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Summary

Øresundsbro Konsortiet has gained valuable experience from its first four years as infrastructure administrator during which there have been substantially fewer-than-expected rail-related faults on the link. This has meant that accessibility to the rail section has been very high.

Incidents and less serious accidents are often wake up calls that can alert employees and managers to hazards, risks, or possibilities that they had not considered before. Every incident is an opportunity to learn valuable safety lessons.

Extensive training in the various safety regulations combined with competence development in the Danish and Swedish language and culture, has very likely eliminated possible misunderstandings or insufficient change of information related to the cross border traffic.

The final report for the HUSARE project “Managing the Human Factor in Multicultural and Multilingual Rail Environments” has shown to be a useful tool in identifying and overcoming the challenges of establishing safe Cross-Border communication on the Øresund Fixed Link.

Ensuring Secure Cross-Border Operation without compromising safety

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Company description

The 16-km Øresund Fixed Link is a joint Danish-Swedish project. The Owner of the infrastructure is Øresundsbro Konsortiet, a shareholding company that is 50 % owned by the Danish State and 50 % by the Swedish State. Øresundsbro Konsortiet has financed the project by raising loans on the international finance markets. The loans, which are guaranteed by the two states, will be paid back by the income from the road toll on the motorway and annual fees paid by the two states for the use of the railway line.

Description of the Øresund Railway Line

The Øresund Line is a two-track electrified railway directly linked to national rail networks in Copenhagen and Malmö. Trains run at speeds of up to 200 km/h on parts of the link. The Øresund Tunnel has a speed limit of 180 km/h while the limit is 160 km/h between Copenhagen Central and Copenhagen Airport, Kastrup. The line can be upgraded to accommodate speeds up to 250 km/h.

The Øresund Fixed Link consists of a 4 km immersed tunnel, a 4 km artificial island, Peberholm, and 8 km of bridges. The immersed tunnel, which is believed to be the world's largest combined rail and road tunnel in terms of volume, has two tubes for rail traffic and two for road traffic. The bridge has two decks, an upper deck for the four-lane highway and the lower deck for the 200 km/h double-track railway. To prevent derailing, the tracks on the approach bridges run in concrete troughs. On the cable-stayed high bridge with a main span of 490 m, concrete has been substituted by steel to reduce weight.



Figure 1: The Øresund Fixed Link

Two countries – two technologies

Although rail technology differs in almost all respects in Denmark and Sweden, the coast-to-coast rail link is designed and constructed so that passengers do not notice the switch from one railway system to another.

Designing the transition between the two ATP & Interlocking systems, the so-called “system border” located on the artificial island Peberholm west of the official border between Denmark and Sweden, was a complex task. Safety regulations differ significantly between Denmark and Sweden and the wayside signals have completely different meanings. All trains crossing the link are therefore equipped with both Danish and Swedish cab signalling and other ATP equipment.

All trains must be equipped with Danish train radio MSR3 linked to the ATP computer and Swedish train radio following the new GSM-R standard. The channels in the Danish train radio are shifted automatically by ATP transponders thereby ensuring that the driver is always connected to the train dispatcher in charge of his actual location. When starting up the GSM-R system, the driver manually has to call the Traffic Control Centre in Malmö to inform which number he is using.

The Danish power system standard with 25kV and 50Hz was extended to the Swedish shore, where it has been separated from the Swedish standard 15 kV and 16²/₃ Hz by a neutral section. The contact wire and all other electrical equipment - can be fed from both sides. This leads to a very high reliability. All electrical trains and locomotives must be equipped with a dual power system.

The technical border for the two national ATP systems is on the artificial island, Peberholm connecting the bridge and the tunnel. Again, the trains will have to be able to adapt to both systems.

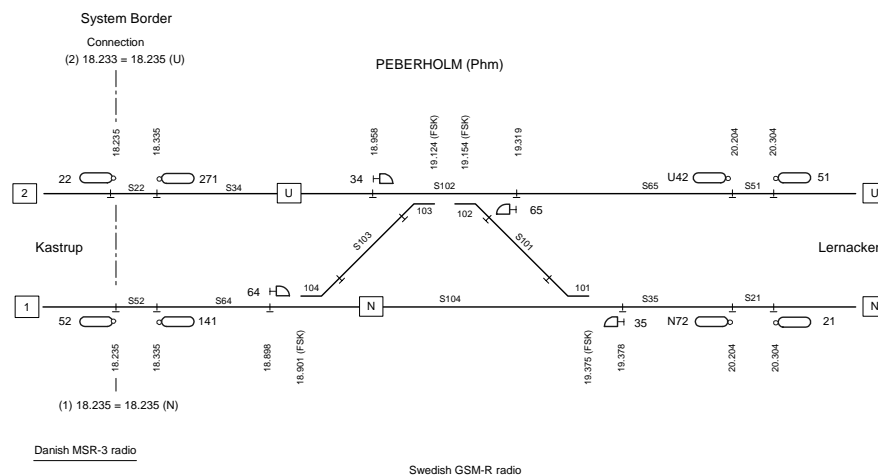


Figure 2: ATP, Interlocking & Radio system border

Operating Experiences

Øresundsbro Konsortiet is as Infrastructure Manager, responsible for operation and maintenance of the coast-to-coast rail line. Since the inauguration of the link first of July 2000, Øresundsbro Konsortiet has carried out this task through maximising existing competencies within Sweden's National Rail Administration and Denmark's National Railways Agency. To a certain extent, the practical tasks are outsourced to the said national administrations.

Daily operation related to the traffic control of the link, are conducted by the National Railways Agency of Denmark and the Swedish National Rail Administration. The two organisations are responsible to Øresundsbro Konsortiet for functions and co-ordination.

Øresundsbro Konsortiet's section of the Øresund Rail line is managed by a safety approved administration department within Øresundsbro Konsortiet, the Railway Department. To date the Railway Department has special focus on System and Safety management.

Safety management involves identifying possible safety risks and through preventative measures, endeavoring to eliminate such risks. Nevertheless, should accident or "near accidents" occur, remedial action to prevent similar incidents recurring again will immediately be taken. In connection with the opening of the Øresund Link, Øresundsbro Konsortiet launched a quality and safety management system aimed at preventing and solving potential problems relating to rail safety. This Safety management system incorporate the basic safety process, described in figure 3, into the management of the Øresund organization.

As one of the first railway infrastructure administrators in Denmark, Øresundsbro Konsortiet has been safety certified by The Danish Railway Inspectorate. The certificate given in December 2003 proves that Øresundsbro Konsortiet complies with a range of stringent safety, organisational and management requirements that are a pre-condition for rail infrastructure administrators to operate rail lines. The certification offers a range of advantages:

- Certainty that the Øresund Bridge's safety policies and the underlying procedures correspond to those areas where the Øresund Bridge has identified potential risks.
- Certainty that current safety legislation and regulations are complied with.
- Documentation that the Øresund Bridge's rail section is managed in a professional and responsible manner.

The safety certificate requirement will become mandatory in Denmark from January 1, 2005.

Øresundsbro Konsortiet has gained valuable experience from its first four years as infrastructure administrator during which there have been substantially fewer-than-expected rail-related faults on the link. This has meant that accessibility to the rail section has been very high. From a safety point of view, the first years of operations have been particularly satisfactory.

The risk policy for the link is defined as follows:

- Recognize that operation of the Link will introduce risks to humans, to the environment and to economical values
- Ensure that all relevant risks are identified at the earliest time in order to eliminate or reduce
- Risk acceptance criteria shall be defined for certain fatalities
- Ensure the risk level will be reasonable and comparable to other similar traffic systems

The risk acceptance criterion for the railway operation is defined as follows:
4 fatalities per 1 billion passages of the Rail link equal to 1 fatality per 20 years of operation.

Overall safety objectives aimed at "keeping safety risks relating to traffic on Øresundsbro Konsortiet's rail section as low as possible at any given time with due consideration for what is technically feasible and economically sound" have been met in full.

No accidents or potentially dangerous situations ("near misses") have occurred. Few incidents have come under the category: "Incidents which indicate that safety systems, regulations or safety behaviour have been breached although no significant risk to traffic safety has been established."

The number of this type of incident totalled 81 in 2001, 70 in 2002 and 71 in 2003. The incidents can largely be divided into three main categories:

- Errors relating to rolling stock, e.g. trains with an erroneous intercommunication system or faulty mobile ATP-equipment
- Incorrect or inadequate safety reports between Danish and Swedish remote control centres or between the remote control centre and engine drivers
- Infrastructure errors, primarily signalling errors.

For all three categories the numbers of incidents have remained constant from year to year. Although, of course, the statistical material is sparse, Øresundsbro Konsortiet believes that the trend is, in fact, falling due to the focus on safety by all parties concerned, including the ongoing registration of all "near miss" incidents.

The present incident risk level does not give grounds for safety concerns on the Øresund Link.

Over the next few years the organisation will concentrate on moves to strengthen rail services even more – by "doing things in the right way" and "doing the right things." These efforts will lead to simplified regulations and procedures and result in cost savings.

Some Features of the Øresund Safety Management System

The management of Øresundsbro Konsortiet recognizes that one unsafe act is all that separates us from an injury or accident. That's why we are so intent upon reaching our goal of zero accidents and zero injuries.

It is our belief that future successes may lie more in altering individual behavioral choices than in improving technology or altering structural operating conditions. First, we see a continuing need to encourage and assure that our railroad workers obey rules and best practices. Yet, we can only make further safety gains if employees rigorously follow those rules: protecting the points of moves, securing equipment, communicating clearly, watching signals, and protecting work zones. Adherence to these rules requires constant vigilance. In this respect Øresundsbro Konsortiet provides extensive training, ensuring employees and supervisors and managers are educated in safe behaviors.

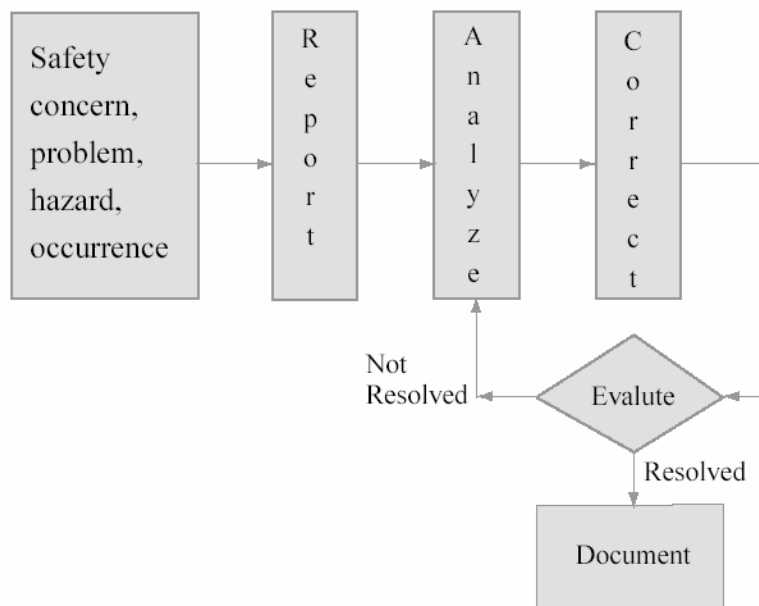


Figure 3: The basic safety process [ref 1]

When an organization develops a safety management policy and procedures, they have to fit into the organization. Safety management has to be comprehensive, but should not be more complex than the rest of the company's management program. Safety management must be compatible, and preferably, integrated into the overall management scheme. The following list shows how Øresundsbro Konsortiet made safety management a reality. Most items in this list will be familiar to safety managers. The fundamental changes are concerned with commitment, roles and accountability of senior management

- *Establishing a safety culture*
- *Establishing a risk & safety policy*
- *Safety information*
- *Establishing safety as a core value*
- *Setting safety goals*

- *Hazard identification and risk management*
- *Establishing a safety reporting system*
- *Safety assessment/audit*
- *Accident and incident reporting and investigation*
- *Safety orientation and training*
- *Documentation*

A safety culture is established when:

- People understand the hazards and risks involved in their own operation
- Staff work continuously to identify and overcome threats to safety
- People understand that errors must be understood but willful violations cannot be tolerated
- The workforce knows and agrees on what is acceptable and unacceptable
- People are encouraged to voice safety concerns
- When safety concerns are reported, they are analyzed and appropriate action is taken
- People are encouraged to develop and apply their own skills and knowledge to enhance organizational safety
- Staff are updated on safety issues by management
- Safety reports are fed back to staff so that everyone learns the lessons

Hazard Identification and Risk Management

A hazard is a condition with the potential of causing injury to personnel, damage to equipment or structures, loss of material, or reduction of the ability to perform a prescribed function. Risk is the chance of injury or loss. This concept includes both the likelihood of a loss and the magnitude.

Hazard identification and risk management are undertaken, at a minimum:

- During implementation of the safety management system and then at regular intervals
- When major operational changes are planned
- If the organization is undergoing rapid change, such as growth and expansion, offering new services, cutting back on existing service, or introducing new equipment or procedures
- When key personnel change.

The most important step in the process of a risk analysis is to identify the context of the decision problem, i.e. the relation between the considered system and/or activity and the analyst performing the analysis:

- Who are the decision maker(s) and the parties with interests in the activity (e.g. society, client(s), state and organizations)
- Which matters might have a negative influence on the impact of the risk analysis and its results
- What might influence the manner in which the risk analysis is performed (e.g. political, legal, social, financial and cultural)

Furthermore the important step of setting the acceptance criteria must be performed. This includes the specification of the accepted risks in regard to economic, public or personnel safety and environmental criteria.

Different techniques for hazard identification have developed from various engineering application areas such as the chemical, nuclear power and aeronautical industries.

Examples are:

- Preliminary Hazard Analysis (PHA)
- Failure Mode and Effect Analysis (FMEA)
- Failure Mode Effect and Criticality Analysis (FMECA)
- Hazard and Operability Studies (HAZOP)
- Risk Screening (Hazid sessions)

All mentioned techniques have so far been utilized both in the design and operations phases. Øresundsbro Konsortiet has moreover developed and applied a Hazard Log Tool (HAZLO) over a number of years. The tool is fully supported by Rambøll via a continuous improvement program.

Incident or near miss reporting as a safety program feature is not a new concept

The management of Øresundsbro Konsortiet argues that for a “high reliability” business like railway transportation, a reliable incident/near miss reporting system is necessary since actual accidents are so infrequent that “lessons” from relatively minor accidents prevent needed organizational learning that is essential for avoidance of major accidents/disasters. Incidents and less serious accidents are often wake up calls that can alert employees and managers to hazards, risks, or possibilities that they had not considered before. Every incident and accident is an opportunity to learn valuable safety lessons. The lessons will be understood, however, only if the occurrence is analyzed so that managers and staff understand not only what happened, but why it happened. Every incident is reported and investigated carefully.

Human factors in Cross-Border operation on the Øresund Fixed Link

Cross-border rail operation generates new human factors problems and associated risks that need to be addressed. As trains pass through national and infrastructure borders, the different technological systems, rules, procedures and cultural characteristics all have profound implications for safe operation. These differences become particularly significant in degraded operations and emergencies, where a high level of communication, cooperation and co-ordination between rail staff are essential.

Swedish and Danish ATP systems are required for cross-border operation between Sweden and Denmark. Therefore, many likely human failures were screened out in an initial phase of the human factor analysis, as the automatic train protection system would intervene and recover these human failures. However, in the event of non-function ATP systems en route, for safety reasons, the driver will have to continue to the next station according to the national rules & procedures for driving without ATP. This justified analyzing some human factors risks primarily arising when driving with ATP system that is not working properly.

With reference to the recommendations in the HUSARE report, “Managing the Human Factor in Multicultural and Multilingual Rail Environments”, scenarios were selected with regard to safety critical human tasks in cross-border operation, such as variations in:

- Language, communications, culture and social conditions
- Training, selection and assessment of competence
- Infrastructure technology and systems
- Rules, procedures and standards
- Information environment
- Geographical/topographical differences

Identifying and overcoming the challenges of establishing common safety rules and standards for cross-border interoperability

The Øresund interoperability strategy has been to adopt the national rules and standards in the widest possible extent. If certain Danish or Swedish rules cannot be used for the cross-bordering operation without amendments, Øresundsbro Konsortiet has to develop its own supplementary rules. These rules are before coming into operation, scrutinized and approved by all parties involved.

As the safety regulations are different, training was needed. A 4 weeks course for train drivers was developed. Swedish drivers are trained using the Danish language and vice versa. Thereby they are learning the language and the regulations at the same time. This includes normal, degraded and emergency situations. Additional courses have been arranged for train dispatchers, maintenance staff, etc.

The Danish and Swedish languages are different too, so a vocabulary has been developed, including some 150 Railway terms. For instance: A ”turnout/point” is named “växel” in Sweden, and “sporskifte” in Denmark. Few words cannot be translated by a single term, because they relate to procedures with no similarities. Numbers should be pronounced digit by digit. It is required that the people involved speak very distinctly and pronounce their words close to the way they are spelled. Need for repetition of messages to ensure clear understanding is prescribed.

All though the train drivers involved in the cross-border operation have had some training in the languages spoken in the foreign infrastructure possible failures are considered like misunderstanding or insufficient information exchange which can occur when an unusual situation arises.

The National Railway Authorities in Denmark and Sweden have required the three Infrastructure administrators involved in operation of the Øresund Rail Link, to conduct a yearly “Language Competence audit”. Moreover four times a year the traffic control centers in Copenhagen and Malmö are obliged to go through the tape recording of the Danish/Swedish communication in order to check for misunderstandings or insufficient change of information. The required evaluation seminars and tape record listening have not so far given grounds for concern.

Determining the safety challenges of introducing a GSM-R system in Sweden whilst keeping an analogue system in Denmark

In the beginning of the nineties an, at-that-time, advanced train radio system was developed in Denmark named MSR3. The radio channel is automatically controlled by ATP transponders to ensure that the driver is always connected to the train dispatcher in charge of traffic. All though the MSR3 radio system was based on analogue technology, it was decided to use this system for the part of the link that is controlled from the Danish traffic management centre in Copenhagen, including control of the 4 km immersed tunnel. As the Swedish Banverket decided in the late nineties to introduce the European standard GSM-R on the main lines linking Stockholm with Malmö, it was agreed that this system should be extended to the Swedish part of the link, meeting the Danish radio system at the “System boarder”. To provide sufficient start-up time for the GSM-R when going towards Sweden, radio coverage is established also for the tunnel section. This means that both systems can be operated in the tunnel, which is a critical object seen from a safety point of view, fulfilling a redundancy should one of the systems fail. Further more is the tunnel fully prepared for the GSM-R system when coming in operation in Denmark.

With respect to the human failures that can arise due to interface problems of using two completely different radio systems, the following aspect was considered:

Even if a driver follows the correct procedure for sending radio alert messages, this involves the risk, that the driver will send the emergency signal via the inactive radio system. When response from the radio partner is received, then the driver will re-examine his action and possibly discover the mistake. These possible failures can lead to delay in sending the alarm to warn other trains. The role of the train dispatcher in reducing the negative consequences of this delay is significant. Possible measures to prevent the failures occurring relate to the ergonomic design of the radio interface in the cab. A further human factors requirement is to investigate the application of a common radio interface for both radio systems installed in the train. The latter suggestion has been abandoned as GSM-R is going to be standard in Denmark within few years.

The first three years of operation has shown no human failures due to interface problems of using two completely different radio systems. The challenge has been to teach the drivers the importance, when starting up the GSM-R system, to call the Traffic Control Centre in Malmö to inform which number he is dialling.

To eliminate any possible human factor errors has Øresundsbro Konsortiet finally established a knowledge sharing “Radio workgroup”, including all parties involved.

Besides the train radio systems GSM-R / MSR3, is the fixed link equipped with the following communication systems:

- Mobile Telephone GSM / DCS
- FM - Radio in tunnel (3 channels)
- Emergency Telephones - Railway
- Emergency Authority Radio Systems (partly)

Assessing the impact that the EU IoP directive will have on Øresundsbro Konsortiet's cross border railway safety strategy

Denmark and Sweden has, similar to other EU-member countries, agreed to the Interoperability directive. The main task for the coming years will be to compare rules, procedures and technical systems for the Øresund cross border traffic in order to identify differences and potential Human factors issues. The HUSARE recommendations will in this respect be of great importance.

Measures introduced so far to support interoperability

- Documentation of the Infrastructure in Danish, Swedish and English versions
- Infrastructure Register with reference to the TSIs
- Simplification of rules and procedures
- Participated in developing an "Access Guide" for new and potential new operators
- Harmonising Health and Safety requirement to Railway personal in Denmark, Sweden and Norway

Future measures to support interoperability:

- Installing GSM-R on the entire Øresund line
- Further development of Personnel, training and competence issues
- Further defining Roles and responsibilities
- Regulations on the criteria for retention of competence in train and route
- Knowledge
- Abandon all-national rules that prevents new or potential new operators on the Øresund Fixed Link
- Harmonising the Danish and Swedish rules and norms related to cross-border traffic
- Working for common safety targets, methods and indicators
- Seeking influence through NIM (Nordic Infrastructure Managers)

Lessons learned

Operational experiences from the first years have demonstrated that it is possible for a small, commercially oriented administrative organisation to create a framework for efficient and safe cross-border rail traffic between Denmark and Sweden.

The overall benefits of the Øresund Safety Management System are that:

- The hazard identification and risk management processes provide the information needed to control risk at acceptable levels
- Our organization learns from investigating incidents and is able to remove hazards as required. This type of data is seen as useful as there over time are many more near accidents than actual accidents
- All staff understand how safety is managed and what is expected of them to make it effective

Extensive training in the various safety regulations combined with competence development in the Danish and Swedish language and culture, has very likely eliminated possible misunderstandings or insufficient change of information related to the cross border traffic.

The final report for the HUSARE project “Managing the Human Factor in Multicultural and Multilingual Rail Environments” has shown to be a useful tool in identifying and overcoming the challenges of establishing safe Cross-Border communication on the Øresund Fixed Link.

Sweden’s National Rail Administration was together with Øresundsbro Konsortiet pioneer in launching GSM-R in Sweden. Experiences from the Øresund fixed link has shown, that it is possible to link the digital GSM-R system to an analogue radio system without introducing technical or human factor complications.

References and information sources

[Ref 1] Introduction to SAFETY MANAGEMENT SYSTEMS;
Transport Canada