

RECENT RAILWAY INDUSTRY ACCIDENTS : LEARNING POINTS FOR THE PROCESS INDUSTRIES

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Following a number of high profile accidents in the railway industry in recent years, there has been a large amount of public debate about rail safety. The lessons learnt from these accidents have raised issues which are applicable to the process industries, particularly regarding safety management, human factors, management of contractors and organisational structures. These issues contribute significantly to many process industry accidents. This paper reviews the press reports and published accident reports for some recent high profile accidents including the Channel Tunnel fire, the Kaprun fire, Southall, Paddington, Hatfield and Selby and identifies learning points which are relevant for preventing accidents in the process industry.

learning from accidents, engineering design, emergency response, COMAH

1. INTRODUCTION.

It is an unfortunate fact that many process industry accidents are similar to accidents that have happened historically in the industry or even within the same company. Recent process industry legislation, such as the Control Of Major Accident Hazards Regulations (COMAH, 1999), includes requirements for operators to learn from accidents on their sites and to review historic records of major accidents when identifying potential major accident hazard scenarios within their Safety Report.

Many early accident investigations focused on the specific technical or direct human causes of the accidents. As more knowledge has been obtained in the field, so more attention has been paid to the wider issues of safety management system failures which often lie at the root cause of accidents. This paper has therefore been produced to explore opportunities for learning from accidents in one industry (the rail industry) and applying the lessons to another industry (the process industry).

This will allow the databank of experience about the causes of major accidents affecting the industry to be widened. **Figure 1** illustrates the sources of this information for a typical multi-national company.

2. OBJECTIVES.

This paper reviews published accident and press reports about seven recent high profile accidents in the rail industry and identifies learning points for the major hazard process industries which can be used to avoid, prevent and minimise the impacts of major accidents to improve risk management.

The paper is structured in the following way :

- identification of the key similarities and differences between the two industries from a risk perspective.
- overview of the seven rail accidents that are reviewed in this paper.
- summary of key learning points in the following areas :
    - structural and organisational aspects.
    - safety management systems.
    - design aspects.
    - operational aspects.
    - hazard management.
    - emergency response and management.
- conclusions about how this information can be used practically in the process industry.

3. SIMILARITIES IN RISK DRIVERS BETWEEN THE TWO INDUSTRIES.

At first sight, the railway industry appears to have little in common with the process industry. A deeper investigation, however, reveals that many of the aspects of the two industries which influence major hazard risks are in fact similar. The similarities are general and do not apply to every rail or every process industry company. They include :

Accelerating pace of change in sector. Massive structural changes are occurring in both industries forcing the rail industry to adapt to the new regime which was created following rail privatisation and the process industry to adapt to constant pressure from the financial markets to restructure and improve efficiency.

Fragmentation of large organisations. The rail industry now operates as a complex web of different operating companies, infrastructure management companies, regulatory bodies and contractors. Large chemical companies have also often started to fragment, outsourcing activities which were once carried out in house such as engineering and maintenance, sharing sites with different operators and contracting out service provision such as energy supply, security and gases.

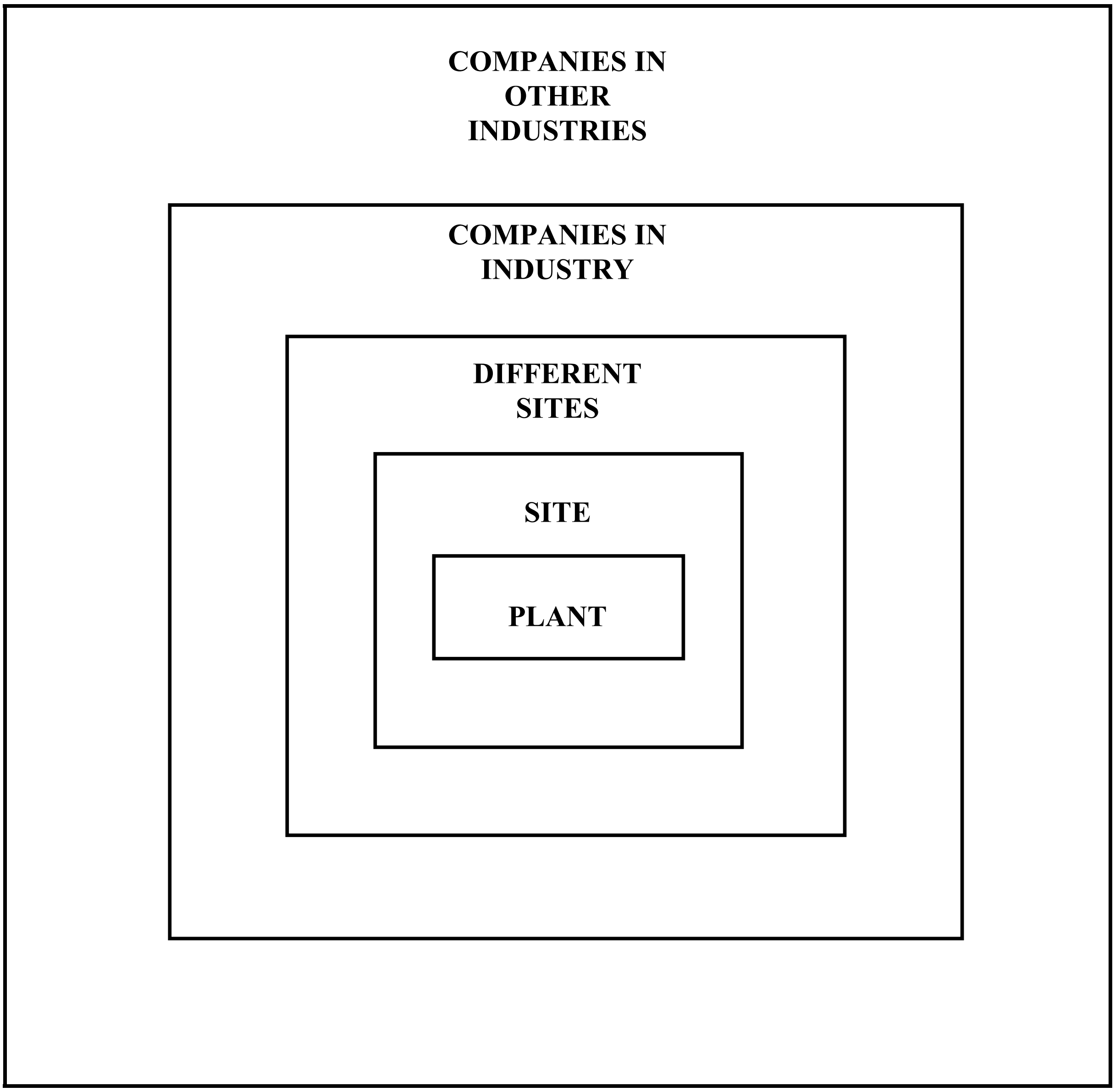
Increasing contractorisation. In order to improve efficiency, many activities which used to be considered to be core activities are now contracted out to specialist companies.

Loss of knowledge and experience. As companies restructure and outsource more activities, so many experienced and knowledgeable staff have been released from the industry.

Major hazard potential. Accidents in both industries have the potential to cause multi-fatality accidents.

High degree of regulation. Because of this major hazard potential, both industries have been tightly regulated and now have to produce detailed Safety Cases to demonstrate that risks within the operation are being managed in an acceptable manner.

Figure 1 : Sources Of Historical Experience About Major Accidents For A Typical Multi-national Company.



Degree of public scrutiny. When things go wrong in the industry, they tend to go wrong in a spectacular manner. Accidents therefore tend to be subject to a high degree of public, press and political scrutiny.

Use of complex automation technology. Advanced and costly control and safety systems are used and are constantly under development in each industry. Difficult decisions have to be made about balancing the costs of these systems and the safety benefits that flow from them.

Development of detailed management systems and procedures. As staff have to perform safety critical tasks in both industries, there has been a historic development of systems and procedures to enable risks to be effectively controlled across relatively large organisations.

4. DIFFERENCES IN RISK DRIVERS BETWEEN THE TWO INDUSTRIES.

The following key differences between the two industries have a significant effect on the risk drivers :

Degree of strategic influence. The centre of decision making for most of the front line companies in the UK rail industry is in the UK. On the other hand, many process companies are headquartered abroad, thus limiting some of their direct influence over investment and their operations.

Asset ownership. Chemical companies tend to own their core assets - the plant and equipment. Railway companies tend to lease their core assets - rolling stock. The priorities of the operating company and the leasing company will often be different.

Strategic national importance of company. If rail companies perform poorly, the knock-on effects of this poor performance are often experienced widely by a large population. This poor performance often has national importance. If a chemical company's production is affected, the effects are normally (but not always) experienced by a much smaller population. There is often, therefore, intense political pressure for a rail company to perform.

Degree of direct political interference. Because of the strategic national importance of the rail industry, the industry is often subject to political interference. This can destabilise or renew management, control investment levels and limit the capital investment priorities (depending on the levels of subsidy and length of franchise awarded). There is much less political interference in the chemical industry.

Populations at risk from accidents. By their nature, any rail accidents are likely to have a direct impact on members of the public as the public is directly at risk in most accidents. Chemical accidents may affect the public but are much more likely to affect employees.

Degree of control over external events. Chemical plants are bounded in limited geographic areas. Rail operations take place over long distances and wide areas. It is therefore much more difficult to control external events on the railways. External events are considered to be events which arise outside the boundary of the operation but cause effects inside the boundary eg. arson.

Availability of resource in an accident situation. Chemical sites are normally manned with teams of experienced people while potentially hazardous operations are taking place. Trains tend to be manned by one or two experienced people (driver / guard). There are therefore very limited immediately available resources for dealing with rail incidents. This is particularly important for accidents in remote areas.

Criticality of human error. Simple human errors (such as failure to see or interpret a signal) can directly cause major accidents on the railways. This problem is rarer in the process industries as it is often possible to deploy technological measures to prevent this condition.

Safety training for populations at risk. Most chemical sites have induction programmes for staff and visitors so that they are trained in how to behave if an accident occurred. This is rare in the rail industry. Populations at risk are therefore unaware of safety procedures and systems if an accident occurred.

Reliance on external emergency response. Many chemical plants have some degree of emergency response capability on site. If rail accidents occurred, great reliance is placed on the timely response of the emergency services.

5. OVERVIEW OF SOME RECENT RAIL ACCIDENTS.

This paper is based on published accident reports and press coverage related to the following seven recent high profile rail accidents :

- Watford South Junction, 8th August 1996.
- Channel Tunnel Fire, 18th November 1996.
- Southall, 19th September 1997.
- Ladbroke Grove, 5th October 1999.
- Hatfield, 17th October 2000.
- Kaprun (Austria), 11th November 2000.
- Selby, 28th February 2001.

The type and extent of information which has been published about these accidents varies. Detailed accident reports tend to be available for the earlier accidents with press coverage and interim accident reports available for the more recent accidents.

This section provides a brief overview of each of the seven accidents.

5.1 Watford South Junction, 8th August 1996.

A passenger train passed a signal at danger and collided with an empty coaching stock train. One passenger was killed, 69 passengers required hospital treatment and four train crew workers suffered injuries (HSE, 1998).

Key factors associated with the accident included :

- the risk of human errors causing SPADs (Signals Passed At Danger) and technological options for reducing these risks with Automatic Train Protection (ATP) systems.
- confusion caused to train drivers due to a speed restriction sign being placed in an inappropriate position and the ambiguity in the railway signalling standard which contributed to the problem.
- the shorter than normal safety margin for the signal that was passed at danger.

5.2 Channel Tunnel Fire, 18th November 1996.

A heavy goods vehicle (HGV) shuttle entered the long subsea tunnel on fire. The 31 passengers and 3 train crew on board were rescued but suffered from the effects of smoke inhalation (DETR, 1997). The fire was intense and caused extensive damage to the tunnel structure and severe disruption to a key European transport link.

The tunnel system was modern and extensive efforts had been made to incorporate safety into the system design from the outset. The fire was a serious test for the system which performed well when the fire occurred.

Key factors associated with the accident included :

- speculation in the press that the fire may have been started deliberately by staff in response to job losses (the cause of the fire is still subject to investigation by the French judicial review process).
- the reliability of the fire detection and fire safety systems and their robustness against common mode failures caused by fires.
- the emergency procedures for responding to incidents including fires and the adequacy of staff training for dealing with emergency situations.
- the adequacy of manning levels in the tunnel control centre for dealing with emergency and abnormal occurrences as well as routine operations.

5.3 Southall, 19th September 1997.

A high speed passenger train passed signals at danger on the approach to a busy London rail terminal and collided with a freight train. Seven passengers were killed and 160 people were injured in the accident (HSC, 2000).

Key factors associated with the accident included :

- the risk of human errors causing SPADs (Signals Passed At Danger) and technological options for reducing these risks with Automatic Train Protection (ATP) systems.
- operating trains knowing that safety critical systems were not functioning. Both the Automatic Warning System (AWS) and Automatic Train Protection (ATP) systems were known to not be working on the journey that lead to the accident.

- the efficiency of fault reporting and corrective maintenance systems so that failures could be quickly remedied and the problems caused by the fragmentation of the industry where different companies were responsible for the maintenance and operation of assets.
- the adequacy of emergency egress facilities from trains that have been involved in an accident.
- the lack of co-ordinated safety related research and development initiatives in the fragmented industry.

5.4 Ladbroke Grove, 5th October 1999.

A commuter train passed signals at danger on the approach to a busy London rail terminal and collided with a high speed passenger train. The collision ruptured fuel tanks and caused an intense fire in the wreckage of the trains. Thirty one passengers were killed and 227 people were treated in hospital following the accident (HSE, 2000).

Key factors associated with the accident included :

- the similarities in terms of causes and geographic location to the recent accident at Southall (see **Section 5.3**) and the delays in investigating the Southall accident.
- the SPAD occurred at a signal which had a history of SPADs and had one of the highest incidences of SPADs on the whole UK train network.
- the consequences of the accident were exacerbated by the intense fire that occurred in the wreckage immediately after the collision.

5.5 Hatfield, 17th October 2000.

A high speed passenger train was derailed when a section of damaged rail broke. Four passengers were killed and 70 people were injured, including four people who were seriously injured (HSE, 2001a). Large sections of the UK rail network were affected by subsequent track closures and speed limits as similar sections of track were investigated. This caused transport chaos in the UK and led to the resignation of the Chief Executive of the rail infrastructure company.

Key factors associated with the accident included :

- management and maintenance of the rail infrastructure and the systems for detecting and correcting fatigue cracks in rails.
- the long delays in responding to identified cracked rails.
- the fragmentation of the industry and resulting difficulties in completing essential work quickly when multiple independent organisations are involved, each with their own priorities and bureaucracies.

5.6 Kaprun (Austria), 11th November 2000.

A fire occurred in a train on a steep funicular railway serving one of Europe's main ski areas. 170 people were killed (Sunday Times, 2000).

Key factors associated with the accident included :

- identifying how a fire could start and spread in a train which was supposed to be fire resistant.
- the absence of fire fighting equipment (eg. fire extinguishers) inside the train or inside the tunnel, making it impossible to extinguish a fire.
- the absence of effective escape routes from the train and the tunnel as the train fitted tightly into a tunnel.
- difficulties in access for emergency services. A long steep walk was required into the tunnel and there were no helicopter landing sites close to the tunnel for evacuating casualties.
- the reasons that the fire doors at the ends of the tunnel were open when they should have been closed to prevent fire and smoke spread.
- the apparent absence of an emergency plan and poor operator training for dealing with an emergency.
- the reliance on unusual and specialist technology (funicular railways in mountain tunnels) with little or no provision for dealing with accidents.

5.7 Selby, 28th February 2001.

A road vehicle and trailer left the carriageway of the M62 motorway and slipped down a steep bank, coming to rest on a railway line. The vehicle was almost immediately hit by a high speed passenger train, causing the train to be derailed into the path of an oncoming freight train (HSE, 2001b). The two trains collided violently. Thirteen people were killed and 100 injured in the accident (Yorkshire Post, 2001).

Key factors associated with the accident included :

- the immediate cause of the accident was not within the control of the railway operating companies but was an interaction from a road transport accident.
- this appears to have been a freak and highly unlikely accident (although a detailed analysis of railway statistics would suggest that an accident of this type was reasonably foreseeable on the railway network).

6. LEARNING POINTS.

The example learning points which have been identified from the seven accidents have been grouped into the following six areas :

- structural and organisational aspects.
- safety management systems.
- design aspects.
- operational aspects.
- hazard management.
- emergency response and management.

6.1 Structural & Organisational Aspects.

These learning points have been obtained from a the Southall accident report and an analysis of press reports following the other accidents and include :

1. *Fragmentation of a business can cause problems with controlling critical safety aspects of the business.*

The Southall accident report identified at least three areas where the fragmentation of the industry had exacerbated safety problems for operating companies :

- the cause of defects and unreliability may be found to lie within the control of companies over which the operator has no formal or informal rights (section 16.13).
- no maintenance checks were carried out owing to differences between the operator and the contractor in interpreting a contract (section 16.14).
- the fragmented industry had been set up to run the railways in their existing state, but there was little incentive to explore research and development issues to the detriment of safety and the long term interests of the industry (section 16.19).

2. *Responsibilities must be clearly defined in fragmented organisations.*

Press reports following some of the accidents on the UK rail network have been very critical of the ambiguous responsibilities that different players in the industry have. This is of particular concern when these responsibilities concern safety critical tasks or operations.

3. *Redundancy programmes can cause skills shortages in an industry.*

Redundancy programmes tend to result in a loss of experienced staff from the industry. These staff tend to be familiar with working practices and safety procedures. If they are replaced with contractors or new workers, this corporate knowledge can be lost.

4. *Businesses can be difficult to manage when contractors are used extensively for critical tasks.*

One of the causes of the Hatfield derailment appears to have been the delay in correcting an identified problem with damaged rails. The response to this problem was bureaucratic and involved at least three organisations : one operating the infrastructure, one inspecting the rails and one laying the rails.

5. *Management must have adequate systems for managing safety critical operations.*

The Southall accident report identified problems with the identification of problems or deficiencies through the monitoring and audit processes which were in place. The following specific issues were raised :

- compliance with rules cannot be assumed without a positive system of monitoring. A different culture needs to be developed to get individuals to perform to the best of their abilities rather than simply delivering minimum service (section 16.10).

- potentially serious deficiencies may develop in detailed maintenance procedures which are not detected by conventional management procedures or audit (section 16.12).

6.2 Safety Management Systems.

These learning points have been obtained from a combination of published accident reports from the Watford South and Southall accidents and an analysis of press reports following the other accidents and include :

1. *Eliminate ambiguity in safety related standards wherever possible.*

The Watford South accident report recommended (#3) that signal standards should be unambiguous where possible as this will minimise the potential for operating systems which do not comply with the intent of the standard.

2. *Ensure that mechanisms exist for listening to the views of operators on the ground.*

Drivers using the section of track around Ladbroke Grove were aware that signal 109 had poor visibility. Mechanisms should be in place for listening to these views and dealing with any relevant issues. This increases the likelihood that the practical issues which are often overlooked by system designers and maintenance staff are addressed.

3. *Learn from previous accidents and incidents.*

Many of the accidents described in **Section 5** had similar causes. In particular, the Southall and Ladbroke Grove accidents were very similar. Signal 109 (where the Ladbroke Grove SPAD occurred) was known as one of the worst signals for SPADs in the whole of the UK. The accident might have been avoided if either a through investigation into the causes of SPADs had been carried out or the lessons from the Southall enquiry had been implemented.

4. *Prompt corrective action is required when safety critical defects have been identified.*

The defective rails which caused the Hatfield derailment were identified many months before the accident occurred but bureaucracy delayed the remedial work.

5. *Nothing should be allowed to delay the opening of an accident investigation.*

This was recommended in the Southall accident report (#80) because serious delays had been caused in the investigation process for legal reasons. This meant that the learning points could not be identified and implemented quickly after the accident.

6.3 Design Aspects.

These learning points have been obtained from a combination of the published Channel Tunnel fire accident report and an analysis of press reports following the other accidents and include :

1. *Fire detection system logic should provide an early indication of fire detection.*

The Channel Tunnel fire detection system logic included an 'unconfirmed fire' signal. This caused a delay in responding to a real fire and it was recommended that a simple logic should be employed (recommendation #1) so that any fires would be detected more quickly.

2. *Critical fire safety systems should be able to withstand the consequences of a fire.*

The Channel Tunnel fire report identified a number of areas where critical fire safety systems performed poorly in a real fire, often because of design deficiencies. These systems need to be robust against fire damage and include communications systems (recommendation #6), fire mains (recommendation #7) and power supplies (recommendation #4).

3. *Fires can occur in areas which are constructed of fire retardant materials.*

The Kaprun fire clearly showed that fires can still occur in systems which are constructed of fire retardant materials. Fire risks in these situations may be low but it is dangerous to assume that fires cannot happen in these systems.

4. *An acceptable basis of safety must be provided for unusual or non-standard technology.*

The Kaprun train used underground funicular technology. This is only used in a few places around the world. Comparatively little operating experience has been gained with these systems and each installation is likely to have it's individual design characteristics. Unfortunately, the design had totally inadequate provisions for emergency escape and rescue. Great care should therefore be taken when using unusual technology.

5. *Even complex automated protection systems will not guarantee that a system is safe.*

The passenger train which was involved in the Southall accident was equipped with a sophisticated ATP protection system. Unfortunately, the system had been isolated as it had been degrading the train's reliability. Complex and expensive safety systems will therefore reduce the likelihood of an accident if they are designed and maintained properly but cannot guarantee that an accident will not happen.

6.4 Operational Aspects.

These learning points have been obtained from a combination of published accident reports from the Channel Tunnel, Watford South and Southall accidents and an analysis of press reports following the other accidents and include :

1. *Procedures should not provide conflicting instructions to operators.*

The Watford South accident report recommended that a full audit of speed restrictions should be carried out to identify areas where conflicting information is provided to drivers (#6).

2. *Great care is required for managing situations where human errors are a significant contributor to risk.*

Press reports following the Ladbroke Grove accident highlighted two factors which may have contributed to the accident :

- the driver of the train which passed the signal at danger was relatively new to the job and may have been inexperienced.
- the government had been putting Train Operating Companies under intense pressure to improve punctuality in the months leading up to the accident. This pressure was invariably pushed straight down to the front line operators, the train drivers. This may have caused drivers to take additional risks to avoid delays, thus increasing SPAD risks. A direct conflict may have developed between punctuality (ie. production) and safety.

3. *Clear procedures and training should be provided for operators covering emergency situations.*

The Channel Tunnel accident report identified the following areas where staff training and procedures were inadequate for dealing with emergency situations :

- a structured emergency management training program should be implemented for all staff (#17).
- members of staff who are likely to observe fires or smoke should be given direct lines of communication with the control centre (#19).
- training should include familiarisation with breathing apparatus kits for all train crews (#22).
- operators should not be faced with an unmanageable increase in workload during an emergency. Alarm management systems should be used (#30).
- review control centre procedures to ensure that they are 'user friendly'. Allocate sufficient qualified personnel to complete their required tasks (#34).
- provide additional staffing to cope with abnormal / emergency situations (#36).

The Southall accident report also recommended that driver training should include operating in abnormal conditions (#4).

4. *An effective and simple near miss reporting system should be provided for front line operators.*

The Southall accident report made the following recommendations :

- drivers should be encouraged to report all actual or suspected faults through a formal incident / fault recording system (#6).
- fault reporting procedures should be made as simple and convenient as practically possible (#17).

5. *Manage operator daily and weekly workload in the light of current knowledge about human behaviour.*

The Southall accident report made the following recommendations :

- review driver's daily and weekly working hours in the light of current research into human behaviour (#9).
- regularly monitor the workload of all maintenance staff (#25).

6. *All safety equipment should be clearly designated and properly maintained.*

The Southall accident report made the following recommendations :

- all safety equipment should be clearly designated as to whether it is vital for the continued running of the train (#12).
- effort should be put into ensuring that safety related equipment does not fail in service through an appropriate system of replacement and maintenance (#31).

7. *Maintenance procedures should require an investigation of the historic failure record of components.*

The Southall accident report made the following recommendations :

- databases should ensure that faults are logged with a history of defects available to management and maintenance staff (#22).
- maintenance procedures should require checking the history of reported defects including repeat faults and ensuring that appropriate action is taken (#29).

8. *Paper based procedures must not become divorced from reality.*

This recommendation was made in the Southall accident report (#69).

9. *Over- optimising infrastructure can reduce safety levels.*

Press reports following some of these accidents have suggested that some of the efforts to improve operational efficiency may have contributed to unforeseen increases in risk levels on the railways. Areas of particular concern were :

- using the same rail lines for high speed passenger and heavy freight operations increases the risks of train collisions and the risk of damaging rails as freight trains are heavier and cause greater stress on the rails.
- running high speed and low speed trains on the same lines, especially where crossovers occur increases the risks of collisions.
- removed multiple lines causes greater congestion on the remaining lines.

6.5 Hazard Management.

These learning points have been obtained from an analysis of press reports following the accidents and include :

1. *External events can cause accidents.*

External events are difficult to manage because they are outside the immediate control of the operating company. Arson is suspected as the cause of the Channel Tunnel fire. The fire safety systems were sophisticated for detecting fires inside the tunnel and dealing with their consequences but they appear to have been deficient at preventing fires from being carried into the tunnel. The Selby rail crash was caused by a road vehicle accident. The railway companies had no direct influence over the design and operation of the adjacent motorway.

2. *Accidents can be caused maliciously.*

There are reports that the Channel Tunnel fire may have been started deliberately by disgruntled employees. Safety systems need to be robust against accidental and deliberate actions.

3. *Accidents can be caused by unforeseen interactions.*

The Ladbroke Grove collision was caused by a SPAD involving signal 109. It appears that the driver's view of the signal was obstructed for a number of reasons, including the presence of a recently constructed gantry to house equipment for the new Heathrow Express rail link. The designers of the new link and / or the organisation responsible for the signaling must have failed to detect this interaction or must have judged that the new gantry did not obscure the driver's vision.

4. *The consequences of accidents are often exaggerated by unforeseen interactions.*

The consequences of the Ladbroke Grove accident were exaggerated by the intense fire which followed the collision. Both trains contained fuel sources. A number of plausible ignition sources were also identified for the fire, including the overhead electric gantry, The interaction of the gantry and the fuel tanks therefore had the potential for increasing the consequences of the accident.

5. *Uncontrollable and extremely unlikely combinations of events can occur.*

It is widely considered that the combination of events leading to the Selby train crash could reasonably be considered to be extremely unlikely and that the events were outside the control of the rail companies.

6. *Situations where simple human errors can lead to major accidents are very dangerous.*

SPADs have caused a number of the rail accidents that have been considered in this paper (Watford South, Southall and Ladbroke Grove). A simple (albeit unlikely) human error has therefore contributed significantly to these major disasters. The basis of safety against these accidents is therefore very dependent on avoidance of human error. Technological back-up systems do exist (eg. ATP) but are relatively expensive. Difficult decisions therefore have to be made about installing these protection systems.

6.6 Emergency Response & Management.

These learning points have been obtained from a combination of published accident reports from the Channel Tunnel and Southall accidents and an analysis of press reports following the Kaprun fire and include :

1. *Portable fire fighting equipment should be provided in areas where a fire risk exists.*

It has been reported that the Kaprun trains and tunnel were not equipped with any fire extinguishers. People inside the trains therefore had no means of extinguishing fires and preventing fire escalation. This suggests that the operating company considered that there was no risk of fire inside the tunnel despite the risk of arson, the combustible nature of the materials transported in the trains and the potential for mechanical friction.

2. *Staff must be given clear procedures and training explaining how to behave in emergency situations.*

It has been reported that the Kaprun tunnel doors were opened during the initial stages of the fire, causing the tunnel to act as a chimney, massively increasing the consequences of the fire. The correct course of action for dealing with a fire in the tunnel should have been incorporated into the tunnel operating procedures and all operators should have known how to deal with this type of incident.

The Channel Tunnel accident report recommended (#5) that procedures for radio use should be improved to avoid system and controller overload by improving radio discipline, making greater use of standard messages and using emergency call buttons.

3. *Emergency procedures should deal realistically with common mode failures.*

The Channel Tunnel accident report recommended (#11) that emergency procedures should address issues such as power loss, loss of communications and loss of firewater supply. If the procedures do not cater for such events, they could well be ineffective in an emergency situation.

4. *Ensure that there are clear procedures for alerting the emergency services in the event of an accident.*

The Channel Tunnel accident report recommended (#15) that this should be improved to ensure that the appropriate emergency services are alerted in a manner that avoids unnecessary delays when dealing with an incident which could escalate.

5. *Routes for evacuation should try to avoid distressing scenes.*

The Southall accident report recommended (#88) that this should be considered where practicable to avoid additional stress to evacuees and the emergency services.

6. *Ensure that practical evacuation routes exist in case accidents happen.*

The Southall accident report recommended (#44) that this should be incorporated in the design of railway vehicles to facilitate evacuation in an accident situation. Particular attention should be paid to egress routes, lighting and communication channels. These facilities were clearly inadequate in the Kaprun fire as the carriage doors were locked and the trains fitted very tightly inside the tunnels with no room for movement between the trains and the tunnel walls.

7. *Ensure that access is available for the emergency services to areas where accidents could occur.*

It was very difficult for the rescue teams to enter the Kaprun tunnel because the only access was via a long steep railway bridge. Helicopter access close to the tunnels was also impossible due to the surrounding terrain. This delayed the rescue teams. The problem would have been revealed if regular emergency drills had been carried out for the tunnel system.

7. CONCLUSIONS.

This paper has shown how useful information about avoiding, controlling and minimising the impacts of major accidents in one industry can be obtained by reviewing published accident reports from other industries. Specific examples of learning points have been produced, but these examples are not intended to be an exhaustive list.

Although the most efficient databank for learning from accidents will normally come from within the industry itself, companies may find it useful to review the reports of accidents in other industries to supplement their knowledge.

Table 1 summarises the areas where learning points have been identified in this paper.

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Table 1 : Summary Of Areas Where Learning Points Have Been Identified.

Structural & Operational Aspects	Safety Management Systems	Design Aspects
1. Industry fragmentation 2. Definition of responsibilities 3. Redundancies and skills shortages 4. Management of contractors 5. Monitoring performance	1. Ambiguity in standards 2. Workforce involvement 3. Learning from accidents 4. Response to identified problems 5. Delays in accident investigations	1. Fire alarm system logic 2. Common mode failures 3. Unusual causes of fire 4. Use of novel technology 5. Effectiveness of safety systems
Operational Aspects	**Hazard Management**	**Emergency Response And Management**
1. Conflicting information in procedures 2. Human errors 3. Training for emergencies 4. Need for near miss / fault reporting systems 5. Monitoring workload 6. Designation of safety critical equipment 7. Maintenance procedures 8. Realism of paper based procedures 9. Production .v. safety conflicts	1. External events 2. Malicious damage 3. Unforeseen interactions causing accidents 4. Unforeseen interactions exacerbating accidents 5. Criticality of human errors	1. Provision of fire fighting equipment 2. Staff training for emergencies 3. Emergency procedures and common mode failures 4. Procedures for alerting the emergency services 5. Practicality of evacuation routes 6. Access for emergency services