、险性事故和一般事故，并将不同事故分类情况及专家判断评分，按事故的大小不同换算成可以计算的计算尺度，根据事故种类不同计算出事故折算因子，根据风险理论的评价方法，建立了地铁风险评价模型，对地铁的危险性进行量化定级，并通过具体实例进行了综合分析评价，具有一定的工程意义。

【关键词】风险评价模型 城市轨道交通 事故理论

RISK ASSESSMENT BASED ON ACCIDENT THEORY IN URBAN RAILWAY TRANSPORTATION

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Keywords

Risk Assessment, Urban Railway Transportation, Accidents Theory

Abstract

The paper analyses accident type of urban railway transportation, including fire, trains accident, platform train interface, station area accidents, explosion, power failure, structural failures, according to the

statistic data, the risk assessment model based on accident theory is established. Our understanding of safety risk should not be based just on perception, but on past evidence and data, and the best information on potential future risk that can be derived from them. The Total Risk Assessment Model is a vital tool in providing this risk insight. It provides a structured representation of the causes and consequences of potential accidents arising from operations and maintenance on the mainline railway. The models could lead directly to injury or fatality to passengers, workers or members of the public. These events include hazardous event train accidents, movement accidents and non-movement accidents. The risk results are presented as a measure of the absolute risk and should only be used as an input to, and not as a substitute for, decision-making. The emerging thinking on safety decision-making within the railway industry has recognised the need to consider the distribution of risk in terms of fatalities, major and minor injuries, as well as equivalent fatalities.

1. Introduction

Risk Assessment assesses the risk from major hazards with the potential to cause fatality to our customers and other members of the public. This includes risks imported to our operations through the activities of other members, such as trains corporation, railline corporation, and station corporation, etc. It also includes the risks to our customers when we operate over management controlled infrastructure. It excludes suicides and medical fatalities. The prime objectives of the risk assessment are to promote an understanding of the nature of these risks and provides a basis for:

(1) Identifying whether adequate controls are in place;

(2) Identifying if any further controls are reasonably practicable.

The sequences of events leading to major hazards are grouped into those which result in similar outcomes. These outcomes are known as 'Top Events' and are Table 1.

The total risk degree is calculated for each Top Event for each of the separate operating lines.

Table 1 List of Top Event

Fire	Station Fires	Station Fire is defined as an incident involving fires in both the public and non-public areas of the station including disused areas and tenancies.
	Train Fires	Train Fire is defined as an incident involving fire on any part of a train both internally and externally.
	Tunnel Fires	Tunnel Fire is defined as an incident involving fire in subsurface or tube sections or open sections but not within the confines of the station head and tail walls.
	Escalator Fires	Escalator Fire is defined as an incident involving fire on an escalator, in the escalator shaft environment and in the upper and lower machine rooms.
Trains Accident	Derailment	Derailment is defined an incident where a train comes off the rails due to an unplanned event.
	Collision Between Trains	Collision between trains is defined as an incident where there is an impact between two (or more) trains.
	Collision Hazard	Collision Hazard is defined, as an incident involving an impact between a train and another object which is not another train.
Platform Train Interface		The Platform Train Interface top event addresses the risks at and/or across the platform and train boundary. It also includes the risk of falling from a train.
Station Area Accidents		Station Area Accidents are defined as any incident or accident which occurs within the station boundary. It excludes fires which are addressed by the Escalator and Station fires top events. Incidents at the platform train interface are considered under this top event.
Explosion		Explosion is defined as any incident resulting from either deliberate

	action or from the accidental ignition or pressure build up of flammable material / gases.
Power Failure	Power Failure is defined as any incident associated with a major system wide power loss which affects, in particular, trains and stations.
Structural Failures	Structural Failure is defined as any incident associated with civil infrastructure collapse/failure with the potential to directly result in harm to customers.

2. Modeling on Total Risk Assessment

The analysis and estimation of risk for a particular Top Event requires the evaluation of the likelihood and the consequences of the hazardous event under consideration.

To determine the likelihood of the Top Event occurring the contributory causes to each of the major hazards are identified and the frequency or probability of occurrence of each is determined. The probability of occurrence of the Top Event is determined through fault tree analysis. In the event of the hazardous event being realised the consequences are defined in terms of the theoretical number of deaths arising from the incident.

This severity and the probability of occurrence of the Top Event are combined (using event tree analysis) to determine the risk associated with each Top Event. This risk is then summed to determine the total risk for each of the Operating lines, each Unit and the Railway.

3.Total Risk Assessment is Founded

The level of risk is expressed as fatalities per year. This figure is the aggregate of a number of possible consequence outcomes for a given Top Event. It takes into consideration the possibility that realization of a hazardous event does not always result in the worst case consequences but may have a number of different consequences including, in some circumstances no fatalities. It also takes into consideration the probability that an incident may occur at any time. For example there is a probability that an event may occur within the next year or within the next 100 years, the risk is the aggregate of these possible frequency and consequence outcomes. The equation of total risk degree calculates that is:

$$\mathbf{R_T = F \times [F_a + 0.1M_1 + 0.01M_2 + 0.005M_3]}$$

The meaning of the symbol is:

R_T--Total Risk Degree

F—The frequency of an event is the number of times an event occurs over a specified period of time eg number of events/year

F_a—Death within one year of the causal incident

M_1--Major injuries

M_2--Medium injuries

M_3--Minor injuries

The actual number of consequences in terms of fatalities used in the model are derived from a combination of historical incident data, consequences analysis (where available) and expert judgement. Coefficient of Equal fatalities is as follows Table 2:

Table2 Coefficient of Equal fatalities

Hurt Degree	Coefficient	Hurt Sort
Minor injuries	0.005	• fracture of digits (fingers and toes) • strains and sprains • scratches, cuts and abrasions • bruising • minor burn

		• general discomfort • minor ill health • minor [temporary] illnesses (e.g. eye strain or back strain) • any injury leading to less than three days off work
Medium injuries	0.01	• fractures (hand, wrist, ankle, etc.) • unconsciousness • major burn • amputation of digits (fingers and toes) • loss of sight or hearing (temporary) • any injury leading to between 3 days and a month off work
Major injuries	0.1	• fracture of major bone or skull • loss of limb or eye • loss of sight or hearing (permanent) • acute illnesses requiring medical treatment • unconsciousness where the person has to be resuscitated • any injury leading to more than a month off work
Fatal	1	• fatality

The numerical scores for each severity and likelihood are added to give an overall risk rating. For this classification, the significance of each risk is considered:

• High: if it scores over 20 points

• Medium: if it scores between 14 and 20 points; and

• Low: if it scores less than 14 points.

The risk rating matrix shown in Fig.1.

LOW 13	MEDIUM 17	MEDIUM 19	HIGH 23	HIGH 25	HIGH 27	HIGH 29	HIGH 33
LOW 8	LOW 12	MEDIUM 14	MEDIUM 18	MEDIUM 20	HIGH 22	HIGH 24	HIGH 28
LOW 6	LOW 10	LOW 12	MEDIUM 16	MEDIUM 18	MEDIUM 20	HIGH 22	HIGH 26
LOW 2	LOW 6	LOW 8	LOW 12	MEDIUM 14	MEDIUM 16	MEDIUM 18	HIGH 22

Fig.1 Risk Assessment Rating Matrix

These risk ratings determine how often risks are reviewed.

High risks are reviewed as a priority to establish tolerability and whether there is a case for immediate action to remove or reduce the associated risk. The level of risk is then reviewed. Any high risks which remain after consideration of options to remove or reduce risks, will be reviewed regularly.

Medium risks are reviewed to determine whether there are any further reasonably practicable risk reduction measures that could reduce the risk, particularly in instances where controls are identified as either ineffective or only partially effective.

Low risks are considered to be broadly acceptable. However, if a low cost risk reduction measure is identified, this will be reviewed and implemented if reasonably practicable.

4. Conclusion

Current developing situation and assessment methods of urban rail transit are explored and the cause of typical subway in operation system leading to accidents is analyzed in this paper. Risk and hazardous factors included subway fire, vehicles digression, vehicles collision et. are determined, and the ponderance of consequences and the frequency of accidents are analyzed. The risk degree affecting subway operations are designed.

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提高船舶高安全的贡献

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【摘要】在最近数十年安全事件的频发，使得在提高服务的安全性和可靠性的船队的投资增加以便提高标准。但问题是，如何找到最危险的地区，安排和制度，还有怎样用最经济的方法来提高船舶的安全性。有多种方式可以提高船舶的安全性。然而建立一个提高服务可靠性和安全性的系统全面和实用的方法是什么呢？电力供应和分配系统在整个船舶安全方面是一个理想的解决方案。这里必须考虑远航的海船的对能源需求在不断增加，而这些类型的活动越来越多地已接近极限。工程师和科学家们一直在寻找办法，找到最佳的解决方案，进行分析，平衡和纳入多方案进入他们的模型并不断优化。在教育实践中结合计算机模拟，仿真和实验室练习是非常有用的。MATLAB 和 MathWorks 在教学过程中是非常有力的手段。MATLAB 在工科和理科方面都能提供专门的图表功能。用 MATLAB 的优化工具箱将遗传算法与直接搜索工具箱紧密联系在一起。我们可以利用遗传算法和模式搜索找到很好的出发点，然后采用优化工具箱求解器或 MATLAB 进一步完善算法。通过整合算法，我们可以提升工具箱和 MATLAB 的优势，从而提高解决方案的质量。对于某些问题，这种方法也将有助于找到总体的解决办法。本文的目的培养海海事人员员和海事大学生（在斯普利特的海洋研究学院）在航海过程中提高安全的和可靠的能源系统方面的能力。

【关键词】船舶能量工厂；安全；能量管理；遗传算法

CONTRIBUTION TO THE INCREASE SAFETY ON SHIP

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Keywords

ship power plant, safety, power management, Genetic algorithm

Abstract

Incidents during recent decades caused an increase of invests in boosting the safety and service reliability of fleet to a higher standard. But the question is how to find the most risky areas, arrangements and systems, also the most cost-effective ways to improve ship safety.

There are numerous ways of increasing safety on board. What has been missing however is a systematic comprehensive and practical method for establishing the most effective ways for increasing safety and service reliability?

The electrical power supply and distribution systems are ideal solutions for the safety of a ship in its entirety. It must be taken in the consideration here that the energy requirement on seagoing vessels is continuously increasing and that these types of systems are increasingly operating close to their limits.

Engineers and scientists are constantly looking for approaches to find optimal solutions, perform analysis, balance multiple alternatives and incorporate optimization methods in their models.

In education practice it is useful to combine computer simulation, simulator and laboratory exercises. MatLab® demos and MathWorks can provide very powerful means in education process. MatLab provides immediate access to the specialized graphic features required in both engineering and science. The Genetic Algorithm and Direct Search Toolbox are closely integrated with MATLAB and the Optimisation Toolbox. We can use the genetic algorithm and pattern search to find good starting points and then take advantage of the Optimisation Toolbox solvers or MATLAB routines to further refine your optimisation. By combining algorithms, we can leverage the strengths of the toolboxes and MATLAB to improve the quality of your solutions. For certain problems, this approach will also help to find global solutions.

The purpose of this paper is to show how education of seafarers and maritime college students (Faculty of Maritime Studies in Split) contributes to greater security and reliability power energy system on board.

1. Introduction

Electrical installations are present in any ship, from powering of communication and navigation equipment, alarm and monitoring system, running of motors for pumps, fans or winches, to high power installation for electric propulsion. As the installed power increases, the normal load currents and the short circuit currents will increase. With the physical limitations on handling the thermal and mechanical stress in bus bars and the switching capacity of the switchgear, it will be advantageous or necessary to increase the system voltage and hence reduce the current levels. High voltage has become a necessity to handle the increase the power demand in many applications. For main distribution 11 kV should be used when total installed generator capacity exceeds 20 MW and also for motors from 400 kW; 6,6 kV should be used when total installed generator capacity is between 4-20 MW and for motors from 300 kW. Low voltage, 690 V, should be used for distribution when total installed generator capacity is below 4 MW and for consumer below 400 kW. For utility distribution lower voltage used e.g. 400/230 V. Safety is an issue of concern when yards and ship owners' changes from low to higher voltages, often leading to a misunderstanding effort to keep voltages as low as possible.

Regulations exist to control the construction, installation, operation and maintenance of electrical equipment so the danger is eliminated as far as possible [IMO, 1995.]. Minimum acceptable standards of safety are issued by various bodies including national governments, international governmental conventions (e.g. SOLAS), national and international standards associations (e.g. IEC), learned societies (e.g. IEE), classification societies (e.g. Loyds).

Crews who serve on board modern ships have technical knowledge of highest standards to enable them to operate complicated machinery correctly. They must be able to operate their ships efficiently and safely.

Marine engineers, nowadays, should have a wide range of professional knowledge and skills: from work with a hand tools to the use of computer technologies, providing both watch-keeping and unattended machinery space. Interactive simulators in comparison with educational facilities equipped with only real on-board hardware, are obviously becoming a powerful tool to achieve the competence of crews defined with STCW 95 convention.

Ships' staff must operate equipment in a safe manner and maintain it in a safe condition at all times. Most accidents occur due to a momentary loss of concentration or attempt to short–circuit standard safety procedures. Making personal contact with any electric voltage is potentially dangerous. At high voltage levels the electric shock potential is lethal. Personnel who are required to routinely test and maintain HV equipment should be trained in the necessary practical safety procedures and certified as qualified for this duty. Prevention is the best medicine for electrical shock. With the respect of high voltage, ships' staff must have knowledge of the principles of electricity, and follow safe work procedures.

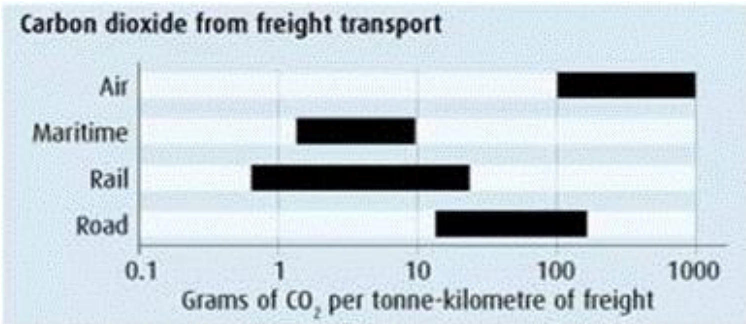
Ship designers and operators must have strong focus on maximizing efficiency, minimizing emissions and applying innovations (dual fuel engines, fuel cells). Higher fuel prices and shortage of skilled personnel are pushing up operating and voyage costs. Solutions that minimize fuel consumption are demanded and there is a huge opportunity for remote control systems that may reduce the need of personnel onboard ship. To ensure reliable usage of new technologies that reduce emission and fuel consumption, support and service is necessary. Safety is becoming more and more important; including many different aspects - safety in cargo handling, safety of crew, safety during operations etc.

2. Safety

2.1. Ship Efficiency Improvements

Shipping is already a very efficient form of transport, in terms of CO_2 emissions per tone/km of goods moved. It compares favourably with rail transport, is more efficient than road transport, and is considerably more efficient than air freight.

Figure 1: Relative Efficiency of Different Transport ModesSource:http://technology.newscientist.com



Nonetheless, because of the volume of seaborne trade, the shipping industry is increasingly expected to share the burden of reducing global emissions of CO_2. The International Maritime Organization (IMO) is currently debating what measures could be introduced to limit or reduce shipping's emissions of CO_2. The dramatic rise in fuel oil prices in recent years is also acting to encourage improvements in fuel efficiency. During 2008, many ship operators, particularly of container ships, have adopted a policy of "slow steaming", i.e. reducing the speed at which a ship operates. This can have pronounced benefits - for example a reduction in a ship's speed from 26 knots to 23 knots can give a 30% fuel saving.

Marine diesel engines are already highly efficient, operating near their theoretical maximum thermal efficiency. Almost 50% of the energy in the fuel is converted into mechanical work in a large marine diesel engine. Effective recovery of waste heat from the engine can further raise the efficiency to nearly 55%.

Will globalization of pollution become a threat for human life? The scientific answers are different but have one common point: we have to minimize the effects by minimizing the causes.

It has been calculated that one single ship can contaminate on one day a volume of water of about 400.000 m^3. In one year this represents 1,460 tons. Taking into account the average number of ships of 40.000 vessels, we get a global amount of about 58 million tons. Scientific research concluded in identifying the main polluting parts of a ship and of which the majority is invisible pollution. The last decades the impact of visible and non-visible contamination of the oceans was detected. The response by the world community followed at the rhythm of the discoveries. Local and international legislation, conventions, directives etc., were introduced and one of the best indicators is the MARPOL Convention with its gradually extended annexes throughout the years.

2.2. Power plant

Although the ship is supplied with shipbuilder's plans and manufacture's instruction books, there is no single handbook which gives complete overview on operating systems installed on board, as distinct from individual items of machinery. The ship safety depends on the care and attention of all on board. Most safety precautions are a matter of common sense and good housekeeping and are detailed in the various manuals on board.

Many of the new developed vessels are equipped with diesel electric propulsion. For conversion project the existing system may also be used. In normal production the electrical power system will supply all electrical consumers on the vessel. The trend today is driven by environmental tax regimes and regulations where emissions to air are important. Production vessels use different fuels as natural gas or marine diesel oil.

For medium size installations piston engines will normally be used. For large installations turbines are normally used in combination with piston engines or combined power and heating. For electrical propulsion system the engines will run a generator producing all necessary electrical energy onboard.

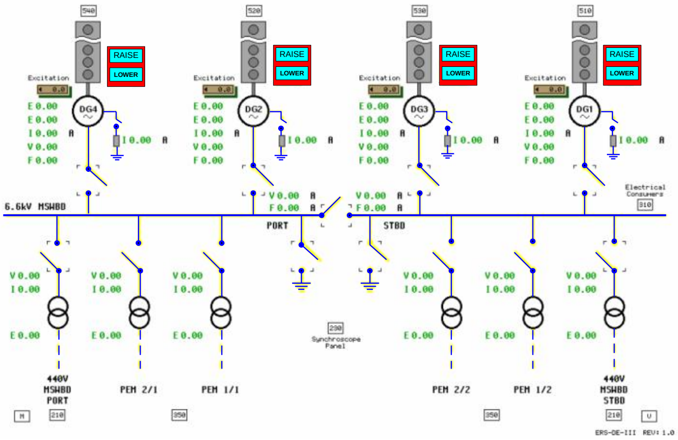
With introducing new fuels or dual fuel concepts the requirements for controlling and monitoring the dynamic performance will also be different. The electrical power system will be distributed throughout the total installation to the end user via transformers, switchboards and converters. The total power system will be monitored and controlled with one or several control systems depending on how these systems are integrated. Power Management Systems (PMS) can be a separate system or integrated in a total Vessel Automation system. Other functionality as Energy Management, Environmental Management may be integrated in the PMS.

Power generation system

The total installed power onboard this type of vessels will depend on the purpose they are serving, but are normally between 6 and 10 MW except for larger construction and anchor handling vessels which can be above 20MW.

Typically in these vessels the power requirement in transit at economic speed is in the order 3500 – 4000 kW. When the ship is unloading / loading at the offshore platforms she is operating on dynamic positioning, DP, with a total power demands in the order 600 – 1500 kW in calm weather increasing to 3000 – 5000 kW in rough weather. In transit at full speed the total power demand is approx. 7500 kW. Figure 2. shows a single line diagram for a typical offshore vessel. The electrical solutions require an extensive use of power electronics and a modern PMS. The PMS must manage a highly dynamic electrical network.

Figure 2. Single line diagram - Engine Room Simulator – Faculty of Maritime Studies in Split



Main power distribution systems

Main power distribution systems may have two or more switchboard parts connected with bus-tie breakers. A typical drilling rig configuration will be a four split switchboard to allow a flexible arrangement where each main thruster's drive can be connected to each switchboard section. Large generation capacity may increase the short circuit level above acceptable values. In these cases additional current limiting devices or restrictions in operation of connected switchgear units has to be implemented. This will give restrictions in how the bus-bar sections can be connected together, but this will anyhow be controlled by the power management system. During bus-tie transfer the breakers can be connected together by a controlled make-before-break system. The alternative is to install new short circuit limiting units in the network. With this arrangement any breaker connections can be allowed.

Power Management System (PMS)

PMS is a group functions and comprises control and monitoring of electric power production and consumption. The system controls and monitors the engine driven generators, switchboards and consumers. In the case of an electrical system fault the power management system restores power in a minimum of time. For electrical propulsion plants there are normally different system interfacing each other. Efficient PMS can also be described as:

- The sum of human experience and an efficient automated control and monitoring system.
- Secure and safe, reliable and efficient system that monitors and controls the electrical power of all important vessel functions in all operational conditions.
- System which cares for available power to execute required manoeuvre in any operational condition.

For electrical propulsion plants there are normally different system interfacing each other. A sophisticated ship power management system usually provides the following main functions: Diesel generator (DG) start, stop control; DG safety system; auto-synchronizing of generators and breaker control; load depend start, stop; load sharing, if droop control; load increase control; blackout monitoring; power reservation of heavy consumers; preference trip (load shedding); frequency control; ship operation mode selection and start sequence program; shaft generator (SG) load transfer.

Redundancy is one important requirement in ship automation.

3. Education and training

Again and again new apparatuses, instruments, devices and machinery appear, destined hopefully to improve the safety and increase the efficiency in shipping. International and national requirements for shipping safety are becoming more and more comprehensive, detailed and strict. Most ship procedures are required to be thoroughly documented in a prescribed manner and all these things are to be observed by the crew. Maritime simulators and training systems have the highest priority in these activities, providing training in standard operations, as well as in emergency situations for all ship services – navigational, radio, engineering and cargo operations. The crew training is crucial for instilling co-operative abilities for time-critical situations, when not only adequate decisions must be made but also quick and efficient implementation should take place. In these situations not only professional knowledge is required but also communication skills and the ability to work as a team.

3.1. Simulator

Crews who serve on board modern ships must have technical knowledge of highest standards to be able to operate complicated machinery correctly, efficiently and safely. The educational process should become more available and progressive to ensure the necessary knowledge level of both cadets and existing officers. Simulators can offer close to reality training in many important operational and safety related tasks for hazardous environment without physical risks. Effective and safe performance in such environment requires both highly skilled individuals and a high degree of team coordination. In the past, simulation training was perceived to be simple and computer based; it was focused largely on the acquisition and assessment of individual technical skills. Interactive simulators in comparison with educational facilities are equipped with a real on-board hardware and they are obviously becoming a powerful tool to achieve effective and safe performance of crew in hazardous environments.

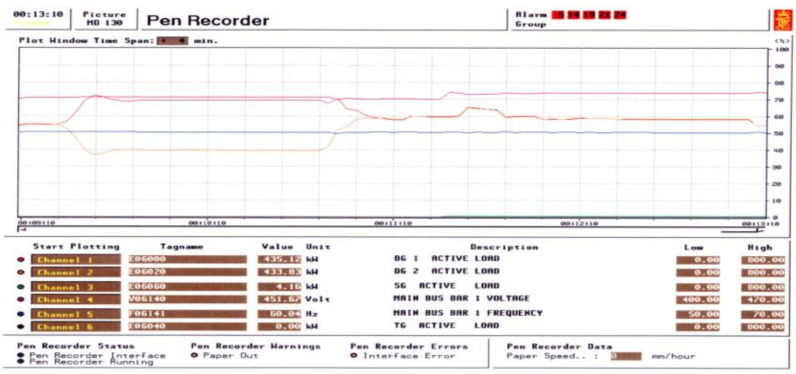
Simulators are being used as excellent training equipment in order to simulate various operational procedures and unique scenarios together, so that effective training can be imparted to the marine professionals to a great extent of realism. Trainings performed on the NEPTUN simulator (simulator on *Faculty of Maritime Studies – Split)* are fully in compliance with the STCW Convention. The whole system has been divided into several sub-systems, whose functions are presented by corresponding mathematical equations. By connecting all mathematical equations the complete process of system operation has been obtained, i.e. the model of system behaviour or a part thereof. Conventional laboratory exercises (engine room simulator) require groups of students to carry out tests in which they solve the problem of load regulation.

Work conditions on the engine room simulator:

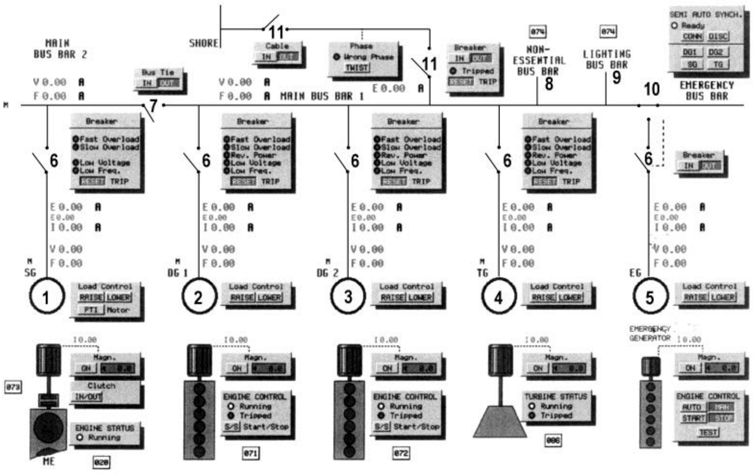
During full mission scenarios, teacher/instructor set up goals and run non-consecutive initial conditions. When the “Cold Ship” initial condition is chosen the goal is to get lights, starting air and power to the switchboard. Following that the next scenario would start with lights, air and power already programmed. The student must get the ship ready to manoeuvre.

Figure 3: a) Diagram of loading of electrical energy generator – pass over from optimum to equal loading; b) Electric power system scheme (440 V)

a)



b)



- The diagram (Figure 3.a.) shows the difference between an optimum and equal mode of loading. Within determined period (initial phase) the system works under an optimum mode of loading, where the priority on DG 1 takes over a greater part of loading, while DG 2 takes over the remaining loading. The optimum loading means the optimum operation regarding the fuel oil consumption, ship/s speed regarding generator characteristics. During subsequent period (Figure 3.b.) the total electrical loading shall be divided into two equal parts (equally loaded generators). When simulating these processes, the values of voltage and main bus bar frequency has not changed (slight deviations are shown by small oscillation). All parameters point at the system stability. It proves that the simulation of the system operation shall be necessary as to identify possible failures.

- The most frequently occurring fault in a power system is sudden trip of a connected generator (especially on high voltage –HV). There are several reasons for a generator trip to occur, and the consequence is that this will give a sudden increase in the load of the remaining generators. Hence, if the remaining generators are overloaded and no action is taken to reduce the generator load, the power system will experience a blackout. In case of a generator trip, the main problem is the time aspect. In case of few generators running, a generator trip may result in generator load in the range of 140 – 160%, and thus the load must be reduced very fast to avoid trip of the remaining generators.

Fault in installed equipment is also an error that occurs from time to time in electrical power system. It the error occurring is an electrical short circuit; the voltage will immediately drop to zero if no actions are taken. Hence if no proper action is taken when a short circuit occur, all connected switchboards will experience a blackout. The short circuit protection devices will isolate the fault by opening the appropriate breakers. With correct design of the selectivity coordination in the protection devices, the fault isolation will happen fast and the healthy part of the system will continue to operate properly. Provided overload of the healthy system does not occur, the vessel can hold its position and, depending on design philosophy, and continue to operate until the fault is taken care of. The power producing capacity on modern vessels are usually less than the total power of the installed consumers, e.g. pumps, thrusters, compressors, etc. The reason is that operational profile is used to reduce the generator ratings to again reduce the investment cost. In addition to this, the use of automatic start / stop functionality of power management system to reduce fuel consumption imply that in operation there will not be enough power for all consumers to use maximum power simultaneously. Obviously, this introduces the possibility for overload of the generators, which again can give a blackout in the overloaded system [Krčum 2005.].

Today the use of Ship Engine Simulators is an integral part of education of ship engineers. Main aspects in getting better results of student training are:

- ✓ Easy and fast understanding of the requested task

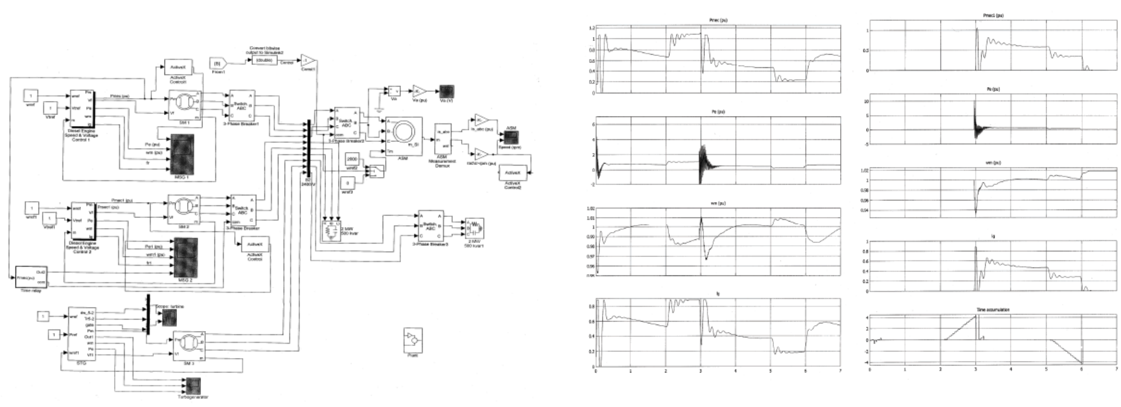
- ✓ Exercises with different level of difficulties
- ✓ Fair and comprehensible assessment.

3.2. MatLab

In education practice it is useful to combine computer simulation, simulator and laboratory exercises. MatLab® demos and MathWorks can provide very powerful means in education process. MatLab provides immediate access to the specialized graphic features required in both engineering and science. Powerful object oriented graphics enable to plot the results of analyses, incorporate graphics into the system models, to quickly render complex 3-D objects, as well as create a high quality output. Advanced visualisation tools include surface and volume rendering, lighting, camera control, and application-specific plot types.

Figure 4: Simulation model in Simulink – results are graphically shown on a) SG1 b) SG2

a) mechanical power b) electric power c) number of rotations d) fuel valve e) time of loading accumulation



Simulink is a program package developed in Matlab surrounding. It provides modelling, simulation and analysis of system's different dynamic conditions and supports linear and non-linear systems modelled in continuous and discreet time. After system modelling, there could be different types of simulations. By using the oscilloscope or other blocks for display of variables, the system's variables could be visible even during the simulation. Simulation's parameters (duration, source frequency...) can be changed with simultaneously monitoring results and simulation's results can be stored for subsequently processing and visualization. During the simulation it's preferable to hold open the oscilloscope's display, to monitor the output variable. When simulation ends, some of the output variables that were generated by the system could be additionally analyzed, processed and graphically displayed [Krčum 2007.].

4. Results

Over a one year period, data was collected for the four different groups - each one having an average of eight students taking the first course of simulator training (except one group - students with practical knowledge). The individual achievements on the various assessments were studied. The results are shown in Table 1.

From this study, it is clear that students, who use Matlab evaluation together with simulator, achieve much better knowledge than those who use only training on the simulator [5]. It has also been noticed that the results of the oral evaluation were almost the same as results of regular students. This raises the question is this new way of training on the simulator not effective as the old one was.

Table 1: Students average grades evaluation

Students Group	Matlab evaluation	Simulator evaluation	Oral evaluation	Average
Student for mechanical engenering - without knowledge of Matlab	-	3,1	3,8	3,45
Student for mechanical engenering -with knowledge of Matlab	3,3	3,8	4	3,90
Student for electrical engenering -with knowledge of Matlab	4,2	3,5	4,4	3,95
Seamens with experience	2	4,5	2,8	3,65
Average	3,167	3,933	3,733	

5. Conclusion

The purpose of simulation work is to develop a model on simulator for study the dynamic behaviour of the ship electrical system, engine room or ship bridge. During the simulation we do some mistakes but we can learn from mistakes especially our own and share with others (during workshop or during the training). Training of students/ship crews can do reliability for certain situation using ship or ship bridge/engine room simulators. The lectures have developed training scenarios with particular attention to human factors.

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Author biography

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Anita Gudelj was born in Split, Croatia (1970). She received her B.S. degree in mathematics and computer science (1993) from University of Split, Faculty of Mathematics. Since 2006 she is a senior lecture at the Maritime Faculty University of Split. Also, she received the M.Sc degree in information science from Faculty of Organization and Informatics, Varaždin, Croatia (2000). Her postgraduate research was "Design and Implementation of Temporal Database". Her research interests include database design, genetic algorithms and Petri nets. Her main activity is focused on performance modelling of automated transportation systems, vehicle dynamics and control, and optimization. She is the author and co-author of several research papers in these areas. She is also a member of several national and international societies (e.g. IEEE, INTERNATIONALSTARS…)

Vicko Batinica was born in Šibenik , Croatia (1946.). He graduated from the Faculty of the maritime Studies - University of Split, where he received his B.Sc. in Marine Engineering. In 2006. he achieved an MS degree in Marine Management, University of Split. Until 1980. he was engaged in marine business with reputable German and Suisse Companies, when joined Croatian shipping company BRODOSPAS, Split, as Technical superintendent. Since 1990. at the position of General Manager and then Chairman of the Board of Directors of BRODOSPAS, Split, has been successful in managing the Company to the recognized reputation and high standards in the marine business in Croatia and worldwide.

For many years, he is a member of professional team for Marine Engineering education courses/training organized by Port Authority of Split. Also he is now a senior lecturer at Faculty of the Marine Studies – University of Split.