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Paper 9100

Index of 1991 Conference Papers

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Paper 9101

David Rayner

Safety Budget Prioritisation

Publisher
2000 International Rail Safety Conference

MEMORANDUM TO: Board Executive

DATE: 17 October 1991

SUBJECT: Safety Budget Prioritisation

SPONSOR: D E Rayner

BACKGROUND

1. Hidden Recommendation 48 stated:

> 'The Department of Transport and British Railways Board shall make a thorough study of the appraisal procedure for safety elements of investment proposals so that the cost effectiveness of safe operation of the railway occupies its proper place in a business operation.'

2. In the summer of 1990, the Department of Transport and I jointly sponsored the Derby Research Division to develop the prioritisation of safety proposals, using risk assessment techniques. The study took 6 varied projects and subjected them to a simplified risk assessment process, in order to establish the safety benefits in terms of lives and injuries that would be saved. The identified costs of the scheme were then calculated to establish an implicit value per life saved.

3. The emerging results from the study were discussed with BR investment analysts and discussions were held with the Department of Transport, Health and Safety Executive (HSE) and the Railway Inspectorate. Support was given in principle to the methodology.

4. In March 1991, I commissioned consultants to assist Director, Safety to develop the methodology and apply it to the 1991/2 safety budget. The work, in conjunction with functional and business representatives, was completed in September; emerging results have been considered by Safety Management Group, by the Safety Investment Panel and informally discussed with HSE and DTp.

5. This paper introduces a presentation that will be made by the Safety Systems Manager, who, as part of the Safety Directorate, has been directly involved in the process, to outline the principles of the methodology used and the emerging results and their implications.

METHODOLOGY

1. Some 250 safety improvement projects from the 1991/92 Safety Budget have been analysed through the prioritisation process. For each project, the safety benefit was calculated and compared with the cost of the project. Safety benefit is defined as fatalities and injuries that would be avoided by implementation of a safety project in its entirety. At this stage of development, it has not been feasible to include other benefits, particularly those of an environmental or business nature. The proposed priority ranking is a unit of safety benefit expressed as a rating per million pounds spent.

2. The Project Manager of each safety proposal is required to analyse his scheme, to identify the type of incident or event that his project is designed to reduce. The project may act by either mitigating the severity or reducing the likelihood of an incident. The Project Manager has to assess the scope of his project for reducing the number of minor injuries, major injuries and fatalities, and calculate the likely effectiveness of his scheme in achieving the desired result.

3. In many cases, data required for this exercise is very specific and available. In other cases the appropriate data is not readily to hand and the calculated outcomes based on historical data of similar but different types of incident and event have had to be made. The Project Manager then uses this data in applying judgement to the effect that his scheme will have.

4. Fatalities, major and minor injuries have been weighted to give a 'unit of safety benefit' indicator. This weighting has been specifically geared, after discussion at the Safety Management Group, to meet the objectives of the Board's Safety Plan. In particular, considerable emphasis has been given to major and time lost injuries in line with objectives in the Safety Management Programme. Previous systems used by the Department of Transport in weighting road safety proposals have concentrated almost exclusively on avoiding fatalities and have given little importance to the avoidance of injuries. It is felt that if we are to address the 'Safety Iceberg', sufficient importance needs to be given to the avoidance of injuries and other lesser incidents involving passengers and staff. HSE have endorsed the relative weightings.

5. After considerable debate, it was decided to treat each type of fatality as equal, irrespective of what category of person was involved. Thus the death of a passenger, a member of the general public, a member of BR staff, a trespasser, or even a suicide has been treated equally. This enables the initial calculations to be done in a relatively straightforward way. However, before the resultant rankings are used to apply priorities for implementation, the category of person needs to be taken into account. A view has to be taken as to whether each type of person should be treated equally.

6. An assessment has been completed for each scheme by its Project Manager and checked for consistency of application both within the Functions and by the Safety Directorate. The results provide broad priority guidelines, although one has to say that there may remain some residual bias in the results because of the substantial use of judgement in these early appraised schemes.

7. Some projects address rare potentially catastrophic events and historic data is inevitably insufficient to reflect the degree of potential catastrophe. Some proposals have the backing of agreed Hidden or Fennell Recommendations, or even a legal requirement. In other cases, a substantial proportion of the expenditure may have already been made and the project has to go forward to completion to capitalise on the benefits, irrespective of priority ranking.

8. After discussion with the HSE and DTp, a number of sensitivity analyses of ranking results have been carried out. Four elements of the process have been tested:

   - the weighting factors between fatality, major and minor injuries;
   - possible enhancement factors for projects designed to avoid 'catastrophic' accidents;
   - different rates of discounting benefits to test impact on long term projects;
   - possible distortion of priorities due to weighting given to trespassers and suicides.

   The analyses tend to increase the number of projects which meet the suggested 'threshold'.

EMERGING RESULTS

1. Two hundred and fifty-seven schemes were ranked using this process, with a cumulative cost in this year's safety budget of £185 million (90% of programme). An estimate of 1992/3 spend on these authorised projects was calculated at approximately £140 million. A further £130 million of unauthorised scheme bids for 1992/3 has been identified. These have been broadly assessed for priority purposes based on the experience in ranking the 1991/2 budget.

2. A group of important 'enabling' projects has emerged from the projects submitted. These are projects such as Total Quality Management, Safety Audit, projects concerned with risk identification and with the development of a safety management infrastructure. Individually, and as a group, these projects underpin the effectiveness of our safety management systems. It is our view that they should be considered as a group and decisions taken on their importance in meeting the Board's safety objectives. There are 60 such 'enabling' projects with a cumulative cost of £42 million in the current budget year.

3. The remaining 200 projects in the main body of the ranking list have been divided into 4 quarters. In broad terms, each of these quarters have certain characteristics. In the top group, the majority of the projects are relatively low cost investments in engineering schemes with targetted and specific safety benefits. They thus rank high.

4. The second quarter has many of the people related projects such as those concerned with the Du Pont recommendations, additional supervision, safety training, etc. In this quarter also are a number of good housekeeping type projects, such as hazard correction and projects concerned with safety at the track-side. They too rank well, given BR's poor record in workforce safety.

5. In the third quarter,there are a small number of major investment schemes with significant safety benefits, such as ATP and driver secure cab radio. There are also a number of major basic cost projects, such as those required to reduce excessive hours and address many of the staffing issues in the S & T function as required by the Hidden Recommendations. These projects rank relatively low, but many address catastrophic risk vulnerability which itself has no special weighting in the prioritisation methodology.

6. In the fourth and lowest quarter, there are a number of other major investment projects such as data recorders and the repair of sea defences, as well as nearly all the projects associated with fire prevention as required by legislation following the Fennell Recommendations. These all rank low in safety benefit.

7. If the cumulative safety benefits and cumulative costs of the projects are plotted on a graph (see Appendix), one sees that the cost effectiveness of the schemes dwindles rapidly as the benefits fall below 0.5 units of safety benefit per million pounds spent. This observation is in line with Health and Safety Executive experience in other industries and is considered by them to be a reasonable threshold for a public company involved in mass transport.

8. There would be broad support therefore by HSE and DTp, to continuing with all projects in the programme that have rankings above this level. Where projects fall below this threshold then they should be subject to three further tests of validity:

i. the post hoc factor of catastrophic risk;

ii. the extent of Board commitment to the scheme as an essential response to either Hidden or Fennell specific recommendation;

iii. the requirements of Safety legislation;

In some of the more major schemes, in depth risk assessments would be appropriate.

9. In the cases of projects concerned with sub-surface stations and fire certification where large scale expenditure is involved, we believe that risk assessments should be carried out on the major station projects before inspections take place with the appropriate fire authority. In that way, informed dialogue can take place between BR and the appropriate authority before excessive expenditure is made or threats of prosecution are served.

CRITERIA FOR ASSESSING THE ADEQUACY OF SAFETY PERFORMANCE

1. HSE have issued national guidelines on the tolerability of risks for certain high risk industries. These do not specifically include railways, but analogies can be drawn. BR's safety performance has therefore been compared with these guidelines.

2. Performance over the years 1920-1947; 1948-1970; 1971-1989 has been analysed. The number of passenger deaths has reduced steadily - most dramatically in the period 1960-1970, when the impact of the Railway Modernisation Plan (1956) took effect. The critical measures were AWS, colour light signalling, long-welded rail and improved construction of rolling stock. Worker deaths have declined, but only in proportion to the number of people employed.

3. A provisional assessment of the 'acceptability' of current performance (1971-1989) is as follows:

- Passengers in train accidents: 1.1×10^{-8} (i.e. 1 passenger fatality per approximately 100 million journeys). This is significantly better than air - either British Airways or world airlines, but not as good as coach/bus. If the risk is calculated per passenger kilometre rather than journey, air, rail and bus safety is very similar.

  This is likely to be viewed by the HSE as at the 'lower' end of acceptability; broadly tolerable, but cost-effective methods should be undertaken to improve. (ALARP).

- Passenger/Public deaths in individual incidents:

  5.3×10^{-8} (i.e. 1 fatality per 20 million journeys).

  The risk is roughly five times greater of an individual being killed in an incident on railway property (this excludes trespassers and suicides). Performance is still, overall, better than air, but worse than coach/bus and also worse than other non-transport industries such as oil/chemicals. This is unlikely to be considered acceptable under HSE developing standards, although BR need to establish its degree of control over deaths reported to HSE under this category.

- Employee fatalities:

  high risk employees 6.3×10^{-4}

  all workface employees 3.6×10^{-4}

  (i.e. 1 fatality per 1,600/2,800 employees in the 'at risk' group).

  This puts BR workface staff in the same band of performance as deep-sea fishing and mining, and is at least an order of magnitude below standards which HSE consider are tolerable.

4. Calculations are still being made about the extent to which Safety Budget initiatives will improve performance against these criteria. It is becoming clear, however, that they are insufficient to move performance even in the longer-term to the required rates, especially for worker safety. One interpretation of this would be that a threshold spend of £2 million per unit of safety benefit would be too low, given the low performance 'start-point'. It also reinforces the BR decision to use weighting factors that give greater emphasis to non-movement accident and injuries.

5. In summary, our work concludes that BR needs to concentrate the effort in implementing safety projects in areas which will result in a reduction in risk to:

   i. workers, whose fatality rates are significantly higher than would be appropriate for a 'safe' industry;

   ii. single passenger fatality events such as movement accidents to reduce the individual risk towards the level of other safer forms of transport (i.e. coach/bus);

iii. improve the current passenger risk due to multiple fatality accidents to further complement the present low fatality rates from such events. Due to the high public interest, further reduction should be considered where practicable, but cost benefit analysis should be applied to the decision analysis.

THE WAY FORWARD

1. The immediate requirement is to use the prioritisation process to support the IFR bid for special safety expenditure in the 1992/3 budget year. This will have to address in particular whether the major schemes in the third and fourth quarters, below the agreed threshold, should be developed especially where there are public commitments from both BR and government.

2. The present methodology has been developed in a relatively crude way to deal with priorities in this and next budget years. However, the prioritisation process sets rankings only between one safety proposal and another. There is a need to develop a long term investment prioritisation system which compares safety improvement expenditure, schemes of renewal with safety implications and ordinary commercial investment. There is then a need to integrate this methodology into BR's financial planning systems as part of a normal mechanism of management. This second stage of safety prioritisation is a priority task for 1992.

3. The present exercise only addresses priorities of existing and known safety improvement schemes. There is no methodology as yet for identifying risks and vulnerabilities which have not yet resulted in accidents. There is an urgent need to develop a methodology which looks at risks on a line of route basis from first principles, as an aid to the new Route Directors. It is proposed to undertake a major pilot study in the coming year, provisionally agreed with the East Coast Mainline Route Director, again with consultancy assistance after competitive tendering.

4. Finally, there is a need to conclude the first stage of the safety prioritisation process by signing off progress on Hidden '48' by submitting a report to the Secretary of State, by November 1991. A second report will be submitted to the Secretary of State in the Autumn of 1992 when the completion of the prioritisation project is made with a methodology for comparing safety expenditures with other investment proposals.

RECOMMENDATIONS

Board Executive is asked to:

1. endorse the principles of the methodology and weightings used to prioritise safety expenditure;

2. note the weighting factors which have to be considered before decisions can be taken to implement the priority ranking and agree these be applied on a post hoc basis of individual scheme consideration;

3. formally endorse the requirement of the Safety Investment Panel that all new submissions should be accompanied by a safety prioritisation appraisal and require the Director of Safety to advise the Safety Panel independently of the validity of the assumptions and realism of the safety benefits claimed for proposals over £100,000 expenditure, to the Safety Panel;

4. support the implementation of the 'enabling' projects and all those specific projects which have a priority ranking higher than 0.5 units of safety benefit per million pounds spent;

5. endorse the continued implementation of Hidden and Fennell Recommendations and related schemes, but where the safety ranking is below the threshold agreed, require sponsors to re-examine the cost and staging of the projects, using risk assessment techniques as appropriate;

6. require appraisals to be undertaken of major fire prevention schemes in advance of joint inspection with the fire authorities;

7. note the comparative performance of BR in safety and that further work is being undertaken in this area;

8. require the Stage 1 paper to be prepared for the Secretary of State on progress on Hidden Recommendation 48 to be completed by November 1991;

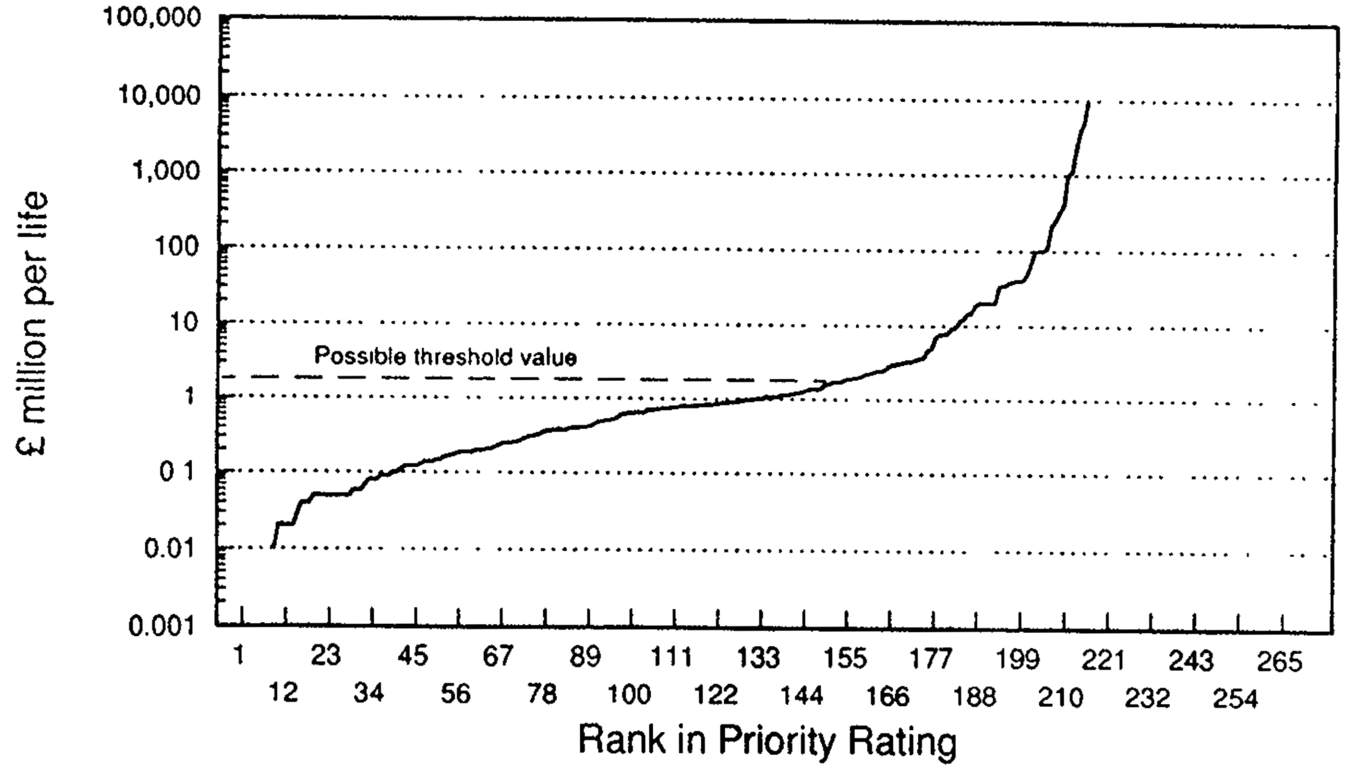
9. endorse the proposals for further strategic risk assessment work during 1992/3, as decribed in Paragraphs 2 and 3 of the 'Way Forward'.

Appendix

SMG22

AT THE LOWER END OF THE PRIORITY RATING LIST, INCREASING EXPENDITURE IS REQUIRED FOR DECREASING SAFETY BENEFIT

- A plot of the reciprocal of the Priority Rating indicates the trend in £ spend required per potential life saved.



- A threshold value of £ spend per potential life saved could be considered as a guide to assessing the usefulness of projects from a safety point of view.

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Pierre Vignes

The New Concept of Safety in the SNCF Driver's Management

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S.N.C.F. DIRECTION DU TRANSPORT
Département TT (TTB)
Pierre VIGNES
Tél. (1)40.08.92.33

THE NEW CONCEPT OF SAFETY IN THE SNCF DRIVERS' MANAGEMENT

INTRODUCTION

Following tragic events which occured in 1985 and 1988, SNCF and especially Traction Departement launched a comprehensive reflexion on the safety management enforced at the time.

Their main conclusions focussed on its limitations or draw-backs in two fields :

1 - the human factor domain, such as tools-design, procedures and organisation,
2 - the structures to be set up to enforce safety, which is the subject that I shall now address in a first time.

* * * * *

Recent events show that, whenever proof were needed, nothing should ever be taken for granted where safety is concerned. Nevertheless, we decided to keep the same course, in safety management, considering that our policy remains basically sound, but needs time to be implemented.

1 - PRELIMINARY PROCEDURE

We have harmonised the Driver's management organisation on the structures adopted by SNCF as part of the process of decentralisation.

And we acknowledge individual roles and responsabilities for each stage of the management :

- Traction Department, as part of the Technical Direction of Transport.
- Regions (23)
- "Etablissements" (700) of wich 73 "dépots"

Relations lay on the principle of customer/supplier contracts, concerted agreements regarding objectives and resources and on ensuring that individuals do understand and bear their responsibilities in the process of implementing change.

We pass from an "on line management" to an "off line" one.

2 - THE PROBLEM : ASSESSING THE SAFETY LEVEL

It is impossible to assess the safety level of the finished product (driver-kilometres) for a particular "Etablissement" or a particular Region. "Etablissement" or Region (incidents, near-misses, etc.) precludes strict application of a statistical approach to obtain a quantitative assessment of results in each case.

3 - ONE PATH TO SOLUTION: SAFETY ASSURANCE

Under these circumstances, assessment can only be made in relation to the safety levels of the various modules making up the production process. Each module is governed by "standards" which are representative of a doctrine or principles (the spirit of the standard).

Safety levels can be deemed satisfactory when both the standard and the spirit of the standard are observed.

This is the philosophy underlying safety assurance (by analogy with quality assurance), which can be expressed in the following terms: "For the safety level of the finished product to be satisfactory, it is first necessary for the safety levels of each of the modules in the production process to be satisfactory".

Any shortcoming recognized in the final product should be REPORTED to complete the cycle of defining standards specific to each module.

4 - DOCTRINE AND STANDARDS

Where driving safety is concerned, the Traction Division of the Operating Department (TT) works out a doctrine, which through standards and recommendations constitutes the company's requirements in terms of the safety of the finished product: driver-kilometres.

4.1 - Standards

A distinction may be made between two different types of standard :

- standards relating directly to railway technology (for example, those governing full brake tests).
- organisational standards (for example, those stipulating the minimum number of times per year inspectors are supposed to travel with drivers in the cabine to monitor performance).

- plans to decentralise the setting of certain standards are under considerating on the understanding that local agreements could be enforced instead, but should remain consistent with the basic company doctrine, all adaptations being conducted under the responsibility of the Regional Director.

4.2 - Recommendations

Recommendations are less imperative than the standards and stipulate principles. They must be enforced at regional level in relation to specific local features and possibilities.

Example of a recommendation : Compilation of an annual, individually-tailored programme of further training for depot supervisors.

4.3 - Completion of the cycle

The cycle should be completed by examining:

a) consistency between regional agreements and central doctrine,

b) the quality of the organisation set up by the region to uphold safety standards,

c) interpretation and application of recommendations.

This exercise will be conducted by the regional safety auditors or by the Safety General Inspectorate (I.G.S.).

Our whole approach aims at making our management staff conscious that strictly applying the texts was not in itself a safety management method. Managing does not consist in a bureaucratic apply of mandatory texts but should encompass a role of change by teaching our staff to assimilate and master the principles and acquire the ability to analyse and alter situations through judicious application of principles and not just rules decreed at national level. This is the challenge that we are attempting to meet with the 1,300 members of the Drivers' management team !

4.4 - The safety charter

The safety charter makes a clear distinction between the relative responsibilities of Region and "Etablissement" and lays down the safety functions of the particular "Etablissement". In principle, it represents a firm, long-term commitment serving as a basis for safety organisation in the region concerned.

The agreement on objectives and resources

These concepts of responsibility and respective roles are given practical form through agreements on objectives and resources between level "a" and level "a+1".

A clear distinction must be made here between:

. 1) the precise objectives undertaken by "a" who is directly involved in their implementation,
. 2) indicators which are a more or less faithful mirror of quality standards.

Objectives are the practical embodiement of the tasks contained in the charter, adapted to the period covered by the agreement. It should be possible to measure the results acquired.

Example : Internal check-up within the "Etablissement" constitute a task that could form part of the safety charter. One target to be included in the agreement may be that of developing and introducing the practical arrangements for internal verifications and deciding who is to be in charge of implementation. The latter will then be instructed to work out monitoring and control procedures.

The values to be taken as a yardstick for assessing results may, where necessary, be shown in a codicil to the agreement.

5 - FOSTERING RESPONSIBLE ATTITUDES

This deliberate, concerted procedure for making staff aware of their responsibilities, should act as an incentive for those concerned.

Confirmation by the hierarchical superior "a+1" that duly debated outside assessments will be incorporated in the performance records of those in positions of responsibility at level "a" is a further motivating factor.

. deviations in relation to resources
  - orders of priority,
  - revision of quality standards
  - optimisation of organisation (achieving more with the same resources)
  - building up resources,
  - sub-contracting.

<u>Such analysis should be conducted in advance, foreseeing developments and organising accordingly rather than reacting after the event</u>.

6 - DISTRIBUTION OF TASKS, A REGIONAL SOLUTION

Clear definition of responsibilities should be synonymous with specific distribution of tasks between region (a+1) and "Etablissement" (a).

This distribution depends on local and regional factors (number and size of "Etablissements", managers' qualifications, volume of tasks, specific job features, etc.) and varies by its very nature from one Region to the next, there is no one single model.

It is the responsibility of the regional authorities to strike the best possible balance.

7 - MANAGEMENT OF SAFETY

The following 4 areas of activity constitute the basis for management of safety in the true sense of the term, enabling heads of "établissement" to fulfil their managerial functions to the full:

. 1) undertaking to meet specific objectives agreed with "a+1", following clear identification of the safety functions to be fulfilled by the "Etablissement" (compilation of the safety charter),
. 2) management of negotiated means and resources,
. 3) optimisation of organisation and control of methods,
. 4) acceptance of the principle of periodical feedback.

8 - THE TOOLS

8.1 - Reports on experience.

Purpose = to improve the reliability of the man-machine system
= to enhance safety.

. **Principles**

1. Greater awareness : it is important for all the links in the safety chain to subscribe to the principle of reporting on experiences and to recognize that all incidents or difficulties may serve the cause of progress, if they are subjected to analysis and fault diagnosis.

   Area :
   - TRAINING
   - PRACTICAL EXPERIENCE WITH REGULATIONS
   - MALFUNCTIONS IN THE MAN-MACHINE SYSTEM (driving incidents, e.g.)

--> forms to be used for describing incidents : to assist in collecting information.

--> IT (information technology) resources to store and process information.

2. <u>Better understanding</u> : The behaviour of the individuals at the heart of the man-machine system is affected by a certain number of factors, such as training, physical and emotional state, ability to respond to abnormal circumstances, working conditions, staff/crew relations, etc. It is essential to take account of these factors to reach a better understanding of the problems.

3. <u>Putting knowledge to better account</u> : This third stage in the proceedings is essential to the success of the venture as a whole. The ability to draw useful conclusions from problems encountered in the field and introduce effective counter-measures at all levels ("Etablissement", Region, Traction Department) should serve to improve safety whilst further motivating the various protagonists, both as regards passing information up the line and analysing it in depth.

Reporting on experience is a process that requires careful preparation, a change of attitude being necessary :

- acknowledgement that human beings are fallible and cannot guarantee the safety of the system on their own, however well they may be trained and however great their motivation.

- concentrating as a matter of principle on identifying and analysing causes, not seeking to apportion responsibilities,

- understanding that punishment rarely prevents recurrence of an incident.

It also requires training in methodological approaches:

- study of a problem: efforts to gather ALL relevant clues, identification, measurement of deviations, etc.

- analysis of causes,

- preparation of a CAUSALITY TREE,

- preparation of a strategy to avoid recurrence of the particular anomaly or contain its consequences,

- application of the solution(s) selected,

- confirmation through feedback.

. Handling individual cases

Success of the reporting technique hinges inevitably on improvement in the atmosphere of trust and confidence. But this procedure, if properly employed, can contribute in itself to improving relations between train drivers and managerial staff.

. Dealing with "mistakes"

- Sanctions should never under any circumstances be the purpose of the investigation. It is far better to intervene in respect of the conditions in which the mistake occurred than to prosecute its perpetrator.

- To influence the conditions in which the mistake was made, it is therefore necessary to conduct a full and impartial analysis, without trying to allot responsibilities,

  A distinction should be made between establishing causes and identifying responsibilities. One way of guaranteeing objective handling and analysis is to have two separate investigations conducted by two independent experts, for example.

. Handling information spontaneously reported by staff

Involvement of drivers in the process of REPORTING EXPERIENCES should result in more frequent spontaneous reporting of errors. These should be handled in such a way as to encourage REPORTS to be made on EXPERIENCES, whilst taking care to avoid counter-productive developments:

- unsuitable or inappropriate punishment may shatter the general atmosphere of trust. Ultimately, the system of REPORTING EXPERIENCES would suffer,

- furthermore, the principles of safety must remain sacred.

. Flexibility and firmness

This technique is not easy to achieve for managerial staff and cannot be enforced by decree. Discussions should be organised by and with the staff concerned to achieve a change in attitudes. Whilst softening our approach to staff guilty of errors, especially those who admit the truth without prompting, we must also ensure:

- firmness at earlier stages, especially in areas involving conscientiousness on the part of staff (vehicle preparation, recommissioning, brake tests, consultation of the weekly line change notification sheets, up-to-date documents, healthy living, etc.),

- efficient subsequent controls,

- enforcement of effective preventive and remedial action.

- sanctions enforced whenever deliberate offences, or gross violations of professional behaviour are committed.

8.2 - Training

We developpe new teaching techniques: teaching by objectives:

- in initial training,
- and further training.

Sophisticated tools:

- procedure simulators: training in recognizing the situation pattern, and therefore applying appropriate conditioned reflexes, maintaining abilities,
  - future-oriented training:

- duty simulator:
  . confirmation of the validity of the solutions adopted (study),
  . training for almost all eventualities
  ---> TransManche Super Train or even suburban stock...

8.3 - Documentation: rewriting the rules

Documentation cannot consist in the official rule book, or of the documents distributed at training sessions. What staff require is a practical manual to which they can refer in case of difficulty or doubts about complex or unusual procedures, where memory alone would not be enough to ensure reliability of execution.

Whence the need for a separation between :

- Reference documents for the particular job category: collection of all texts (train running safety rules, staff safety, technical leaflets, etc.), that provide a precise description of the job of a train driver.

- Training documents:

  . training objectives,
  . training structures and instruments,
  . literature.

- Application manuals as back-up.

CONCLUSION

This brief presentation will, I hope, have given you a general idea of the developments taking place in the Traction Department in terms of managing safety. First results are indeed already discernable:

- roles are more clearly defined, the cast knowing their parts and recognizing their responsibilities,

- structures are gradually being adapted to take account of basic principles and local peculiarities. "Etablissements" are compiling charters and procedures to guarantee safety,

- tools are being introduced and are beginning to produce results,

- the working atmosphere is improving and a feeling of trust is again emerging.

It is, however, too soon to measure the effects on safety but we have every confidence in our undertaking and have every reason to hope that safety assurance will enable us gradually to come to grips with the system.

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David Maidment

Monitoring Safety Performance, Individual and Organisational Behaviour

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DRAFT

PAPER TO THE INSTITUTION OF OCCUPATIONAL SAFETY AND HEALTH

ANNUAL CONFERENCE, HARROGATE, 12 NOVEMBER 1991

MONITORING SAFETY PERFORMANCE, INDIVIDUAL AND ORGANISATIONAL BEHAVIOUR

By David Maidment, Safety Systems Manager, British Rail

What is BR Trying to Achieve?

British Rail are in the middle of a major programme to improve safety performance. We are measuring to check that our intention is carried into effect. But what are we measuring? What is safety? And how do we know when our performance is acceptable?

Railways traditionally have had a high public reputation for safety. Comparisons made with other transport modes and with railways in other countries have tended to show British Rail in a favourable light. The technical revolution in the 1950's and 1960's involving the complete re-equipment of our signalling and rolling-stock systems eliminated a high proportion of the more sensational train crashes that catch the eye of the media. And each time an accident occurred, the railway system instituted a thorough going investigation that lead to recommendations to improve technology or the operating rules. Thorough, but of course reactive to the circumstances and wise after the event.

The 1970's and early 1980's were a period of consolidation as far as safety was concerned. Improvement continued at a slow rate, but the railway management was mainly concerned with the problems of financial performance, productivity and increasingly, the attractiveness and quality of the product for passenger and freight customers. Safety was not ignored, but a drive to improve safety was not the top priority.

Then in 1987 came the catastrophic fire at Kings Cross Underground station, followed by the hard hitting Fennell inquiry which brought questions about systems of managing safety. British Rail looked afresh at its own systems and began to seek improvements. A new Safety Directorate was established, with the appointment of the new Director in November 1988. Two weeks later British Rail suffered the calamity of the accident at Clapham Junction, which killed 35 people. Our systems for managing safety again came under the deepest scrutiny.

During the course of the inquiry set up under Sir Anthony Hidden QC, British Rail committed itself to a thorough review by external experts of its safety systems. This investigation was carried out during the Autumn of 1989 and early 1990 by the Du Pont Safety Services Organisation. This review highlighted both strengths and weaknesses of the existing systems, but highlighted in particular the fragmented way in which BR measured and monitored safety. There was no clear definition of what BR meant by safety. Too few managers were aware of their safety performance, either in relation to their customers or to their own staff. Different aspects of safety were managed in different pockets of the organisation.

And when the accident statistics were scrutinised, what was one to make of what one found? In five of the last ten years, there had been no passenger fatalities in train accidents. Many judged us on this sort of statistic. But how did we feel about statistics that showed that 25 or more passengers were killed in any one year joining and alighting from trains or falling from trains en-route? Did we accept staff fatalities running between 10 and 20 per annum? And what about the 150 trespassers killed every year on our system, let alone the 150 suicides?

In the spring of 1990, the British Rail Board committed itself to the recommendations made by the Du Pont organisation and developed its own safety programme. A couple of years previously the Board had adopted a policy of total quality management with its emphasis on continuous improvement of performance. This philosophy was now to be applied to safety, an extremely important element of quality. We would adopt targets of safety performance improvement, but to do this we had to bring about a change in attitudes and behaviour - in short, a revolution in our safety culture. The Du Pont review had identifed that we had placed too much store in technical and rule based systems and had not paid enough attention to the human factors in our activities.

The other key component of our change in culture was to be pro-active in what we did - to identify potential incidents and accidents before they happened and take protective measures to prevent them coming about.

We brought together our policies and plans in the British Rail Safety Plan which we published in February 1991. As well as clearly defining what we meant by safety, and the policy that we were now adopting, we set out in this plan 17 key objectives which we submitted to the Secretary of State for Transport. The first three of these were to reduce injuries and fatalities to our customers, the general public and our own staff, including those contractors who worked for us.

The next nine objectives, however, were all concerned with the management processes that we were to put into place to bring these reductions about.

Some of these objectives were clearly concerned with instituting the new culture and the commitment that BR was making to change its attitude to people and by its people in the management of safety. Programmes involve staff in discussing safety at local level, identifying hazardous conditions and correcting them, more importantly identifying unsafe acts and educating people to be aware of these, improved supervision and training.

On the other hand, we balanced these 'people' issues with some hard systems developments. We were applying British Standard 5750 to many of our engineering activities and these would be developed wider into all production functions. We were developing a new information monitoring system, we were implementing a layered system of safety audit, at the higher levels using the International Safety Rating System. We were beginning to apply techniques of risk assessment to some of BR's major projects.

In 1991 we agreed with government a special funding arrangement for safety improvement initiatives and the resources and finance for this special safety budget were vetted and developed by a Safety Investment Panel, chaired by one of our Board Members. At the same time, a project team was created to develop the core standards and programmes for safety management training for senior and middle management.

This programme, all these initiatives are now well underway. How are we to measure their progress?

Monitoring Safety Performance Through Accident Statistics

From the days of the private railway companies, there has been legislation requiring the railways to report fatalities and injuries to passengers, the public and BR staff that come under well defined categories and codes. Even after the railways were nationalised in 1948, the Railway Inspectorate continued to pull together the accident statistics and publish these annually with their commentary in the Chief Inspecting Officer of Railways' annual report.

Typically, the annual reports include statistics about train incidents - collisions, derailments, trains running into obstructions, level-crossing accidents, fires on trains, rolling-stock failures of a hazardous type, permanent way structure failures and so on. Train accidents are again analysed by their primary causes, such as staff error, technical defects, weather related incidents, actions by the general public, etc. Further tables analyse casualities, both injuries and fatalities by type of person, by type of incident, by general cause. A further analysis concerns incidents and casualities of a 'non-movement' nature such as incidents at stations, with machinery, electric shocks, faults, etc.

This information had a number of major drawbacks, comprehensive though it was in many ways. Not being compiled by British Rail staff, it was often not available until many months after the incidents concerned. Trends could not be reviewed in a timely manner. And the data dealt with incidents and accidents that had consequences only of a reportable nature and ignored many other lesser incidents and near misses which held equally valuable information.

In the last 2 years, British Rail has been developing its own incident monitoring system (BRIMS). In the first instance, it brought onto the system at BR headquarters all those incidents and accidents previously reportable directly to the Railway Inspectorate. A second stage implemented in June 1990, was to computerise on the same system all lost time injury statistics for BR's staff and contractors. A third stage, now being introduced progressively, is to bring onto the system many previously non-reportable incidents and events which are of a potentially hazardous nature. This would include information about derailments and minor incidents in marshalling yards, information about signalling irregularities and signals passed at danger which did not lead at the time to any consequential damage, and failures of equipment which could have had potentially serious outcomes.

Many of these equipment failures have already been monitored for some years within the Engineering Departments' own computing systems. Hazard ratings are now being applied to those failure events which have safety implications, so that the engineering computing systems and BRIMS can be linked to automatically highlight safety incidents on the BRIMS system.

Monthly reports of the key BRIMS statistics are now made to the Board itself and other senior management committees of British Rail, as well as being available to business managers and local managers throughout the system.

Monitoring Safety in a Pro-Active Way - Audit Data

Even with the much improved access to comprehensive accident and incident statistics, the criticism can be made that much of the data is of necessity re-active. The incidents and injuries have happened. Data on which predictions can be made before the incidents occur is limited. As I said earlier, the Board has now set out 17 safety improvement objectives, of which nine refer to the implementation of new safety management systems.

These objectives are supported by action plans with key dates, and it is the intention for BR not only to monitor the implementation of these internally, but to publish our progress in Safety Plans, issued annually.

For example, the safety management programme developed from the Du Pont recommendations has clear action plans which each Route Director is committed to, after implementation of new organisational proposals now taking place. The new structure of safety meetings involving all staff have to be put in place within 6 months of a new organisation being cut over, and the business managers concerned are accountable on a quarterly basis to the Board's senior railway management group.

The safety management programme itself builds in monitoring devices. The requirement for monthly safety meetings cascaded from the Chief Executive down to supervisors with small numbers of staff at the workface, will not only be monitored in terms of frequency of meetings and coverage of all staff, but will also require notes of topics raised, actions recommended and implemented.

Safety tours and inspections, both with supervisors and trade union safety representatives, will log unsafe conditions, will use a simple means of prioritising them in a numerate fashion, and will have a reporting system that elevates uncorrected unsafe conditions within certain laid-down timescales.

More importantly, we are concentrating on equipping managers and supervisors to observe staff and their work practices, and in a supportive way to counsel and correct where they see unsafe acts taking place. These observations on regular and laid-down safety tours, are again logged and categorised and the trends will be monitored by both local managers and on a sampling basis by senior managers.

Production managers, both operating and engineering, have been using check lists for some time to audit and monitor compliance with professional standards. In the past, this has not always been properly systematised, and breeches in this discipline were identified in the aftermath of the Clapham accident. British Rail has now adopted the formal International Safety Rating System promoted and licensed by ILCI, and has set up its own Safety Audit Directorate, which from next April will report independently to the Board Member responsible for operating systems and safety. Teams, out-based throughout the country will audit the safety management systems being applied and implemented by the Board's business managing directors and their route directors, sampling as necessary the validity of their findings at individual depots and work locations.

The businesses themselves will own small audit teams using the same basic audit systems and these methods will be adapted by the engineering and operating line managers within the businesses to check compliance with their professional railway standards.

None of these audit activites absolve the line managers from assuring themselves through their own monitoring that their staff are properly complying with the Board's laid down standards. Local managers or business units, if they have particular concerns about their safety performance or are seeing trends that require investigation, may call on the assistance of one of the audit teams to support them. It is intended that the audit process will be seen as helpful to management and not an imposition.

The activities of the audit teams will produce not only reports but numerate assessments of the performance of the activities that they have sampled over a number of specific safety management headings. British Rail intend to monitor these 'audit scores' to monitor progress in implementing safety management systems and in setting improvement targets for local and business managers.

British Rail at any one time has a plethora of schemes for change. Technical projects, organisational changes, operating method changes, product and business changes, all impose opportunities and risks on BR staff which have to be managed.

A series of organisational changes are currently taking place between April 1991 and April 1992 affecting Board Headquarters, and the regions and businesses. Because of the fundamental nature of the change in responsibilities taking place, the Board have set up under the Director, Safety, a safety validation process by which all new proposals are vetted. Some 162 audit type questions have been developed to test each new organisation proposal on issues such as the adequacy of its safety policy, its organisational structure for managing safety, its documentation control, its safety communication strategy, its safety training programme and so on.

An intrinsic part of this validation process is the Board's safety management training initiative. Foundation and strategic safety management courses have been developed for middle and senior management of the new organisations, and the accreditation of these personnel by exam and assessment is a necessary part of the validation system. The training courses themselves, their content and delivery, are auditable and the results in broad terms are monitored by the Board.

Up to now, the validation process has only been applied to major organisational proposals. However, discussions are taking place with businesses and production functions on the need to validate major new initiatives of change, such as investment schemes in safety equipment, like automatic train protection or major schemes to change conditions of service and patterns of work as are being developed for groups of staff such as our drivers. A key part of this validation process will be the development of the indicators by which these initiatives and their safety impact will be judged.

Much investigative work on accidents has concentrated on the errors at the local level, i.e. the individual operative at fault. British Rail has been working through its Research Division with Professor James Reason of the Department of Psychology, Manchester University to investigate more fully the causes of human error.

Initially the work concentrated on the way in which decisions by supervision and management conspired to create the conditions under which staff made errors. The research work identified that a substantial proportion of accidents had their origin in decisions that were made at quite senior level that created the environment and culture in which people took decisions, short-cuts and broke rules, not with ill intent but often as the best way of achieving expectations.

The research work has progressed to look at the factors which characterise organisations with good safety records and equally those organisations that have more than their share of accidents. The critical factors have been grouped into what Professor Reason calls 'general failure types' which can be applied to any of the main production activities such as design, build, operate and maintain. Research amongst a sample of BR managers and supervisors has identified in each of these activites which are the failure processes of most concern in the BR system - weaknesses in planning, management control, lack of awareness of the conditions under which staff actually carry out work and lack of training.

Professor Reason is helping us to design indicators that will monitor our safety performance at a much earlier stage. As I have said earlier, our BRIMS system measures accident outcomes, and increasingly information about rule and technical lapses that result in near misses. The audit systems and the monitoring of unsafe act and conditions inspections will give earlier monitoring information about the weaknesses in systems and conditions that allow errors and lapses to occur. The aim in this project is to go one step further back and to identify the weaknesses in the management decision taking processes which create the conditions which are unforgiving to the operator in the field.

We are now on the point of identifying some local activities in which the search for such indicators can be started. It is the intention to interview staff at ground level and their supervisors about the events which lead to near misses and violations of instructions, to identify those causes and elements of safety culture which lie behind them which can be monitored at a higher level.

Measuring the Adequacy of the Standards

A lot of what I have said has been about ensuring compliance with the standards and plans that have been laid out by the British Rail Board. But how do we know whether these standards are good enough? And how do we know which of the many action plans that we have described will have most effect?

In 1991, the Board have identified and are progressing over 250 individual safety improvement initiatives. Not only do these cost a lot of money, they also involve significant management and staff effort and resource. Over the last year, we have made significant strides in developing a system to set priorities. Each safety scheme project manager is asked to identify the type of incident that his scheme will address. The frequency of such incidents and the average outcome in terms of fatalities and injuries is assessed from past accident data. The project manager then has to assess the impact that his project will have in either reducing the frequency of incident or mitigating the consequence of that incident. Using a simplified form of risk assessment, a broad safety benefit can be calculated for each initiative and compared with its overall cost.

The programme as a whole can then be considered, by comparing the number of lives and injuries claimed to be avoided progressively with the sums of money and resource necessary to achieve this.

The impact of this total safety programme can also be presented in graphical form as an 'FN (frequency/number) curve'. This is a way of plotting the frequency of accidents and the number of people affected. Comparisons can be made with other industries or other firms in the same line of activity and then reference made to the guidelines given by the Health & Safety Executive on the tolerability of risk. This work on BR is only its infancy and it is too early yet to outline any major conclusions. A first appraisal however, seems to point to the need for BR to improve its own staff safety record and to give more attention to the types of incidents affecting passengers and the general public where fatalities occur which do not always claim the attention of the media. Admittedly, recent incidents on footpath crossings and the publicity about passengers falling from trains have been picked up by the media, but do not appear to get anything like the same attention as the rare train accident, such as Cannon Street, Purley or Clapham Junction.

Conclusions

Until recently, we believed on British Rail that monitoring safety performance was about getting comprehensive and reliable accident data. Our experience of the last 2 years has taught us that we need to place much more store, without eliminating the importance of proper outcome data, to the collection of information about our performance in instituting those safety management measures that are necessary to pro-actively control safety.

We are adopting therefore, a 'holistic' approach. We believe safety performance has to be measured in many ways, both individual actions, organisational indicators, and audit systems.

All this activity is not going to correct or improve BR's safety performance in terms of accident results overnight. It is a long term strategy to reach a new plateau of performance and requires a change in culture and attitude that takes a lot of hard work to achieve. Let's face it, this is the way that we and many other organisations like us, have been managing and monitoring financial performance for many years. Safety performance for both humanitarian and economic reasons demands no less.

We learned this lesson the hard way - although we had started applying the lessons of Zeebrugge, Piper Alpha and Kings Cross when the tragedy at Clapham Junction struck at us. Learn from our experience!

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Steve Maxwell
David Hyland
Jim Kennedy

Ranking of Infrastructure Renewals within a Suburban Railway Environment

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BIOGRAPHICAL NOTE

Steve Maxwell is general manager, Network Maintenance CityRail, State Rail Authority of NSW. He has 21 years experience in engineering infrastructure maintenance and renewal in the NSW State Railway system. This experience has been predominantly in the Civil Engineering discipline but in recent years expanding to the Signalling and Electrical disciplines.

David Hyland has spent 20 years in the railway industry in construction, maintenance and planning. He began his career in 1970 with the Public Transport Commission of NSW, including 12 months secondment to the Federal Bureau of Transport Economics.

Following a period in the railway supply industry, David has been providing consulting services, predominantly in railways for the past ten years. In particular, David's consulting experience has provided advice on the development of computerised management information, and project management systems and reviewing railway operations and engineering functions for the NSW and Victorian Rail systems.

Jim Kennedy has spent 21 years in a military maintenance engineering environment as a prelude to a career in the railway industry.

Except for a break of two years in a state of the art joint US/Australian military design project, Jim has spent the remainder of this time since retiring from the military in the railway industry.

Key appointments have been Group Manager Logistic Support in the former Metropolitan Transit Authority and Project Manager for the development of maintenance plans for infrastructure assets in the Public Transport Corporation.

Jim is currently assisting CityRail in the development and application of a comprehensive maintenance engineering function to support CityRail Signalling, Electrical and Civil disciplines.

Jim's expertise resides in Integrated Logistic Support, Maintenance Management, Risk Management and Total Quality Management.

Ranking of Infrastructure Renewals within a Suburban Railway Environment

Steve Maxwell, State Rail Authority of NSW

David Hyland, Hyland Joy & Wardrop Pty Ltd

Jim Kennedy, Hyland Joy & Wardrop Pty Ltd

October 1991

ABSTRACT

In 1989 the Booz Allen & Hamilton report on CityRail recommended spending $2 billion to rehabilitate the infrastructure of CityRail to that of a world class railway by 1995.

To enable projects to be ranked to provide maximum return on investment and to ensure that only work that would have a significant impact on the operation of the system is done, risk analysis techniques, using as a comparative measure the loss exposure that could result from not doing the work, were used.

This provided a benefit/cost ratio for each project as the first and major step in the determination of actual expenditure priorities.

This evaluation uses only dollar values as the comparator.

It relies on the specification of acceptable ranges of quality of service from assets, the lower bounds of which are considered unambiguously safe for all possible operations and allow management to:

* Identify the safety & service risk that could be eliminated by doing specific projects

* Assess the cost of providing a specified level of service and safety, or alternatively the levels that can be provided for the funding available

1. INTRODUCTION

In 1989 the Booz Allen & Hamilton report on Cityrail recommended spending $2 billion to rehabilitate the infrastructure of CityRail to that of a world class railway by 1995.

While the first year of the program (1990) produced a significant increase in infrastructure renewal, competition for scarce resources demanded a strategy that would examine both infrastructure and maintenance needs and establish work priorities, the time frame required to achieve the necessary rehabilitation and the total cost of the work.

This strategy, the CityRail Infrastructure Maintenance and Renewal Strategy, required a program of works that would ensure the work was done in the order of greatest payoffs, in the optimal combinations to:

a. Ensure efficient use of resources

b. Minimise interference to service

c. Minimise inconvenience to customers and public

d. Optimise impact of reconstruction on system reliability and infrastructure integrity

In August 1990 Hyland Joy and Wardrop were engaged to develop an infrastructure reconstruction program for CityRail.

In order to prioritise works listed for inclusion in the program, risk analysis techniques, using loss exposure as a comparative criteria were used to address all elements targeted by the strategy.

2. OBJECTIVE

This paper defines the process which provided the comparative measures to rank projects proposed for inclusion in the program.

3. TASK SIZING

At the time of writing, some 3500 tasks, with a total cost of $1.1billion had been identified for ranking. They consisted of:

Trackwork	$280.4M
Signals	$523.8M
Electrical	$198.4M
Bridges & Structures	$26.6M
Cuttings & Embankments	$34.0M
Drainage	$16.2M
General Work	$8.5M

4. FACTORS AFFECTING RANKING

It was agreed from the outset that any ranking process should attempt to take into account:

* Safety
* Importance of the section operationally
* Probability of failure
* Effect of failure on train running
* Savings in maintenance cost
* Improvement in train running time
* Savings in operations costs
* Importance of section commercially (people carried, capacity of line)

It was also recognised that the statistical data available would be limited so that in constructing any ranking model all assumptions needed to be set out in detail to allow agreement by consensus wherever statistical data was not available in the form needed.

5. DEFINITION OF RISK

We accepted Rowe's definition of risk (1) as " the potential for the realisation of the unwanted negative consequences of an event", with the measurement of risk defined as "the expected range of possible loss values".

Risk is generally deemed to be a function of the likelihood of an event occurring and the severity of the outcome.

To identify what loss exposures could result from infrastructure assets, the probability and consequences of these exposures was estimated and what level maintenance and renewal actions would reduce those loss exposures determined. This meant:

a. Identifying problem areas (Loss Exposures), and quantifying the risks associated with these exposures

b. Assessing the effect of particular maintenance and renewal actions on these risks, and

To quantify the risk the event probability was multiplied by the event consequence.

6. RANKING METHOD USED

To enable projects to be ranked to provide maximum return on investment and to ensure that only work that would have a significant impact on the operation of the system is done, the application of risk analysis techniques using as a comparative measure the loss exposure that could result from not doing the work was used .

In applying the concept of risk to the management of CityRail's infrastructure assets, three types of risk or loss exposures were considered possible :

a. Safety Risk which involves an exposure to liability claims from customers, staff and the public at large

b. Service Risk which involves community loss, organisational revenue loss and the additional costs associated with either the complete or partial loss of asset function and/or the need to provide an alternative

c. Economic Risk which is the ongoing financial commitment inherent in the unchanged configuration and condition of the asset

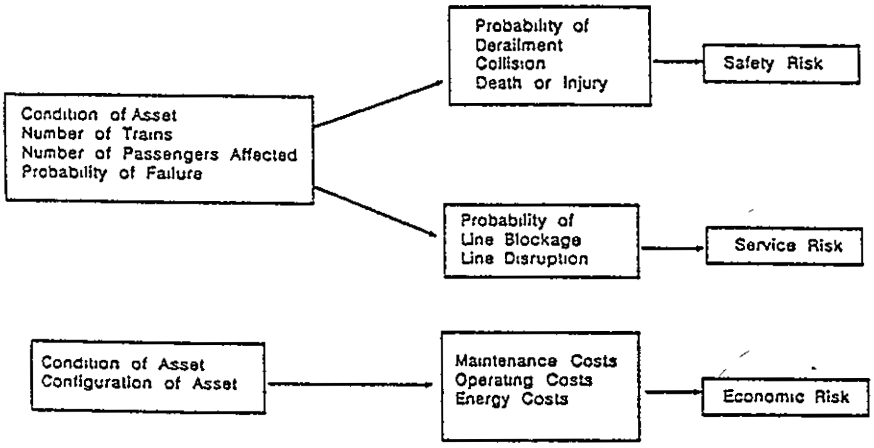

Fig 1

The standard approach to quantification of risk associated with a particular event requires the detailed construction of a combined fault/event tree.

This process was considered too time consuming and was simplified in the manner shown in Figure 2 to provide a more cost effective approach. The simplification was achieved by using:

a. The expected failure probabilities associated with up to two primary failure modes taking into account system condition and system usage, and

b. The expected outcome of a particular event taking into account the number of passengers that could be effected

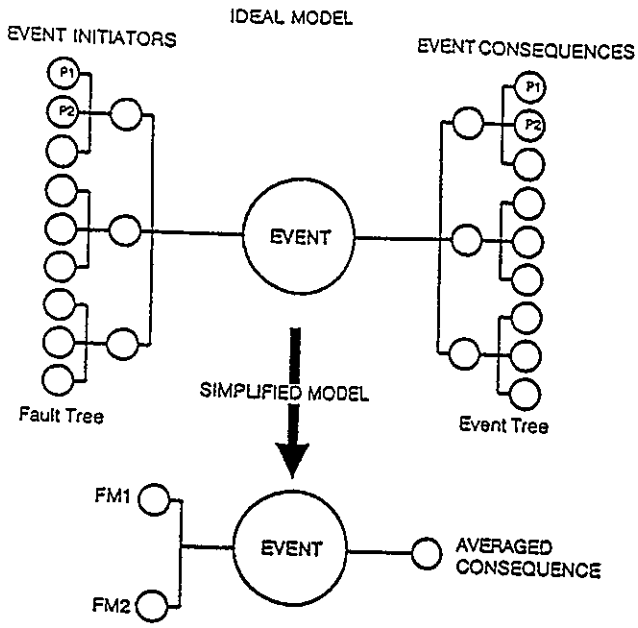

Fig 2

The technique applied in quantifying the risk exposures associated with not doing identified infrastructure maintenance and renewal tasks is shown diagrammatically in Figure 3 and detailed in the following sub-paragraphs:

a. Determine those loss exposures which have the most significant impact on CityRail against which all proposed works are assessed

b. Identify the types of maintenance/renewal tasks which will eliminate or reduce the identified exposures

c. Estimate the probability of failure in the next 12 months if the work is not done taking into account the condition of the asset, the number of trains running through the section and the type of traffic involved

d. Assess the cost of disruption occurring (consequence) taking into account the site, the number of passengers involved, the speed and the type of trains involved

e. Calculate the risk exposure by multiplying the probability of failure by the consequence

f. Assess the risk exposure after the work proposed is done

g. Calculate over the life of the project the net present value of the reduction in risk exposure by doing the work

h. Estimate the net present value of the maintenance, operational or energy savings that will result from doing the project

i. Calculate the investment ratio for the project by dividing the net present value of the reduction in risk exposure and maintenance, operational or energy savings by the total cost of doing the work

j. Determine the average probability of failure for each top event

k. Define what is an unacceptable probability of failure

l. Define what is an unacceptable service risk exposure for any line

m. Identify any project where the safety risk exposure or service risk exposure exceeds these values

n. Rank all projects according to their investment ratio where the safety risk exposure or service risk exposure exceeds preset levels

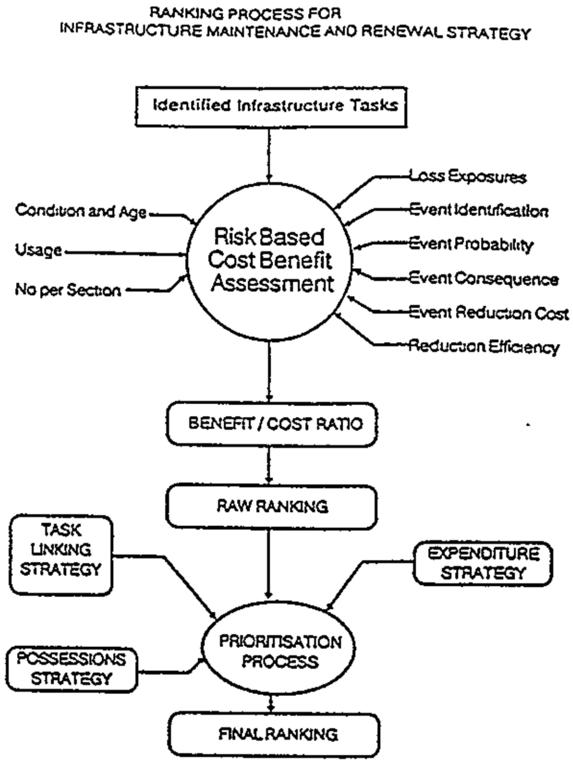

Fig 3

The technique provided a common baseline (reduction in total loss exposure per $ spent) that enabled a consistent comparison of proposed maintenance and renewal works across the four CityRail regions.

6.1 Loss Exposures

The application of classic fault tree analysis first requires the selection of the "top Events" to be used in the analysis process. These "top events" drive the subsequent allocation of risk, that is, the realisation of loss exposures flowing from not doing identified packages of work.

In assessing the impact of any work on CityRail the following "top events' were considered:

a. Train derailment

b. Train collision

c. Line blockage

d. Line disruption

e. Asset collision

6.2 Maintenance /Renewal Tasks

An audit of all trackwork, documenting the condition of the ballast, sleepers and track throughout CityRail, had been completed in 1989. This data was used together with the results from a questionnaire sent to each of the four engineering regions to determine:

a. What work was considered necessary to bring the infrastructure to defined standards

b. The identification of where the work was to be done

c. The estimated cost of the works including ancillary costs such as alternative transport where full possession was necessary

d. Possession requirements

e. Preparatory work requirements

f. Expected impact on safety, operations and future maintenance costs if the work was not done

These results formed the basis of the project database which enabled all works in a particular line/section to be grouped into logical packages ready for prioritisation.

6.3 Probability Of Failure

Wherever possible, verifiable failure and consequence data was used in the ranking model.

Hard data for the average reliability values of signals and electrical system components was collated for the last 5 years and derailment statistics for the last 20 years. Additionally, values for operational statistics such as train and passenger flows were readily available.

However, more elusive statistics such as the impact of system condition on average reliability and the probability of an event occurring given the occurrence of a certain failure mode, required the application of the Delphi decision technique to create agreed decision tables.

This was done by forming specialist groups for each of the maintenance renewal areas examined to identify:

* The primary failure modes which are eliminated or reduced by doing the work

* The range of failure probabilities that should be used taking into account the condition and location of the asset

With each project, an assessment of the probability of a derailment, collision, line blockage, disruption to traffic or injury to a member of the public occurring was made, taking into account the condition of the asset, the number of trains running through the section and the type of traffic involved.

Wherever possible we tried to ensure that predicted outcomes were consistent with actual values.

6.4 Cost Of Disruption

Costs included both SRA costs and the cost to the community if a failure occurred.

Community costs were based on those in the NSW Roads & Traffic Authority document "Parameters for Use in Economic Evaluation" (2).

The cost of disruption was adjusted to take into account the number of passengers that would be affected if a failure occurred. This provided a range of values for each type of incident but assumed on average, certain estimated costs flowed from the occurrence of a particular top event. The estimation process applied the Delphi technique to estimate death, injury, damage and delay values along with their corresponding cost impact.

6.5 Risk Exposure

The risk exposure associated with each task was determined using the following procedures:

a. Identification of up to two primary failure modes effected by the nominated task

b. Identification of the expected probability of each loss exposure (top event) occurring for each identified failure event

c. Identification of the probability of each failure mode occurring per unit quantity of asset affected in the next 12 months

d. Determining the number of units of each asset involved

e. Calculating the risk exposure for each top event by multiplying the probability of event/unit by the number of units in the section by the cost of disruption if the event occurred

f. Calculating the total risk exposure by summing the risks for the identified failure modes assuming non concurrency

TASK RANKING PROCESS CHART

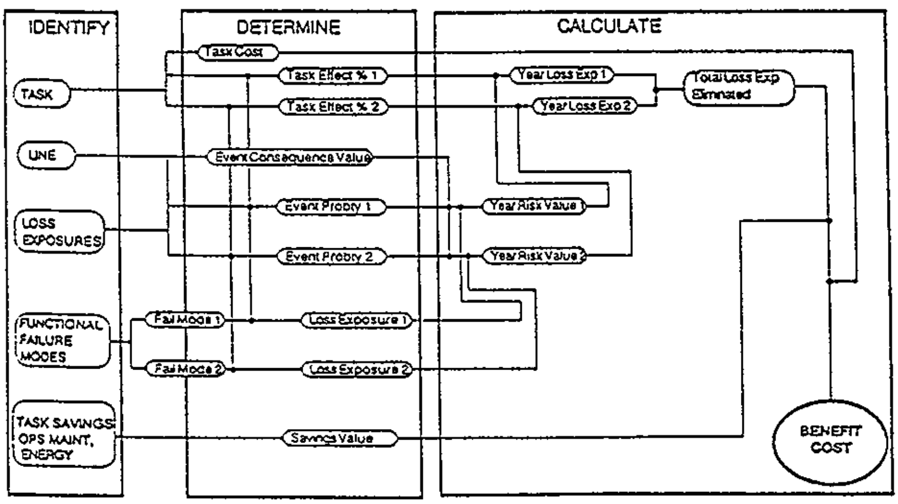

Fig 4

6.6 Risk Exposure Reduction

This was done by estimating the effectiveness of the task in reducing the risk over the life of the project and multiplying the current risk exposure by the allocated task effectiveness .

6.7 Investment Ratio

The investment ratio was calculated for each project by dividing the net present value of the benefits by the cost of doing the work , where the benefits included:

a. The reduction in safety risk exposure

b. The reduction in service risk exposure

c. Future maintenance savings as a result of increasing system reliability and/or decreasing system mean time to repair

d. Future operational savings

e. Future energy savings from increased efficiency

The net present value of the yearly benefits which were identified for each task was calculated assuming constant yearly savings over the expected effective life of the task .

6.8 Defining Acceptable Levels of Safety & Service

Risk curves of occurrence frequency versus the severity of the outcome in terms of working day lost to the community were prepared from existing CityRail data. Curves relating to infrastructure risk were also plotted.

These curves were used to provide a bench-mark to help determine whether a particular project or situation poses a greater hazard to passengers than the average level of risk across the whole system.

It was decided that if the risk at a particular location or section was 10 times greater than the average risk for CityRail described by the relevant infrastructure curve then the work needed to bring the risk below the average would be included for safety reasons.

With service risk, the cumulative affect of not doing the work identified can be calculated for any line and compared with what is acceptable. The value of work needed to be done to ensure that these figures are not exceeded can then be established.

7. THE MODEL

The model was tried out on a spreadsheet before being transferred to a database. A worked example is shown in Figure 5 below.

DISCIPLINE Civil
TASK Junction Renewal - Syd Meeks rd. (TCI 116)
Task Effectiveness % 90

ProbE = Probability of the loss event occuring given a failure
ProbF = Probability of Failure per Unit
Units = Number of Units in Section

FailM1 Geometry Exceedance

	ProbE	ProbF	Units	Freq/yr	Events/Yr	Cons	Risk
LOSS EXPOSURES							
Derailment	0.001	1.00	4	4.000	0.004	$1,890,667	$7,956
Train Collision	0.0001	1.00	4	4.000	0.000	$3,818,667	$1,527
Line Blockage	0.00001	1.00	4	4.000	0.000	$1,451,667	$58
Line Disruption	0.06	1.00	4	4.000	0.242	$88,750	$21,446
Asset Collision							

	Total Risk	$30,988
Risk Reduction ($/Year)	(Total Risk)*(Task Effectiveness)=	$27,889
Total Risk Reduction over	20 years	$295,457
Task Cost $K	$350,000	
Risk Reduction Ratio	0.84	
Maintenance Savings		$13,333
Operating Savings		$0
Energy Savings		$0
Total Savings		$13,333
Total Benefit		$41,222
Total Benefit over	20 years	$436,710
Investment Ratio		1.25

Fig 5

The model allows the user to vary any of the assumptions used and quickly assess the impact on the investment ratio as well as ensuring the assumptions used for particular activities are consistent.

8. SENSITIVITY TESTING

Despite the best intentions to obtain rigorous data to support the model, considerable effort was necessary to obtain even the limited data available.

Potential users expressed doubts regarding the sensitivity of the model to some of the assigned estimates of probability and consequence.

In recognition of this, considerable effort was expended in testing the sensitivity of the model to the typical error levels that users considered may be possible.

The results indicated that the model had considerable robustness, with significant orders of magnitude variation in estimates necessary before any significant impact on results occurred.

However, all assumptions were defined and those areas where statistical data needed to be collected were highlighted to allow further refinement of the model.

In addition the assumptions were further checked by comparing the predicted number of "top events" with the number actually occurring and adjusting the probabilities used until good correlation was achieved.

9. CONCLUSIONS

The application of standard risk analysis techniques, using, as comparative criteria, loss exposure resulting from not doing identified maintenance and renewal works, provides a benefit/cost ratio for each work package as the first and major step in the determination of actual expenditure priorities.

Using risk analysis techniques CityRail management have been able to:

* Identify the safety risk that can be eliminated by doing specific projects in terms of the probability of a derailment/collision and the consequence if an incident occurred

* Identify the service risk that can be eliminated in terms of the probability of a line blockage/disruption and the consequence if an incident occurred

* Rank projects to provide maximum return on investment and to ensure that any work that would have a significant impact on the operation of the system was done

* Assess the cost to provide a specified level of service and safety or alternatively the levels that can be provided for the funding available

10. ACKNOWLEDGEMENTS

The authors acknowledge the considerable assistance of CityRail staff and Viner Robinson and Jarman in developing a "back of the menu" concept into a viable methodology for prioritising a long term program of works that takes into account the interests of CityRail's customers and ensures that expenditure decisions match the business plans of the organisation.

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Bob Galvin

Introduction of Risk Management into Queensland Railways.

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INTRODUCTION OF RISK MANAGEMENT INTO QUEENSLAND RAILWAYS

Prepared by Bob Galvin, Group Manager Rolling Stock Maintenance, Queensland Railways

The following paper, which has been prepared by the author, reflects the author's beliefs and not necessarily those of Queensland Railways.

1. Introduction

Approval-in-principle was given to introduce the principles of Risk Management into Queensland Railways in late 1989. Since the approval-in-principle was given the following has occurred:

- Development of a draft corporate policy statement and implementation plan.
- Trial risk assessments on earthing mats for 25KV traction system masts and the Kuranda scenic railway.
- Preparation and presentation of training courses to 25 risk management facilitators and 100 practitioners.
- State wide risk audit/scoping study of Queensland Railway's system.
- International risk management data survey and analysis undertaken.
- Initiation of development of railway risk acceptance/criteria curves.
- Liaison between railways in Victoria, New South Wales and Queensland regarding development of industry standard management risk acceptance criteria curves.

The progress of introduction of Risk Management has been intentionally held back due to the impact on the organisation and staff of our major organisational restructuring and other programmes such as Award Restructuring, Quality Management etc. It is now felt that the introduction could again progress to coincide with Queensland Railway's new commercial business drive. Analysis of capital investment, improved safety at optimum cost and the general management of uncertainty are all potential benefits.

2. **Proposed Approach to Risk Management**

It is proposed that the responsibility for management of risk within Queensland Railways be delegated to the relevant line managers rather than to a Risk Manager. While the ultimate responsibility for management of financial losses or injury lies with the Board through the Chief Executive Officer, its management can be effectively delegated provided there are policies, guidelines and risk criteria developed which are approved by the Board to ensure a common and standard approach to risk management. This is a critical issue in effective management of risk and will provide Senior-Executive with the satisfaction of knowing it has effectively delegated its management and control.

Even without the formal introduction of Risk Management, staff are, in effect, addressing risk in their management and design decisions, but it is in an unstructured manner and without the benefit of understanding the Board's requirements. The advantages of a Risk Management policy is that the extent of exposure to loss or damages can be predetermined by Senior Executives and then effectively managed by the various Business Units in accordance with the guidelines set.

It needs to be recognised that the term "Risk" does not solely relate to safety of public and employees. Safety is a major element of Risk Management which requires a delicate balance of financial, ethical, social, moral and legal criteria. However, it also relates to the management of that risk which exposes the organisation to financial loss through damaged equipment, poor investment decisions, replacement costs, legal costs and damages, insurance premiums, etc. While the principles of identifying and measuring the financial costs and benefits of these two issues are similar, they need to be considered separately since the management of safety issues is impacted on by specific legislation, common law precedent and community expectations while financial matters are measured and managed by their effect on the "bottom line" of financial reports.

These are many elements which form the total process of Risk Management. They include elements from financial administration, contract administration, occupational health and safety, safety audit, engineering design, train operation, business decisions, etc. It is strongly believed that the management of all these issues depend on:

(a) the actual management of the risk being the responsibility of line managers and staff in the various Business Units and Support Groups.

(b) the establishment and approval of policy, guidelines and risk acceptance criteria by Senior Executives.

(c) an independent audit or review of the Business Units' and Support Groups' management of risk issues particularly in relation to accidents which have caused death or injury or had the potential to do so.

(d) ensuring that the main categories or areas of risk are identified and that the party responsible for the various categories are identified and made aware of their responsibility.

3. <u>Issues Effecting Organisational Structure</u>

It is contended that there are several categories of Risk Management which are interdependent and interrelated but have different issues impacting on them. These elements can be delegated to different parties to manage but all have an effect on the decisions made by each party. Broadly, these categories are Occupational Health and Safety, the safe working of trains, capital investment decisions and divesting of risk exposure. Many others could be identified.

Matters governed by Workplace Health and Safety relate to the health and safety of employees and the public in situations where they enter upon a "workplace". All issues relating to these matters can conveniently and practically be grouped.

The safe working of trains with the associated rules, regulations and investigations of any related incidences involving accidents or potential accidents form another convenient and practical grouping. Civil and criminal court action can be more associated with this group.

The safe operation of trains can be differentiated from the efficient operation or trains. Investment in capital assets/infrastructure which satisfies safety criteria and recognises uncertainty in the future while minimizing expenditure or maximizing return is a major issue with the commercial approach which railways are adopting. Hence this is another category which requires different tools and management approach.

The decision to reduce of risk exposure by transferring the risk to others, must also be made. The data required to determine a level of insurance and premiums is related to issues in all the categories above. While different line managers may have to make the decision a common, comprehensive data-base is essential in supporting good decisions.

While all these categories and issues are the responsibility of line management in various Business Units, I believe they require process support and auditing by a central Risk Management function. It would therefore appear that a corporate Risk Management audit, process support and co-ordination function would be beneficial.

The application of technical standards and procedures is the responsibility of line managers. However, economic and other pressures can lead to a lapse in adherence to standards to the point where unsafe situations can arise. I believe the responsibility for monitoring (auditing) the Business Unit adherence to safety standards, in order to protect the Boards's interests, should lie with a unit external to the Business Unit. It is important however that the "safety audit" unit fulfils only an audit/investigation role with power to report to Business Units or Senior Executive and not a role of directing line management. If this occurs, I believe that line management accountability is lost and commercial imperatives clouded. Effective communication and management structure will provide the necessary safety measures and platform for commercial practise.

A common computer data-base containing details of accidents, injuries, deaths, financial losses, etc., should also be established and maintained. A well disciplined and structured means of collecting data is also needed to support the data base. It would appear that most other systems surveyed, including Queensland Railways, either do not keep a compiled data-base or have several un-related data-bases or have a data-base which is not comprehensive and is out of date. It is suggested that the corporate unit responsible for risk audit and process support should manage the collection of all relevant data and maintain a single data-base structured to satisfy the needs of all the parties involved in the management of risk.

4. Risk Acceptance Criteria

One of the processes involved with the implementation of Risk Management is the establishment of risk acceptance criteria. By this term, I mean criteria or parameters which are established by considering community expectations, industry standards, legal precedent, insurance premiums and other relevant input and which then form the basis upon which departmental officers base decisions which involve uncertainty. This then provides some uniformity with decision making and decisions made in accordance with corporate guidelines.

There is some objectivity that can be built into the criteria but, like all engineering and operations, Risk Management is an art not a science and thus is difficult to define by absolute values. The crucial point with risk acceptance criteria is that it requires the acceptance of the senior executive and it be included in corporate policy and guidelines issued on Risk Management.

Risk for any particular situation or event can be estimated with a defined factor of reliability. It is however meaningless if it can't be compared with a compatible acceptance criteria to determine if it is over or under a corporately acceptable level. However, the issue of generating risk acceptance criteria should not be over simplified. While establishing railway industry standard risk acceptance criteria would be of major benefit, it does present some difficulty in accounting for variations in operations and environment across the industry and across countries. I do believe however that they are achievable.

As previously indicated in this paper, a questionnaire has been circulated to all the Australian railway systems and to numerous rail systems overseas in order to attempt to establish a base of date upon which to establish a possible set of risk acceptance criteria.

Unfortunately, the questionnaire was designed to gather a minimum of information in order to encourage participation from the railways. With the benefit of hindsight, it is now realized that the format of data requested was not as useful as intended.

I can report that analysis of the date was not illuminating but the reason for this was a combination of the type of data requested and the quality of data held or provided by the responding railways.

This statement is not made as a criticism of the respondents; I am thankful that they took the time to do so. The main point is that very few railways, if any, maintained data that was readily accessible and that the data which was kept was in a format which differed between all railways; this included Queensland.

The questionnaire and resultant analysis if nothing else, did show a need to develop a specification for the type of data collection which, if followed, would provide potential to compare compatible risk acceptance criteria on an industry basis.

The survey did provide the names of several railways which are interested and willing to participate in further development of data collection and analysis.

Three of the railways in Australia have already met to compare the approach to risk management which each are undertaking. Each were independently working towards the development of risk acceptance criteria but have agreed to investigate and develop a means of achieving this result in a co-operative manner.

It has been decided to concentrate our combined efforts on commuter train operations and establish a set of standard specifications for the compilation and recording of data and the development from this date of risk acceptance criteria. A means of accomplishing this is presently being considered.

Some work is also being done on criteria for freight operations. There will be a degree of similarity between commuter and freight operations but the extent of similarity will not be evident until after the data has been analysed.

5. Training

When risk management is adapted by the whole organisation as a tool for assisting decision making, it will be necessary that sufficient staff from management, operations, design, human resources, finance etc have been trained with the skills and understanding. To achieve this, a training course was developed for Queensland Railways. Past experience with risk management in railways is scarce which provided some difficulty in finding relevant case studies. To alleviate this problem, a comprehensive case study which included many aspects of railway systems was invented and used progressively through the whole course to tie it together.

The course was developed for two levels of attendees; facilitators and practitioners.

A practitioner is one who practices risk management skills in designing or developing systems or making decisions with regard to the operation.

A facilitator is one who is able to provide support to the practitioner with respect to the skills and process; this person is not responsible for decisions made and is only included if the practitioners feel they require assistance. Their training is similar to a practitioner but more emphasis and time is spent on the case study.

To date, 25 facilitators and 100 practitioners have been trained. They have been selected to give a good cross section of staff from finance, human resources, engineering, operations and maintenance. All levels of the organisation were represented. The response from attendees and their managers regarding the suitability and practicality of the course and of risk management in general has been positive. It is proposed that another 300 practitioners be trained.

An early problem encountered with the course development was its emphasis on engineering. This occurred because the concept of its introduction into Queensland Railways originated in an engineering area. However, as the realisation occurred of the applicability of risk management in all areas of an organisations business, the course content had to be modified to make it suitable and relevant for all the disciplines. This need was emphasised during feed back sessions following the training when non-engineering participants expressed strong interest in the risk management principles and requested more emphasis on non-engineering issues. Consideration is being given to developing two streams of training; engineering with some commercial flavour and commercial with some engineering flavour.

6. State Wide Risk Scoping Study

As previously mentioned in the paper, Queensland Railways has carried out a broad risk audit or risk scoping study of its system. The purpose of the study was to obtain an overview of our whole system reasonable quickly. We wanted to determine the possible existence of any situations or activities which warranted urgent attention.

To achieve this, 16 engineers and train operators with experience in all areas of the state, all engineering disciplines and in all facets of maintenance were brought together. Using an external risk management facilitator the whole state system was analyzed.

Some 300 situations were considered by sub-divisions of activity, undesirable event and category of effect,. The severity of incident, frequency of event per year and effect of protective response were postulated by the attendees and the resultant risk factor obtained by multiplying the postulated values. The situations were sorted in order or risk factor for each category of effect. Once sorted in order of risk factor, the group of railway experts considered the order of ranking and the relative scores to gauge if the results "felt right". Of the three situations which they perceived to be out of order, each had a mathematical error. Upon correcting the error, the three events fell into positions which were believed to reflect a true picture of their relative risk. By this approach, the process was "validated" by the only means which could be identified; a jury of many man years of experience.

It was intended to isolate the situations which contributed to 80% of the risk factor. The results indicated that for each effect category, only 5 or 6 situations generated 80% of the total risk factor.

Now that sufficient officers are trained, the results of the study will be distributed to each division for a more detailed study and evaluation of the top 80% of each category.

Conclusion

Within Queensland Railways, more consideration will be given to risk management once the energy being put into the organizational restructuring has decreased and can be directed elsewhere. In the mean time, its interests will be served by continued training and the joint association between the state railways. Pursuing the generation of risk acceptance criteria will continue for Queensland Railways and from an industry standard view point.

Development of a standard specification for the data upon which standards can be developed would be beneficial. Consideration must also be given to how the standards could be applied to the various environments and types and sizes of railway systems which operate within the industry.

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D. G. Elms
J. B. Mander

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LOCOMOTIVE ENGINEER HAZARDS

A RISK ASSESSMENT STUDY

D.G. Elms and J.B. Mander

ABSTRACT

Comments are given on the use of quantitative risk assessment techniques. The paper describes the use of a quantitative risk assessment in determining the overall level of risk faced by locomotive engineers and the relative risk depending on whether or not another man is in the cab. The overall risk is shown to be low, as also is the difference in risk between single and two- man crewing. Multiple fault trees are used, and the process by which a believable result is obtained from sparse and sometimes low-quality data is described: it requires an iterative approach bearing in mind a set of guiding criteria, which are described.

INTRODUCTION

The various techniques of quantitative risk assessment (QRA) are major tools in assessing environmental risk. Used wisely, they can provide a clear and powerful analysis of environmental problems. Their use has many pitfalls, however, and they can lead to misleading or erroneous results if not used with great care. The present paper discusses a number of practical issues to do with using quantitative risk assessment. To make matters clearer a case study is used, but in following it the reader should bear in mind that the real thrust is to show both the power and limitations of QRA and propose criteria for its appropriate form and use.

In 1986, New Zealand Railways realised that to remain viable it had to reduce its manning levels. For train operations, it was clear that for most trains a single locomotive engineer would be sufficient rather than the two-man crew used at the time. However, a major question was whether driving a train with only one man aboard would be markedly less safe than with two. There were two reasons for needing to know this: if it could be shown there was little difference it would remove a possible cause of unnecessary discussion in union negotiations, and if it were shown to be a more hazardous practice the Railways management wanted to be able to take action to make driving a locomotive at least as safe as it had been before.

The paper describes the resulting quantitative risk assessment of locomotive engineer hazards.

Fortunately, the objectives of the exercise were very clear. So was the use to which the results would be put. The two are different, though related, and both are vitally necessary for the success of a quantitative risk assessment. The objectives were three:

(a) To establish the overall level of locomotive engineer safety

(b) To assess the amount if any the safety level would be changed by moving to single manning

(c) To determine the most effective measures for increasing locomotive engineer safety

The proposed use of the project was, as stated above, to remove a major point of discussion from management/staff discussions. The project thus had an advantage over many, as QRA exercises have often been rather vague in their aims and intended uses. There are, of course, often good reasons for vagueness. It may be, for instance, that at the beginning of a project little is known of its nature, in which case it is a perfectly legitimate strategy to start a pilot study as a means of learning about the system in question and of discovering both what needs to be done and what is feasible. However, a full-scale study is expensive and not to be taken lightly, so that it should never be done without clear objectives. Indeed, there are so many advantages to starting with a pilot study that it would seldom if ever be sensible to move straight into a full-scale QRA.

The locomotive engineer risk study was in itself a pilot study. Rather than tackle the whole railway system, it was decided to concentrate initially on a single stretch of line, the 165km of the North Island Main Trunk line between Palmerston North and Taihape. Once the methodology had been worked out for that, it could then be applied to other typical stretches of line. As will be seen later in the paper, it was just as well it was a pilot study, as a number of false leads were started before the final problem structure was established.

To return to more general comments, the final use of quantitative risk assessment should not be seen as an end in itself, but necessarily in the context of a broader risk management objective. It is the risk management which is the important thing, not the risk assessment, which can never be more than the means to an end. Thus the first thing to be established is the risk management strategy or context. The point is emphasised as most examples of risk assessment to be found in the considerable literature on the subject discuss the assessment alone and make no mention of the context.

Broadly speaking, it could be said that management has two main tasks: allocating resources to achieve some best result, and detecting whether problems exist in an ongoing operation so that they can be dealt with at an early stage. The same two tasks are also a feature of risk management, and both are directly addressed by the aims given above for the railways risk example.

OVERALL RISK LEVEL

Risk is a complex notion. In a sense it belongs to fairyland as it deals with events which have never happened. If they do occur, they are then facts, or history. Yet risk also belongs very much in the present as it is primarily concerned with decision making. Besides this, it is a binary idea with two distinct components: the likelihood (or probability) of an event, and its consequences. Numerically, it is the product of the two. A high-probability event can be a low risk if the consequences are negligible, but some events with extremely low probabilities can pose unacceptably high risks if the consequences are grave, such as a nuclear disaster. A quantitative risk analysis thus needs two sets of numbers: probabilities and consequences. There is usually difficulty with both, but for environmental risk situations the major problem often lies in deciding on a common and accepted measure of the consequences of an event. How, for instance, could a major chemical plant accident involving loss of life, injury, property damage and environmental damage easily be assessed in dollar terms? Fortunately in the present instance there is no such problem as we are concerned only with the risks facing locomotive engineers. We shall neglect injury, and take loss of life as the measure of the consequences of accidents.

More specifically, as we are not concerned with the magnitude of railway accidents, but only with the risk faced by a locomotive engineer in his cab, we shall use the Fatal Accident Frequency Rate (FAFR) (also called, more sensibly, the Fatal Accident Rate (FAR) as the basic measure of risk, defined as

$$\text{FAFR} = \text{no. of deaths/person at risk/hour exposed} \times 10^8$$

It can be thought of as the number of fatalities per 1000 working lives of 40 years, each year being 2500 hours. Table 1 gives some typical values.

TABLE 1 Typical FAFR values (Kletz, 1978; Lees, 1980)

construction erectors	67
travelling by car	57
coalmining	50
railway shunters (UK)	45
metal manufacturing	45
agriculture	10
chemical process	5
staying at home	1

Notice that the FAFR depends on what one is doing at the time. Thus a coalminer might start the day at home with an FAFR of 1, travel to work by car at a level of 57, and then work as a miner with an FAFR of 50.

The overall FAFR value for locomotive engineers was obtained very simply from the known fatalities during Railways operations. A more detailed analysis would not have been possible as adequate data was not available, but in any case a very precise result was not required. All that was wanted was a rough figure, sufficient to tell management whether driving a locomotive was as safe as or safer than comparable occupations such as bus or truck driving.

Roughly speaking, there has been about one death every 10 years over the last hundred years of railway operation. In a year, trains travel about 21×10^6 km. Dividing the annual fatality rate of 0.1 by the distance travelled, dividing by 2 for the number at risk and multiplying by the average speed of 55 km/h on the Palmerston - Taihape line (from timetable information) gives the fatality rate per hour of exposure. Multiplying this by 10^8 gives an FAFR value of 13. This figure should be compared with those given in Table 1. The risk is about a quarter of the risk of travelling by car or of being a coalminer, and so is relatively low.

The data is sparse and very general, applying not only to all the different parts of the railway network but also gathered over 100 years of operation, during which time many aspects will have changed. The FAFR must thus be treated with caution. It is probably a high estimate, though, as nowdays there are fewer trains (hence less chance of collision), and track improvement on the North Island Main Trunk line has decreased the likelihood of an accident.

Where data is sparse, the results must be corroborated wherever and however possible. In this case, experienced locomotive engineers were asked for their perception of the fatality rate. Their independent estimate was also one death in ten years. Confirmation of the trend was obtained from railway accident statistics. Over the two years to 31 December 1986, there were 59 locomotive engineer injuries compared with 3273 to all other railway employees. As locomotive engineers comprise about 11% of railway staff, the implication is that being a driver is about seven times as safe as the average of all other employees. This confirms the indication that driving a train is a relatively safe occupation.

COMPARATIVE RISK - - SINGLE AND DOUBLE MANNING

To estimate the comparative risk levels for single and double manning, greater detail was needed. The major choice at this stage was the degree of detail to be chosen, given the constraints of time and data availability was not known at this stage, a guess had to be made with a view to refining matters at a later stage. It seemed sensible to err on the side of greater detail, as it would be easier to contract a model at a later stage than to expand it.

As a first step, accidents were categorised into the following types:

1. Head-on collision at a crossing loop
2. Tail-on collision at a crossing loop
3. Tail-on collision in a following movement
4. Collision running under Mis.59 rule
5. Collision running under pilot working
6. Tip-over at a tight curve
7. Tip-over at a turnout
8. Derailment due to track fault or mechanical reason
9. Collision with an obstruction
10. Collision with maintenance equipment

The first three types involve collision between two trains under normal running conditions. The line from Palmerston North to Taihape is single track, as is the case for most of New Zealand, with various crossing loops placed so that trains can pass each other, or in some cases overtake. Most signals govern entry to and exit from crossing loops, though there are a few intermediate signals where the distance between loops is large. It is assumed that inter-train collisions will involve signals.

If a signal is inoperative, then trains cannot move except under two operating conditions. Either authorisation has to be given by a train controller over the radio (trains are in radio contact) using a special form known as Mis.59, or the train has to be accompanied by a designated pilot past the inoperative signals. In either case, procedures are such that collision is impossible. However, they have occurred, so there is a finite risk and the two modes have to be taken into account.

As for the other categories, tip-over situations are reasonably common, due to the narrow track gauge used in New Zealand and the mountainous nature of the country. There are a number of possible derailment causes due to track faults, such as broken rails or heat buckles. Mechanical faults are more likely to lead to wagon rather than locomotive derailments. The category "collision with obstruction" covers many possibilities including slips, washouts and level crossing incidents. Collision with maintenance equipment involves an accident with Railways track maintenance equipment.

For the first seven accident types, the aim is first to be able to find the probability of a train having an accident at a "critical point"; for instance, the probability that a given train would have a head-on collision with another train standing at a specific crossing loop. The other three accident types require the calculation of the probability of an accident per kilometre as it is not feasible to differentiate between various stretches of line as to the likelihood, for example, of running into a slip. This could of course be done, but it would mean working at a finer level of detail than that used for the other accident types. By combining the accident probability with the probability of a fatality given that the accident had occurred, and knowing the number of critical points in a trip and the time involved, the contribution of each accident type to an FAFR value could be calculated.

Fault trees were developed for accident types 1-7 and 9. Probabilities for the remaining two were obtained directly from accident statistics and could not be broken down further. In any case, it was judged that the associated hazard level would be unaffected by the number of people in the cab.

Fault trees have the great advantage that not only do they provide a means of calculating probability values, but they also make it very clear how the component parts of the calculations fit together. Figure 1 shows the fault tree used for a tip-over accident at a tight curve. The events lower down the tree contribute to the occurrence of those higher up. Where "and" is specified, all contributing events must occur for the next highest event to happen, but for an "or" gate, the higher event will occur if one or more of the contributing events takes place. Double underlines indicate input probabilities. For "and " gates probabilities are multiplied and for "or" gates they are added, the latter being an approximation justifiable for small probabilities. All the fault trees were placed on a single spreadsheet together with a list of input data and a table of results. The spreadsheet format had the advantage that all calculations were linked so that changing an item in the data table would automatically affect all the relevant numbers in the trees and in the results. This was helpful as it allowed an easy switch from double to single manning data. Capital letter references in the fault tree such as "E= speed warning board missing...." refer to items in the entry data table. Figure 2 gives another example, still part of the same spreadsheet, in which one of the items in the fault tree was obtained from an event tree set up to compute the probability of a train colliding with an obstruction, given that the obstruction exists.

The procedure used for developing the fault trees was as follows. The first step was to get their structure right, or at least as right as possible pending further amendment as the process is iterative. To do this it was first necessary to learn about the nature of the problem, of how railways operate, possible causes of accidents and so on. The learning process involved reading, discussions with various people and physical inspection. The latter was important in getting a "feel" for the whole project, and it was made easier because of the decision explained earlier to do a pilot study first and confine investigations to the Palmerston - Taihape line.

With the tree structures provisionally determined, the next step was to find the data to fed into them. Some data was specific and reasonably well documented. Other information, while equally important, was much harder to pin down, such as the degree to which sleep would affect the average driver. The strategy adopted was first to insert the better- documented information items, and then to estimate the rest from whatever information was available, adjusting the latter figures to ensure that the results from the fault tree analyses fitted known overall figures (such as the FAFR value) as well as possible. The known figures were used to "peg" the tree models to reality: in a sense it was a process of calibrating the models.

Consider now the trees of Figure 1. Basically, a locomotive would only tip over if it were going too fast when it reached a tight curve: there are three such curves in the stretch of line being investigated. It could only be going too fast if the brakes did not work, or if the driver was unaware he was going too fast because the speedometer did not work, the required trackside curve warning board was not in place correctly, or he was not paying attention due to a variety of factors. Working down the tree from the top, a tipover must be caused by three factors, all of which must be true for an accident to take place. Firstly the train must be capable of travelling fast enough to tip over. Some trains are speed-restricted, so that only the remainder of the trains could tip over. The proportion is known from timetable information. Secondly, the train must be travelling at an excessive speed, given that it can do so; that is, it must be moving at a speed substantially greater than the posted speed for the curve. Thirdly, given that the train is moving too fast, it must then tip over.

The only part developed further is the event that the train travels too fast. It is assumed that excessive speed is due either to a train hardware problem in either the speedometer or the brakes, or to an external system problem, meaning in this case that the warning board is missing or in error, or to a driver problem. Let us consider them in turn.

Some rough statistical figures are available on speedometer failures. However, a train is not allowed to run without a working speedometer, so that the probability of a train having an inoperative instrument while running is very low. Even so, if the speedometer is not working the locomotive engineers know their road so well that is unlikely there would be an accident. We guessed a probability figure of 10^{-4} for this as being a reasonable estimate. Greater refinement is not needed as examination of the tree shows that train hardware problems contribute less than 1% to the tip-over probability as a whole.

Brake failures are exceedingly remote, though they have been known to happen. In any case, most trains have essentially three braking systems: train brakes, independent locomotive brakes, and regenerative braking on the locomotive. The likelihood of all three being out is very small. Records indicate a probability of about 10^{-8} would be roughly right. Once again, this has little effect on the final probability. A more likely braking failure would result from a careless or distracted driver running down the air pressure in the auxiliary reservoirs in each vehicle faster than they can be recharged (point L on the right hand side of the tree). At least two runaway trains have resulted from this, but fortunately there were no fatalities. The figure of 10^{-8} was chosen after examining incident records and discussions with Railway staff. Once again, the precise figure is unimportant as it is overshadowed by the performance factors deriving from item G - K at the bottom of the tree and entering on the other side of the "or" gate.

In terms of their effect on the result, the most important entry items in the tree are the factors G - K affecting the performance of the driver in the cab; that is, confusion, distraction, misjudgement, sleep and illness. They are also the most difficult to quantify. The procedure adopted was this. Two industrial psychologists from the Palmerston North based firm OPRA examined the operations of driving locomotives, and based on their study they were able to recommend the use of the five performance factors and also to specify the relative importance of each, both for single and double manning. They could not, however, give any indication of absolute values of probability. The five performance factors also entered several of the other trees. The next step was therefore to work backwards from known accident frequencies to get the combined probabilities of the performance factors for double manning. This was done primarily using the fault trees for head-on or tail-on collision. It was assumed that the performance factor probabilities would be the same for tip-over accidents.

Thus it was necessary to know the overall results first, before the more detailed trees could be put in place and their numbers refined. The strategy was appropriate as the fault trees only had to be roughly right before a comparative analysis between single and double manning could be carried out.

RESULTS

The results of the study are summarised in Table 2, which shows the overall FAFR values and the contributions deriving from each accident type.

The effect of changing from double to single manning is about 8% which is small. To make sure of this conclusion, a sensitivity study was carried out which among other things took the worst possible case of the differential effects between the two manning levels. It was concluded that the FAFR could be increased by at the very most 13%, which is still only a relatively small change.

Table 2 also gives an indication of the strategies that could be taken to improve the single-manning FAFR and match the two values. Two accident types clearly predominate: collision with an obstruction and tip-over at a tight curve. Much work had already been done on both for the section of line considered, by eliminating all but three tight curves, and by various measures such as widening cuttings so that slips would fall by the side of the track and over it. As most of the historical and system-wide data applied to the situation before track improvements had taken place, it could well be that the FAFR for the North Island Main Trunk had already been reduced below the original double-manning figure. To improve safety further, the best strategy would be to concentrate on collision with obstructions. As it is a catch-all category containing a number of somewhat different accident types, the first step would be to consider its components separately.

A safety-improving strategy finally adopted by Railways management was to improve radio communication so that nowhere, not even in a tunnel or other blind spot, would a train be out of radio contact.

Table 2 Comparative Risk Levels Compared by Accident Types

Accident Types	Double Manning	Single Manning
Head-on coll. at loop	0.76	0.80
Tail-on coll. at loop	0.11	0.12
Tail-on coll. at 1/2- block	0.29	0.36
Mis. 59 collision	0.34	0.34
Pilot running collision	0.07	0.07
Tip-over at curve	5.76	6.67
Tip -over at turnout	0.98	1.15
Derailment	0.83	0.83
Coll. with obstruction	6.90	7.02
Coll. with equipment	0.28	0.28
FAFR totals	16.32	17.62

DISCUSSION

Some aspects of the process of producing the QRA described above are worth elaborating as they are not immediately obvious. The project was fairly complex, and the strategies and procedures used for handling it were not entirely straightforward. Generally, iteration took place at different levels, with both data and tree structure being "massaged" until there were no detectable anomalies. Data comparisons have been described above, where hard data items were fixed first as "pegging points", followed by a shifting of other data items between defined limits to ensure the results matched overall relativities and levels determined from experience and input from a number of sources. Besides this, the tree structures themselves had to be changed as understanding of the system grew. In some instances the trees gave probabilities which did not initially match known accident relative frequencies. This needed considerable thought, and was generally resolved with the realisation that some facet of railway operation had been incompletely understood. For example, for the tree of Figure 1 it was not initially realised that some trains could not tip over, which involved the addition of another tree element at a later stage.

Throughout the process of iterating through structure and data, guidance was given by the overall aim of the project and the use to which the results would be put. In addition, five underlying principles were followed to help form an appropriate final structure to the problem. They were: correctness, completeness, consistency, balance and appropriate level of detail.

"Correctness" refers primarily to the correctness of the logical structure of the trees, which involves a thorough understanding of the problem. "Completeness" means there should be no omissions or gaps, which is not always easy to achieve. "Consistency" requires that the different parts of the problem, the different branches of the trees, should be at as consistent a level of detail as possible. "Balance" is somewhat similar and is concerned with the "chunking" of the problem, such that the degree of disaggregation is similar throughout. Finally, there is the requirement that the level of detailed achieved should be appropriate to the needs of the problem; to its aims, and to the quality and completeness of the data available. To illustrate the last point, the fault trees used for the locomotive engineer safety project would have been totally inappropriate for predicting an overall FAFR level because of the paucity of available data and because the required result did not need their complexity and detail. However, they were very appropriate for finding the variation in risk between double and single manning.

A useful way of helping the five criteria to be met was to talk to others about the project as it developed, and to get continual feedback from people intimately involved in railway operations. Though this might have lengthened the time taken for the project, it was both an invaluable help and also a safeguard against error.

An interesting question is, what would we have done differently by hindsight? Mostly, there would have been little change. However, we would probably have split up "collision with an obstruction" further as it turned out to be the most important accident category and it contains a number of quite different types of incident. We might also have paid more attention to the problem of combinations of rare events, "normal accidents" as they have been called for complex system failures (Perrow., 1984). For instance, suppose an equipment failure of some sort caused an unusual situation that a driver had to concentrate on to rectify. It might be that being distracted by this, he forgot the normal braking procedure and ran out of air, leading to an accident. Each such combination is exceedingly unlikely, but there are so many that the likelihood of one occurring becomes uncomfortably large. Indeed, the example just given did happen. However, we decided that though it is a real problem for predictive QRA's, it would have made little difference to the comparative study which was the main focus of the project.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the permission granted by NZR for publishing the information contained in this paper and willing help given by many Railway personnel.

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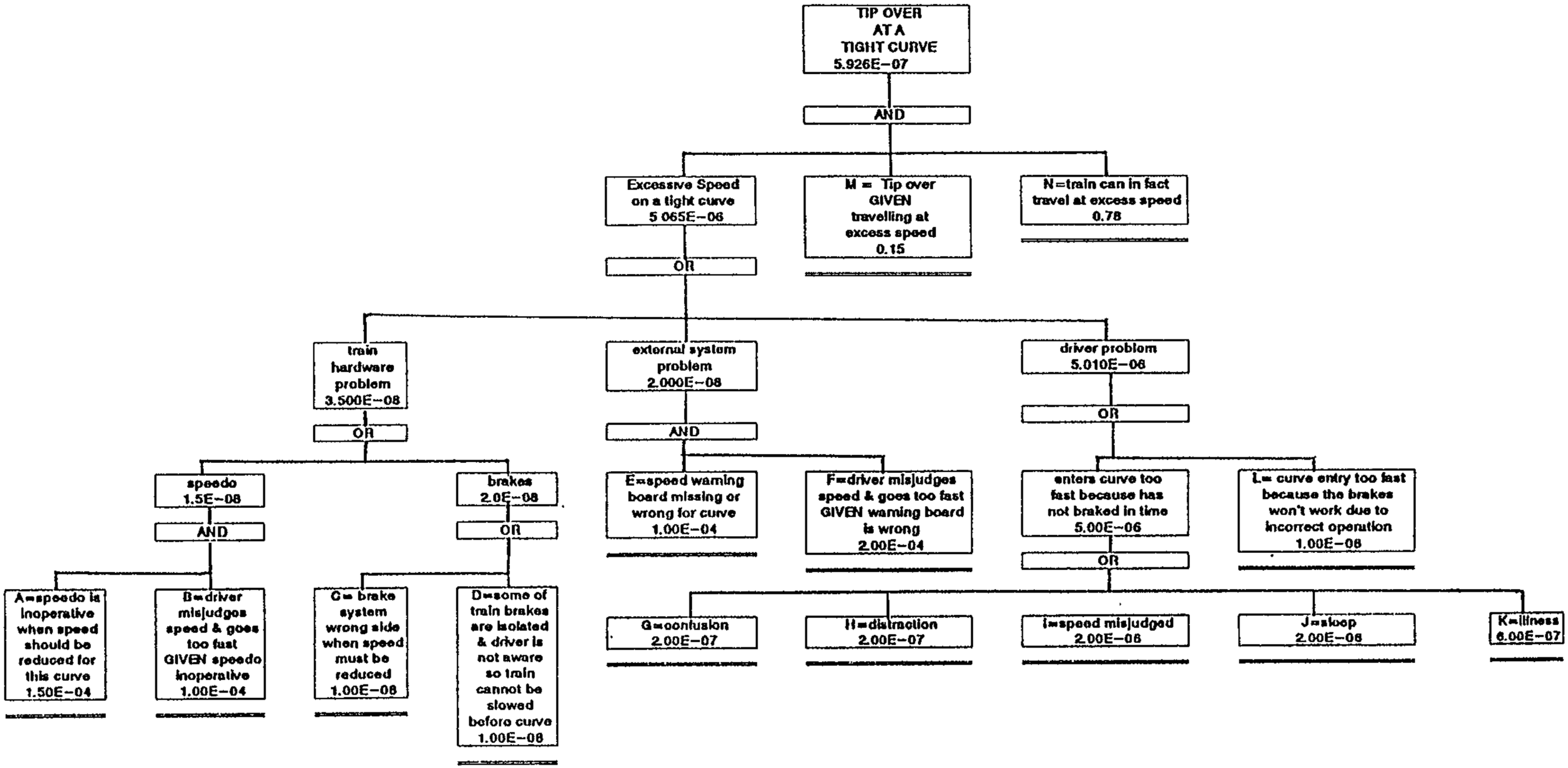
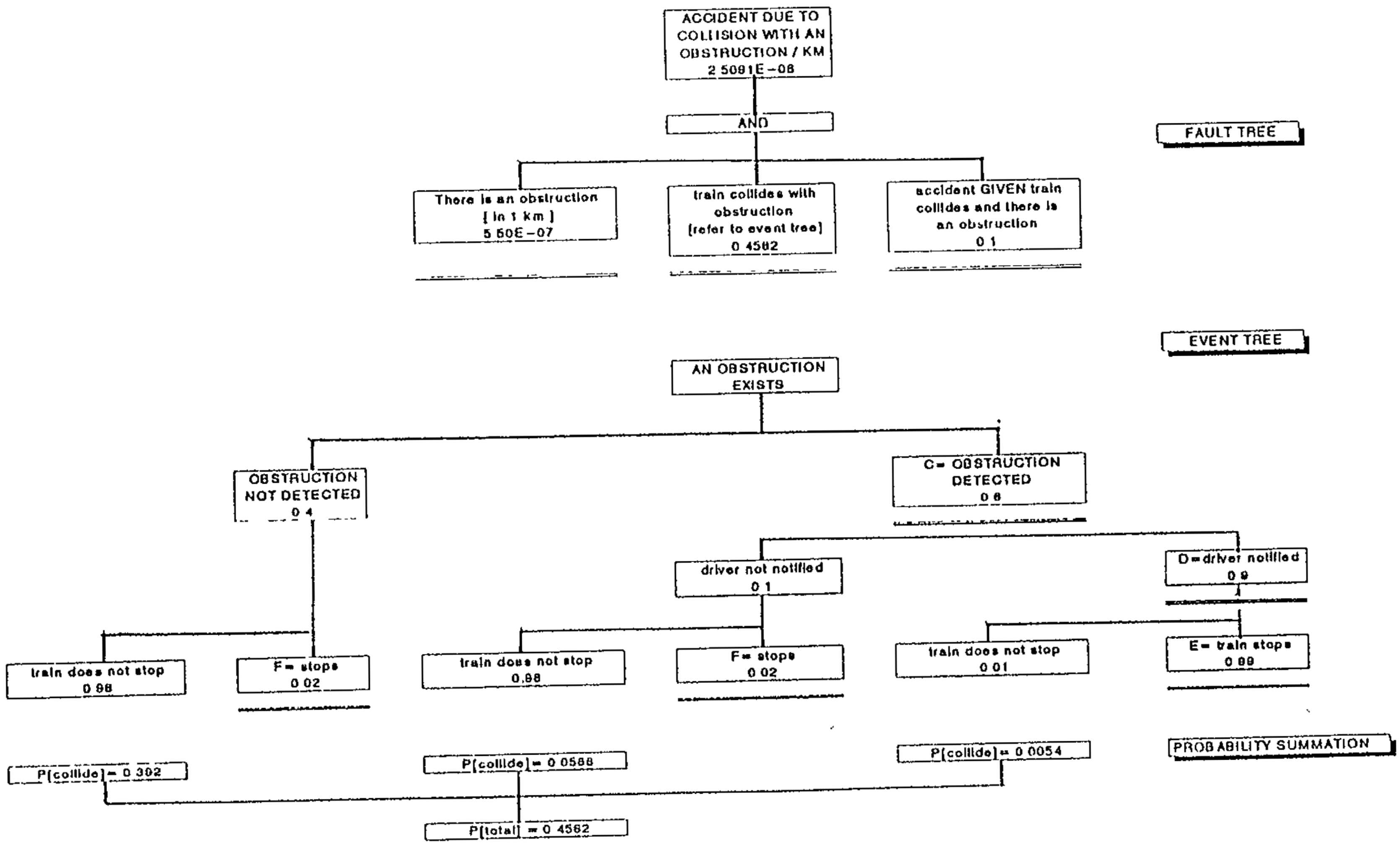
Figure 1

TIP OVER AT A TIGHT CURVE



COLLISION WITH AN OBSTRUCTION

Figure 2



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LEGISLATIVE DEVELOPMENTS - GENERAL

In its Plan of Work 1991/92 the Health & Safety Commission (HSC) has indicated a great deal of activity on the legislative front. Proposals for amendments to regulations, etc. are at various stages of completion and include the following areas which are likely to affect BR:

Lead
Accident Reporting
Man Made Mineral Fibres
Noise
Radiological Protection
Pressure Systems
Construction
Asbestos
Training
Standards and Approved Certification
Confined Spaces

In the period December 1990 to June 1991 there were issued:

4 Approved Codes of Practice
16 new or revised Guidance Notes
3 Consultative Documents

The HSC has also indicated that it sees the Health & Safety at Work Act as more appropriate than railway legislation in maintaining the safety of staff and the public.

The above list does not include any of the European Legislation which derives from adopted Directives.

EUROPEAN DIRECTIVES

The EC Directives comprise a Framework Directive and a number of individual Directives:

- Framework Directive (89/391/EEC) on the Introduction of Measures to encourage improvements in Safety and Health of Workers at Work.

- Minimum Health & Safety Requirements for the Workplace (Directive 89/654/EEC)

- Minimum Health & Safety Requirements for the Use of Work Equipment (Directive 89/655/EEC)

- Minimum Health & Safety Requirements for the Use of Personal Protective Equipment (Directive 89/656/EEC)

- Minimum Health & Safety Standards relating to Display Screen (VDU's) (Directive 90/270/EEC)

- Minimum Health & Safety Requirements for Manual Handling of Loads (Directive 90/269/EEC)

Summary details of the above framework and individual Directives are attached.

All the Directives have to be enacted by Member States by 31.12.92, it is therefore anticipated that we shall have a flood of Consultative Documents in the second half of this year. In addition to the above there will be other Directives relating to:

Risks from Biological Hazards at Work

Temporary or Mobile Worksites.

Machinery Safety Standards

THE CONSULTATION PROCESS

Formal consultation is required by the 1974 Act. Under this process the Health & Safety Commission will issue their proposals which will be channelled down through the CBI and the TUC to both sides of industry. My Health & Safety Section has the task within BR of dissemination of the Documents to Businesses, Functions, Regions, etc., of receiving the comments of the various groups and of formulating a formal corporate response. This response will normally go to the CBI but we shall be sending it also to the Health & Safety Executive via the Railway Inspectorate to ensure that our specific problems are not lost sight of in the inevitable "watering down" process inherent in industry-wide responses.

In addition to the above formal arrangements I have had, and will continue to have, discussions with the Railway Inspectorate on the development of UK legislation in the face of the EC Directives. At these meetings the opportunity will be taken to monitor developments and potential problems for BR in any proposals arising. Every opportunity will be taken to represent the Board's point of view but it will be crucial to that process that Businesses and Functions give full and prompt consideration to the proposals as they arise to ensure our position is properly understood and our responses adequately formulated.

THE FRAMEWORK DIRECTIVE (89/391/EEC)

This Framework Directive must be implemented by 31.12.92 and a Consultative Document is anticipated this year. It is reported that the HSC has prepared draft proposals for regulations under the 1974 Act to cover:

Risk Assessment
Designation of Personnel for Health & Safety Purposes
Provision of Training and Information

It is thought by observers that the Framework Directive is already largely catered for by the 1974 Act and the 1977 Safety Representatives Regulations though some significant changes to health & safety legislation might be necessary.

The Directive covers a wide range of Health & Welfare requirements which:

apply to all sectors of work

assigns primary responsibility for safety to employers

sets out the general principles for employers to follow including -

- Assessing workplace risks & finding appropriate preventative measures
- developing coherent overall prevention policies
- adapting work to the individual
- co-operation between employers

requires employers to designate competent personnel to take charge of safety activities or use competent outsiders

provide First Aid, Fire and emergency arrangements

provide employees with information and training and to have proper consultation on safety

requires employees to co-operate with these measures

The HSC has adopted proposals which reflect the principles of the 1974 Act, modernise un-refurbished pre-1974 legislation and covers more premises than the Factories Act and the Offices, Shops & Railway Premises Act; these Acts may well go. Professional observers feel that changes may have to be made to the Fire Precautions Act, 1971 and the existing law on unfair dismissal; there may also be a need to more clearly outline the duties of employers with regard to development of protection and preventative services and the provision of training and information.

The General obligations upon employers are set out in Article 6 of the Directive and include principles inculcated in the recent Control of Substances Hazardous to Health Regulations and the Noise Regulations such as the requirement to make assessments to prove that a situation/process is safe, a hierarchy of action to prevent or limit risks and employee involvement. The duties require employers to:

- To take measures necessary for the protection of health & safety of workers at work including the prevention of occupational risks and the provision of training as well as the necessary means and organisation to do these things. Employers have to be alert to the changed circumstances which might mean a change to their arrangements and must seek to improve existing situations.

- The above measures are to implemented on the following basic principles:

    avoiding risks

    evaluation of risks which cannot be avoided

    combating risks at source

    adopting the work to the individual especially in the design of the workplace and choice of production methods with a view particularly of alleviating monotony and work at a predetermined rate

    adapting to technical progress

    replacing the dangerous by the non-dangerous or less dangerous

    developing a coherent overall prevention policy covering technology, organisation, work conditions, social relationships, environmental factors, etc.

    priority of collective measures over individual measures

    provision of instructions and training for workers

    co-operation of employers to protection of workers where there are several undertakings at a workplace

  measures taken must in no way involve workers in financial cost

Article 8 of the Directive also provides workers with what has been described as a limited right to stop work in the event of "serious, imminent and unavoidable danger". In doing so they must not be placed at any disadvantage because of this action and are protected from unjustified consequences at law.

THE WORKPLACE DIRECTIVE (89/654/EEC)

The Directive applies to most fixed, permanent workplaces. Exclusions include means of transport, temporary or mobile worksites, extractive industries, etc.

Workplaces brought into use for the first time after 31.12.92 must comply with minimum safety & health requirements for such elements as:

- structural stability & solidity
- electrical installation
- emergency routes & exits
- fire precautions
- ventilation, temperature
- lighting (emergency & artificial)
- floors, walls & ceilings
- windows & skylights
- doors & gates
- dangerous areas & traffic routes
- travelators & escalators
- loading bays & ramps
- rest rooms including provision for non-smokers
- first aid rooms
- handicapped workers, etc.

Workplaces presently in use must comply by 31.12.95 to a list of requirements similar to the above though lacking some of the detail in some cases. However, in the event of modifications, extensions and/or conversions to existing workplaces after 31.12.92 then those workplaces must comply from that time with requirements in the above areas.

Employers will be required to keep all escape routes and emergency exits clear, to keep workplaces clean, carry out maintenance and rectify faults as soon as possible and to regularly maintain and check safety equipment where failure or partial failure are likely to pose hazards. The requirements in themselves appear to be broadly common sense and, for the most part, probably covered by existing legislation/good practice though we shall have to wait to see whether individual UK proposals are more onerous than existing requirements

USE OF WORK EQUIPMENT

Directive 89/655/EEC dated 30.11.89 to be enacted into national legislation by 31.12.92.

The Directive sets out minimum Health & Safety requirements for any activity involving the use of equipment at work, including:

Starting and stopping the equipment
General use of the equipment
Transportation of the equipment
Repair/modification
Maintenance and cleaning

The equipment must be suitable for the work for which it is used and employers must consider any risk associated with the equipment/task and minimise any which cannot be removed. When there is a risk associated with the equipment/task, it must only be used by those designated to do so and repairs must only be carried out by those designated to do so. Equipment must be maintained to meet minimum standards in the Directive.

Employers must obtain and use equipment which, if provided for the first time after 31.12.92, complies with this directive. Equipment already in use at that time must comply within 4 years of 31.12.92.

Information must be provided to workers in a comprehensible format concerning:

Conditions of use
Foreseeable abnormal conditions
Conclusions about use from the benefit of
experience.

We shall no doubt have to survey our machinery and plant to see whether we comply in all respects to the requirements of the Directive. The Health & Safety Executive see the Directive as including trains and locomotives so if, for instance, some locos do not comply in all respects there will be the cost of modifications to long life classes. We shall have to ensure, in common with other industries, that the required features are designed into any equipment, plant or vehicles that we build or buy in.

It is understood from the Railway Inspectorate that Regulations are being drafted and may be seen quite soon. It is anticipated that the regulations will apply to contractors and the public and this latter point could raise practical difficulties - for instance, in providing adequate guarding around slam doors of passenger stock.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

(i) Directive 89/686/EEC dated 21.12.89 which must be enacted into national law by 31.12.91 with effective operation from 1.7.92 defines provisions for design, manufacture, free marketing and marking for PPE. Two standards will be applied - CEN (European Committee for Standardisation) and CENELEC (European Committee for Electrotechnical Standardisation which replace national arrangements such as British Standards and the German DIN standard, etc.

Because of the amount of work likely to arise as a result of the above changes equipment with UK markings may be manufactured and supplied up to 31.12.92 provided there is no CEN standard applied in the meantime. The HSE have indicated that PPE in the pipeline "on the shelf" may be excluded from the new arrangements.

(ii) Directive 89/656/EEC dated December, 1989 must come into effect by 31.12.92. This Directive sets out the rules for the selection, maintenance and correct use of PPE at Work.
The latter Directive will require employers to:

- assess risks which cannot be avoided by other means

- select PPE which:

    - is appropriate to the risks involved
    - is suitable for the worker, and fits after necessary adjustment
    - is compatible with the work
    - complies with the PPE Product Directive

- provide the PPE free of charge

- maintain the PPE in clean, good working order

- involve workers or their representatives in selection of the PPE

- provide information, instruction and training on its use

It is understood that new implementing regulations are being drafted to make explicit the requirements which are implicit in the 1974 Act and Consultative Documents are expected this summer.

Implications for BR:

- much will depend upon the degree to which UK standards are accepted by CEN as appropriate and transferable otherwise we shall have to have a review of everything we provide though it is anticipated that equipment "on the shelf" will be allowed to work through the system. PPE issued will be free to staff, as now.

- it is possible that since CEN approval procedures are likely to be higher, that PPE will also cost more,

- we have not hitherto involved the Trade Unions when choosing our PPE, we shall have to do that from 31.12.92.

- it looks as though all HV clothing will have to have reflective stripping at prescribed points and that HVV's and tabards will have to have a "pull-apart" design to prevent snagging hazards. We already have the question of strips on all HV clothing under active consideration.

V.D.U. REGULATIONS

Directive 90/270/EEC dated 25.9.90 which must be enacted into national law by 31.12.92. The Health & Safety Executive (HSE) wish to develop Regulations while the CBI are pushing for an Approved Code of Practice.

The Directive lays down basic conditions for VDU workers and their working environment specifically covering display screen equipment, keyboards, peripherals and ergonomics of the workstation. The new rules are to be applied to new workstations as from 1.1.93 and to existing workstations as by 31.12.96 at the latest.

Evaluations will be required to be made on the following elements:

- risks to eyesight
- problems of physical and mental stress

Workers shall be entitled to "an appropriate eye and eyesight test"

- before commencing display screen work
- at regular intervals thereafter
- in the event of visual difficulties

and, where necessary, "special corrective appliances provided".

The Directive does not apply to Drivers' cabs or computer systems on board a means of transport or to systems for public use. It is also felt by the Railway Inspectorate that the Directive will not apply in the case of multiple arrays of screens in signal boxes though the situation is less clear with level crossing Close Circuit Television.

It is anticipated that the Health & Safety Commission will issue a Consultative Document this summer proposing regulations and updating the 1983 Guidance - there may also be an Approved Code of Practice.

Implications for BR will depend to a degree upon a number of points on which the CBI is seeking clarification from the Health & Safety Executive (HSE), these include:

- a definition of "worker" affected by the proposals: article 2(c) defines a worker as someone who habitually uses display screen equipment as a significant part of their normal work. It is possible to infer from the Directive and the Health & Safety Executive attitude to a report by Dr Tom Cox (Nottingham) relating to breaks for VDU workers, that the workers that the Directive have in mind are those continually inputting data into computer systems, rather than staff who might use microcomputers as adjuncts to their normal everyday equipment.

- Breaks recommended by Dr Cox include 12-15 minutes every 50-60 minutes of exposure to the task.

- Clarification is being sought as to how the eye testing is to be applied since article 9(5) says that tests may be provided as part of a national health system.

- There will have to be written assessments made of all VDU workstations to evaluate safety and health conditions which might give rise to eyesight or physical problems or give rise to mental stress.

MANUAL HANDLING OF LOADS REGULATIONS

Directive 90/296/EEC dated 29.5.90 in response to which the Health & Safety Executive (HSE) have produced draft Regulations and Guidance. A draft was produced in January and BR was one of the organisations which received a privileged view of the first draft. This was circulated and few comments were received. A further preliminary draft has just been received and response to this document is required by 21.6.91.

The regulatory proposals are in themselves quite basic and are well illustrated by the attached flowchart. As may be seen the Regulations themselves appear relatively innocuous however, to assist with the assessments mentioned numerical guidelines are provided to establish approximate boundaries, "within which manual handling operations are unlikely to create a risk of injury sufficient to warrant further detailed assessment."

Assessments of handling operations have to take account of four parameters:

The Task
The Load
The Working Environment
The Capability of the Individual

The intention of the guidance document is that it should form a general framework within which individual industries and sectors will be able to produce more specific guidance appropriate to their own circumstances.

Over the last 8 - 10 years there have been various attempts to frame suitable regulatory control and in response to earlier proposals the DCE was alarmed at effects which would unduly constrain work where, for instance, there was much isolated manual handling where appliances were not always available and there was a need for team lifting of rails, etc. Those comments have not been reiterated but, presumably, remain valid. It is also the case that the Director, Parcels feels that this legislation will have a major impact on his business and is particularly concerned about station working when moving trolleys in and out of trains. He has estimated that a 20Kg limit for individual lifts would represent a revenue loss of 8%; a 25Kg limit - 2 to 4% loss and a 50Kg limit 1% loss. The guidelines envisage a maximum of 25Kg in ideal conditions for certain types of lift with lower maxima as conditions deteriorate dependant on distance from and/or relationship to the body. (See attached diagram and flowchart).

It will be necessary to ascertain from the Health & Safety Executive (HSE) just how the they will view the guidance and limitations arising from the guidance bearing in mind that it is not an Approved Code of Practice (ACoP), though there is little doubt that they will see the limitations set as having to be closely followed. Clarification of this is essential as we need to be aware of the effects which will be applied (or not applied) by those firms with whom we interface and with whom we may be in competition; it will also assist managers in knowing just what they have got to meet and avoid arguments around the finer points of legislative requirements of ACoP's vs Guidance.

There have been two privileged views of the latest consultation document and we anticipate that it will be issued formally later this summer. There is brief mention in the draft about team lifting but it is not likely to provide much comfort to the Engineering functions.

There is a feeling that the regulations will bring with them a large training requirement and at first sight this would seem to be the case. However, we should always have been doing training in kinetic lifting and carrying and the carrying out of assessments for lifting tasks would seem to be one requiring common sense and managerial skills rather than intensive training; what will be important will be understanding of what is required and commitment to that need.

MACHINERY SAFETY REGULATIONS

Directive 89/392/EEC dated 14.6.89 has to be enacted into national law by early 1992 and operate with effect from 1.1.93. Member states may, until 31.1.95, put on the market and into service machinery which conforms with national legislation in force in that country on 31.12.92.
We are not aware of any proposals for UK legislation at the time of writing

The Directive covers the broad spectrum of manufacturing and processing machines including peripherals and power supplies. Machines not covered include mobile equipment, lifting equipment, manually operated equipment and medical equipment.

Mandatory Health & Safety requirements laid down include broad statements on such elements as:

Principles of Safety Integration

- elimination or reduction of risks by design
- information to users on normal and extended use
- reduction of operator fatigue and stress
- personal protection requirements (PPE)

Materials and products in construction
Lighting aspects
Safe operation
Safety of Controls & control devices
Starting & stopping (inc. emergencies)
Complex installations
Mode selection and override controls
Failure of Power Supplies
Protection against mechanical hazards
related to moving parts, sharps, ejections, etc
Machine Guards and their fitment
Other hazards including electrics, fire, extreme
temperatures, explosions, noise, vibration, radiation,
dusts & gases, etc.
Maintenance
Indicators & Warning Devices
Marking with the CE mark

Portable hand held machinery is covered by these requirements.

As may be seen the provisions are comprehensive and what could be expected so far as machines are concerned. It is not possible to say what the likely effect will be on BR since we do not know the extent to which individual machinery conforms to the broad parameters laid down. It is also not known whether these requirements will apply to trains, though it is reasonable to suppose that they would since trains are probably not mobile machines in the sense of the Directive.

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Dieter Metz

Is it possible to quantify the human error rate in railway operations?

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TRANSLATION

Ministerialrat Dieter Metz
Zentrale der Deutschen Bundesbahn
Friedrich-Ebert-Anlage 43 - 45
D - 6000 Frankfurt am Main 1

Is it possible to quantify the human error rate in railway operations?

0. Introduction

In railway operations the implementation of safety functions is being transferred increasingly from man to machine. This develop-ment arises from the known fact that the error probability of man is considerably higher than that of the machine.

This state of development is characterised by the wide ranging substitution of functions with a high risk potential by technical equipment to the point of full automation, e.g. route safety and train journey sequences, safety of level crossings. Furthermore, modern technology also enables a high degree of technical safety to be achieved when monitoring and regulating speed during train journeys.

Nevertheless, operating aspects still remain, where man continues to bear a more or less significant part of responsibility for safety, e.g. when checking the running safety of vehicles marshalled in a train or during shunting. It should not be forgotten - with dangerous goods on the increase - that man retains a major share of responsibility for the safe loading of goods for carriage.

In terms of safety strategy it needs to be remembered that

- for regulating functions in high risk operating areas on the railway the pre-conditions for substitution have been created to a large extent.
- regulating functions with an increased risk still remain, however, for which technical solutions still need to be developed,
- furthermore, man exercises a back-up function, when technology becomes faulty or fails, and that he must then again assume responsibility for safety.

1. Definition of the problem

In the design or further development of technical systems for railway operations inadequate consideration is at present frequently given to whether man can again be expected to assume full responsibility for safety, when the system becomes faulty. Technical backup facilities, or at least technical support - such as expert systems - are rejected with the argument that they cause additional costs. This reasoning must then be accepted, because there are no suitable methods for determining the human error rate and to assess the prevention of probable damage in money terms.

As part of the programme "*Safety related system planning on the DB*" the Rheinisch-Westfälische Technical University Aachen was therefore asked to undertake a research project under the title: "Transfer of responsibility for safety to man in the event of technical faults on the railway".

A review of the first results is given below.

2. Human error response

The term "human error response" evokes negative associations in everyone's mind; this makes an unbiased and scientifically rational treatment of the phenomenon of human error response more difficult. Nobody is infallible and psychologists even postulate that the "commission of errors" is an established element of valuable human properties: flexibility, adaptability, improvisation and creativity.

However, if human error responses are considered to be an unavoidable fact, the question arises of the probability, with which such errors occur and what factors affect this error probability? To answer this question an analysis of the findings obtained by different scientific disciplines is required. These were assembled in an extensive search of literature and only a brief summary of the result is given here. According to ergonomic findings poor ambient conditions such as

- poor lighting
- noise
- vibrations
- adverse climatic conditions (high temperature, high humidity) or
- harmful chemicals

lead to an increase in human error responses.

Medical studies show that man can absorb much more information through his sensory organs than his brain can perceive and process. The magnitude of the information loss taking place is of the order of $1 : 10^7$! It is possible, therefore, that man does not even perceive important information, so that he cannot process it, and human error response occurs in consequence.

The act of information processing in the human brain is also error prone and this effect increases, the longer and more complicated processing becomes. Here, man can apply only comparatively simple decision rules so that, when time is pressing, complex decision situations cannot be dealt with adequately. Additional stresses on man due to ergonomically adverse working conditions, due to a large number of tasks to be solved in a given time, or due to the social environment, additionally cause a stress situation, in which human error responses increase beyond normal rates.

Good motivation of man, on the other hand, results in a clear decrease of human errors and even can balance out the negative consequences of high stress. This can be demonstrated by reference to a test made with radio operators on ships in different ambient conditions (see Fig. 1). While a poorly motivated group makes more and more errors with increasing time and, above all, higher effective room temperatures, an increase of the error rate, however, is hardly noticeable in a well motivated group in the same conditions.

3. Measures for the prevention of human error response

The various influences on man act on him in complex relationships. Only integrated planning of measures in technical, ergonomic, organsational and psychological aspects, therefore, can lead to an improvement of human error behaviour. Here, psychologists set clear priorities related to the differing effectiveness of these measures:

1. Primary importance is always attached to the safe design of the machine, the man-machine interface and the physical surrounding.

2. Only then can organisational measures be introduced for solving safety problems.

3. This can be followed by behavioural measures for motivation and teaching suitable responses.

4. Only as a last resource can persons unsuitable for handling some technical equipment be eliminated by selective procedures.

4. Probability model for human error response

In technical railway literature values for human error probabilities have hitherto appeared only in a few places and then they were not backed by test data but were only estimates. However, extensive data sources in this connection are available in the field of safety science, especially in American technical literature relating to the safety of nuclear power stations. This information has the disadvantage that it is valid only, when the corresponding action is carried out on the same apparatus and in the same ambient conditions.

In order to overcome this problem, individual actions are combined into action classes, which are based on a psychological model for human information processing by the Danish scientist Jens Rasmussen. At the beginning of the 1980s Rasmussen created a model, which provides for 3 levels of different human responses with different degrees of difficulty of information processing (see Fig. 2).

The action classes corresponding to the 3 response levels are then associated with 3 ranges, within which the human error rates for the respective actions lie (see Fig. 3). Since the Rasmussen model is a generally accepted psychological model of human information processing and is generally valid for different workplaces and different ambient conditions, the error rate classes thus obtained will form the basis for further discussion.

Taking into account the relationships obtained between the human error rates and the ambient conditions and the stress level, the data sources mentioned above finally yield the following values for the human error rate in a man-machine safety system (see Fig. 4). It is clearly seen how badly the error rates deteriorate under very adverse ambient conditions, and that under stress and adverse ambient conditions the extremely poor error rate of 1.0 (i.e. all decisions are wrong) must be expected at the knowledge based response level. However, actions normally occurring in railway operations only fall into the skill and rule based response levels.

5. Relationships of several elements in a safety system

In a man-machine system several elements always work together, each of which having a specific failure probability. In order to be able to determine the overall failure probability of the man-machine system, the mathematical rules of probability calculus for systems in parallel and series arrangement must be applied.

Since errors with a common cause (so-called "common mode errors") between the various human actions and the machine actions can be excluded, very simple calculation rules are obtained for a man-machine system in parallel arrangement, i.e. a system, in which the system elements monitor one another (see Fig. 5): The overall failure probability is obtained from the product of the individual failure probabilities.

With a man-machine system in series arrangement, i.e. a system in which the system elements do not monitor one another, an exact calculation of the overall failure probability is more complicated, because of the presence of sum and product terms. Since many individual failure probabilities are only approximate values, approximate calculation with rounding off to the safe side is justified in this case. It can be shown that the approximate solution obtained contains an error of less than 1% of the exact solution per addition step with failure probabilities smaller than 10^{-2}. The approximate solution for the overall failure probability of a system in series arrangement, in which the individual failure probabilities are smaller than 10^{-2}, is then obtained as the sum of the individual failure probabilities, when the number of system elements is limited (see Fig. 6).

Using these calculation rules, the overall failure probabilities of man-machine systems can be easily determined in a very good approximation tending to be on the safe side, even when the relationships are complex (see hypothetical example Fig. 7).

6. Use of the risk as a safety parameter

If a dangerous situation is to be quantified, not only the probability of its occurrence, but also the magnitude of any possible damage must be considered. Only then will it be possible, for example, to justify the permissibility of shunting, where safety measures are largely based on human reliability, because during shunting safety related events must be expected to occur much more frequently than in train traffic, while, on the other hand, damage arising as a result of individual shunting events is much smaller. The risk, therefore, should be used as a safety parameter (see Fig. 8); the risk is defined to be the product of the probability of occurrence and the extent of damage to be expected.

The unit "DM/Year", related to the whole DB network, is suggested as a dimension for damage and risk; it offers several advantages to those responsible for DB operating safety:

- The operating safety, being one of the most outstanding system advantages of the railway, becomes measurable in a cost related dimension.

- The increase of operating safety, when the Operators commission a service from the Engineers, can be represented directly in money terms, which removes the reasoning difficulties safety experts today still have to overcome.

- The order of priority of inherently dangerous operating situations and the measures resulting therefrom will become more objective, when based on risk, than is at present possible, as it is based on the number of accidents and the reaction to rare but spectacular individual cases.

7. Model for determining the probability of the occurrence of damage

A multi-stage model is used to describe the transition of the man-machine system from the state of "no danger" to the "damage state". The probability of the occurrence of damage is here regarded as the combination of the probability of confrontation with adverse circumstances w_k with the probability of the failure of the prevention measure w_v and the probability of the continuation of circumstances until the occurrence of damage w_b (see Fig. 9).

The probabilities w_k and w_v depend on the operational boundary conditions and w_v represents the probability of the failure of the man-machine system.

8. Further work

By reference to the statistical data the DB will first attempt to determine the risk of a train colliding with another train. The collation of data, in particular, proves to be very expensive, because data are used by several technical departments and, in part, have regrettably been collected unsystematically. The calculated risk can then be compared with the accident statistics and the fit of the model with reality can then be tested. In order to establish an evaluation method for operational safety questions, the acceptable risk limit must then be defined and introduced to the method. This is because, in the end, operating safety will be judged by not allowing this acceptable risk limit to be exceeded.

A MEASURES FOR PREVENTING HUMAN ERROR RESPONSES IN ORDER OF PRIORITY:

1. Safe design

   - of the machine
   - of the man-machine interface
   - of ambient conditions

2. Organisational measures to solve safety problems

3. Measures to guide behaviour

   - for motivation
   - for training

4. Psychological tests and selection methods only as a last resort

B HUMAN ERROR RESPONSES INCREASE

. in poor ambient conditions due to

  - poor lighting
  - noise
  - vibrations
  - adverse climatic conditions (high temperature, hugh humidity)
  - harmful chemicals

. with increasing length and complexity of the information handling process in the brain

. especially strong in stress situations

C Formula for a system in series arrangement

Approximation formula for a system in series arrangement
(when $a_i < 10^{-2}$ and the number of n is limited)

D ADVANTAGES OF USING RISK AS A SAFETY PARAMETER (DM/YEAR)

. Operating safety can be expressed in a cost related dimension

. When the Operators commission a service from Engineers, increased operating safety can be directly expressed in money terms

. Arranging the order of priority of potentially dangerous operating situations, and the measures resulting therefrom, is more objective than the usual present reaction to rare, but spectacular individual events

Fig. 1 INFLUENCE OF MOTIVATION, AMBIENT AND TIME STRESSES ON ERROR RESPONSES BY SHIPS' RADIO OPERATORS

Number of errors per hour

hours
room temp.
°C effective

poorly motivated group
medium group
well motivated group

Fig. 2 RASMUSSEN'S MODEL OF HUMAN INFORMATION PROCESSING

Objectives

Knowledge based behaviour	Identification	Response decision	Response planning
Rule based behaviour	Recognition	Association of condition and task	Stored rules for tasks
Skill based behaviour	Formation of characteristics		Automated sensory-motorised reaction models
	Sensory inputs	Time-state-information (response feed-back messages)	Responses

Skill based behaviour:

Man has clearly understood the task set and can carry it out by virtue of his training with automatic sensory-motorised reactions.

Rule based behaviour:

Man can associate the task set by reference to specified symptoms from a learned collection of behavioural rule of the "If-Then" form and carry it out in accordance with the rule thus found.

Knowledge based behaviour:

Due to lack of experience man can carry out the task set only by using his knowledge of the functioning of the system in order to evaluate the complex or even equivocal information, make a decision based on general objectives and then take action.

Fig. 3

COMPARISON OF RASMUSSEN'S MODEL AND ERROR RATE CLASSES OF ACTIVITIES GROUPED ACCORDINGLY

		Objectives		
Identification	Response decision	Response planning	KNOWLEDGE BASED BEHAVIOUR	$5x10^{-3}$ $5x10^{-1}$
Recognition	Association of condition and task	Stored rules for tasks	RULE BASED BEHAVIOUR	$5x10^{-4}$ $5x10^{-2}$
Formation of characteristics		Automated sensory-motorised reaction models	SKILL BASED BEHAVIOUR	$5x10^{-5}$ $5x10^{-3}$
Sensory inputs		Time-state-information	Responses	human error rate

Fig. 4 PROBABILITY MODEL FOR HUMAN ERROR RESPONSE

Human behaviour level	favourable ambient conditions			adverse ambient conditions		
	Stress by under-working	Optimum stress level	Stress by over-working	Stress by under-working	Optimum stress level	Stress by over-working

Skill based behaviour:

Man has clearly understood the task set and can carry it out by virtue of his training with automatic sensory-motorised reactions.

Rule based behaviour:

Man can associate the task set by reference to specified symptoms from a learned collection of behavioural rule of the "If-Then" form and carry it out in accordance with the rule thus found.

Knowledge based behaviour:

Due to lack of experience man can carry out the task set only by using his knowledge of the functioning of the system in order to evaluate the complex or even equivocal information, make a decision based on general objectives and then takes action.

Fig. 5 FORMULA FOR A MAN-MACHINE SYSTEM IN PARALLEL ARRANGEMENT

Reciprocal monitoring of system elements

System in parallel arrangement

Failure probability x_n of a system with n elements

Fig. 6 APPROXIMATION FORMULA FOR A MAN-MACHINE SYSTEM IN SERIES ARRANGEMENT

No reciprocal monitoring of system elements

System in series arrangement

Failure probability x_n of a system with n elements

(The error can be neglected for an individual failure probability $a_i < 10^{-2}$ and limited number of n)

Fig. 7 EXAMPLE OF THE DETERMINATION OF THE OVERALL FAILURE PROBABILITY

Assumed system

with

= individual failure probability of elements

and i = 1 ... n

Overall failure probability w(f) of the system

Fig. 8 RISK AS A SAFETY PARAMETER

R = Risk (Dimension: magnitude of damage)
W_s = Probability of occurrence of the damage
S = Damage (dimension: magnitude of damage)

Fig. 9 MODEL FOR DETERMINING THE PROBABILITY OF THE OCCURRENCE OF THE DAMAGE

No risk

Confrontation with adverse conditions W_k

Latent risk

$(1 - W_v)$ Defensive measures successful

Risk eliminated

Defensive measures unsuccessful W_v

Acute risk

$(1 - W_b)$ accidental disappearance of at least one adverse condition

Conditions continue until damage occurs W_b

Damage situation

MAßNAHMEN ZUR VERMEIDUNG MENSCHLICHER FEHLHANDLUNGEN IN DER REIHENFOLGE IHRER PRIORITÄT:

1. Sichere Gestaltung
   - → der Maschine
   - → der Schnittstelle Mensch-Maschine
   - → der Umweltbedingungen

2. Organisatorische Maßnahmen zur Lösung von Sicherheitsproblemen

3. Verhaltensbeeinflussende Maßnahmen
   - → zur Motivation
   - → zum Training

4. Erst zuletzt psychologische Tests und Ausleseverfahren

ZUNAHME

MENSCHLICHER FEHLHANDLUNGEN

- bei Belastungen aus der Umwelt
  - schlechte Beleuchtung
  - Lärm
  - Vibrationen
  - ungünstigem Klima (hohe Temperatur, hohe Luftfeuchtigkeit)
  - schädlichen Chemikalien

- je länger und komplizierter der Prozeß der Informationsverarbeitung im Gehirn

- besonders stark in Streßsituationen

Rechenregel für ein System in Reihenanordnung

$$x_n = \sum_{i=1}^{n} a_i - \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (a_i \cdot a_j) + \sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} \sum_{k=j+1}^{n} (a_i \cdot a_j \cdot a_k) - + \ldots - (-1)^n \cdot \prod_{i=1}^{n} a_i$$

Näherungsrechnung für ein System in Reihenanordnung

(wenn $a_i < 10^{-2}$ und begrenzte Anzahl n)

$$x_n = \sum_{i=1}^{n} a_i = a_1 + a_2 + a_3 + \ldots + a_{n-1} + a_n$$

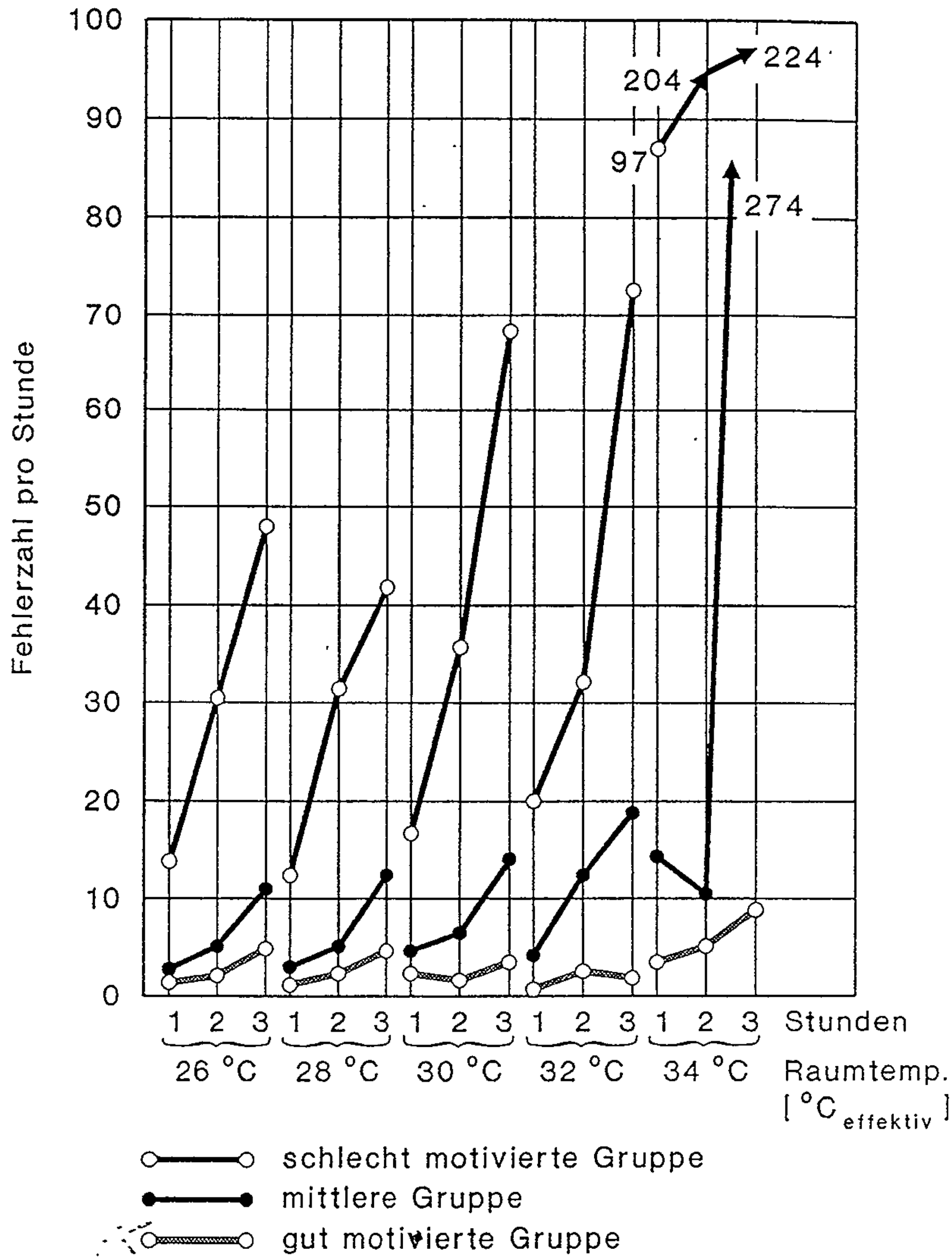
VORTEILE DER SICHRHEITSKENNGRÖßE RISIKO [DM/JAHR]

- Betriebssicherheit auch in kostenbezogenen Dimensionen meßbar

- Erhöhung der Betriebssicherheit bei Aufträgen der Produktion an die Technik ist unmittelbar in Geldwerteinheiten darstellbar

- Dringlichkeitsreihung der gefahrenträchtigen Betriebssituationen und der sich daraus ergebenden Maßnahmen ist objektiver als das z. Zt. übliche Reagieren auf seltene, aber aufsehenserregende Einzelfälle

EINFLUSS VON MOTIVATION, KLIMATISCHER UND ZEITLICHER BELASTUNG AUF DIE FEHLHANDLUNGEN VON SCHRIFFSFUNKERN



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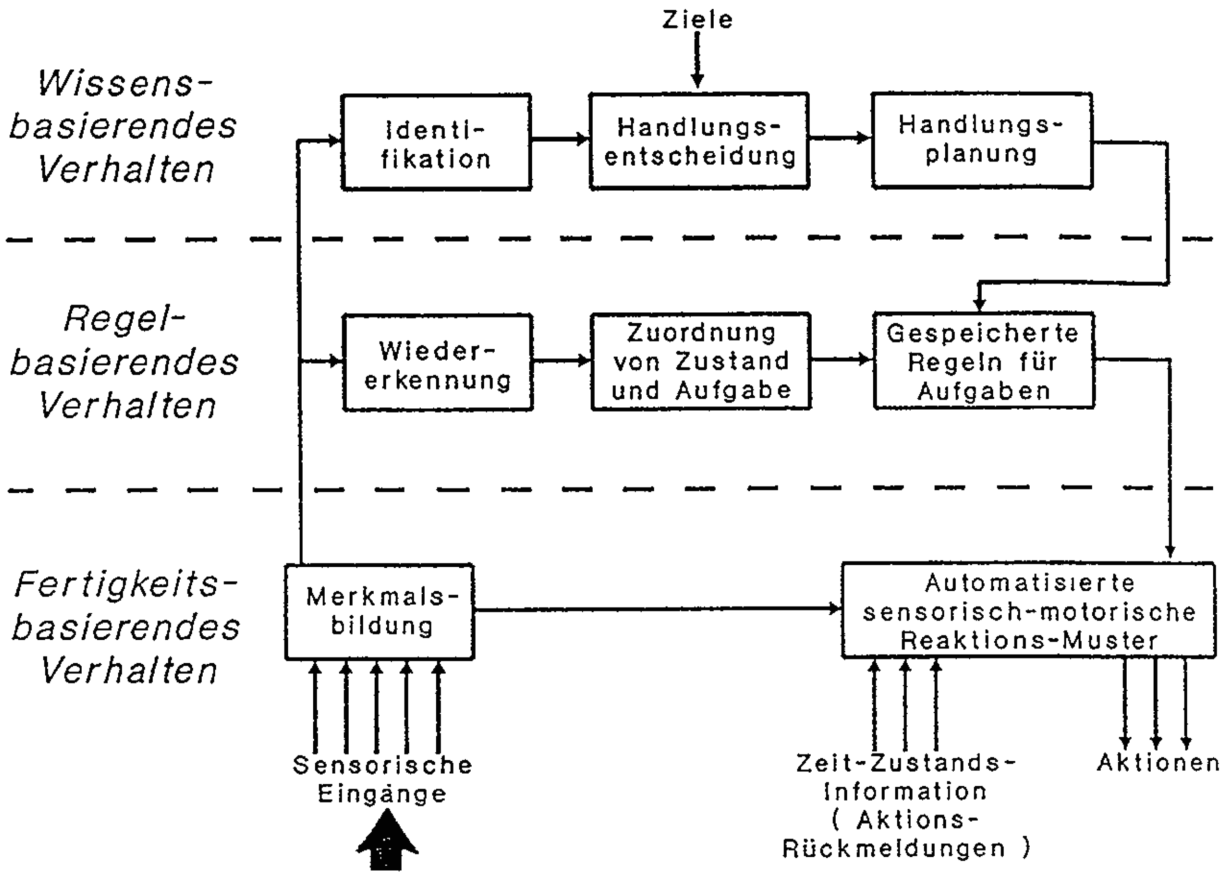
MODELL DER MENSCHLICHEN INFORMATIONS-VERARBEITUNG VON RASMUSSEN



Fertigkeits-basierendes Verhalten:

Der Mensch hat die ihm gestellte Aufgabe eindeutig verstanden und kann sie aufgrund seiner Ausbildung mit automatisch ablaufenden, sensomotorischen Reaktionen ausführen.

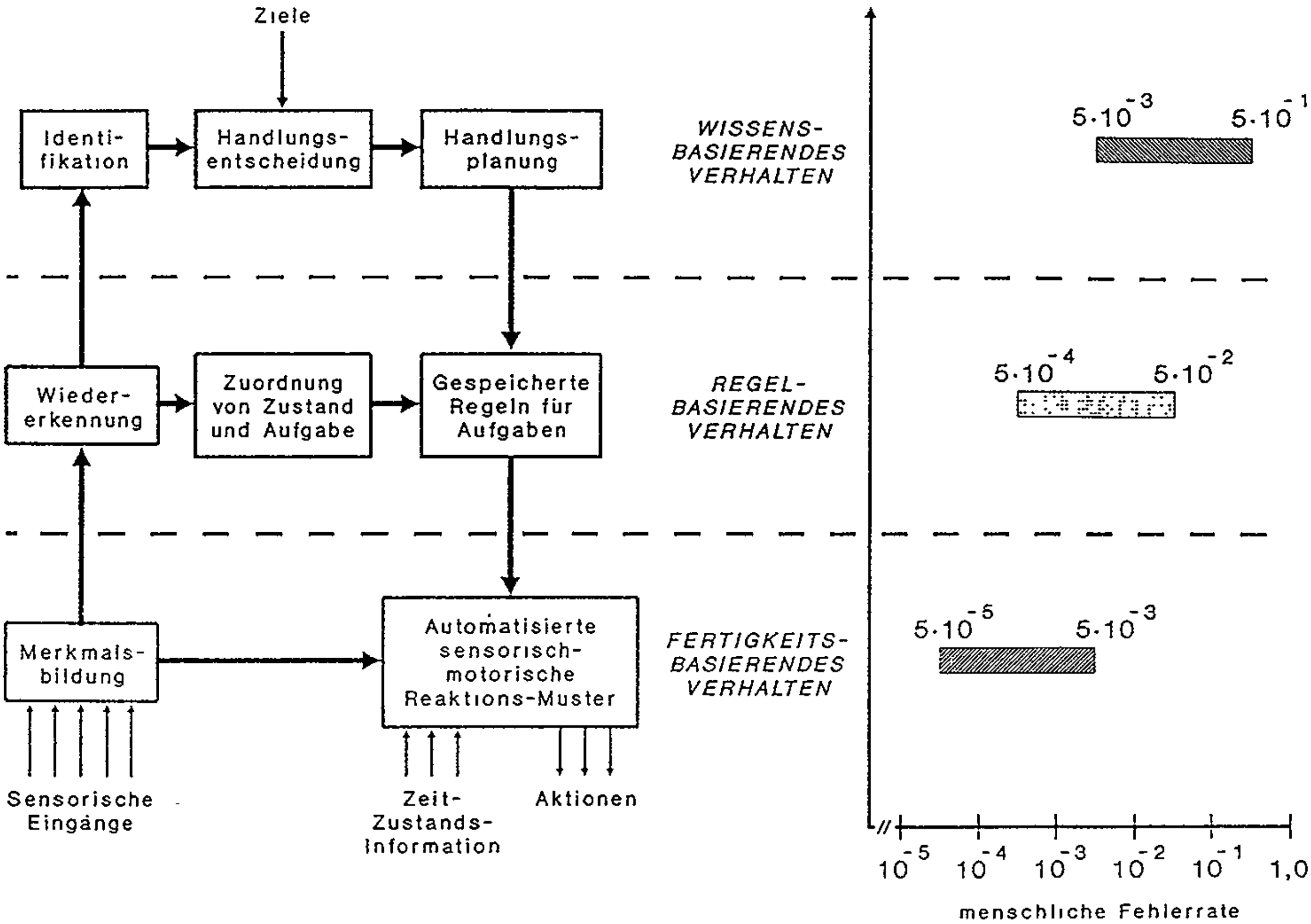
Regel-basierendes Verhalten:

Der Mensch kann die ihm gestellte Aufgabe aufgrund festgelegter Symptome einer gelernten Sammlung von Verhaltensregeln der Form "Wenn-Dann" zuordnen und mit der so gefundenen Regel ausführen.

Wissens-basierendes Verhalten:

Der Mensch kann die ihm gestellte Aufgabe aus Mangel an Erfahrung nur lösen, indem er seinen Wissensschatz über die Funktionsweise des Systems nutzt, um die komplexen oder gar mehrdeutigen Informationen auszuwerten, eine Entscheidung aufgrund allgemeiner Ziele trifft und dann handelt.

GEGENÜBERSTELLUNG DES MODELLS VON RASMUSSEN UND DER FEHLERRATEN-KLASSEN FÜR DANACH GRUPPIERTE TÄTIGKEITEN



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WAHRSCHEINLICHKEITSMODELL FÜR MENSCHLICHES FEHLVERHALTEN

Menschliche Verhaltens-ebene	günstige Umweltbedingungen			ungünstige Umweltbedingungen		
	Streß durch Unterfor-derung	optimales Streß-niveau	Streß durch Überfor-derung	Streß durch Unterfor-derung	optimales Streß-niveau	Streß durch Überfor-derung
fertigkeits-basierend	$2 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$2 \cdot 10^{-3}$	$1 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	$1 \cdot 10^{-2}$
regel-basierend	$2 \cdot 10^{-2}$	$1 \cdot 10^{-2}$	$2 \cdot 10^{-2}$	$1 \cdot 10^{-1}$	$5 \cdot 10^{-2}$	$1 \cdot 10^{-1}$
wissens-basierend	$2 \cdot 10^{-1}$	$1 \cdot 10^{-1}$	$5 \cdot 10^{-1}$	1,0	$5 \cdot 10^{-1}$	1,0

Fertigkeits-basierendes Verhalten:

Der Mensch hat die ihm gestellte Aufgabe eindeutig verstanden und kann sie aufgrund seiner Ausbildung mit automatisch ablaufenden, sensomotorischen Reaktionen ausführen.

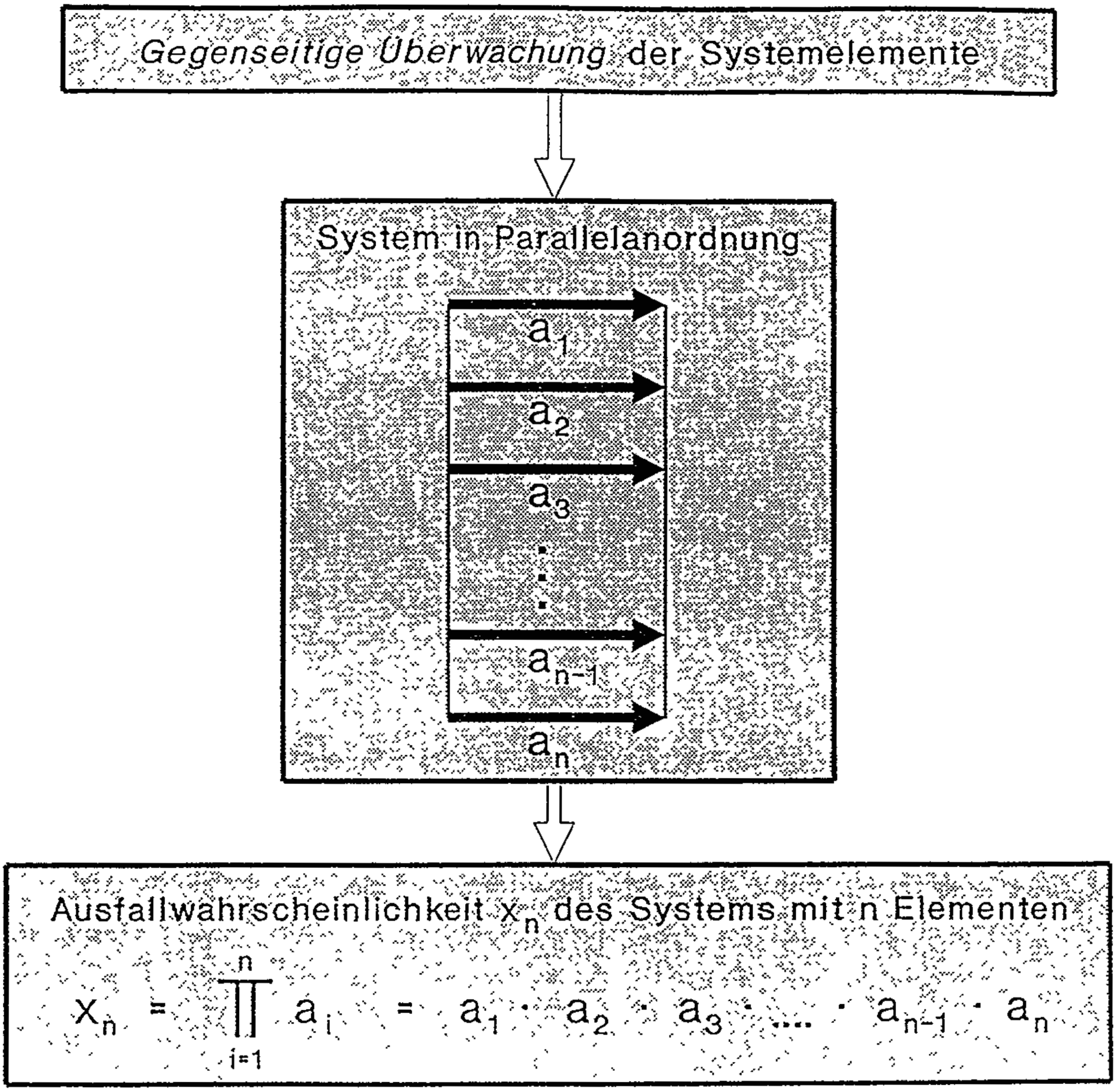
Regel-basierendes Verhalten:

Der Mensch kann die ihm gestellte Aufgabe aufgrund festgelegter Symptome einer gelernten Sammlung von Verhaltensregeln der Form "Wenn-Dann" zuordnen und mit der so gefundenen Regel ausführen.

Wissens-basierendes Verhalten:

Der Mensch kann die ihm gestellte Aufgabe aus Mangel an Erfahrung nur lösen, indem er seinen Wissensschatz über die Funktionsweise des Systems nutzt, um die komplexen oder gar mehrdeutigen Informationen auszuwerten, eine Entscheidung aufgrund allgemeiner Ziele trifft und dann handelt.

RECHENREGEL FÜR EIN MENSCH-MASCHINE-SYSTEM IN PARALLELANORDNUNG



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NÄHERUNGSRECHNUNG FÜR EIN MENSCH-MASCHINE-SYSTEM IN REIHENANORDNUNG

Keine *gegenseitige Überwachung* der Systemelemente

⇓

System in Reihenanordnung

$a_1 \rightarrow a_2 \rightarrow a_3 \rightarrow \dots \rightarrow a_{n-1} \rightarrow a_n$

⇓

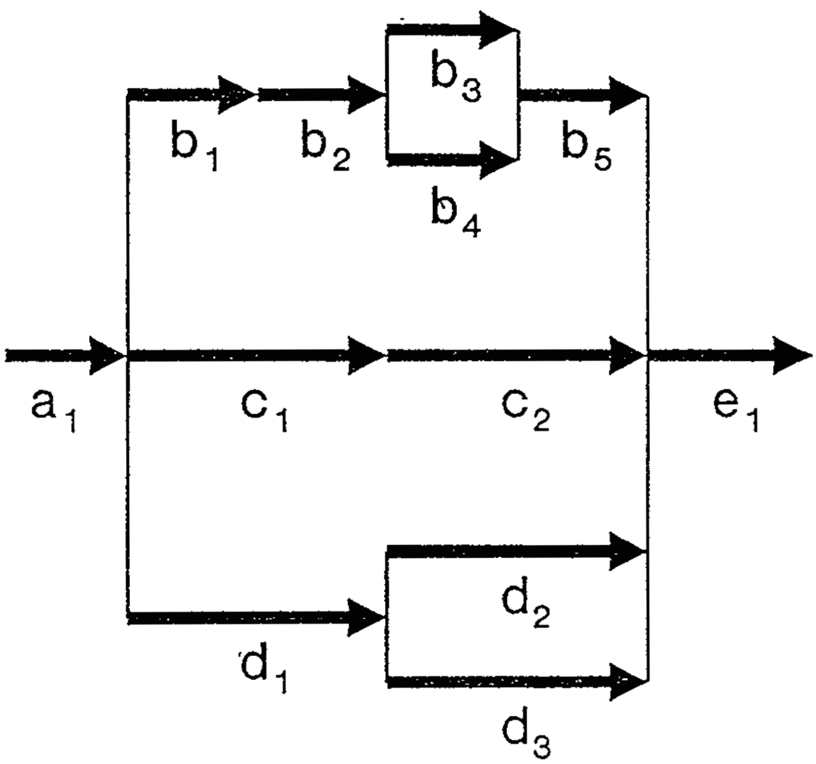
Ausfallwahrscheinlichkeit x_n des Systems mit n Elementen

$$x_n = \sum_{i=1}^{n} a_i = a_1 + a_2 + a_3 + \dots + a_{n-1} + a_n$$

(Fehler vernachlässigbar für Einzel-Ausfallwahrscheinlichkeiten $a_i < 10^{-2}$ und begrenzte Anzahl n)

BEISPIEL FÜR DIE ERMITTLUNG DER GESAMT-AUSFALLWAHRSCHEINLICHKEIT

Angenommenes System



mit a_i, b_i, c_i, d_i, e_i = Einzel-Ausfallwahrscheinlichkeit der Elemente

und $i = 1 \dots n$

Gesamt-Ausfallwahrscheinlichkeit w(f) des Systems

$$w(f) = a_1 + [(b_1 + b_2 + b_3 \cdot b_4 + b_5) \cdot (c_1 + c_2) \cdot (d_1 + d_2 \cdot d_3)] + e_1$$

DAS RISIKO ALS SICHERHEITSKENNGRÖSSE

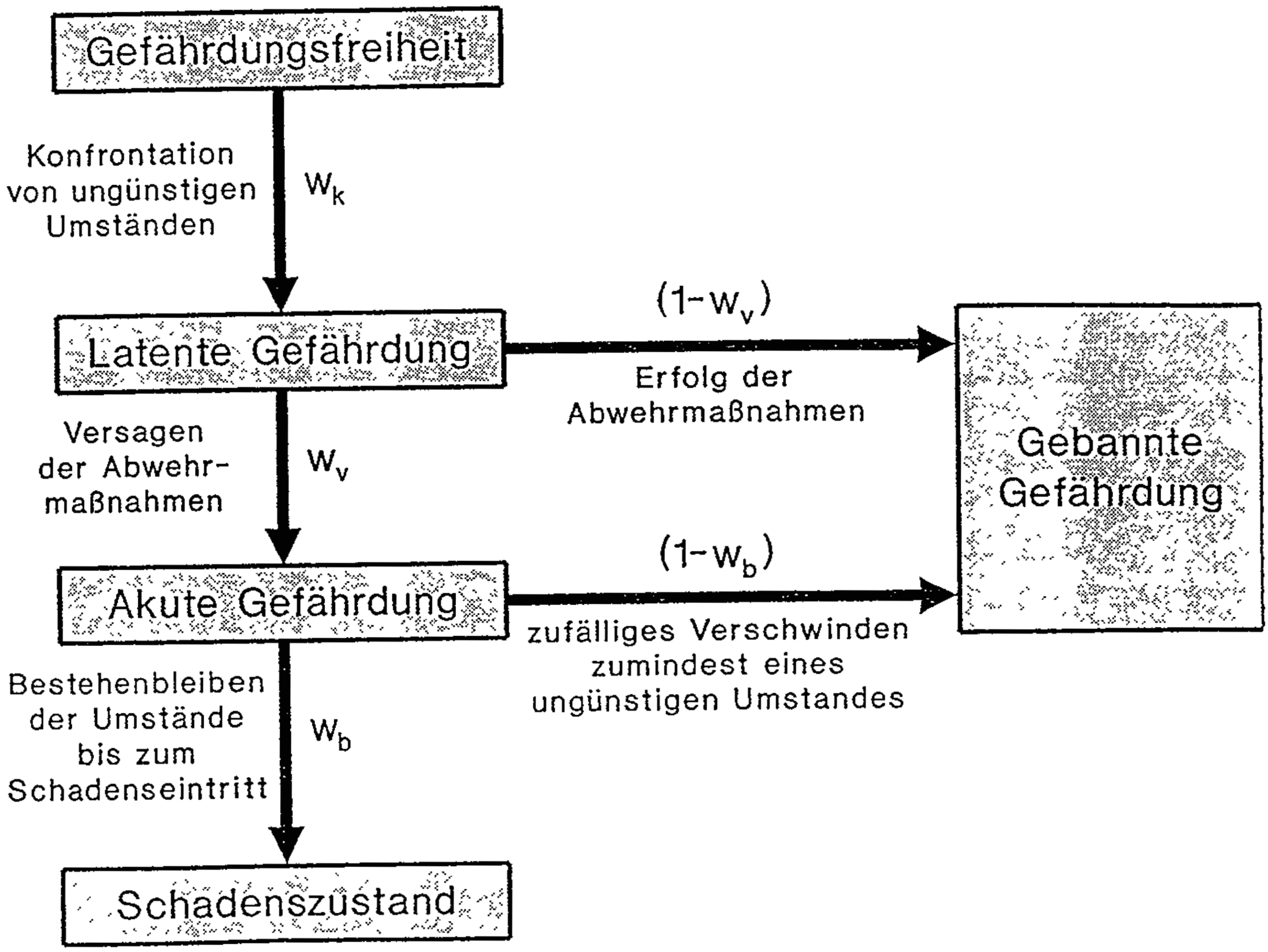
$$R = w_s \cdot S$$

R = Risiko [Dimension: Schadensgröße]

w_s = Wahrscheinlichkeit für das Eintreten des Schadens

S = Schaden [Dimension: Schadensgröße]

MODELL ZUR ERMITTLUNG DER EINTRITTSWAHRSCHEINLICHKEIT DES SCHADENS



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R. K. Taylor

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Scientific Services
British Rail Research
P.O Box 2
London Road, Derby, DE2 8YB
England
Telex 378138 Fax 0332-386720
Tel 0332-42442 ext 3514

SAFETY ON BRITISH RAIL -
RESEARCH INTO THE HUMAN FACTOR

R K TAYLOR

Human Factors Advisor

British Rail Research

International Safety Seminar **1 November 1991**

SAFETY ON BRITISH RAIL - RESEARCH INTO THE HUMAN FACTOR

R K Taylor, British Rail Research

Paper presented at the International Safety Seminar, Latimer House, 1 Nov 91

Introduction

The purpose of this paper is to report progress made with the study addressing the following objective of the 1991 BR Safety Plan:-

> *"To develop a deeper understanding of the mechanics and psychology of human error through the research project being carried out jointly by the British Rail Research Division and the Department of Psychology, Manchester University."*

It is intended to give an outline of the approach adopted, the findings to date, mention some of the benefits coming from the study and indicate future developments.

The study was aimed at developing a better understanding of those factors influencing railway safety in order to assist the formulation of a proactive approach within future strategic safety policies. A common strand runs through independent railway safety management reports and accident inquiry reports indicating that people are the most important factor influencing safety. Consequently this study concentrated on improving understanding of the **human** contribution to the overall safety of BR and the factors affecting it.

Resources

The work was carried out by British Rail Research with the additional support of Professor Reason, who provided his theoretical insight of human reliability and its impact on safety management within complex organisations. The Human Factors Team's experience of applying knowledge of psychology and ergonomics to railway problems and the secondment to the project of a station manager ensured that theoretical understanding was applied to the practicalities of day-to-day railway operation.

Progress

Activity Based Model

A basic model for all BR's activities was proposed(Fig 1) which contains 4 main components Design, Build, Operate and Maintain (DBOM) interconnected within a railway culture all of which is subject to political and economic constraints. An early phase of the research demonstrated the suitability of this DBOM Model to diverse spheres of activity within BR. The model had two uses, as a framework for field work and as a basis for data collection.

Field Work

The purpose of this phase of the work was to observe day-to-day activities as they are carried out in their normal way. The observations are not made in the same way that a safety inspection might be, they are not based on clipboard and pencil visits. A member of the research team joins the work units for sufficient time to become an accepted member of that unit. Under such circumstances the observer is seen merely as a working member of the unit and the work is carried out in the same way as normal.

The field work assignments have concentrated on those involved in track work by joining both permanent way staff and those installing and maintaining signalling equipment. It has provided practical experience of the problems faced by workers, the way they respond and a realisation of the frequency at which problems occur across the total BR network. The way in which these problems are overcome includes what could be described as "unsafe acts" and rule violating behaviour.

A few examples of the type of behaviour witnessed are given in Figure 2. It is insufficient to look at those acts in isolation, it is necessary to look beyond at the underlying causes generating the perceived need for such actions in the minds of those involved. In all the instances listed the actions were not taken out of malevolent intent but in order to achieve the perceived goal and to overcome obstacles which might hinder progress to that end. In short a misguided enthusiasm to get the job done.

The qualities such as a high degree of initiative, resourcefulness and problem solving ability which are essential to keep the railway running are often the same qualities which lead to violations. It is not argued that all unsafe acts, errors and violations on BR have their origins in such well intended motives but it is clear that the majority do.

Data Collection

In order to gather information about the General Failure Processes, the things that go wrong, existing in the DBOM Model a knowledge elicitation technique was used. Subjects, from supervisors to executives, were invited to simply list the ways things go wrong in the design, build, operation and maintenance components of BR's activities. The lists are generated rapidly, the items that most readily spring to mind are those most frequently encountered in their work.

Analysis of the returns revealed a lack of awareness as most widely quoted problem in **design** (Fig 3). The failure to take account of site practicalities, operator needs and maintenance requirements at the design stage featured in 75% of all replies. This category far outweighs problems seen in other areas, failure in management control and specifications being quoted by 45% of the subjects.

The picture is less clearcut for **build** (Fig 4), where the availability and quality of materials (48%) is the most dominant category closely followed by management control, staff factors, design, and planning(each over 35%). Training(58%) is seen as the major problem in the **operate** (Fig 5) phase due to deficiencies in the adequacy, frequency, comprehensiveness and commitment to training. Planning(57%) is seen as the cause for most concern in the **maintain** (Fig 6) phase due to problems caused by budgeting, time constraints and scheduling.

Evidence of the inheritance of problems from failures of design are seen in build(42%), operate(38%) and maintain(32%). The lack of awareness in design is therefore seen as the single feature most influential throughout the DBOM model and of greatest potential for introducing error enforcing conditions to the system.

Properties

Safe organisations possess 3 essential characteristics with respect to safety, namely awareness, commitment and competence. An organisation must possess an **awareness** of the nature and origins of the dangers, it must possess a **commitment** to the pursuit of safety improvement and ensure that it has the **competence** to achieve high safety targets. The possession of each of these corporate properties is essential but the most important is awareness. Although the qualities are difficult to quantify, the extent to which they are present determines the level of safety and ultimately the accident rates.

Currently BR is displaying the commitment from the upper echelons of the of the organisation but the extent to which it transcends through to lower levels is not clear, however the Board's commitment is not recognised as being present by those at the "sharp-end". Deficiencies of competence are being addressed as demonstrated by the strengthening of resources within the safety directorate, the provision of additional resources to support line management and the development of a safety management programme including training modules. Yet the area BR remains most deficient in is awareness. This view has been supported by both field work observations and results of the DBOM study.

A positional paradox (Fig 7) appears to exist in BR where the potential for unsafety, human error and cause of accidents is perceived as being greatest by the workers involved in "sharp-end" activities. The errors are often seen as being a product of the individual involved in an accident and the conditions leading to the error are ignored. In reality it is the error producing conditions which are the most influential in producing the unsafe acts rather than a peculiar personality trait. Greatest control for these conditions lies with the decision makers at the strategic level, it is they who have the greatest potential to introduce latent failures into the system leading to the more widespread problems. The seeds of their errors lie in the system awaiting the chance combination of events or a local trigger before they result in an accident. Even then their contribution to the accident may be overlooked in the subsequent investigation and inquiry, particularly if one of the principal actors in the accident event is seen as guilty of "human error".

It is ironic that even with total commitment and improvements in competence, the efforts will be misdirected unless it is accompanied by a true awareness of the state of the system. Yet a situation remains where most decisions are aimed at improving performance at the sharp-end from a distance without being aware of the situation.

Safety initiatives continue to be launched in a style and form appropriate to the immediate target audience - the senior managers. At best they are then "cascaded" down the organisation with a dilution of commitment and belief to reach those on the ground floor with varying degrees of success (or failure). Similarly changes to rules and instructions are promulgated in the belief that once issued they form the basis of actual behaviour. In reality the work units, such as track gangs, display a great deal of "self-optimisation". Faced with the issue of new procedures there is a tendency to revert to established working practices which the group have found to be successful in getting the job done to the satisfaction of the group.

Development of PRISM

The next phase of the research programme is the development and evaluation of a British Rail specific package for proactive safety management. The package entitled PRISM (Proactive Railway Instruments for Safety Management) is being designed to provide a means of identifying local practical actions to improve safety and to inform those formulating strategic safety management policies. PRISM is being designed for use at all levels of the organisation to reveal its true safety health.

Many of the day-to-day problems encountered on the railway originate in the decision making process at the strategic management level and are brought about by a lack of awareness of the implications of those decisions. The decision making process might be considerd as the first step in the accident causation process (Fig 8), which introduces general failure processes which in turn lead to error enforcing conditions. PRISM will provide strategic managers with a feedback loop to the general failure processes to assist proactive decision making to reduce accidents.

A reader friendly PRISM Handbook will be produced to explain the underlying principles of proactive safety management and the way in which it is being developed specifically for BR. A draft will be sent to diverse parts of the organisation for comment and feedback. At the same time an extended programme of field work will begin to gather the information necessary to generate the indicators for the failure processes. Field trials of the PRISM profiling methods will then take place before revision and completion of the PRISM Handbook.

Benefits

A corporate base of knowledge and understanding of the factors affecting human contribution to railway safety has been established. Promulgation of the knowledge is taking many forms, a presentation by the Research Team forms an integral part of the Strategic Management Course making senior managers more aware of the findings of the field work and of the in-house research being conducted.

The secondee has been promoted back to the operational railway as an Area Safety Adviser to put into practice theoretical understanding gained from involvement in the project. The combination of these actions and the presentation of the work to diverse audiences within the industry is widely promoting the principles and philosophy developed.

Fig 1 THE DBOM MODEL

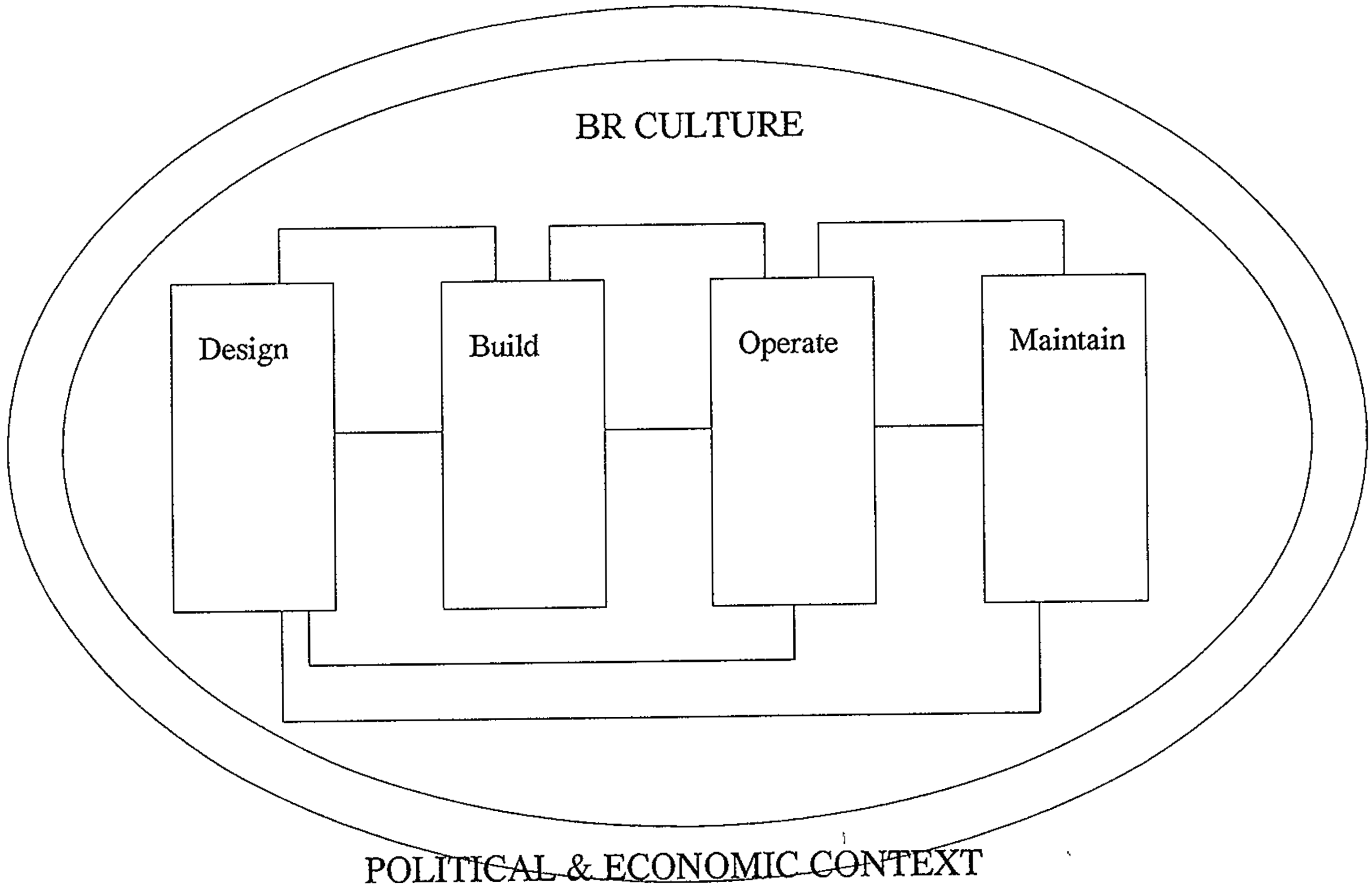


Fig 2 EXAMPLES OF UNSAFE ACTS

Example 1.

An S&T team open up a sealed unit in a location contrary to working instructions. Upon opening unit they find the unit intact although a previous team has strapped across the fuse with a wire.

Example 2.

On a Permanent Way gang the lookoutman is working on the jack. He misses the approach of an HST and the gang is called out by someone else.

Example 3.

Two S&T New Works gang members are standing on a rickety old ladder attempting to drill a supporting post for a set of barrier lights. The posts had been installed the previous day and up to that point had been lying on the ground by the carpark.

Example 4.

A member of a track gang searches around the track for chippings. He leaves the gang and crosses from side to side. Lookout protection had only been provided in one direction.

Example 5.

An S&T New Works gang hold up a barrier lights post with the lights attached partially balanced on a slab of concrete troughing for 3/4 of an hour. An installer strips off the insulation from around the lights cable before threading it through the "elephant's trunk" and wiring up to the lights.

Fig 5 OPERATE
Failure profile for operate

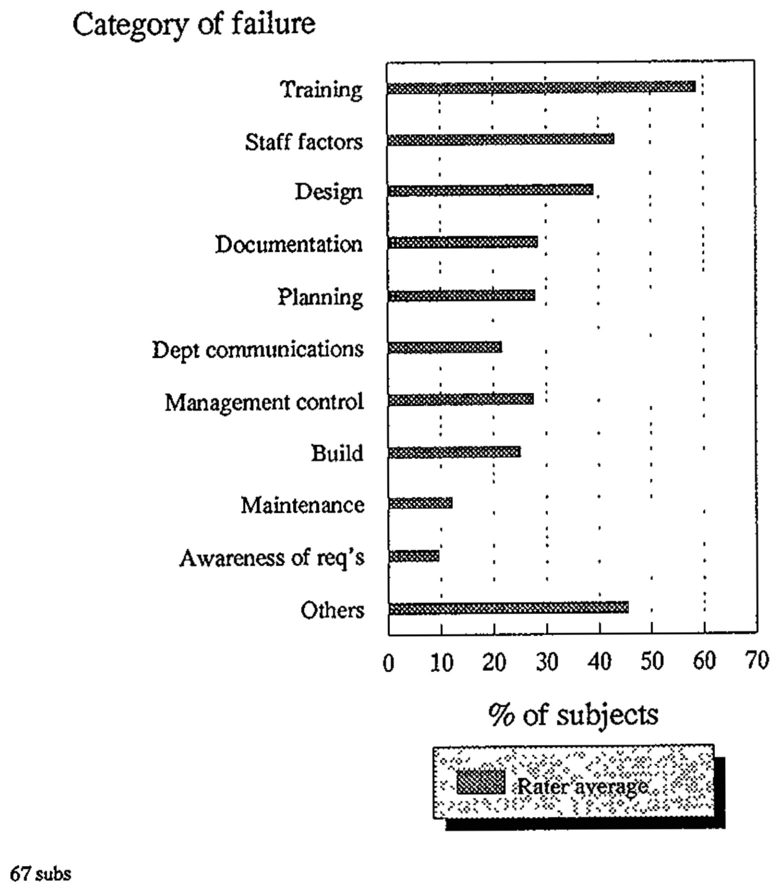


Fig 6 MAINTAIN
Failure profile for maintain

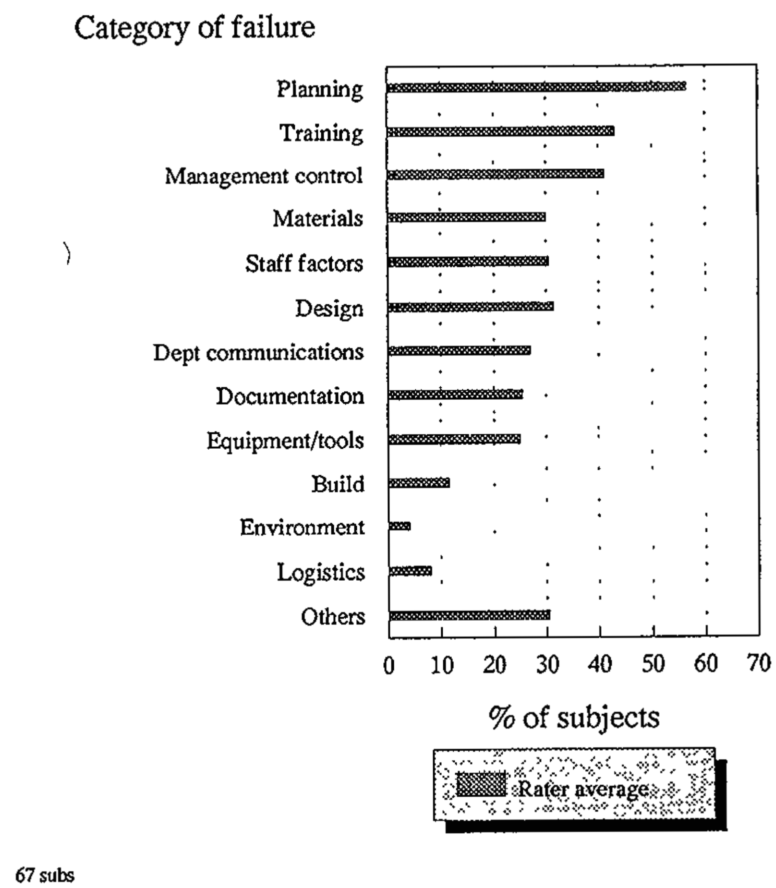


Fig 7 POSITIONAL PARADOX

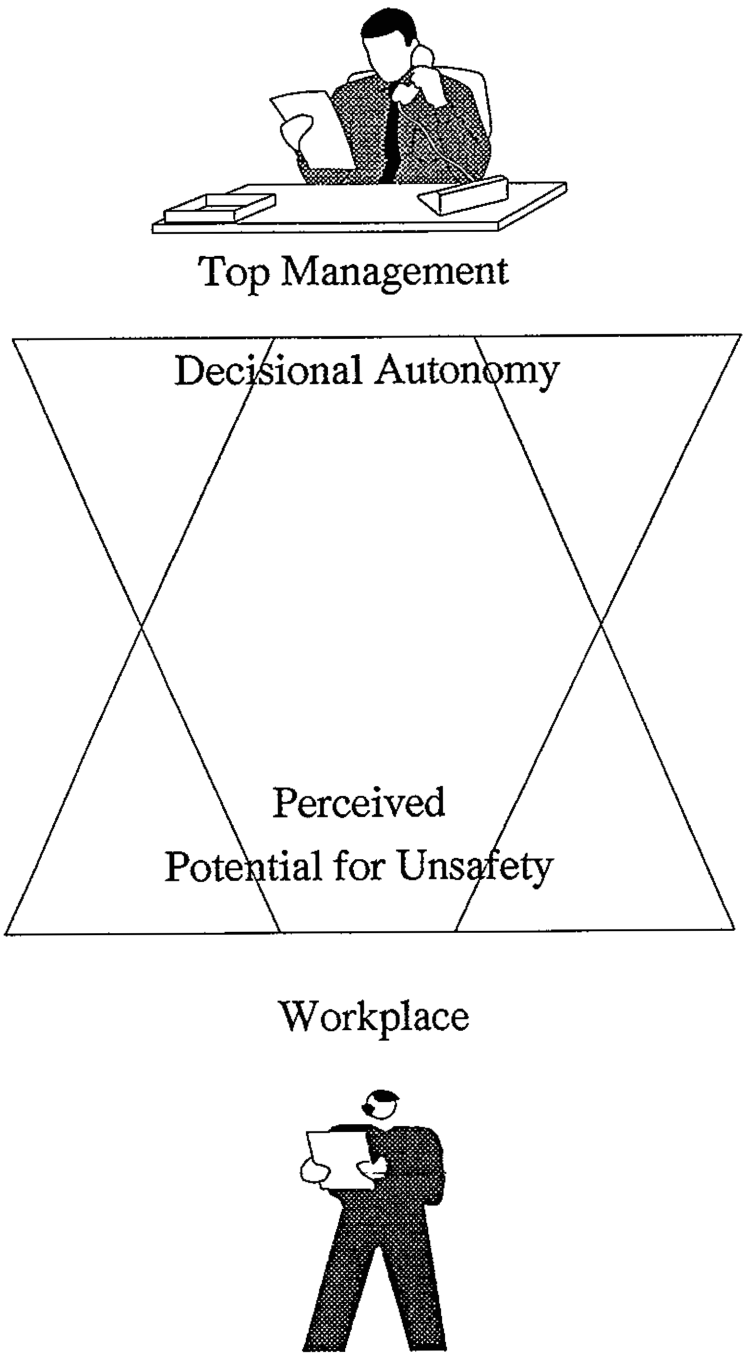
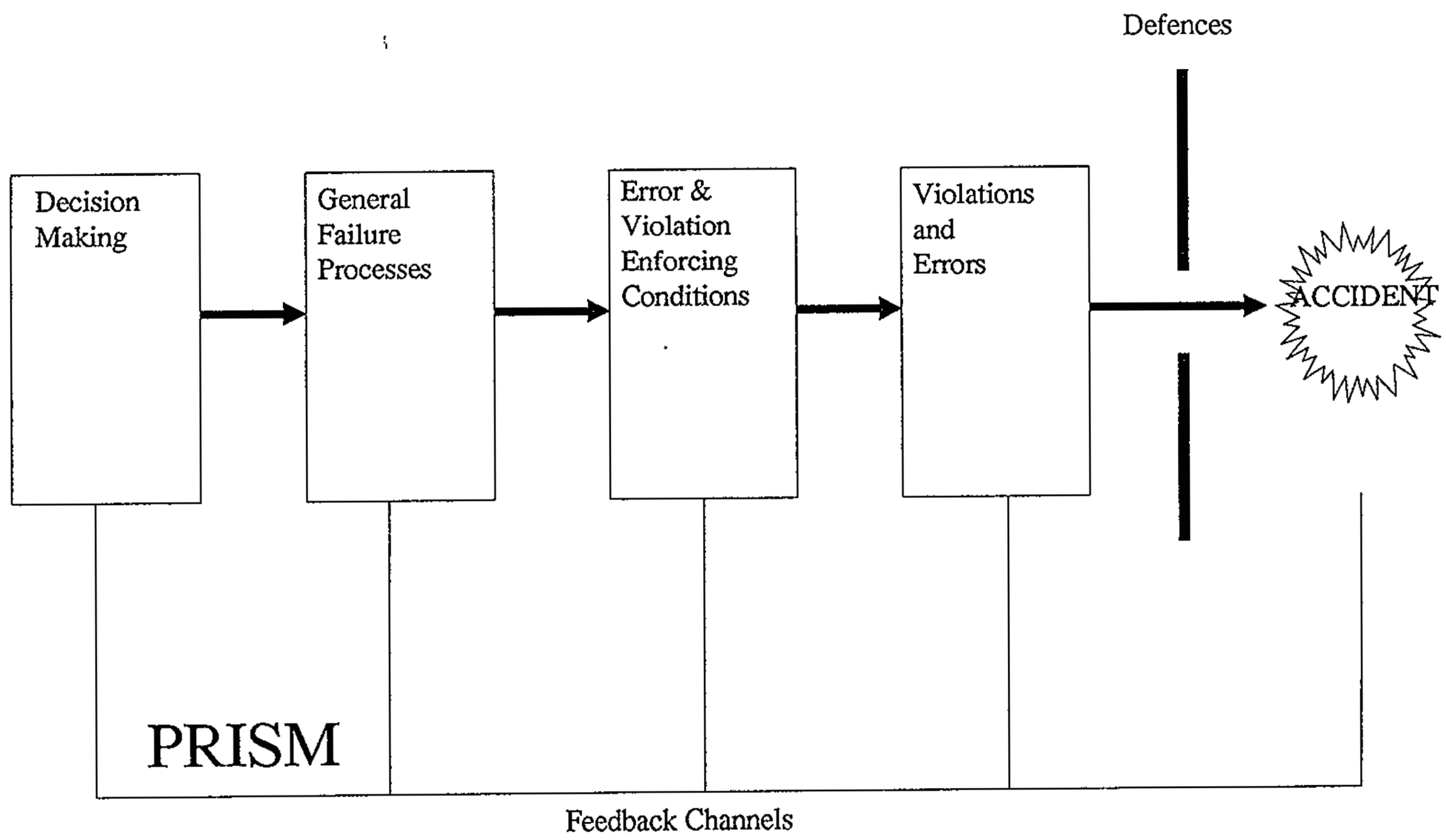


Fig 8 Accident Causation and Feedback Channels



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Michel Joing

Feedback on Hazardous or Dangerous Occurrences

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DELEGATION GENERALE A LA SECURITE

INTERNATIONAL RAILWAY SAFETY SEMINAR

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Paper presented by M. Michel JOING, Head of the Centre for safety studies at SNCF's Headquarters.

DELEGATION GENERALE A LA SECURITE

M. Jean-Louis MEYER

Tél : (1) 42.85.92.10

CENTRE FOR SAFETY STUDIES

M. Michel JOING
Tél : (1) 42.85.63.07

Human Factor Expert

Dr. Francine KERAVEL
Tél : (1) 42.85.63.10

Mechanical and Electrical Engineering Expert

M. Bruno COZZI
Tél : (1) 42.85.84.59

Civil and Signal Engineering Expert

M. Gérard MADELENAT
Tél : (1) 42.85.92.15

Opération Expert

M. François PINTON
Tél : (1) 42.85.83.15

GENERAL INSPECTION

M. René SAVARZEIX
Tél : (1) 42.85.62.20

LA DELEGATION GENERALE A LA SECURITE

The unfortunate series of accidents which occurred in 1988 on SNCF led the representatives of all functions within the company, at various echelons, to review safety matters thoroughly. This work was supplemented by recommendations made by a commission of experts both from French Railways and other industries.

At that time, the overall safety policy was reviewed so that :

- the reliability of the various components in the safety system could be improved,
- a human failure would be made less likely,
- the railway facilities and traction/rolling stock could be developed and protected against their environment.

The review of our safety system gave rise to the setting up, on January 1st 1990, of the Delegation Generale à la Sécurité, as one of the support services at Headquarters' level. This body is not placed along the line of command in charge of developing and implementing the train-operating safety system since this responsibility still rests on the functional engineering departments.

The Head of the Délégation Générale à la Sécurité is accountable to the Chairman of the Board and Director General who call upon his team for advice and guidance as to the overall safety policy of the railway.

The Délégation Générale à la Sécurité is sub-divided into two units :

- the Inspection Générale de Sécurité (Safety Audit),
- the Centre d'Etudes de Sécurité (Centre for safety studies).

The Inspection Générale de Sécurité, set up in 1957, is in charge of noting how train-running requirements are actually met on the railway premises. Following inspections carried out in local railway units (operating, civil and signal engineering, mechanical and electrical engineering), the representatives of the Inspection Générale de Sécurité have to :

- keep advising the area and regional managers as to the actual deviations between the existing situation and the prescribed safety standards,
- advise the top managers of the railways accordingly.

To fulfill these tasks, the Inspection Générale de Sécurité has called upon experts of the relevant disciplines : i.e. operations, civil and signal engineering, mechanical and electrical engineering.

Whilst the Inspection Générale de Sécurité has to identify the deviations between the prescribed safety system (human and technical resources, procedures) and the actual results on the railway premises, the Centre for safety studie's remit is to contribute to the enhancement of the safety system at the design and development stage.

In this respect, **the Centre for safety studies is involved in the feed-back process whereby incidents or failures are subsequently analysed to prevent their occurrence.** Some of these actions are undertaken within the commission centrale de sécurité (central safety commission) a multi-disciplinary body for which the Centre provides organisation and secretarial services.

The Centre for safety studies is also in charge of the statistical risk-analysis or studies on reliability, availability, maintenability and safety.

These studies do not infringe on the respective fields of competence of the functional departments. Made up of people from different backgrounds, the Centre takes a different approach, i.e. encompasses the whole railway-safety system and identifies areas for potential progress. A stronger emphasis is placed on the human factor and human studies have a greater input. Finally, the Centre for safety studies keeps other safety systems, either railway-related or otherwise, under constant review in order to draw lessons from comparisons made between various systems.

The members of the Centre for safety studies come from every railway-function :

- mechanical and electrical engineering,
- fixed installations,
- operations (stations and depots),
- human factor - occupational medecine and ergonomics.

Considering the themes selected for this seminar, we have decided to expand upon two major areas in which the Centre for safety studies is involved :

- feed-back and the use of a data-base for the recording of critical events within the railway system,

- risk-analysis illustrated by an example of a study conducted to enhance the safety-level with an automatic train protection system.

THE FEEDBACK ON HAZARDOUS OR DANGEROUS OCCURRENCES

As part of its supervising task over the whole railway system, the Centre for Safety Studies has developed a database related to significant accidents and failures occurred on main lines. This database is characterized by its system-wide extension, all the failures or errors being recorded for any critical occurrence (human, technical, organizational and regulatory failures/errors). A special emphasis has been placed on the integration of human factors.

The database development task is facilitated by the multi-disciplinary character of the centre.

THE HAZARDOUS AND DANGEROUS OCCURRENCES

As a support service to the general management, the centre aims at tackling events under their multi-functional aspects. The database supplements the existing tracking and tracing systems developed individually by each functional Department and Region.

For efficiency purposes, the data volume to be captured is now wittingly restricted to a statistically-representative sample of hazardous or dangerous occurrences. The comprehensive data feedback for a specific field is still incumbent on the relevant functional Departments.

The hazardous or dangerous occurrences under record for train operations are those having major repercussions on the safety of people, ie accidents or failures affecting main lines, either directly or indirectly.

RISK ANALYSIS IN THE RAIL MODE

The most frequently-used overall indicator of any state of danger or risk is the product of EXTENT OF DAMAGE OR CASUALTIES x DEGREE OF PROBABILITY for any hazardous or dangerous occurrence within a chain or combination of events.

No hourly rate of probability of occurrence for any hazardous event is available today. Inductive risk analyses such as the one carried out in 1990 about the probabilities for a train to pass a signal at danger, will give new insights into the field of probabilities. Along this path, and without pre-empting the results from the manifold investigations in progress in the industrial and nuclear fields for the development of classification scales related to the extent of damage/casualties and the nature of hazards and dangers, as well as the relief equipment to be used, the Centre for Safety Studies has developed, as an early approach :

- a classification scale related to the extent of damage and casualties,

- an approximated risk assessment scale

The scale related to the extent of damage and casualties is a reflection of the human and material consequences resulting from a hazardous or dangerous event affecting the safety of train operations. This scale includes the following seven degrees:

Serious accident with fatal injuries	among passengers	6
	among train crews	5
Serious accident with injuries suffered by passengers or train crews	severes injuries	4
	light injuries	3
Accident only involving damage to property	major (> 1 MF)	2
	minor	1
Failures or near-failures		0

An approximated risk scale has been developed by amalgamating :

- the actual consequences in the event of a serious accident (levels 2 to 6 on the above scale),
- the absence or existence of protective safety loops in order to minimize the consequences of accidents or to prevent their occurrence. The risk scale presently includes three degrees.

The indicators of the first type already give an objective base to classify and evaluate the trends on railway accidents and failures.

THE ANALYSIS OF THE HUMAN FACTOR

The basic function of the Centre for Safety Studies is to go beyond the mere acquisition of data identifying the nature of the event and the severity of its consequences and to get an insight into the multifunctional and multidisciplinary aspects of the safety systems and procedures. The deep causes can therefore be analyzed and, in particular, thoses related to human behaviour.

The quality improvement of the human environment of the railway system should be based on the real diagnostic of the causes and processes leading to errors. From the data collected by regions and on tne basis of the psychological profile of the expected physical performance, the human factor analysis enables to record :

- the type of failure,
- the failure stage,
- the origins of the failure.

Depending on the expected effects of any action, the failure may be due to :

- an omitted action,
- an inappropriate action,
- an early or belated action compared to the prescribed response time.

The failure is then studied from the angle of the psycho-physiological aspects affecting the treatment of data for the various stages: detection, interpretation, decision-making process and action or response.

The origins of the failure may result either from the behaviour of the operator himself, or from his immediate environment , or from both (quality of the man/machine interface). Such causes are codified according to a classification adjusted to the railway requirements.

The current analyses of human factors based on the major performance or skill categories, already show a number of trends which should be substantiated statistically and refined, so that prevention schemes may be set up.

When observed in her work environment or her everyday life, it is easy to understand that any person responds to the stimuli of manifold space and time data specific to the system in which that person is placed. Such stimuli are perceived via physiological functions and are acted out with more or less thought or awareness. If the data causing brainwork or the results from her action can be easily identified or recorded, it is far more difficult to analyse the thought processes preceding action.

The investigation into the thought processes will shed new light on the many features related to personality, knowledge, know-how, culture, etc...

New indicators are being developed to evaluate the performance level of an operator carrying out a given task and we should know more about :

- the thought processes called up by an operator before acting out,

- the impact of some environmental factors in order to identify a better level of adequacy between indivivuals and the safety posts they hold.

Each of the failures detected is analyzed in order to determine whether the data treatment for the operator to act out requires :

- skill and routine aspects,

- rules and diagnostics,

- knowledge.

In this way, it will be easier to :

- identify anomalies in the data treatment,

- specify the difficulties experienced by operators,

- improve the overall safety performance.

THE DATA COLLECTION

The knowledge about events is based on :

- the analysis of daily train running reports,
- the data generated by the safety inspection by the French Railway Directorate,
- the link-up with the data inputted into the existing database from functional departments.

From the selection of critical events in train operations, the Centre for Safety Studies requests from the relevant regional manager the provision of an accident report including multifunctional data from regions. This report is subsequently analysed and computerized by the experts of the Centre for Safety Studies.

THE TRACKING AND TRACING SYSTEMS

All the variable data, whether coded or uncoded are stored into a micro-computer for statistical purposes. The goals to be attained are the following :

- identification of the improvement areas, enrichment of the thoughts from the Central Committee on Safety and guidance for the development of a general safety policy.

- feeding of internal studies related to accident cases, selection of investments, the assessment of the human factor performance (pschological, physiological and behavioural aspects).

- provision of official statistics for internal or external use (in particular of the French Ministry Department of Transport).

STUDY INTO THE OPERATING SAFETY OF THE BEACON-BASED INTERMITTENT AUTOMATIC TRAIN PROTECTION SYSTEM

In the second part of this paper, the intention is to illustrate the various stages and main conclusions of an operating safety study conducted into the benefits of an intermittent automatic train protection system and to highlight the technical and economic criteria to be taken into account in any investment decision.

It is important first of all to understand the issues at stake and the problems that resulted in the decision to install a speed control system on board trains.

Statistics show that the number of times per year stop signals are overrun on the SNCF has remained more or less constant over the past 15 years, despite a slight upwards tendency over the last 3 years. The average figure for the last four years is 145. And it is unlikely that this average will drop of its own accord.

Over the last 15 years, however, the proportion of serious accidents (with fatals consequences) in which a train passed a stop signal has been 19%. The number of occasions on which signals are overrun is high but, fortunately, the likelihood of a serious accident occurring as a result is in the region of 10^{-3}. The particular point protected by the signal is fouled in 36% of all instances of signal overrun, which counts practically as an accident in itself. The margin between passing a stop signal, even when the crucial point is fouled, and occurrence of a serious accident is still fairly large: approximately 3.5 serious accidents per thousand instances of signal overrun with fouling of the point protected by the signal. Passing a stop signal is never a minor occurrence despite what these figures may seem to suggest. For the margin between incident and accident is contingent upon a number of poorly identified, little understood factors that may suddenly alter for no apparent reason, triggering a further spate of accidents.

Action was therefore required to improve the situation: whence the decision to install an intermittent automatic train protection system.

Following this statistical data we shall now move on to address a series of different aspects:

- assessment of the best possible intermittent automatic train protection system for three different line and vehicle equipment scenarios.
- the impact of speed control failures on signal overrun.
- economic aspects as a guide to investment choice for intermittent automatic train protection systems.

EFFICIENCY OF AN INTERMITTENT AUTOMATIC TRAIN PROTECTION SYSTEM

Assessment of intermittent automatic train protection system efficiency was based on a statistical analysis of the 1987 and 1989 figures for stop signal overrun, for three different scenarios regarding the number of signals and vehicles fitted with the system :

. Scenario A - 2,300 signals and 3,600 motive power units

. Scenario B - 3,800 signals and 3,600 motive power units

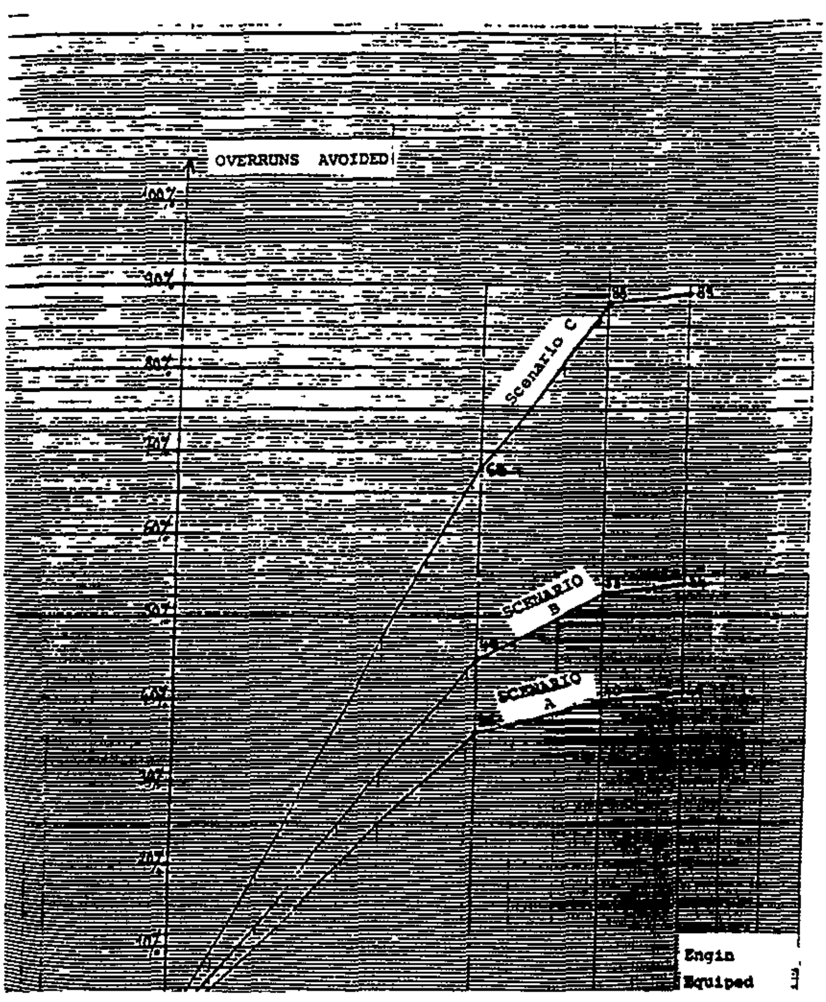
. Scenario C - All signals and 5,000 motive power units.

Scenario B corresponds to 1994 (investment already approved) and should reduce the number of cases in which trains pass a stop signal by 45%.

Scenario C involves equipping all signals and motive power units (other than shunting locomotives) with the system and should prevent 88% of such incidents. Of the 12% remaining, 7.3% would have less serious consequences because of the presence of an intermittent automatic train protection system, 2.8% would be ascribable to the fact full network coverage (lines and vehicles) is still not guaranteed even with this maximum working hypothesis and 2.26% would be residual brake or adhesion-related overruns.

The criteria adopted for investment scheduling seem therefore appropriate. The marginal benefits of each extra signal or vehicle fitted decrease in reverse proportion to system expansion:

EFFICIENCY WITH ATP FULLY FONCTIONING



IMPACT OF INTERMITTENT AUTOMATIC TRAIN PROTECTION FAILURES ON SIGNAL OVERRUN

This stage is to ascertain the loss of efficiency ascribable to intermittent automatic train protection system or brake malfunction. The study relates to a probabilistic model.

For the mathematical model proposed for purposes of calculating the probability of a train passing a signal at danger and the loss of efficiency due to intermittent automatic train protection or brake malfunction, it is necessary to be in possession of data concerning :

- driver failure probability,
- intermittent automatic train protection system reliability and availability
- brake failure probability.

Driver failure probability was evaluated in two different ways.

The first consisted in working out the mean number of signals passed at danger per hour of driving time.

The second involved ascertaining driver failure in relation to the total number of stop signals encountered. This corresponds to the probability of a driver approaching a signal at stop with the usual advance warning and still passing the signal, even though his brakes are working normally.

The probability of driver failure is in the region of 2.10^{-5} per stopping sequence. It is close to the best that may be expected for such a large category of personnel. There is therefore scant hope of being able to make any considerable improvements in this rate through training and practice.

Before the **reliability of the intermittent automatic train protection system** was investigated, an Analysis of Failure Modes, their Effects and Criticality (AMDEC) was conducted. Calculations were essentially based on data taken from a study carried out by the system's manufacturer. Mean repair times for calculating availability were taken from statistics relating to the repair times for similar types of equipment: automatic block failures, for the "ground" equipment, and sample repair times for drivers' safety devices (VACMA), for the train-bound equipment.

For a stopping sequence the unavailability rate for the ground-based part of the intermittent automatic train protection system is $1.7 \cdot 10^{-4}$. This is largely due to the encoders and to certain connectors. The unavailability rate for the on-board equipment varies between $38.7 \cdot 10^{-4}$ and $10.3 \cdot 10^{-4}$ depending on the policy in force in respect of withdrawal of faulty equipment. At 10^{-4} errors in the coding of train characteristics are negligible. It should, however, be noted that this value can only be obtained with well-trained and, more especially, highly motivated staff. In all, for a stopping sequence, unavailability of the intermittent automatic train protection system ranges between $12 \cdot 10^{-4}$ and $40.4 \cdot 10^{-4}$. The train-mounted equipment is the principal culprit.

The intermittent automatic train protection system reduces the probability of a stop signal being passed by between 33 and 147%, if the brake has an unavailability rate of $5 \cdot 10^{-7}$ per braking sequence. Lastly, the intermittent automatic train protection system reduces the number of stop signal overruns by 99.6% if the brake is in perfect order and if all signals and motive power units are suitably equipped. The figure drops to 97% if the brake is in less than perfect condition. Braking reduces efficiency by 0.56 to 2.6%, whatever the working hypothesis. These values are very similar to those obtained from statistical analysis, which adds credence to the notion that a failure rate of $5 \cdot 10^{-7}$ for braking is a reasonable supposition.

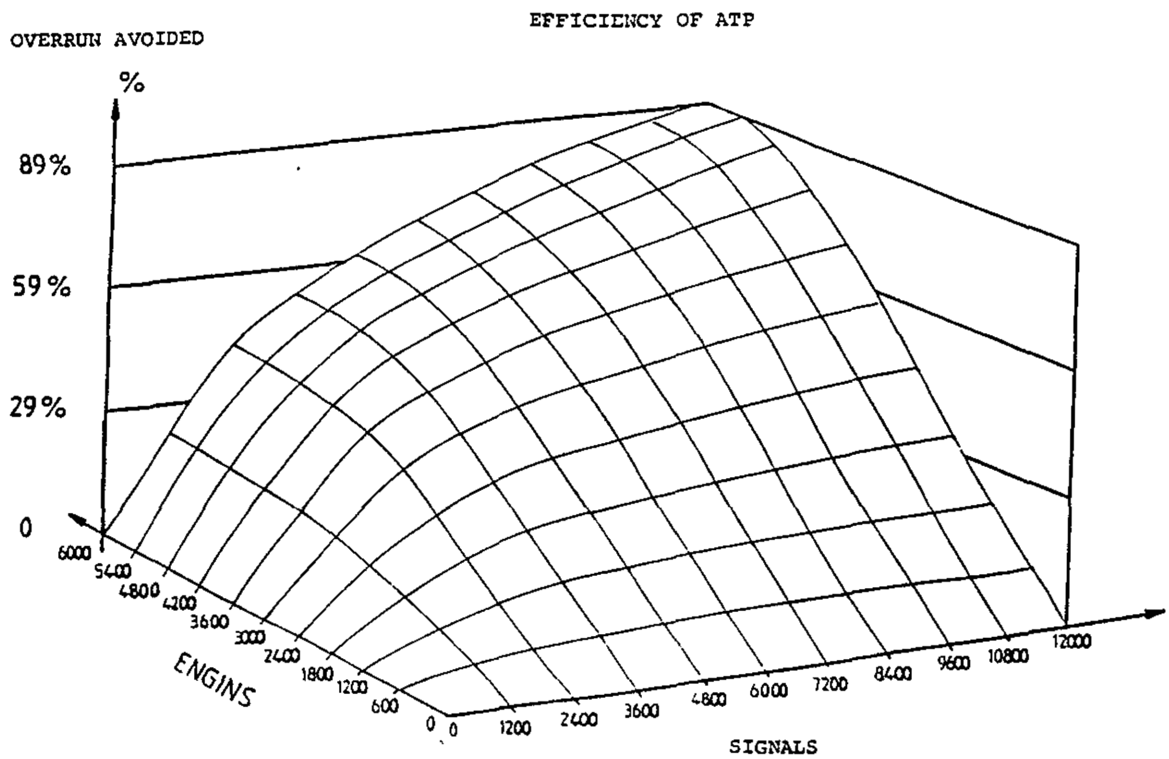
ECONOMIC ASPECTS

An analysis was made of the potential effectiveness of additional investment in relation to the number of signals and vehicles already selected to be fitted with an intermittent automatic train protection system.

The principle consists in starting from the investment levels already decided and estimating the marginal benefits to be derived from the amounts invested in signal and vehicle equipment expressed as a percentage of signal overruns prevented per unit of investment.

Two methods were adopted for calculating the marginal benefits: a graphic method and a technique based on modelling.

The graphic method consists in taking a continuously sloping line representing the signals and a discontinuous sloping line for the tangents of the graph representing the equipment mounted on the motive power units, to allow for the different vehicle series.



For the technique based on modelling, the shape of the surface obtained from approximation by means of "Spline" functions for the 10 known values of efficiency suggests an analytical form of this surface via a model with constant elasticity.

The conclusion drawn from these two approaches is that at this stage of investment, it is economically more worthwhile to continue fitting intermittent automatic train protection devices on signals only, until reaching approximately the 10,000 mark.

CONCLUSION

The probability of a stop signal being passed moves from $1.9 \cdot 10^{-5}$ without an intermittent automatic train protection system to $5.45 \cdot 10^{-7}$ with an intermittent automatic train protection system, putting the probability of a serious accident in the $5.45 \cdot 10^{-10}$ range for each signal at danger approached by a train fitted with the intermittent automatic train protection system. This is a satisfactory accident probability rate.

Throughout the study, it was assumed that the intermittent automatic train protection system had no effect on driver behaviour.

To come as close to this objective as possible, it is recommended that the information displayed in the driver's cab be kept to the strict minimum and that the system of intermittent signal repetition be maintained, to ensure maximum consistency in driver behaviour in all cases, with or without the intermittent automatic train protection system.

Efforts should also be made to prevent any loss of motivation among drivers as regards the problem of overrunning signals at stop. This will be particularly important in view of the long period in which there will be a mixture of signals with and signals without the intermittent automatic train protection system.

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Jean-Pierre Macaire

Selection and Monitoring of Safety Staff Aptitudes and Human Reliability

Jean-Pierre MACAIRE
Head of psychology Departement
of the S.N.C.F.
45 rue de Londres
75379 Paris
Tel : (1) 42 85 60 31

SELECTION AND MONITORING OF SAFETY STAFF APTITUDES AND HUMAN RELIABILITY

Paper for the International Seminar on Railway Safety at Chalfont & Latimer (Great Britain) on 31 October and 1 November 1991.

Human factors and errors in railway safety.

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SELECTION AND MONITORING OF SAFETY STAFF APTITUDES AND HUMAN RELIABILITY

Selection of safety staff has been one of the main concerns of French Railways for more than six decades.

Psychotechnical selection methods used since the psychology laboratory was founded by J-M Lahy (1) in 1931 have been the subject of numerous publications, in particular in the field of job validation.

In 1991 developments in railway technology also brought about profound changes in safety systems. **Despite higher human performance levels** and the introduction of automated control systems, **man has remained an essential link in these systems.**

Consequently, it can well be understood that for the S.N.C.F., selection of staff for jobs in the field of safety has remained a priority task because the majority of job recruitments is aimed at positions in these fields (more than 3 000 out of a total of 4 000 in 1991).

The Psychology Department is contributing to job recruitment activities as part of efforts to improve railway safety. It is involved at two levels:

- staff selection,
- permanent monitoring of the aptitudes of safety staff employed.

Staff selection and even more so the process of monitoring aptitudes is made up of several stages:

- Analysis of job requirements and changes in these jobs,
- Identification of selection criteria,
- Preparation of selection methods.

Monitoring of safety staff aptitudes over the course of time has remained a task for management and the medical corps in close collaboration with the Psychology Department. **Its very existence and the quality of this monitoring process are essential pre-requisites for maintaining the reliability of our safety system.**

(1) J-M Lahy: 1872 - 1943
Precursor of occupational pyschology in France.
Director of the Laboratory of Applied Psychology at the Ecole des Hautes Etudes until 1942.

1 - ANALYSIS OF JOB REQUIREMENTS.

This stage of analysis of job requirements (or human factors) and of job positions is a fundamental and inevitable phase in the staff selection process. However, it must be updated frequently because jobs and work change in the course of time. For this reason, the Psychology Department keeps an open ear to technical departments and other rail locations (through its consultant psychologists) to identify changes and adapt examination techniques accordingly.

Studies of safety-relevant jobs are recent (two or three years for the oldest). However, train drivers' jobs and jobs on installations and equipment are currently being studied in depth.

Knowledge about jobs and work is a prior stage in the process for each psychologist, because they must subsequently convert requirement criteria into aptitude or selection criteria.

2 - SAFETY STAFF SELECTION CRITERIA.

Safety tasks involve two aspects:

- **understanding of work sequences** and the constraints involved,
- **personal restraints** in connection with the requirements arising from these constraints.

Consequently, the criteria taken into account are those which make it possible **to carry out these tasks with all of the reliability required:**

2.1 - On the intellectual, psychomotor, and motor planes, which are fields of knowledge and know-how:

- **flexibility in perception and processing of information,**
- **the quality of reactions,**
- **the quality of memorisation,** both short-term and long-term,
- **ability to withstand intellectual and mental fatigue** in particular:
    - ability to withstand monotony (maintain attention),
    - ability to cope with stress and mental burdens (in terms of volumes of information to process and time available to process it).
- **the individual pace of adaptation and change** in particular for:
    - complex and varied activities occurring frequently,
    - complex activities occurring rarely.

2.2 - On the behavioural plane, a field of the state of being:

- **adaptability to new situations,**
- **emotional control** in the face of disruptions, inhabitual or unknown situations,
- **the ability to comply with strict instructions,**
- **the ability to view events from a distance** and for self-re-assessment.

3 - PSYCHOLOGICAL EXAMINATION TECHNIQUES.

Psychological aptitudes compatible with these requirements are evaluated on the basis of job requirement criteria or degrees of involvement of human factors, by means of tests and interviews.

Hence it can be seen **that changes in jobs must be accompanied by permanent changes** in examination techniques in order to take account of all the transformations under way (or foreseeable ones):
- in the man-machine team,
- in the organisational, professional and technological environment,
- in the sociological environment of employees or recruitment candidates.

An initial overall approach has shown that **the psychological level of job requirements have increased** on a cognitive (mental burden) and behavioural (acceptance of constraints, etc.) plane, **whereas physical job requirements have diminished.**

Changes in examination techniques and selection methods have made it possible to introduce improvements and achieve more reliable and more valid results in the course of the last decades. The S.N.C.F. Psychology Department has in fact never abandoned **the method of tests; on the contrary, it has developed use of tests in greater depth, and improved upon and and enhanced them.**

Considerable progress has been made on two levels since 1980 **when tests began to be computerised:**

- the quality of selection methods:

- the greater amount of information supplied,
- better conditions for undergoing tests (better standardisation, allowance for the individual pace of doing tests, test learning pedagogy),
- greater availability on the part of the psychotechnician to observe behaviour,
- better social acceptance of these new tests by young generations and also, despite initial fears, by the less young (very good apparent validity of tests in respect of the current job environment),
- higher reliability as a result of these improvements,
- immediate availability and better presentation of test results for psychologists,
- more frequent up-dating of yardsticks.

- lower costs for the company:

- time saved in correcting tests,
- lower test equipment investment and maintenance costs,
- time saved in carrying out studies (new tests,yardsticks...)

In addition, computerisation has made it possible to create new more efficient tests used in particular for selection of safety staff. Indeed, it ensures **far superior validity and reliability** of results by comparison with conventional tests because of the quantity of information which can be processed. Today it can be said **that computer-based psychometry** has become **clinical psychometry** and has revolutionised the conventional approach to evaluation of safety staff.

4 - SELECTION OF SAFETY STAFF IN 1991.

The psychological examination for this selection process is multi-faceted and consists of:

- the test method,
- observation of behaviour during tests,
- clinical interview with the job candidate.

The synthesis of this examination is made by a qualified psychologist who has been trained in knowledge about the jobs concerned, is familiar with the Psychology Department *techniques and is responsible for relations with managers in the field.*

4.1 - The test method:

The system of computer-based tests carried out by the S.N.C.F. Psychology Department is made up of:

- The factorial series of aptitude tests (BFTA).

It is designed to identify a profile of **intellectual aptitudes** by means of eight factors. Computerised technology makes it possible to gain a better idea not only of **how information is processed, the personal pace of the candidate, intellectual fatigability,** but also of rigour, the manner of resolving a problem, steps in approximate analyses, types of errors, hesitations and "regrets", which **are important indicators of behavioural reliability.**

- The elementary reaction test (TREL).

The candidate is subjected to a stressful flow of stimuli in this test. The test yields essential information, not merely about **the quality of reactions**, but also about **behaviour:** power of concentration, flexibility to adapt to situations, self-control, changes in behaviour in tense situations.

- The computer-based turner test (TTI).
It provides the same wealth of information as J-M Lahy's mechanical turner for which validation studies have shown the excellent degree to which it predicts job success. The latter two are more reliable and have replaced former tests such as the diffused attention *and checking tests*

- The performance monitoring attention test (ASP).
This type of situational and behavioural test was designed with the dual objective of:

- **Measuring the ability to remain alert**: the candidate is placed in a situation where he is heavily solicited by associations of complex and repetitive stimuli, the pace of which differs in the course of the test.
- **Measuring the ability to react to stressful situations**: the candidate is confronted with a series of events for which he is not prepared.

- An active safety test (ESA).
This is mainly designed for station safety staff. It is a *situational test which requires* candidates to perform tasks not calling for specific job know-how, but in which their future adaptation to the job can be judged (organisational ability, specific intelligence, mnemonic ability, ability to analyse and synthesise, etc.).

- A personality test.

In addition, there are other computer-based tests: **memory test, questionnaire concerning tastes and job interests.**

Furthermore, the series of computer-based tests is supplemented by the non-computerised MKP (Mira y Lopez Miokynetic Psychodiagnosis). This psychomotor test reveals certain psycho-neurotic traits in candidates (anxiety, emotivity, etc.).

4.2 - Behavioural observation:

This is done during tests and it too provides **an important source of information about a candidate's personality.**
The method consists of the psychotechnician **describing** as precisely as possible what the candidate does when he is carrying out a given task, **noting** as objectively as possible the external manifestations of the action performed in order to achieve the objective set.

4.3 - The clinical recruitment interview:

The analysis, synthesis and cohesiveness of the results of all of these tests are established by an experienced psychologist who is well versed in railway jobs and keeps permanently in touch with the field. In the course of the interview with the candidate, the psychologist validates his various assumptions, in particular in the field of motivations and acceptance of constraints, **then draws conclusions and prepares advice for the decision-makers responsible for human resource management.**
The general label "aptitude for a safety job" is given only after analysis and synthesis of all the results of the psychological examination. **The psychologist must durably succeed in establishing the man-job equation.**

Major advances made in recent years have made it possible to raise the overall level of our selection techniques to a high performance level **with in particular, the integration of the computer-based test system in our computer-based management system.**

4.4 - The results of psychological examinations for recruitment selection:

Out of **5 211 psychological examinations** in 1991 from January to September for candidates for safety jobs (train drivers, track maintenance gangs, traffic control staff, etc.):
29.8% of candidates received a **favourable assessment** for recruitment (good applicants),
23.3% of candidates received a **favourable assessment with reservations** for recruitment (moderate quality applicants),
46.9% of candidates received an **unfavourable assessment** for recruitment (ill-adapted applicants).

5 - PERMANENT MONITORING OF HUMAN RELIABILITY.

When a psychologist makes a favourable evaluation of a candidate for a safety job, this does not necessarily mean that the there are no risks in the prognosis for success in the short term future. **Pedagogical conditions for training, practice in the job, which lead to acquisition of skills and qualification, as well as job monitoring, are also decisive factors in safety staff job success and reliability.**

Moreover, the favourable prognosis itself **may change with time under the effect of the sociological, working and technological environment, and also through ageing of aptitudes and attitudes.**

A person who is "highly reliable" at 20 years of age may prove to be "a person who is a potential risk" fifteen years later.
The three stages of human reliability:

- **selection,**
- **training,**
- **qualification,**

which yield a reliable safety employee are unfortunately not stable over time, **hence the importance of periodical re-evaluation of the person in his job environment. This re-evaluation contributes to maintaining human reliability and prevents the emergence of risks for the company.**

At present, selection and monitoring of staff assigned to safety jobs are carried out on S.N.C.F.:

- **before the job** is held with regard to physical, physiological and psychological abilities,
- **annually by the medical officer** with regard to physical and physiological abilities alone,
- ***at the request of management, training managers and the medical corps*** as part of the permanent monitoring of aptitudes.

At present the S.N.C.F. *does not carry* out a periodical check of psychological aptitudes as many railways do every three or five years. It is more a question of a psychological and social situation in the company than an affirmed policy. It is certain that a periodical psychological examination for safety jobs can help to exercise better control over human reliability. However, it must not be confined to a simple curative check or considered as an alibi or a punishment. Nor should it relieve management of responsibility by shifting responsibility for reliability solely to psychologists.

For the moment the S.N.C.F. **has opted for monitoring of the behaviour of all safety staff** as part of the process of introducing participative management.
Management is in the best position to carry out this monitoring work (lifestyle, motivation, rigour in performing tasks, etc.) in liaison with the medical officer. However, if there is any doubt, it can always obtain assistance and advice from the Psychology Department.

The practice of monitoring of behaviour in respect of safety is designed to foster changes in mentalities and attitudes. **The permanent, concerted and cohesive action of the various agents involved** (management, training officers, medical officers, psychologists) **must ensure that we maintain the reliability of our safety system and incorporate human factors.**

The request for an examination to confirm aptitudes is left to the initiative of management or the medical corps, but should be preceded by **an individual interview between the employee and the person requesting the examination.** *In practice,* it is arranged most often after incident involving safety or in the event of behaviour considered to be alarming.

I shall now describe this examination in detail.

6 - EXAMINATION TO CONFIRM APTITUDES.

6.1 - Contents

The methods used in this examination are based on the same principles as those used for selection of staff for recruitment, but are more complex because **in this instance, the medical dimension supplements the psychological approach.**

This examination consists of:

- **clinical interviews** carried out by a psychologist and a psychiatrist. They focus on following the personal development of the employee and establishing a psychiatric diagnosis.

- **psychomeric tests**, the choice of which is closely linked to the problems posed or supposed. **They explore the cognitive and psychomotive capacities, and personality traits.** Some tests are **particularly sensitive to alcoholism** or to deteriorations or illnesses affecting the central nervous system.

The psychiatrist and psychologist compare the result obtained from this examination with those from previous examinations **to note any deterioration in aptitudes.** Then they contact management to advise it if necessary about what is needed to return the person to his job **and contribute to resumption of reliable behaviour on the part of the person concerned.**

In addition, for each examination to confirm aptitudes, they receive the following:

- **job information provided by management,**
- **medical information sent by the medical officer.**

6.2 - Results.

The Psychology Department carried out **420 examinations for confirm aptitudes** from January to September 1991.
The outcome led to **four types of recommendations** for safety staff:

- **staff maintained in the job without any specific restrictions: 28.9%**
- **staff maintained in the job with specific restrictions: 43.5%**
- **temporary withdrawal from the job: 18.8%**
- **definitive withdrawal from the job: 8.8%.**

In these examinations, the advice given by psychiatrists and psychologists has a considerable pedagogic effect. **Monitoring of these cases not only ensures prevention of risks for the company, but it also preserves the chances of re-integrating the operator in his job** or eases his re-deployment when this is the case.

6.3 - Analysis of human errors.

Most of the examinations requested by management or by the medical officer to confirm aptitudes provide a very beneficial field of experience where **psychologists and psychiatrists must understand the reasons which led to human failures.**

***The study of human errors* by psychologists and psychiatrists** cannot overlook the **external factors** fostering such errors (work hours, climatic, technological and ergonomic conditions in the job environment, etc.).

It must focus above all on the analysis of **the person's internal factors,** in particular any **mental mechanisms which may be defective.** This analysis is an opportunity for an exchange with the operational staff in the field who can note only a fragment of human behaviour.

7 - CONCLUSION.

Selection of safety staff is a highly difficult task given the safety matters at stake. However, even when it is successful through use of modern techniques by computerisation of tests, and is mastered by experience, **it merely constitutes a prior means of guaranteeing safety staff reliability.**

The favourable diagnosis for a safety operator **may indeed change** with time not only under the effect of the sociological, professional and technological environment, but also with ageing of aptitudes which are not always compensated by experience acquired.

The safety system where man is involved must be ***subject to permanent, preventive*** **monitoring by training officers, management and medical officers;** through the methods they use, **psychologists are able to help to foresee the risks for the company** while at the same time preserving the chances for returning the safety operator to his job.

Human reliability in the company depends directly on the cohesiveness of the multidisciplinary team in charge of preventive monitoring of the aptitudes of safety operators in exercising their job.

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D.G Elms

Safety and Risk Assessment of the Auckland Light Rail Project

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NEW ZEALAND RAIL LIMITED

SAFETY AND RISK ASSESSMENT

OF THE

AUCKLAND LIGHT RAIL

PROPOSAL

A presentation to an International Railway
Seminar at British Rail October 1991

R S Ryan
Executive Manager
Quality & Safety
NZRL

D G Elms
Dept of Civil Engineering
Canterbury University NZ

NEW ZEALAND RAIL LTD

SAFETY AND RISK ASSESSMENT

OF THE

PROPOSED AUCKLAND LIGHT RAIL SYSTEM

Introduction

The Auckland metropolitan area is the largest in New Zealand. It has a population of approximately 1 million people. The public transportation system consists principally of diesel buses run by local authorities and private operators. New Zealand Rail Ltd (NZR) operates locomotive hauled passenger trains at peak hours to the North and South of the city. In the earlier days, electric trolleys and trams also complemented the train services.

In the early 1930's , the Central Railway Station was moved to a new site, somewhat remote from the downtown focal point. From that time, the rail patronage did not maintain its share of the urban passenger market.

Since the mid 40's many schemes have been proposed to bring rail passengers back to the heart of city by way of the "underground" All have faltered because of parochialism, perceived cost implications and adverse public opinion, in an era of motorcars and motorways.

In the 1970's a proposal for a mass transit scheme which integrated cars, buses and trains serving the "Southern Corridor" of the City with the possibility of extending to the east, west and north nearly got underway save for a change in the political leadership of the country. The proposal was for electric multiple units on separate tracks within the railway right of way which was connected to the downtown mid city areas by an "underground loop". The 25 kv traditional multiple units formed the transport backbone with integrated feeder buses and "park & ride" facility for the local citizens The principal stumbling block was "justification" for the capital costs, and funding of the "deficit" in the operating costs. The proposal died following the untimely death of the then Prime Minister, Norman Kirk.

In the early 80's various proposals were initiated, the stimulus being the advent of the "Railbus". Safety and reliability concerns using these vehicles in fully track circuited territory amongst "heavy" goods trains was the main factor contributing to the dismissal of those proposals.

In the late 80's NZR prepared a proposal based on modern light rail vehicles operating on the streets and in the railway corridor on the same tracks and amongst the NZR freight and Intercity passenger trains.

Safety was again a fundamental consideration. The safer option was to provide dedicated light rail transport (LRT) tracks within the corridor, with grade separation at junctions. A less expensive but equally safe system was to use the existing tracks excluding freight and long distance passenger trains except for specific narrow "operating windows" to maintain safe segregation. Another option was to provide a separate track for freight operations leaving the LRT service standards deemed critical for freight operations in a truly deregulated competitive freight market.

The final and most attractive option was to allow unrestricted combined use provided the risk to the passenger and crew safety was acceptable.

Precedents for this combined operation exist, the notable case being a LRT system in Karlsruhle, West Germany. However, in that operation both LRT and heavy rail DB trains are equipped with Automatic Train Protection.(ATP). It is a key facility in the eyes of Railway designers where safety performance is being evaluated.

A risk assessment exercise was therefore undertaken with the objectives comparing the safety levels to passengers with various levels of protection along the proposed Railway route for different operating regimes. The street operation was not evaluated.

The Auckland LRT Operational Options

The total thrust of the risk analysis was aimed at the mixed train and LRT operation to the north (single track, centralized traffic control crossing loops) and to the south (double track automatic signals.) A diagrammatic layout is shown in Appendix 1.

Within each corridor, it is important to recognise that very different physical, operational and associated factors exist. The analysis takes account of all these issues in a global sense, to arrive at a predicted accident frequency rate for comparative purposes.

In addition to the two geographical regimes there are also two operational regimes. The first covers fully signalled and controlled movements, and the second, when, for maintenance or malfunction reasons, movements are controlled by verbal authorisation. The strategy adopted was to investigate a number of different accident types and to calculate their relative contributions to the overall risk level in the system.

Firstly an assessment was made of the overall safety level of the proposal and whether it was considered adequate. Secondly a qualitative risk analysis was carried out with the aim of providing an overview of the comparative contributions of various sources of risk.

The distinction between the two aspects analysis is important. For the comparative risk assessment, a quantified risk analysis is carried out. The data used and many of the underlying assumptions were such that the risk predictions obtained by the approach could not be substantiated in any absolute sense. They could not be used by themselves but only in a comparative manner.

Whether or not the proposed LRT system would be adequately safe is largely a question of judgement. No system can be completely risk free, so that the safety is to do with ensuring the risk level is sufficiently low. Assessment of the safety of the system was therefore a question of ensuring that the likelihood of collisions between LRT's and between LRT and heavy trains was to be sufficiently remote.

Risk Issues

Under normal running conditions, collisions could not happen. Provided that the signal/interlocking systems are functioning, that there is no major equipment malfunction such as brake failure, that the track is adequately maintained and that the human element operates correctly at all times, there should not be an accident.

Safety therefore requires two things: that the physical and operational systems are maintained to a high standard by maintenance, inspection and regulatory control, and that the human factor is adequately reliable.

In most cases, a human-factor breakdown will not lead to an accident. A train-controller error, for instance, might lead to operational inefficiency but not to an unsafe situation, except, perhaps, in the case where signals are not functioning and manual control is being used. However, this is not the case for locomotive engineers, who could cause accidents by running through signals, overspeeding and other means. Instances of driver failure are rare, and these remarks should not be interpreted to mean that drivers are other than responsible and vigilant. Rather, the point is that the existing rail system is not protected against human failure, other than by the vigilance alarm systems installed in mainline locomotives. While effective in protecting against many accidents, the system would still allow errors to occur which could lead to accidents if the errors occured at critical points along the way.

If an Automatic Train Protection (ATP) system were installed, the human factor would be removed and the system would then be adequately safe, given the proviso made above that the risk management system was adequate.

By ATP is meant a system which automatically ensures a train does not pass a stop signal, which is thus a more stringent requirement than, say, the AWS system used by British Rail. It might be that an AWS system would be adequate for LRT operation because of the short emergency stopping distance of such vehicles.

Indeed, it is possible that in such a case, LRT operation on rail tracks could be safer than operation in a street environment with its attendant risk of traffic-related accidents, though this seems to be regarded as acceptably safe in overseas operations. On the rail however, the total consequences of an individual accident which could involve may more people, could be considerably more severe than is likely with road traffic accidents.

The question, then, became one of the effect on the overall safety level of the installation of ATP, for if its effect is small there would be little point in providing it. Alternatively, if its effect on safety can be assessed, then it may be possible to carry out other, and cheaper, measures to achieve the same level of safety as that provided by

ATP. This is one of the major reasons for the comparative study discussed in the next section.

Comparative Risk Study

The following analysis provides a risk profile in which the contributions to overall risk arising from different accident types are identified separately.

The two major sections of line, from Papakura to Auckland (double line automatic signal) and from New Lynn to Mt Eden (single track CTC with passing loops) are treated separately as their operating conditions are somewhat different. Results are produced with and without the installation of ATP.

Possible accident types are as follows:

1.. Head-on collision between LRV and train
2. Collision between LRV and a train involved in a crossing/shunting operation
3. Tail-on collision with train running into an LRV
4. Tail-on collision with LRV running into a train
5. Head-on collision, LRV to LRV
6. Tail-on collision, LRV to LRV
7. LRV derailment
8. Collision of LRV with derailed train
9. Collision of train with derailed LRV
10. Level crossing collision with road vehicle

However, not all were considered further as some accident types appeared to be too remote to justify inclusion. Item 4, tail-on collision with an LRV running into a train, was omitted as it is assumed that in most cases an LRV, with a maximum emergency stopping distance of less than 100m, would be able to stop before a collision occurred. Items 5 and 6 were not considered further for the same reason. Item 9 was omitted on the grounds that an LRV derailment is in any case very remote, and the low density of heavy rail traffic makes the joint occurrence of a derailment and collision with the derailed vehicle by a train a very remote occurrence. Thus we were left with six accident types.

To summarise, two different approaches were used depending on the accident type. The first three accident types, that is, head-on, crossing/shunting and tail-on collisions, were taken to be site-specific. They would only occur at or associated with particular locations, usually stations, for it is at these points that trains will stop, shunt, cross tracks and face signals. The approach used was to determine the probability, at one such point, of an accident occurring to a particular LRV, given that another train was present. The probability was determined using a fault tree. The probability was then found of another train being present, and the two were combined. The accident probability could then be averaged over the whole length of line, for all stations. The other three accident types were dealt with on a per kilometre basis.

Analysis Results

All calculations were laid out on a single spreadsheet, which the consultant gave to NZRL for use for use with any subsequent sensitivity studies. The fault trees within the analysis are "conditional" in that they deal with the probability of an accident given that another train is present. Clearly, the full probability of an accident must also include the likelihood of another train being present. This latter probability was established by analysis of train and proposed LRT timetables and the duration of train, exposure at critical points along the way. Two fault trees are shown in Fig 2 and Fig 3.

Each fault tree has the same logical structure, (for ease of development in the spreadsheet) with some items being assigned zero probabilities if it is judged they have no effect in a particular instance. Working down from the top of a tree, a collision will happen if both of two things happen: a failure of some sort has to happen in the system, such as a brake problem on a heavy rail train or a driver error, or that the train or LRV is unable to stop in time and so avoid an accident. Numerically, the two items at the second level are multiplied to get the probability of the top event.

The third level lists five general possibilities, any one of which could cause failure. Numerically, the probability values are added, which, although not strictly correct, is justified when the probabilities are small. Because the values are summed, it is easy to see which of them are dominant. For the head-on collision tree of Fig 3 the most important contributions to risk come from driver error, followed at a lower level by unsignalled operation. Thus any means of reducing driver error, by for instance improving the vigilance alarm system or indeed by introducing ATP, would directly affect the risk of a head-on collision.

For each accident type and for each critical point, the probability of an accident occurring in a specific hour is the product of three items: the conditional probability of an accident occurring to a particular LRV given that another train is present, the probability that another train is present in that hour, and the number of LRV's in that hour. The daily accident probabilities can then be summed over all the relevant stations for each line.

Given the number of LRV's trips a day each way on both lines and knowing the lengths of the lines, the daily distances travelled by the LRV's can be calculated. From these figures the accident rates per million train kilometres are calculated and transferred to the first three row entries in the results Tables 1 and 2.

The results in Tables 1 and 2 show respectively the comparative risk levels for the system without ATP and with ATP on both LRT and NZR Rail Locos. Five types of result are shown. The expected number of accidents of each kind are shown in terms of the number per million train kilometres (MTK) and of the number per year. The former is a useful index for comparison with the performance of other rail systems, but as noted above the figures here cannot be used in an absolute sense. Rather they can give an idea of the relative contributions of the different accident types. The total values, which are the sums for all accident types, can be used to ensure the numbers used for the analysis are of roughly the right order of magnitude, so helping to calibrate the model.

The number of fatalities per MTK is not easy to assess as it relies on a judgement of the likely average fatalities per accident, which in turn depends on a number of factors such as the average number of passengers travelling in an LRV set.

The rows labelled "Accident rate" need more explanation. They are concerned with the likelihood of an individual passenger being involved in an accident. They are defined as the likelihood of a passenger being present in an accident per 10^8 hours of exposure· The fatal accident rate (FAR) is somewhat similar, and is the likelihood of a passenger being killed in 10^8 hours of exposure. It is a measure of the ambient risk level faced by an individual passenger while riding in an LRV, and so it does not depend on how many passengers are present.

The results show the accidents to be very much dominated by the incidence of level crossing accidents. It has been assumed that the incidence of such accidents will be the same as it has been in the last ten years, on a probability per million train kilometres basis. One way to look at this is to note how much smaller are the likelihoods of the other accident types compared with level crossing accidents.

Considering the other accident types and looking at the accidents/MTK shown Table 1, it can be seen that for Papakura - Auckland all are roughly the same order of magnitude except for collision following a train derailment fouling the opposing track, which is an order of magnitude smaller. For the New Lynn - Mt Eden section, the same pattern can be seen except that crossing/shunting collisions will be fewer as there are not many situations where this could occur. The possibilities of head-on and tail-on collisions are also smaller, as there are fewer heavy rail trains.

The fatal accident rates, again looking at Table 1, are dominated by crossing/shunting collisions for Papakura - Auckland, closely followed by head-on collisions. For New Lynn - Mt Eden, level crossing FAR's dominate, being 10 times the value for the other section. Collision FAR's are considerably less than for Papakura - Auckland.

Consider now the effect of introducing ATP. Table 2 gives the effect of ATP on both trains and LRV's. ATP will not affect level crossing accidents, and neither will it influence the incidence of the two derailment accident categories. Its effects must be considered on the other accident types. Roughly speaking and looking at accidents/MTK, its introduction to both trains and LRV's will reduce the incidence of the three collision accident types by a factor of 10. However, while the introduction of ATP to either trains or LRV's will reduce head-on collisions by the same amount crossing/shunting and tail/on collisions are only affected by introducing ATP to heavy rail trains. The reason for this is that in both the latter collision types, an LRV is assumed to be the passive partner, as it were. Remember that tail-on collisions in which an LRV runs into the back of either a train or another LRV are not considered because of the LRV's ability to stop quickly acting as a further degree of protection beyond that afforded by the signalling/interlocking system.

Overall, and neglecting the contribution of level-crossing accidents, the effect of introducing ATP on the total accidents/MTK is a reduction of roughly 40% which is not great. There are limits to the effectiveness of ATP as if it reduces collision accidents, then other accident types begin to dominate.

The effects on the total fatal accident rates for the two sections of line differ. For Auckland - Papakura, FAR's are reduced by a factor of 5, while for the other line the reduction is less due to the dominance of level crossing accidents.

The implications of these results with regard to the need for installing ATP are interesting. Given our earlier definition of a "completely safe" system as one with ATP installed, we could use the total FAR figure of 1.015 (say 1.0) for the Papakura - Auckland section as a guide. It is clear this figure could easily be achieved for the other line by halving the incidence of level crossing accidents.

If this could be done, and it would seem to be feasible, there would be no case for the use of ATP on the New Lynn - Mt Eden section. Of course, the figures given are not exact and are affected by the various assumptions that have been made. Nevertheless they are believed to be of the right order of magnitude.

For the southern section, the major contributors to the total FAR are crossing/shunting collisions and tail-on collisions. It could be that modifications to operational procedures and to physical layout together with tight monitoring of regulations would lead to an equivalent reduction in risk without the need for ATP. On the other hand, the introduction of ATP would undoubtedly guard against the possibility of some of the worst accident scenarios. Whichever the choice, some additional commitment to safety would seem to be required. The matter is clearly one requiring careful thought.

Fig 4 gives an indication of relative values of elements contributing to the fatal accident frequency rate for various levels of protection afforded by fitting or not fitting ATP to LRV and or HR as calculated for the Southern Corridor operation

Major Conclusions were:

- The safety of the system would be adequate if ATP was installed. This level of safety can be achieved by other means. For the North Auckland Line, the installation of ATP would be unnecessary.

- The greatest number of accidents are those occurring at level crossings, but these would seldom result in passenger fatalities. The largest contributions to the fatal accident rate would come from tail-on collisions with trains running into LRV's, and from side-swiping collisions during shunting or cross-track movements.

- However, the incidence of such accidents appears to be sufficiently low that they can be dealt with by suitable changes in operating regime and the maintenance of a thorough risk management regime to ensure the quality control of all safety systems, both physical and regulatory.

Comment

The risk model made the best use of available data. If the proposal had proceeded, the spreadsheet would have been an extremely useful tool to evaluate various safety issues to ensure the most effective solutions were chosen. As better information became available, sensitivity studies could have been performed for guidance of decision makers.

Epilogue

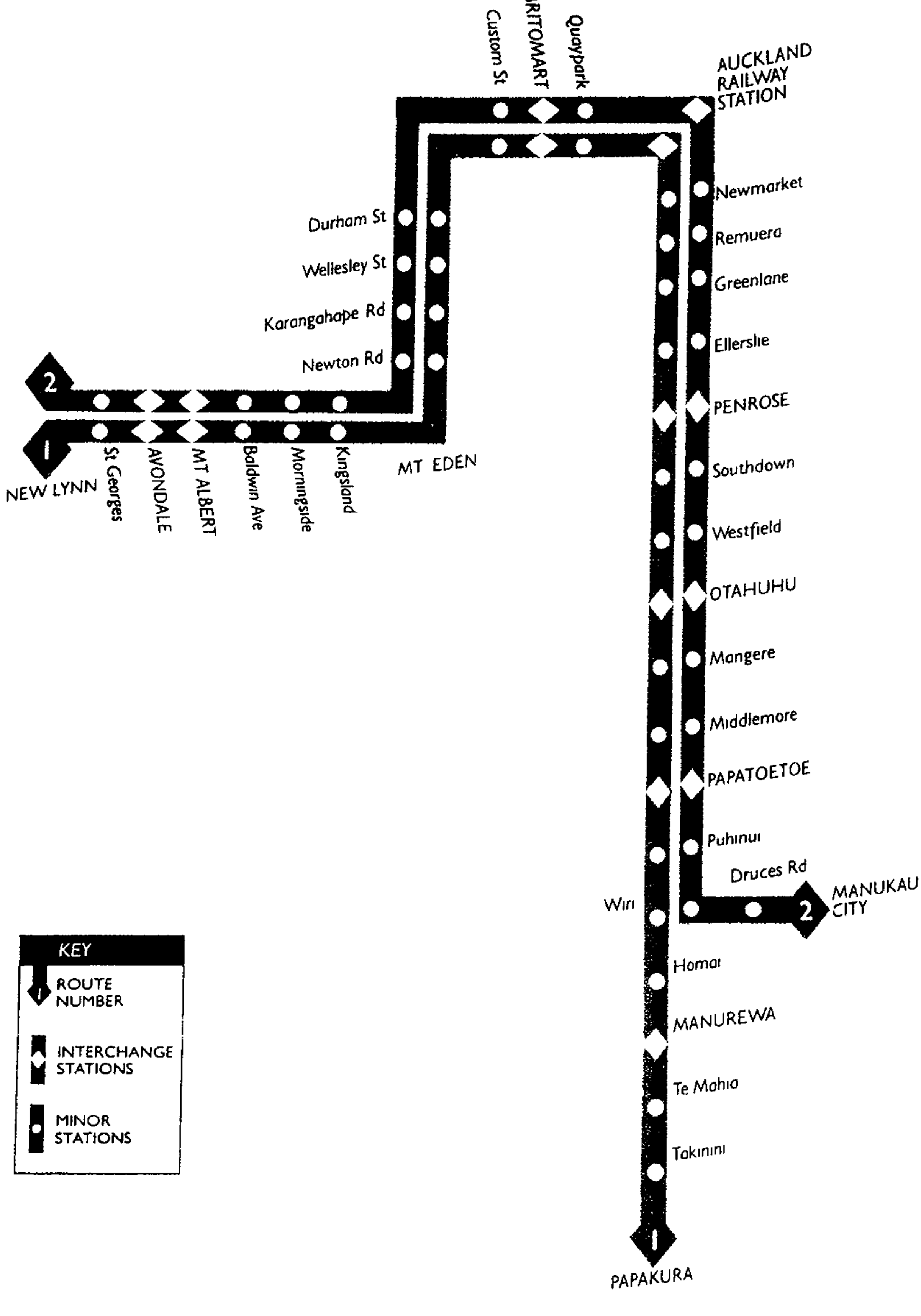
Late in 1991 it became evident that the Auckland public passenger system incorporating a rail element was being buried yet again.

The proposal development process has almost become institutionalised over the past 50 years, as Engineers, planners, politicians and dreamers wrestle with the issues of public perception, public good with dollars being the most significant criterion.

Perhaps the growing interest in environmental issues will see the proposals with a rail element resurrected again in the future as decision makers learn to deal with the public whose values are changing as we move toward 2000.

R S Ryan & D G Elms

Fig. 1



AUCKLAND LIGHT RAIL TRANSIT STUDY

STAGE 2

Figure 2

TAIL-END COLLISION -- HR TRAIN HITS LRV

No ATP Installed

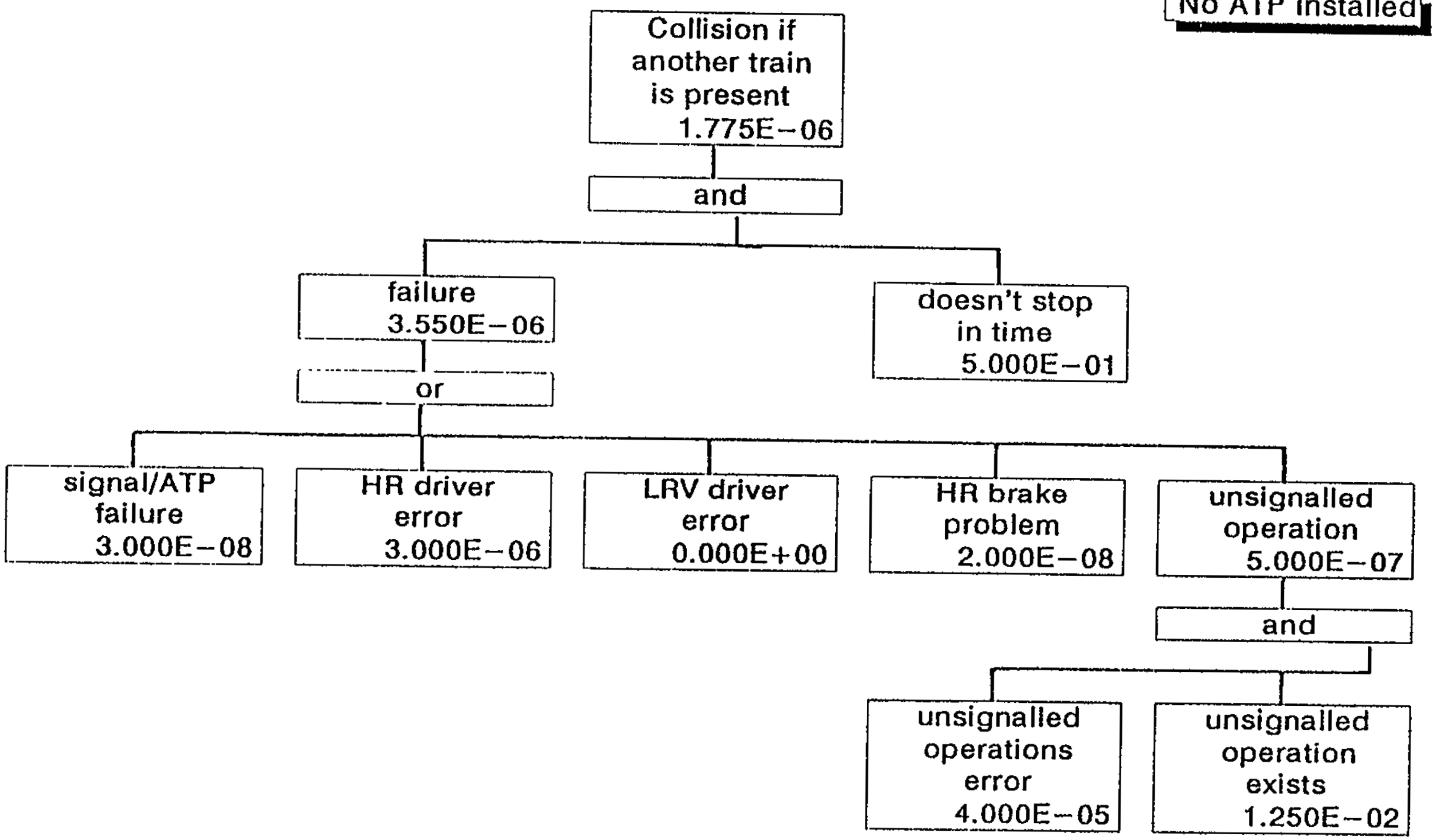
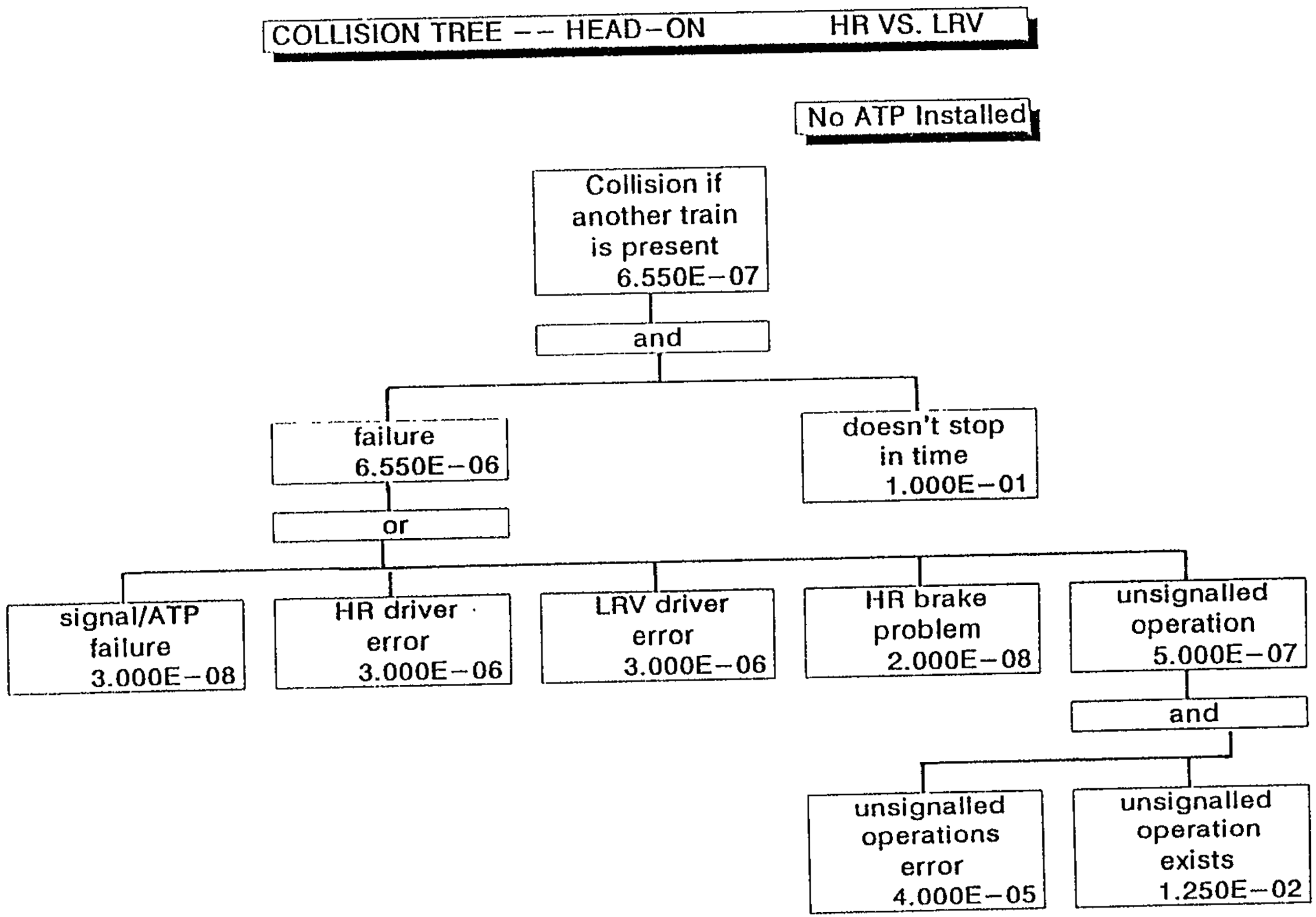


Figure 3


COLLISION TREE -- HEAD-ON HR VS. LRV
No ATP Installed
Collision if another train is present 6.550E-07
and
failure 6.550E-06
doesn't stop in time 1.000E-01
or
signal/ATP failure 3.000E-08
HR driver error 3.000E-06
LRV driver error 3.000E-06
HR brake problem 2.000E-08
unsignalled operation 5.000E-07
and
unsignalled operations error 4.000E-05
unsignalled operation exists 1.250E-02

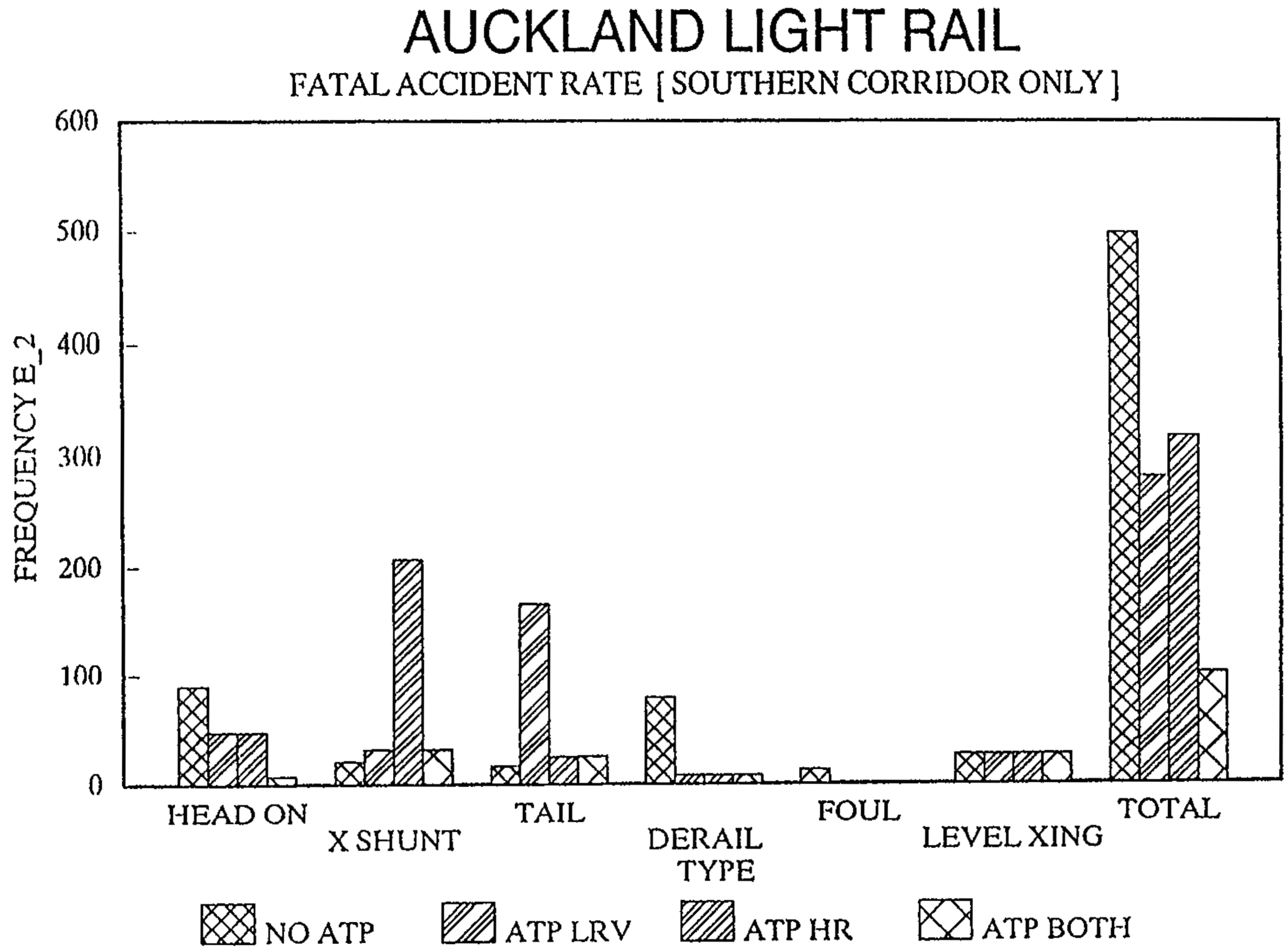

AUCKLAND LIGHT RAIL
FATAL ACCIDENT RATE [SOUTHERN CORRIDOR ONLY]
FREQUENCY E_2
600
500
400
300
200
100
0
HEAD ON
X SHUNT
TAIL
DERAIL TYPE
FOUL
LEVEL XING
TOTAL
NO ATP
ATP LRV
ATP HR
ATP BOTH

FIG.4

TABLE 1

RESULTS

ATP not installed

Papakura – Auckland (Stage 2)

Accident type	head–on	cross/shunt	tail–on	derailment	fouling/coll.	level crossing	total
Accidents/MTK	9.955E–04	2.300E–03	3.687E–03	7.000E–03	2.893E–05	2.400E–01	2.540E–01
Accidents/year	1.313E–03	3.035E–03	4.864E–03	9.240E–03	3.819E–05	3.168E–01	3.353E–01
Fatalities/MTK	7.964E–03	1.840E–02	1.475E–02	7.000E–04	1.157E–04	2.400E–03	4.433E–02
Accident rate	4.480E+00	1.035E+01	1.659E+01	3.150E+01	1.302E–01	1.080E+03	1.143E+03
Fatal accident rate	8.959E–01	2.070E+00	1.659E+00	7.875E–02	1.302E–02	2.700E–01	4.987E+00

New Lynn – Mt Eden

Accident type	head–on	cross/shunt	tail–on	derailment	fouling/coll.	level crossing	total
Accidents/MTK	5.052E–04	8.205E–05	9.965E–04	7.000E–03	5.786E–06	2.300E+00	2.309E+00
Accidents/year	1.964E–04	3.190E–05	3.874E–04	2.723E–03	2.251E–06	8.947E–01	8.980E–01
Fatalities/MTK	4.042E–03	6.564E–04	3.986E–03	7.000E–04	2.314E–05	2.300E–02	3.241E–02
Accident rate	2.274E+00	3.692E–01	4.484E+00	3.150E+01	2.604E–02	1.035E+04	1.039E+04
Fatal accident rate	4.547E–01	7.384E–02	4.484E–01	7.875E–02	2.604E–03	2.588E+00	3.646E+00

TABLE 2

RESULTS

ATP on both LRV and HR trains

Papakura – Auckland (Stage 2)

Accident type	head–on	cross/shunt	tail–on	derailment	fouling/coll.	level crossing	total
Accidents/MTK	8.359E–05	3.564E–04	5.712E–04	7.000E–03	2.893E–05	2.400E–01	2.480E–01
Accidents/year	1.103E–04	4.701E–04	7.535E–04	9.240E–03	3.819E–05	3.168E–01	3.274E–01
Fatalities/MTK	6.687E–04	2.851E–03	2.285E–03	7.000E–04	1.157E–04	2.400E–03	9.020E–03
Accident rate	3.761E–01	1.604E+00	2.570E+00	3.150E+01	1.302E–01	1.080E+03	1.116E+03
Fatal accident rate	7.523E–02	3.207E–01	2.570E–01	7.875E–02	1.302E–02	2.700E–01	1.015E+00

New Lynn – Mt Eden

Accident type	head–on	cross/shunt	tail–on	derailment	fouling/coll.	level crossing	total
Accidents/MTK	4.242E–05	1.271E–05	1.544E–04	7.000E–03	5.786E–06	2.300E+00	2.307E+00
Accidents/year	1.649E–05	4.942E–06	6.003E–05	2.723E–03	2.251E–06	8.947E–01	8.975E–01
Fatalities/MTK	3.394E–04	1.017E–04	6.176E–04	7.000E–04	2.314E–05	2.300E–02	2.478E–02
Accident rate	1.909E–01	5.720E–02	6.948E–01	3.150E+01	2.604E–02	1.035E+04	1.038E+04
Fatal accident rate	3.818E–02	1.144E–02	6.948E–02	7.875E–02	2.604E–03	2.588E+00	2.788E+00

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Paper 9113

Ray Ryan
D.G Elms

Risk assessment Experience, An overview of Four Case Studies

Publisher
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NEW ZEALAND RAIL LIMITED

RISK ASSESSMENT EXPERIENCE

AN OVERVIEW OF FOUR CASE STUDIES

An Address to International Railway Seminar
at British Rail October 31 1991

R S Ryan
Executive Manager
Quality & Safety
NZRL

D G Elms
School of Engineering
University of Canterbury NZ

NEW ZEALAND RAIL LIMITED

Overview of Four Case Studies

> When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your own thoughts advanced to the state science.
>
> Lord Kelvin, 1883
> English Physicist

NZ is a country of 2 Islands, about the size of Great Britain, or slightly smaller than Japan, with a population of 3.3 million. The land is geologically young with the result that much of it is mountainous and sparsely populated. The stability of the topography is a principal factor impacting on the reliability of the rail system.

As early as 1870 it was resolved that all railway construction would be 3ft 6" gauge (1067m) as a response to both the difficult terrain and economic constraints.

Today NZ Rail Ltd is a State Owned Enterprise. It operates long distance passenger and freight operations on a network of total 4300 km of 1067mm gauge track. Approx 8 million tons of freight and 11 million passenger are transported each year. There are 170 number of Diesel Electric Main Line Locomotives, 120 shunting locomotives 9000 freight wagons, 100 passenger carriages for long distance services. Signalling systems are Centralized Train Control, Single Line Automatic and Track Warrant Control.

A suburban system operates in Wellington City. The fleet consists of 150 Electric Multiple Units. The power system is 1500 volts DC.

In addition to the above, NZRL operates 3 Interisland roll-on - roll-off rail ferries across Cook Strait. Passengers, commercial road vehicles, passengers cars, and railways wagons are transported.

The Company has a staff of 5300 total.

The company was formed as a result of a series of organisational restructuring over a six year period. Major rationalisation of facilities, methods of operating and service quality initiatives were implemented. Financial restructuring was also a major activity.

Over the six year period, a steady decline in the country's economic activity has seen significant reduction in transport demand. NZRL has, however maintained its market share in a fiercely competitive deregulated environment.

Assets have been significantly reduced as well as staff from a level of 22000 in 1986 to 5300 in 1991.

SAFETY ISSUES

Part of the productivity improvements were achieved by critically reviewing standards for inspection, maintenance and operating procedures. The traditional approach of safety at any cost came under scrutiny. This lead to a discussion of "How Safe?" and "what is safe enough" and how is it to be defined and accounted for.

The safety responsibilities for NZR are laid down in Railway Legislation (The NZR Restructuring Act 1990). It requires that the Chief Executive receives annual certificates from the Engineering Managers that standards set have been achieved in the year. The law also allows for the establishment of inquiries and Commissions of Inquiry into any matters (including accidents) as appropriate.

For safety related inquiries the tendency in the past, has been for the outputs to push blame to the lowest level of the organisation in general terms.

Modern safety management principles recognise that the combination of technical standards, operational procedures and compliance (human performance) are the key elements to Safety. Integration of all standards is necessary and that the review and feedback from experiences is a essential part of the safety management system.

The debate within NZR centred around how safety performance could be assured under the new commercially oriented regime. It was resolved that the definition of safety would hinge around that proposed by the British Board of Health, ie:-

"A thing is provisionally assessed as safe if the risks are known and deemed acceptable".

This definition has yet to be ratified by the NZRL Board.

RISK MANAGEMENT

Given the above definition, the concept of risk sharing followed in that modern safety management principles hinge to the greatest extent on the Management System (a management responsibility) as apposed to the former concepts of safety at the workface.

It was with this background that the use of the structured risk assessment technique for safety related issues was started in NZR. In practice all of the decision making processes inherently include risk assessment but not in a formal, structured or sometimes conscious way. At this stage, the structured risk assessments process has not been applied to other business activities.

The principal objectives of the structured approach to safety issues were:-

(a) as an aid to decision making where safety was a principal issue.

(b) being able to demonstrate, to a third party if necessary, that due care and a responsible approach had been taken in the decision making process

RISK ASSESSMENT PROJECTS

NZRL has documented 4 case studies where the formal use of this structured technique has been used.

These are:-

Single Manning of Main Line Trains :	Quantified Risk Assessment
Auckland City Light Rail Proposal :	Quantified Risk Assessment
Hazardous Goods Transportation :	Qualitative Risk Assessment Scoping study
Wellington Suburban Passenger Operation :	Qualitative Risk Assessment Scoping Study

Separate companion papers are available detailing each of the above projects.

PROJECT OUTLINES

1. Single Manned Trains in NZRL

The restructuring process in NZRL encompassed massive staff reductions. Train crews had been reduced from 3 to 2 leaving 2 locomotive engineers as the first stage. Given that NZRL is principally a "freight railway" and the rationalisation of freight handling activities was leading to point to point trains, the question was asked "can the trains be manned by a single person?" In a locomotive engineers register of approx 1500, a potential reduction of 250 could be achieved by this regime yielding a cost saving of $12,000,00 annually.

The principal issues to evaluate were, safety of the locomotive engineer (and hence trains), health and stress of loco engineers, productivity payments, technical and operational adjustments for the new regime.

The quantified risk assessment described in the companion paper by Elms and Mander was a key piece of work that lead to the introduction of the "Alternative Train Crewing" (ATC) regime.

A consequence of this approach was that NZRL completed an industrial agreement for the introduction of ATC in 16 weeks, a significant achievement given the timeframe experienced when reducing train crews from 3 to 2. The agreement covered introduction phasing, technical facility improvements, operational procedures, and productivity payments. The full introduction has extended over a 3 year period.

2. Auckland Light Rail Proposal

The development of mass transit schemes for NZ's largest metropolitan area (Auckland) has been almost institutionalised over the past 50 years. Financial and political issues, amongst other things, have been the issues debated mostly.

In late 1988 NZRL put forward a cost effective proposal which was based on modern Light Rail Vehicles moving along the Railway right-of-way on the same tracks, intermixed with tradition Heavy Rail freight and long distance passenger services. The LRV's also moved along the city streets as the trams of old.

A quantified risk assessment was undertaken to assist with decision making on safety issues. The study looked at 2 distinctly different operating geographical areas for given heavy and light rail operating timetables. The probability of accidents to passengers on the LRT was assessed for selected types of incidents. Scenarios using different levels of protection afforded by a "No ATP" and "Full ATP" (plus variants) fitted to LRT and heavy rail locomotives were undertaken.

The companion paper "Safety and Risk Assessment of the Proposed Light Rail System" describes the evaluation process and conclusions reached.

The Light Rail Proposal was presented to the local authorities, and although some further development work has proceeded, it focused on evaluative work comparing alternative transport modes.

3. Hazardous Goods Scoping Study

During the past decade there has been a growing concern in New Zealand over the hazards and risks posed by the usage, handling and transportation of these goods.

NZRL carries a wide range of hazardous goods on its freight services. However they consist of only about 3% by volume of all goods carried. Although the volume of hazardous goods transported on Rail has considerably reduced over the past six years, NZRL had not undertaken a review of its procedures and compliance for handling and transportation of these commodities for some time.

A risk assessment was commissioned with the view to develop an effective risk management regime, to ensure obligations were met for optimising safety in terms of employees and the public at large.

The qualitative risk assessment was used to provide a preliminary prioritisation of risks for the purpose of resource allocation. Based on data from 10 years of operation, it established mechanisms of failures, categorised goods into groups then assessed impacts on people, property and the environment. A risk evaluation matrix was formed so that a "Total Risk Score" was produced on which priority for further works was based.

The matrix was subjected to a sensitivity analysis before results were confirmed.

4. Wellington Urban Rail Scoping Study

The Wellington urban area is served by an Electric Multiple Unit Rail System which leads into the city in 3 principal "arms".

The routes converge in the Wellington Railway Yard where Depots, freight handling Interisland ferry terminal activities are performed. The city station is on the end point of the converged routes.

Two serious accidents occurred in the yard area; one in 1979 resulting in 44 injuries and the other in 1980 resulting in 2 deaths and 77 injuries.

The Wellington Urban Rail System has the highest level of public involvement of any of the Companies activities. It operates on the right-of-way sharing tracks, signalling and traction power with long distance passenger and heavy freight trains. Like most urban passenger systems, revenue generated does not cover full operating or financial costs. Local authorities subsidies contribute to funding (by way of contract) but economic pressures from many quarters contribute significantly to lengthening the negotiating process.

Public expectation of safety performance of the system is high. In 1990 a risk assessment study was embarked upon with the principal objective of identifying the elements in the whole operating system that needed to be addressed for the maintenance of safe operation. The 1st stage of the assessment was a scoping study. The study proceeded by initially undertaking a pilot study on one line, Wellington to Trentham (near Upper Hutt).

The scoping study has been completed. Its aim was to set the foundations for obtaining measurable and comparable values of the risk to passengers, staff, other persons and property in the Wellington Urban area. The work led to a better understanding of the issues affecting the risks associated with Rail Transportation and the factors affecting railway incidents and accidents. The decision to develop the scoping study into a Quantified Risk Assessment has not yet been made.

EXPERIENCE GAINED

Experience gained from the four risk assessments described above can be summerarised in the following points:-

i) The development of fault trees requires considerable thought and investigation to ensure that all possible sources of risk are accounted for. It forces a deeper understanding of the systems leading to incidents and accidents.

ii) The Quantified Risk Assessment (QRA) shows the various contributions to risk and their interactions so that sensitivity studies can easily be carried out.

iii) The QRA became a powerful management decision- making aid especially when the results are combined with cost consequences of various actions.

iv) The QRA was not always exhaustive. This is because some sources of risk were deliberately omitted on the basis that the probability is extremely remote; a matter of judgement. Others may be inadvertently omitted no matter how carefully the model is developed.

v) In large complex situations, a pilot scheme approach is the most practical. It cuts the issues down to a manageable size so that the model can be calibrated with confidence.

vi) Data needed for the fault trees took a considerable amount of research. It ranged from hard factual information, through statistical trending to "value judgements".... a team process where advisors, managers and practioners pooled their knowledge and experience for assessing probabilities.

vii) The QRA is not so good for low probability high consequence events. A contributing factor is the difficulty of obtaining reliability data for low probabilities.

viii) In complex situations, such as derailments, the causes are invariably a combination of events. Records only define "principal cause" so considerable effort was required to use the factual information effectively.

ix) The derived overall risk level results were good for COMPARATIVE purposes but less reliable for ABSOLUTE values ie., in the case of the single manning analysis, good for comparing the risks associated with 2 man with those for one man operation. It was of less value for comparing locomotive engineer safety with community risk .

x) Communication, understanding and use the of the risk results by third parties was a major problem. It is likely that at some stage an accident is inevitable, given enough time for it to occur. Though the use of the technique is a responsible management approach, it cannot be a substitute for good sound management practice involving quality assurance of the existing safety systems, both physical, operational and regulatory.

xi) Quantification of issues removed a lot of emotion from discussion and negotiation with affected parties.

This was the principal reason for achieving an Industrial agreement for the single manning proposal in a 16 week timeframe.

xii) The culture of the organisation is key to the effort to be put into the QRA. In NZR, the "best-value-for-money" (apart from the Single manning analysis) has been obtained by completing the scoping phase.

xii) sound common managerial sense is still an essential part of the ultimate decision making process.

THE FUTURE OF RISK ASSESSMENT IN NZRL

NZRL is now perusing the cause of TQM. While "non-safety" had been promoted as a drain on the business, it was not until the principles of TQM became understood that the connection between "continous improvement and Loss reduction(non-safety!)" was made in the minds of many of the managers. NZRL is now a lean-mean-machine and has to be to survive in the economic climate of the future.

Now that some stability in the organisation is becoming evident, an increasing interest in safety management is showing up. This is also being fueled by the publicity being given to outputs of inquiries into overseas disaster where the linkages of accident outcomes to management responsibilities has an increasing focus. It is the allocation of resources that is so critical in the success or failure of the company and the risk assessment techniques are seen as valuable tool for this purpose.

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Author Unknown

Liverpool Street Redevelopment

Publisher
2000 International Rail Safety Conference

Project Director
Liverpool Street Redevelopment
June 1991

LIVERPOOL STREET REDEVELOPMENT

1. The redevelopment of Liverpool Street Station started in May 1985. This paper briefly describes the background to the project, the proposed works and the construction programme.

2. The BR Board's objective for the project is to modernise and improve the station facilities, the interchanges with underground and buses and the track approaches into the station and to finance all these works by means of an associated property development.

3. The necessary planning application was submitted in 1976 and, following a public inquiry, outline planning permission was granted in 1979. The BR and LRT Acts of Parliament received Royal Assent in 1983. Works started in May 1985.

4. The railway works comprise the closure of Broad Street Station and the diversion of its last remaining train service via a new link line into the adjoining Liverpool Street Station, the rebuilding of all the facilities in the latter, improvements to the layout of platforms and the immediate track approaches (including resignalling) and the construction of new underground and bus interchanges.

5. The property development, totalling nearly 4m sq.ft. of offices and known as 'Broadgate', is partly located on the former Broad Street Station site west of Liverpool Street, around a public square with restaurants and shops, partly over the east side of Liverpool Street Station adjacent to Bishopgate and partly to the north of the Station over the approach tracks and ends of the platforms, around another public square.

6. A summary of the main elements of the scheme is shown in Appendix 1, sketch plans of the new site layout in Appendices 2 & 3 and of the original layout in Appendix 4.

7. The railway works extend over a period of almost six years, due to the need for staging of works in order to maintain train services and station facilities throughout the reconstruction. The property development works extend over the same period. The overall project will be completed by Autumn 1991.

8. The total cost of the overall project is about £2,000 million, of which £150 million is for the railway works.

013/nd

APPENDIX 1

LIVERPOOL STREET REDEVELOPMENT

MAIN ELEMENTS OF SCHEME

1. Closure and demolition of Broad Street station and diversion of North London Line Watford/City service into Liverpool Street station via new connecting line at Graham Road, Hackney (completed in June 1986).

2. Rebuilding of Liverpool Street station, involving demolition of 50 Liverpool Street, Harwich House and Hamilton House.

3. Provision of new station facilities, including:

   3.1 Total of 18 platforms, as before, but with more long platforms and with calling-on facilities to permit two trains to occupy one platform.

   3.2 All 18 platforms extended or reconstructed to common entrance barrier line.

   3.3 Single concourse, free from parcels/Post Office tractors/trollies, with escalators, lift and stairs to street level.

   3.4 Segregation of pedestrian and road vehicle movements.

   3.5 Improved customer and staff facilities.

   3.6 Improved taxi/car facilities, including short wait car park.

   3.7 Improved parcels, Post Office and coach facilities.

4. Retention of existing 6 approach tracks, on their existing alignments, but with some remodelling of track layout in area immediately outside station, giving facilities for more flexible and parallel train movements than the previous layout permitted.

5. Complete resignalling of Liverpool Street station area and approach tracks towards Bethnal Green, with new signal box of sufficient size for equipment of control of wider area to link with Colchester and Cambridge signal boxes (completed in April 1989).

6. Electrification of two short sections of freight lines in the Stratford area enabling more flexible operation of passenger services at Stratford.

7. Provision of improved interchanges between BR station and London Regional Transport underground and bus services, including new bus interchange.

8. Provision of property development (Broadgate), totalling nearly 4 million sq.ft. of offices, plus shops, restaurants and public squares.

January 1991.

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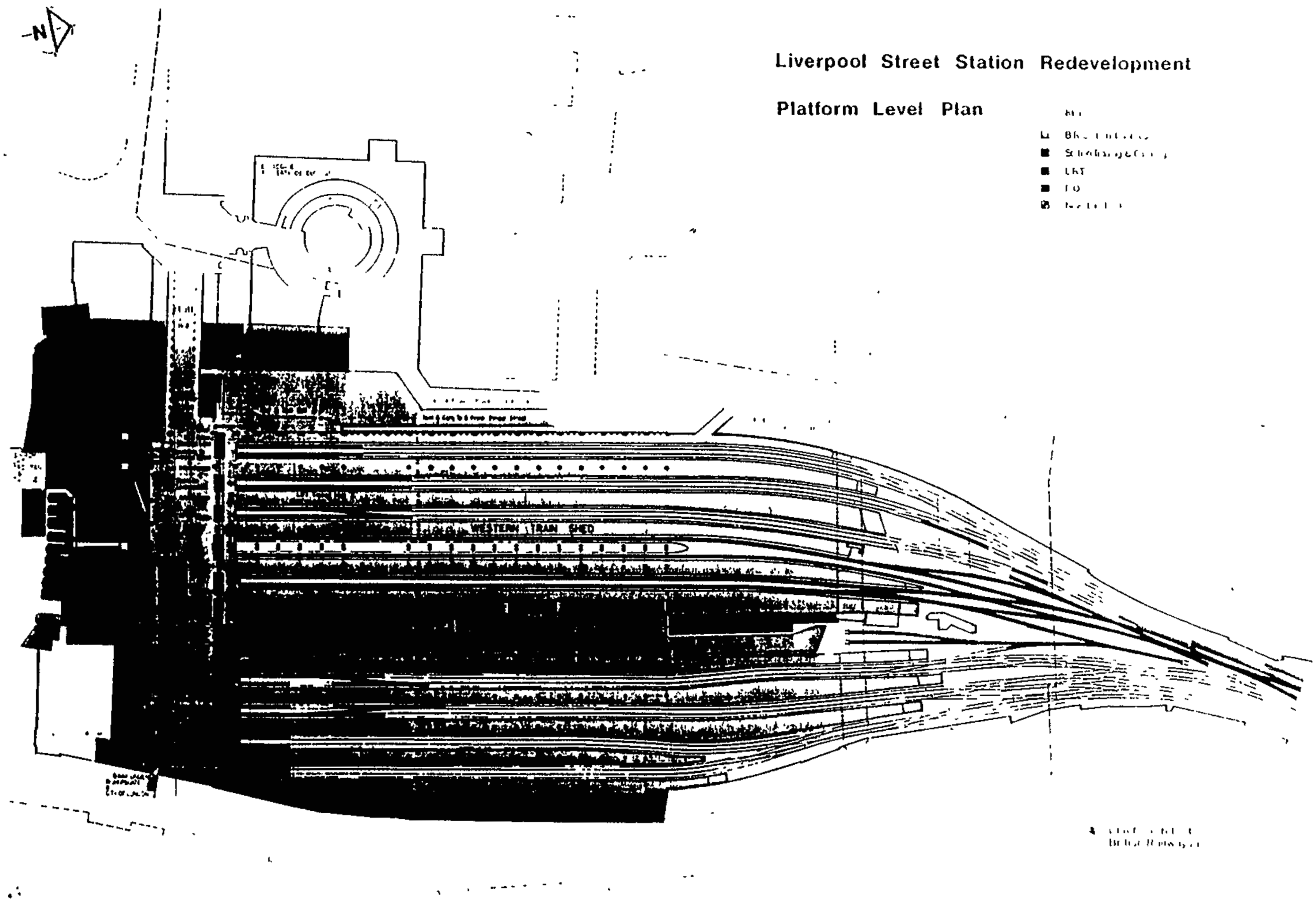
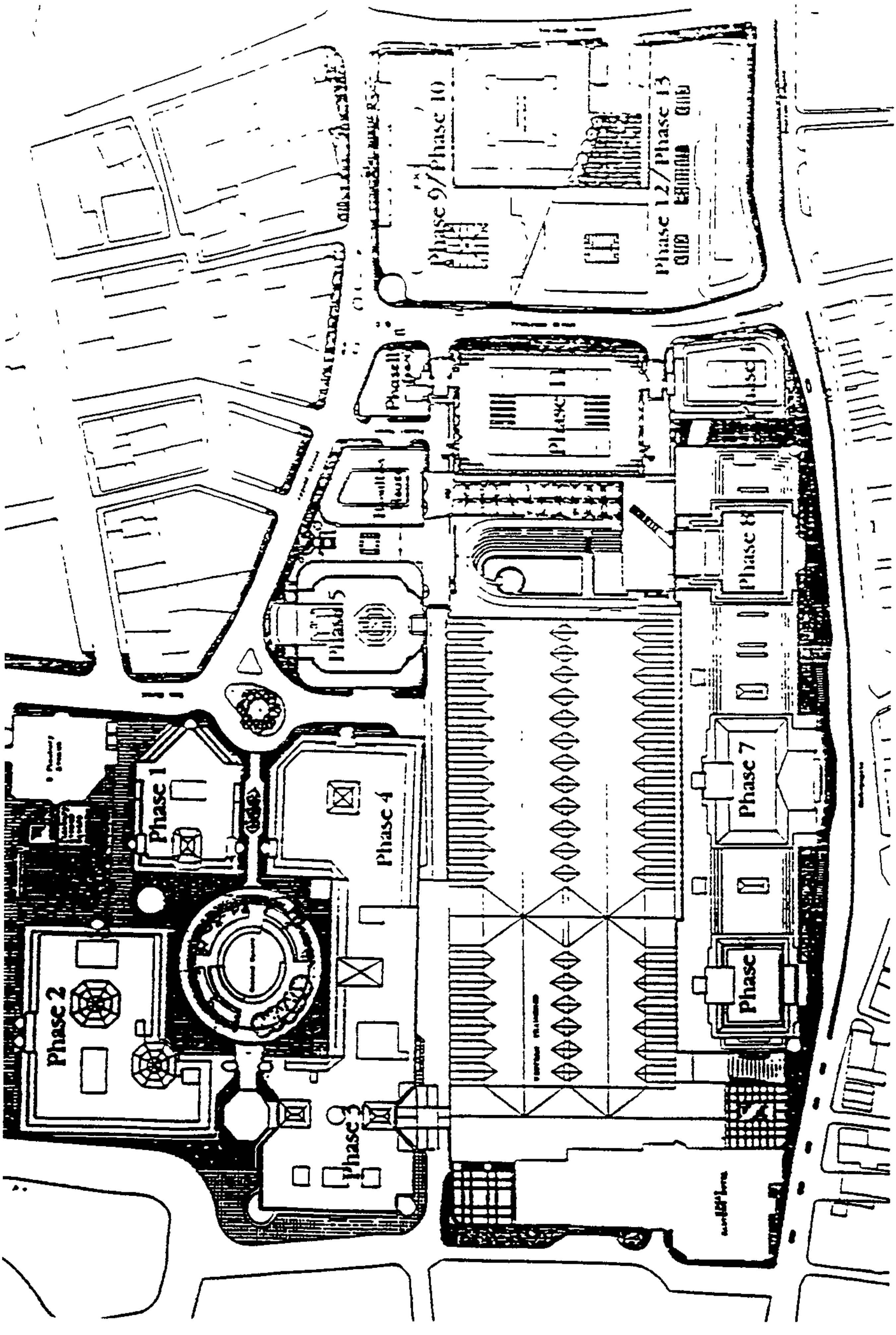
APPENDIX 2



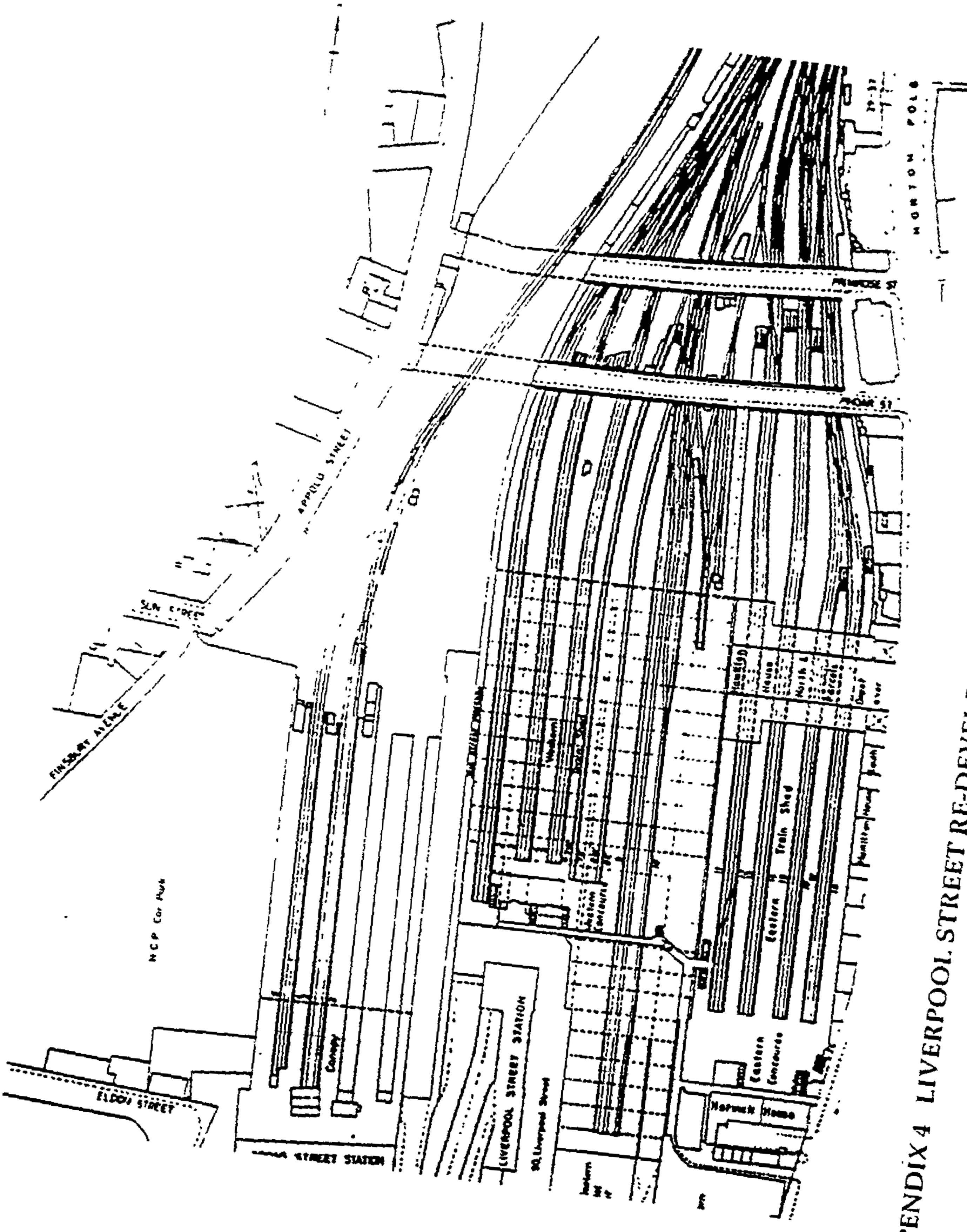
APPENDIX 2 LIVERPOOL STREET RE-DEVELOPMENT - PLATFORM LEVEL PLAN

APPENDIX 3



APPENDIX 3 BROADGATE - MASTER PLAN

APPENDIX 4



APPENDIX 4 LIVERPOOL STREET RE-DEVELOPMENT - LAYOUT PRIOR TO START AS AT 1.5.85

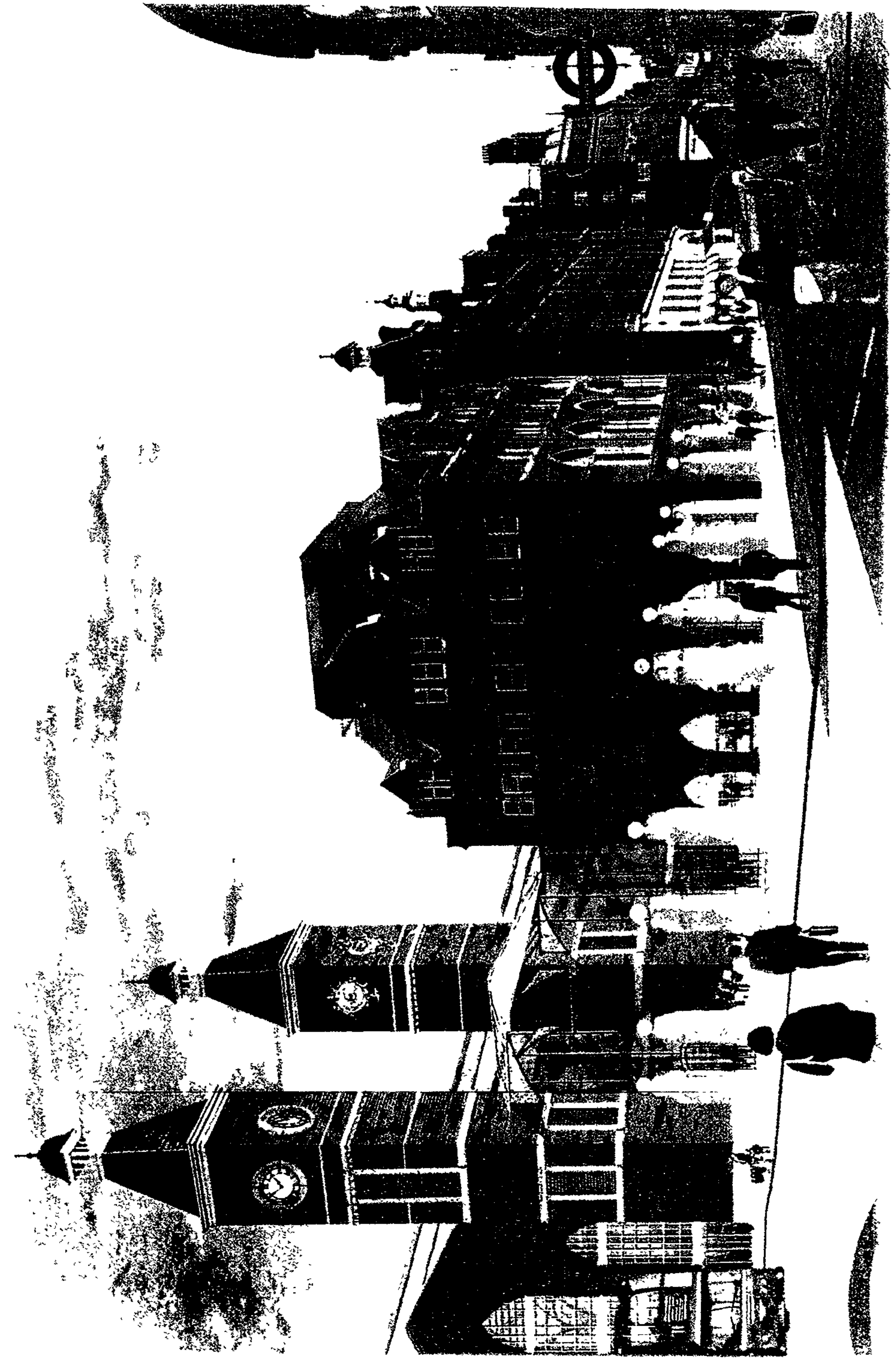
6th March, 1991
Ref: 300/115

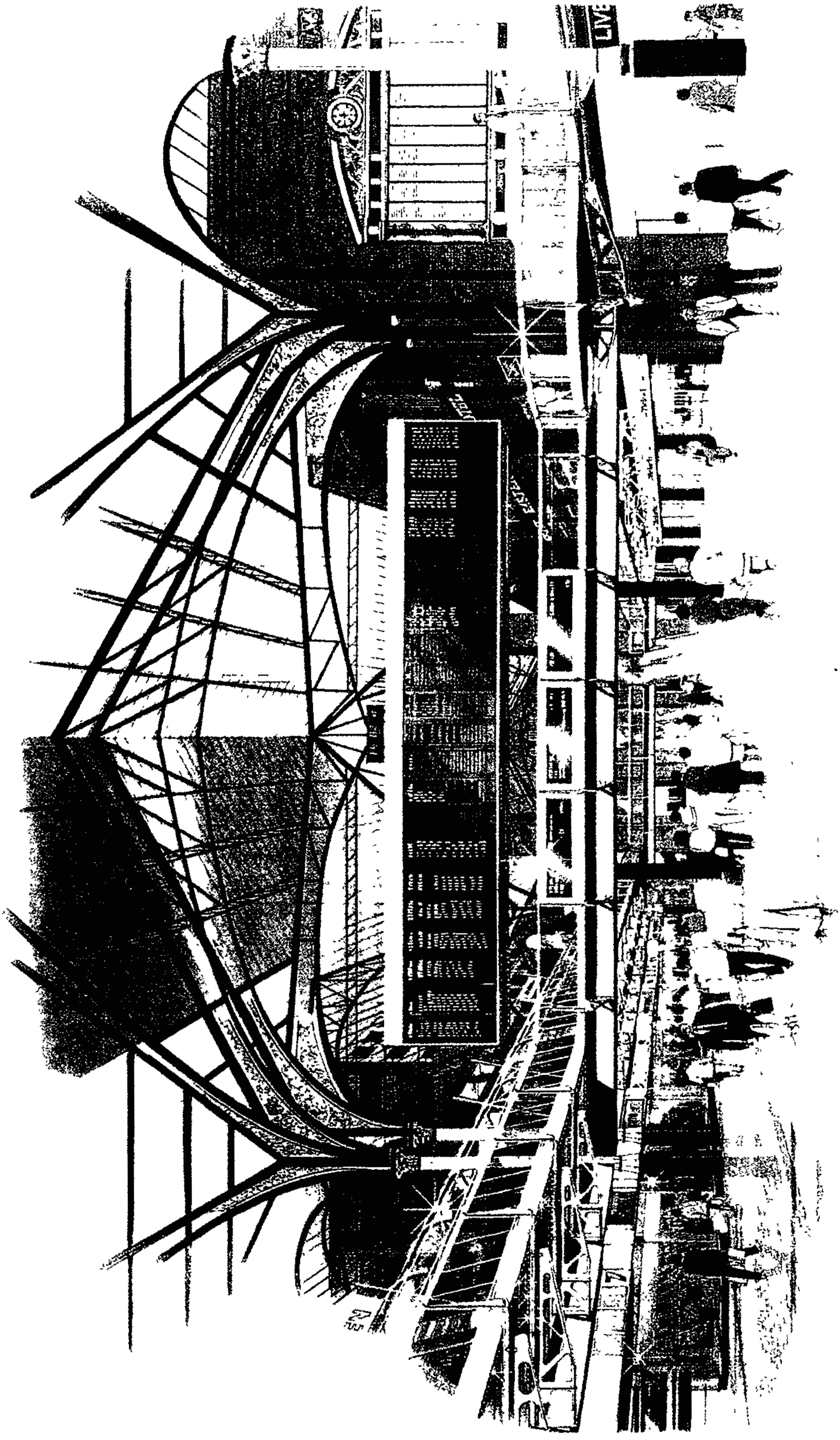
LIVERPOOL STREET REDEVELOPMENT

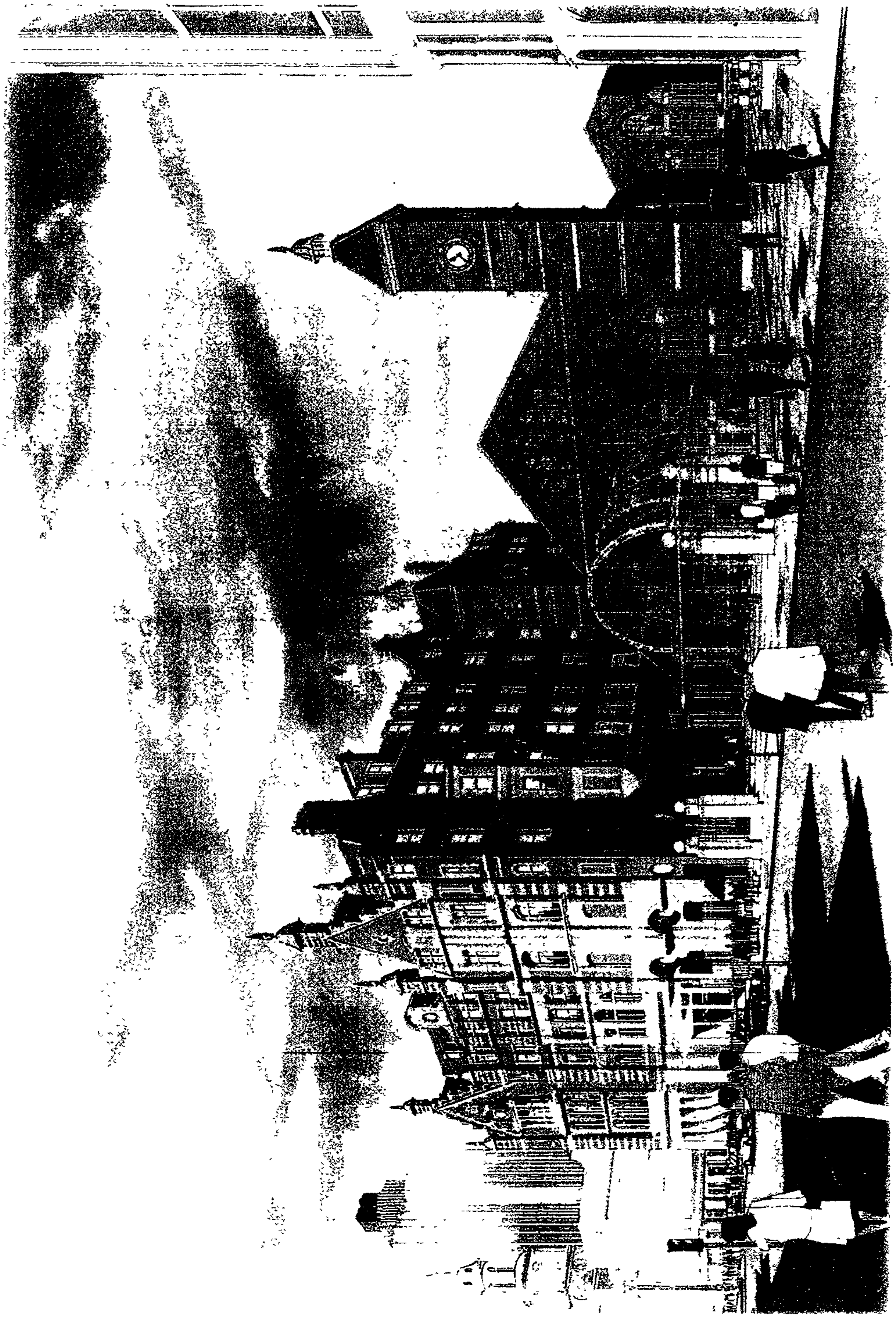
PROPERTY DEVELOPMENT: PLANNED OFFICE AREA BY PHASE
(FIGURES IN MILLION SQ FEET)

Phase	Gross Office Area	Position and Tenant	
1	0.17	OCCUPIED	Security Pacific
2	0.36	OCCUPIED	Shearson Lehman
3	0.44	OCCUPIED	Union Bank of Switzerland
4	0.29	OCCUPIED	Mitsui Bank Trust Wm De Broue and Rosehaugh Stanhope
5	0.23	OCCUPIED	Bankers Trust
6	0.41	OCCUPIED	National Westminster Bank
7	0.47	OCCUPIED	Northern Trust Framlington, Sumitumo, Guardian Royal Exchange and Bank of Scotland
8	0.45	UNDER CONSTRUCTION	
9&10	0.34	OCCUPIED	Alex. Laing Cruikshank
11	0.46	OCCUPIED	Herbert Smith Strauss Turnbull
12)) 13)	0.39	SEEKING PLANNING CONSENT	
14	0.18	UNDER CONSTRUCTION	
Total	4.20		

NB: Phases 8 and 14 - Negotiations with prospective tenants currently in progress







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Ray Ryan
Ms Susan Wood

Hazardous Goods Risk Assessment. Scoping Study

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2000 International Rail Safety Conference

NEW ZEALAND RAIL LIMITED

HAZARDOUS GOODS RISK ASSESSMENT

SCOPING STUDY

A Presentation to International Railway
Seminar at British Rail October 1991

R S Ryan
Executive Manager
Quality & Safety
NZRL

Susan Wood
Consultant
GCNZ Woodward Clyde
Auckland NZ

NEW ZEALAND RAIL LIMITED

HAZARDOUS GOODS RISK ASSESSMENT

Executive Summary

During the past decade there has been a growing concern in New Zealand over the hazards and risks posed by the usage, handling and transportation of these goods.

NZRL carries a wide range of hazardous goods on its freight services. However they consist of only about 3% by volume of all goods carried. Although the volume of hazardous goods transported on Rail has considerably reduced over the past six years, NZRL had not undertaken a review of its procedures and compliance for handling and transportation of these commodities for some time.

A risk assessment was commissioned with the view to developing an effective risk management regime, to ensure obligations were met for optimising safety in terms of employees and the public at large.

The qualitative risk assessment was used to provide a preliminary prioritisation of risks for the purpose of resource allocation. Based on data from 10 years of operation, it established mechanisms of failures, categorised goods into groups then assessed impacts on people, property and the environment. A risk evaluation matrix was formed so that a "Total Risk Score" was produced on which priority for further works was based.

The matrix was subjected to a sensitivity analysis before results were confirmed.

NEW ZEALAND RAIL LIMITED

HAZARDOUS GOODS RISK ASSESSMENT SCOPING STUDY

Background

Modern safety management has recognised that accidents contribute significantly to loss of image and profit, and that it is imperative to implement effective safety and loss control programmes to protect and preserve human life, the environment, and property. NZRL commissioned a study in view of the current trends emerging both nationally and internationally towards improved management of hazardous materials, and any activities and operations working with such materials within the company. The findings were incorporated into safety and loss control programmes of the various business groups.

Study Terms of Reference

A comprehensive risk assessment of all the hazardous goods related operations and activities of NZRL would be a major undertaking. It would initially be of limited value in the identification of priorities for a safety and loss control programme. It was considered that most benefit would be gained by firstly, limiting the scope of the initial risk study and secondly, developing the overall work programme in stages. The strategy was therefore to commence with a scoping exercise.

The scoping study covered a coarse investigation of the risks posed by the handling and transport of hazardous materials within the NZR freight operation. The Interisland ferries were excluded. These limits were set on the basis that within this operation, the largest volumes of hazardous materials are handled. Also, accidents occurring within the rail operation (such as mainline derailments and collisions) have the potential for large scale consequence to people, the environment, and property. Nonetheless, it was recognised that the other areas of hazardous goods usage and handling within NZR may also present significant hazards.

For the purposes of the study, the NZR rail operations was defined as follows:-

> All activities directly or indirectly involved with the transport of hazardous materials via rail; comprising procedures and documentation, the physical loading/unloading of goods, as well as shunting, marshalling, and the movement of trains. This definition excluded the operation of private sidings used for the loading and unloading of bulk hazardous goods (these areas are outside of the control of NZR as private sidings are owned by commercial operators).

The principal objectives of this scoping study were:-

to describe and gain a general understanding of all NZR rail related operations, procedures and safety management programmes related either directly or indirectly to the handling/transport of hazardous materials:

to describe the types and quantities of hazardous materials transported by the NZR rail operations by time, route, and mode of transport (bulk or small goods consignment):

to describe, in broad qualitative terms, the main hazards presented by the hazardous materials and activities with a potential impact on people, property, and the environment:

to analyse the available relevant existing incident/accident statistics and to evaluate the contributing causes:

to develop coarse-scale fault trees for defined failure modes and accident scenarios:

to use a qualitative risk assessment technique enabling the preliminary prioritisation of risks:

to outline preliminary recommendations for a hazardous goods risk management programme, and recommendations for future risk assessment work.

Study Rationale

The concept of risk can be defined in a triplet of; "what can go wrong (the event), how likely is it to happen (the probability) and what are the damages (the consequences)". There is no constant formula for conducting a risk assessment. Because the risk assessment process is an analytical tool, the methodology is often tailored to suit the specific requirements of a study. The scoping study consisted of five basic parts and focused on three components (ie hazard assessment, determination of failure modes, and identification of impact descriptions). Two following steps (consequence and risk assessment) were addressed partially and qualitatively only.

The risk assessment carried out in the scoping study was developed in steps which involved:

- the collation and review of pertinent information about the rail transport system, hazardous goods transport data, as well as accident/incident data.

- the identification of hazards and main accident scenarios involving hazardous materials. This comprised the analysis of initiating events and contributory causes, and the documentation of qualitative fault trees.

- the definition of the impact groups potentially affected by accidents involving hazardous materials.
- the determination of pathways leading to impacts and estimation of the resulting consequences.
- the quantitative assessment and preliminary prioritisation of the identified risks.

The methodology is diagrammatically illustrated in figure 1.

Hazardous Goods Statistics in NZRL

A preliminary review of available data in NZR indicated that there were two freight categories which need to be addressed in the assessment of the risks involved in the transport of hazardous goods. These were the bulk transport of materials such as petrol, fuel oils, LPG, etc and the transport of hazardous goods in small consignments in general goods or BTO (Bulk Tonnage Operator) container wagons. In general, the quantity of hazardous goods is small when compared to the total freight handled by NZR; 1988 only 3% by volume of total freight.

Bulk hazardous goods (petrol, fuel oils, chemicals, LPG, oil etc) constitute about 143000 tons of freight per year (1988). The majority are transported via a few main routes. In general bulk tankers are shunted from private sidings and placed on regular scheduled trains.

In assessment of the risk presented by the transportation of hazardous goods, information such as, kilometres travelled, tonnes hauled, travel time from one terminal to the next, schedules, timing in marshalling yards and traffic densities needed to be understood, so that exposures and probabilities could be assessed.

Hazardous goods are also transported as small consignments in general goods or BTO wagons. Although quantities are significantly less, other factors such as packaging, storage and handling practices are factors to be understood in the risk assessment process.

Hazards Presented by Class of Hazardous Materials

By their nature the different types of hazardous materials present different types of hazards and risks to people, the environment, and property. To facilitate the understanding and managements of these hazards, similar types of materials are generally grouped into classes.

Mostly hazards only arise if a loss of containment occurs. However, some materials can spontaneously ignite or explode upon physical impact, or when heated, such as by an external fire. Explosives, gases, flammable and combustible liquids, flammable solids, oxidising agents, materials with toxic properties and corrosives present hazards ranging through fire, flash fire, vapour clouds, dust explosion, toxic gases, toxic and corrosive spills.

The consequences depend on the types and quantities of material involved and impact distance. In addition consequences vary depending on the target; (people, property or the environment).

NZRL has always had a reporting system for incidents and accidents involving hazardous goods. However, its adequacy in terms of modern safety management principles appeared to be in need of overhaul, especially in the relation to definition, responsibilities, consistency, and completeness.

Data was scrutinised, and augmented by sample investigations to help understand the existing regime. Figures 2 & 3 illustrates some of the findings relating principally to the "immediate" causes. The objective of a proactive safety management requires establishment of the "basic" or "fundamental" cause around which management action can focus for improved performance.

Figure 4 illustrates the principal loss causation model.

Accident Scenarios

This part of the scoping study focused on defining the main accident/incident scenarios involving hazardous goods, and on developing fault trees which showed the logical sequence and internetting of contributory causes leading to an accident. This was based largely on the evaluation of historical accident/incident data.

Primary Fault Trees

In the construction of primary fault trees, the main objective is to define the principal accident/incident scenarios, and their "immediate" causes. As focus was placed on accidents/incidents involving hazardous materials, the number of principal accident/incident scenarios was limited.

Due to the nature of hazardous materials and their handling procedures, risky situations will arise if a loss of containment or control occurs. In other words , hazardous materials can be very safe so long as they are stored, handled, and transported under appropriate conditions. However, if for any reason a loss of containment occurs, and a hazardous material escapes or spills, through the resulting leak there is the potential for consequences which are determined by the nature and quantity of the material leaking, and the surrounding circumstances of the event. For example, an escape of LPG only becomes hazardous if a source of ignition is available, and the extent of the resulting event (eg, BLEVE, fire, flash fire, or vapour cloud explosion) is determined by the quantity of LPG released, and site-specific conditions such as wind speed, etc.

There are circumstances where, without loss of containment, hazardous materials can cause accidents or incidents. This is the case with hazardous materials which can spontaneously react or ignite. Such accidents/incidents are generally triggered by outside causes, such as heating (in an external fire, or when exposed to sunlight), impact, or contact with potentially incompatible substances. However in comparison to accidents/incidents which are a result of loss of containment, they are comparatively rare. As a consequence, emphasis was placed on investigating the former accident/incident scenarios, and analysing the contributory causes. It should be noted in this context that many of the immediate causes leading to loss of containment are also immediate causes for other types of accidents/incidents.

The fault trees developed therefore were all based on one accident/incident scenario, which is, the leak, or loss of containment of a hazardous substance. There are five primary immediate causes leading to loss of containment, but there are possibly other, less significant causes as yet not identified.

Fault trees describe combinations and mutually excluding causes which can lead to a specified accident/incident. As fault trees are based on probabilistic theory, individual causes and cause branches are linked with each other via gates. If causes are additive, e.g., if an accident only occurs if a combination of causes eventuate, then these causes are linked by an "AND" gate. If causes are alternatives, e.g., if an accident only eventuates as a result of one cause out of several, then these causes are linked by "OR" gates.

To remain within the brief of the scoping study, only primary and secondary fault trees were developed in order to avoid unnecessary complexity. Contributing causes of lower hierarchy were listed, but not set up as a fault tree structure, so that focus could be centred on immediate and basic causes. As the principal objective of this exercise was to illustrate the causation hierarchy leading to specified accident/incident scenarios, the resulting fault trees were kept entirely descriptive and qualitative; i.e., no probabilities were assigned to any of the pathways.

The main immediate causes established were :-

- derailment
- collisions
- failure of containment/equipment (of bulk rail tankers)
- inadequate storage
- faulty packaging

Existing information with NZR on accidents involving hazardous materials has shown that "inadequate storing and faulty packaging of goods" are the most frequent causes for loss of containment. A negligible proportion were caused by either derailment or collision. Loss of containment caused by equipment faults (eg leaky valves, ruptured tanks etc) were slightly more frequent. However, these conclusions may have been somewhat misleading.

Firstly, faulty packaging and inadequate storing mostly concerns small goods consignments with limited inventories. Therefore while these accidents are known to happen frequently they are expected to have limited consequences.

Secondly, catastrophic accidents normally require a bulk load to be involved. Bulk loads are subject to stringent storage and transport and other safety related regulations. Therefore, not only are accidents resulting in the release of bulk loads expected less frequently, but the actual release itself is less likely.

Thirdly, the period of data review is short for assessment of low probability-high consequence events.

The qualitative fault trees developed (examples figures 5 & 6) are conceptual. The true risk of specific accident scenarios could only be assessed once the probability of occurrence had been assessed and a full analysis of the impacts made. The methodology is diagrammatically shown in figure 1.

Prioritisation of Risk

A coarse, qualitative risk assessment technique was developed using a risk evaluation matrix. The main objective of this technique was to develop an understanding of the relative importance and magnitude of risks by calculating "risk scores". These risk scores do not represent an absolute risk value, but help to put the different types of risk into perspective. The technique involves the application of professional judgement. Some important circumstantial factors, such as the quantities of materials involved, or the location of an accident, were not taken account of in this matrix.

Despite some drawbacks, the approach has merit in the preliminary appreciation and evaluation of risks, and finds wide-spread support (GCNZ Consultants, and H M Tweeddale Consulting Services 1989; McDonnel, 1989; Reid 1989; and Waite and Shillito 1988). In the initial stages of a risk assessment, such a technique can be an extremely valuable tool to rank and prioritise risks whilst avoiding expenses for detailed quantitative risk assessment work. It should be noted that an initially qualitative approach does not pre-empt the need to carry out targeted quantitative assessment work at a later stage.

Risk Evaluation Matrix

The adopted risk assessment technique consisted of a simplified scoring matrix (risk evaluation matrix). In the matrix, the six types of hazards representing the main hazardous goods transport categories were evaluated:

- General goods (comprising all small goods or bulk tonnage operator consignments, and hazardous classes.

- LPG (bulk)

- Petrol (bulk)

- Chemicals (bulk liquid)

- Chemicals (bulk solids)

- Fuel Oil, Oil, Diesel (bulk)

The main categories of impact considered in the risk evaluation matrix were people, property, and the environment. Under these categories, further sub-categories were created to allow the distinction between NZR employees and the public, and between NZR and public property. This distinction was made to allow NZR management to differentiate between internal and external safety decisions.

For the matrix, three different types of scales were developed. The first was used to describe, in relative terms, the likelihood of accidents involving a specific category of hazardous material. This was based on evaluating the historical frequency of such accidents. The second defined the scale of the resulting consequences to people, property, and the environment. The third assessed the likely magnitude of cumulative effects. Cumulative effects, which are relatively less important, arise if the same types of accidents occur on a repetitive basis. Each scale was assigned a range of scores between 1 - 6, which are outlined in Figure 7. To give each of the three impact groups an equal weighting in determining the total risk score, the value of the environmental risk score was doubled to compensate the weighting of the people and property risk scores.

The calculation of risk scores for each of the identified hazards and total risk score involved the following steps:

- Multiply the historical frequency (F) for each hazard, by the severity scores (S) assigned to each type of impact, to arrive at individual risk scores (in parentheses)

- Multiply the environmental risk scores by a factor of 2.

- Determine the total risk score by adding risk (sub-total) scores within the same hazard group, plus the cumulative impact score.

Evaluation Of Risks

The risk evaluation matrix is presented in Figure 7. The highest total risk scores were attributed to general goods accidents involving hazardous materials and bulk LPG transport, followed by the bulk transport of liquid chemicals. The bulk transport of petrol, fuel oils and bulk solid chemicals featured relatively lower rankings and were therefore rated less significant in terms of risk priority.

The risk presented by general goods transport was characterised by a high probability of occurrence of accidents (as indicated by historical accident records), but only small to medium scale consequences. Major factors contributing to the magnitude of the risk score were risks to NZR employees and possibly emergency services, as well as damage to NZR property. A high cumulative score in this context was considered to be a function of the highly repetitive nature of these accidents.

The risk presented by bulk LPG transport was mainly influenced by events with potentially large-scale and catastrophic consequences, which however had a comparatively lower probability of occurrence. High individual risks were predicted equally for NZR employees and property, as well as public life and property.

Liquid chemicals were interpreted to present a risk to human health or life (either by direct exposure, or volatilization of toxic components) and also the environment. The extent and magnitude of these risks is significantly determined by the type of chemical concerned. Generally, it can be said that the bulk chemicals transported by NZR are moderately hazardous (such as acids and bases).

The main risk presented by petrol is a high flammability, which can result in injury or loss of life (both NZR employees and the public), and damage to NZR and public property mainly through heat radiation. Also, petrol can cause significant damage to the environment if substantial quantities are split and dispersed.

A significant part of the risk presented by the bulk transport of fuel oils resulted from the potential damage to the environment in the case of spills. Risks to people and property were of lower significance due to the low flammability of the materials. Bulk solid chemicals feature at the bottom end of the total risk score. This was mainly due to the consistency of the materials and their low potential for dispersion.

Sensitivity Analysis of Matrix

This analysis was undertaken by assuming different "weightings" within the groups of impact targets. In general it was concluded that the initial risk scores were a sound basis on which to allocate resources for an action plan for further development.

Principal Actions Taken

As a result of the study the ongoing programme included:-

1. A review of accident/incident reporting systems to enhance quality, reliability and effectiveness of information flows.

2. Safety audits of procedures, handling and documentation activities was undertaken at terminals focusing on small consignment of hazardous goods.

3. A quantitative risk analysis was proposed for the LPG operation. However, subsequent to completion of the study, volumes reduced significantly. A safety audit of the whole operation from customer loading point to empty return was undertaken instead.

4. A more rigourous approach to accident/incident monitoring and

analysis was set up with particular emphasis on the relatively lower ranking hazardous groups as defined in the matrix.

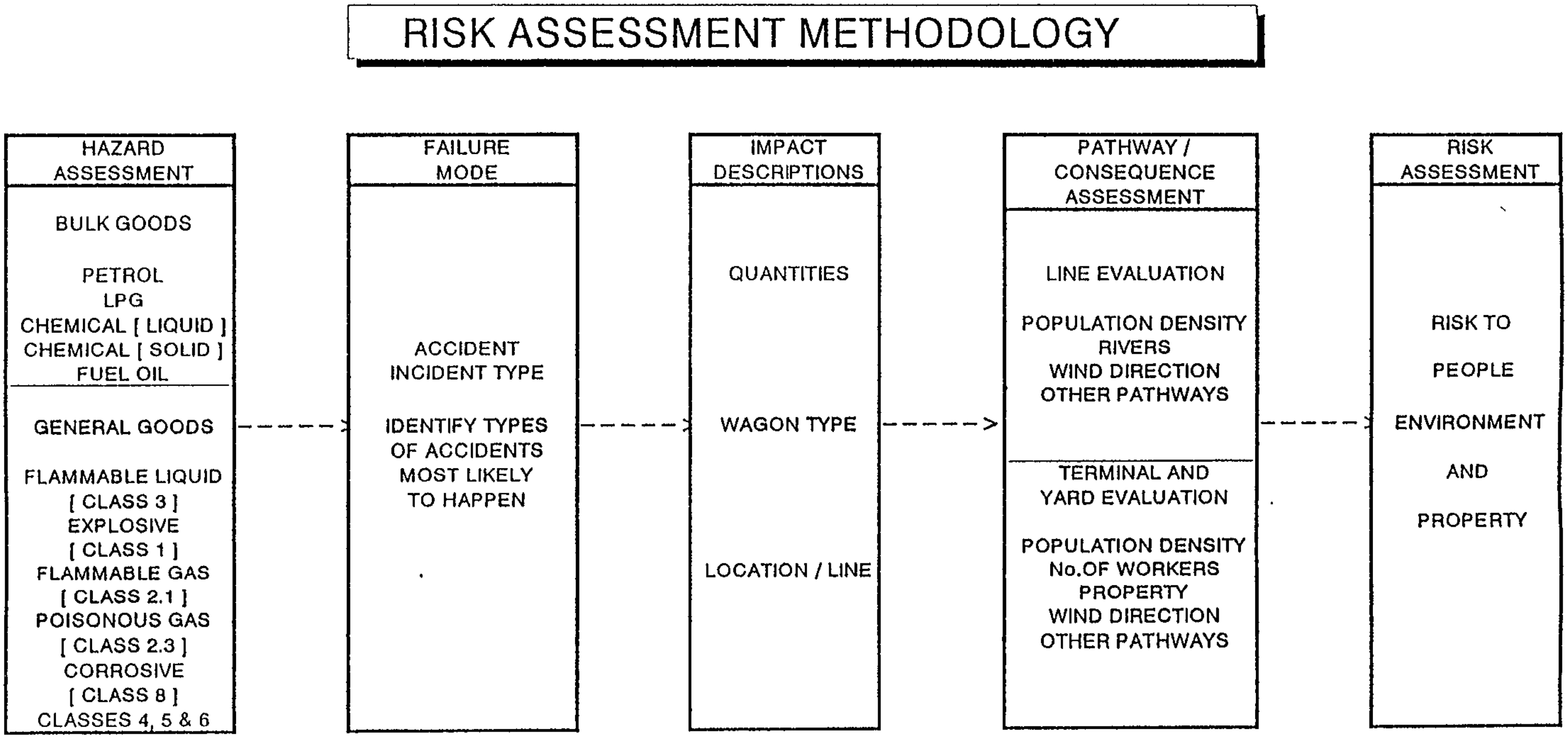
Epilogue

NZRL has been undergoing continuous restructuring involving major downsizing preceding, during and since completion of the risk evaluation exercise. In addition, the New Zealand economy has been in a severe retrenchment mode. Changing market conditions, staff deployment and resource allocation meant that acceptance and progressing of the issues arising from the review have been somewhat slower that anticipated. This has not detracted from the value of this report both in setting a strategic plan for action in this sphere and a demonstratable rationale for justification of resources should the need arise.

Acknowledgements

New Zealand Railways Commissioned GCNZ - Woodward Clyde to undertake this risk assessment scoping study. Susan Wood and Phillip Brown of that Company fulfilled the commission. David Elms, Professor of Civil Engineering, Canterbury University advised on methodology. R S Ryan of NZRL managed the project through the development and on-going phases.

FIGURE 1


RISK ASSESSMENT METHODOLOGY
HAZARD ASSESSMENT
BULK GOODS
PETROL
LPG
CHEMICAL [LIQUID]
CHEMICAL [SOLID]
FUEL OIL
GENERAL GOODS
FLAMMABLE LIQUID
[CLASS 3]
EXPLOSIVE
[CLASS 1]
FLAMMABLE GAS
[CLASS 2.1]
POISONOUS GAS
[CLASS 2.3]
CORROSIVE
[CLASS 8]
CLASSES 4, 5 & 6
FAILURE MODE
ACCIDENT INCIDENT TYPE
IDENTIFY TYPES OF ACCIDENTS MOST LIKELY TO HAPPEN
IMPACT DESCRIPTIONS
QUANTITIES
WAGON TYPE
LOCATION / LINE
PATHWAY / CONSEQUENCE ASSESSMENT
LINE EVALUATION
POPULATION DENSITY
RIVERS
WIND DIRECTION
OTHER PATHWAYS
TERMINAL AND YARD EVALUATION
POPULATION DENSITY
No.OF WORKERS
PROPERTY
WIND DIRECTION
OTHER PATHWAYS
RISK ASSESSMENT
RISK TO
PEOPLE
ENVIRONMENT
AND
PROPERTY

SPILLAGE BY CONTRIBUTORY CAUSE

1981 – 1988

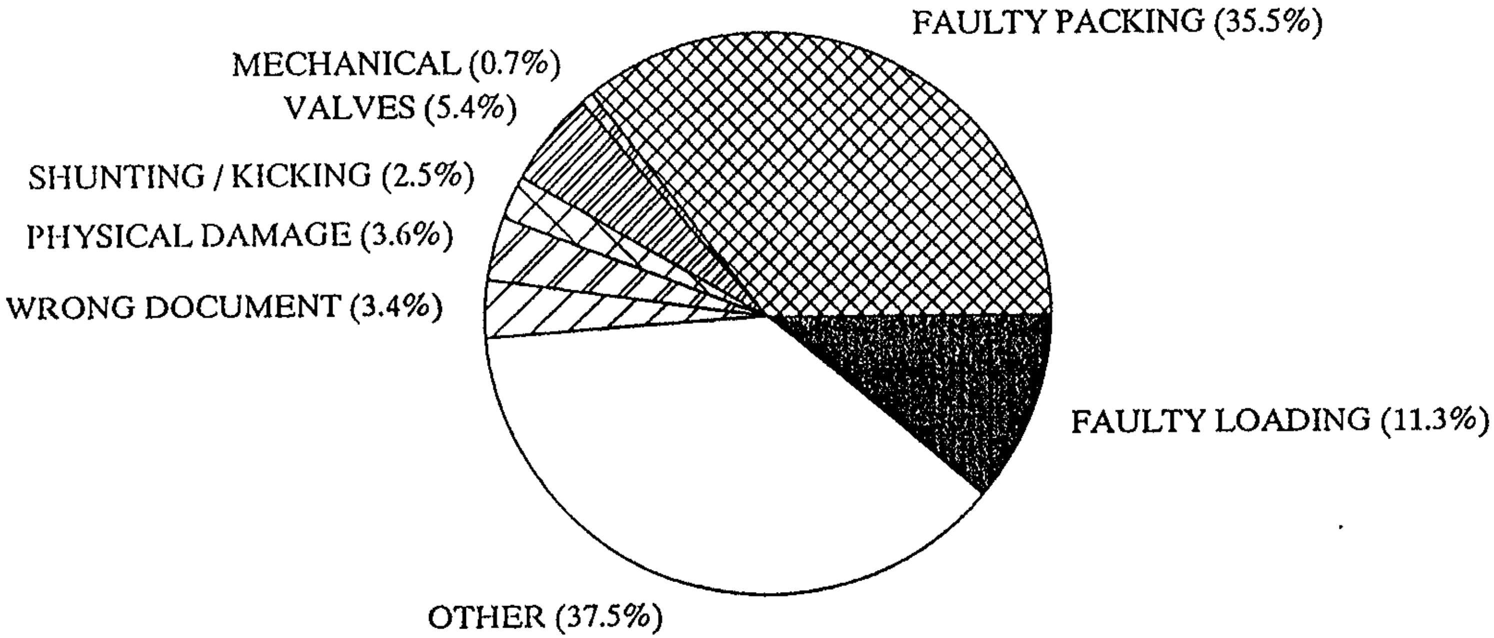


FIGURE 2

SPILLAGE PER WAGON TYPE

1981 – 1988

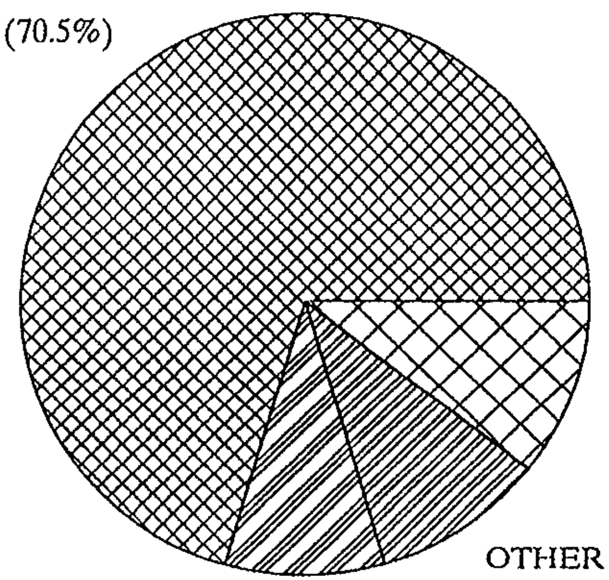


FIGURE 3

FIGURE 4

LOSS CAUSATION MODEL

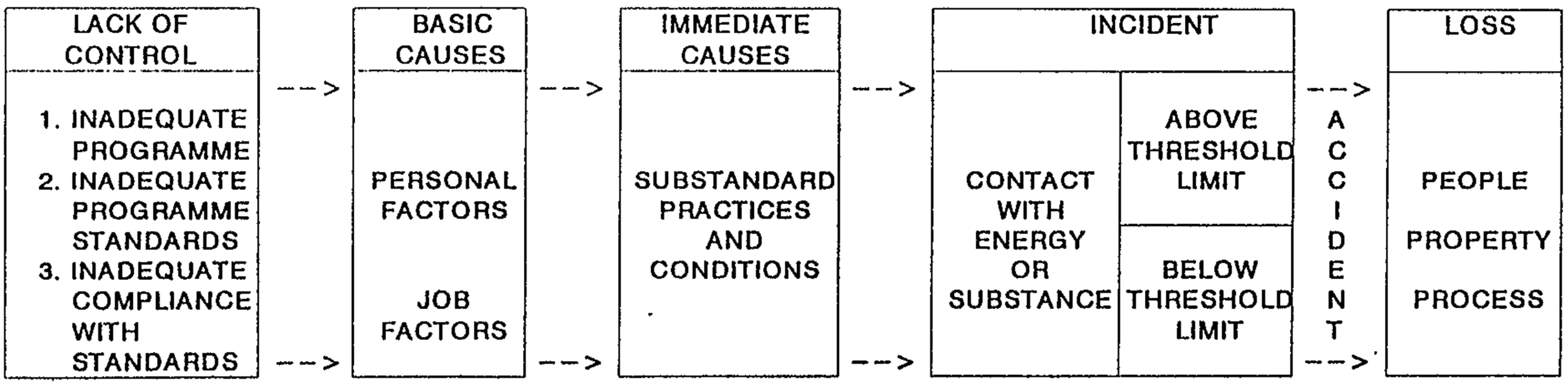


FIGURE 5

YARD ACCIDENT SCENARIOS

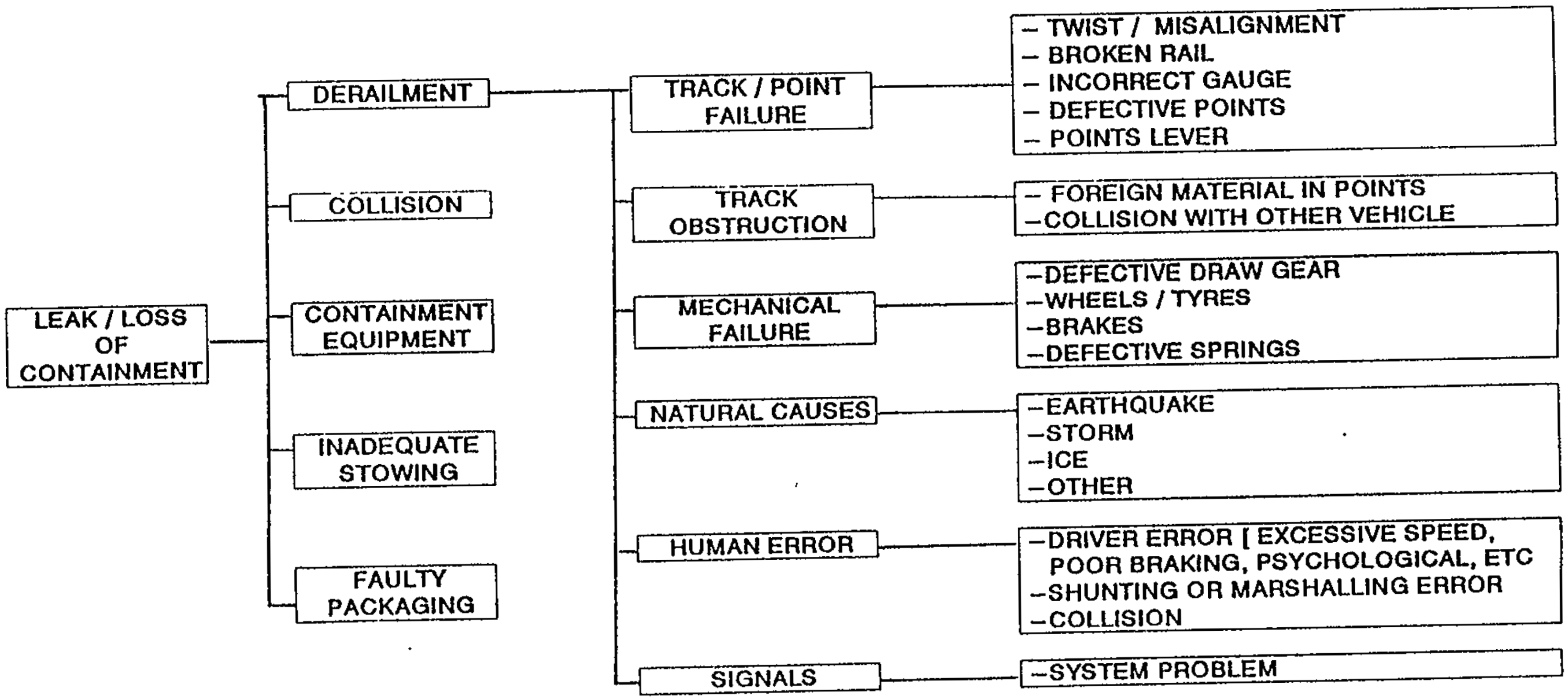


FIGURE 6

INADEQUATE STOWING ACCIDENT SCENARIOS

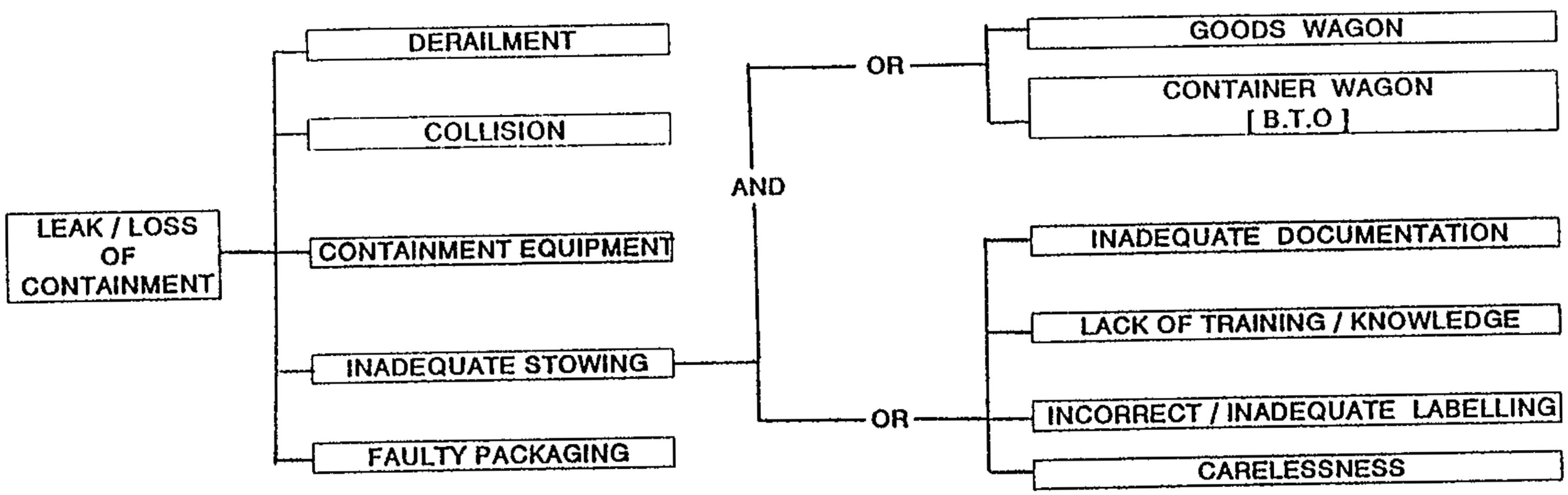


FIGURE 7

RISK EVALUATION MATRIX

HAZARD	GENERAL GOODS			LPG			CHEMICALS LIQUID			PETROL			FUEL OIL OIL, DIESEL			CHEMICALS SOLID		
IMPACT GROUP	F	S	F	F	S	F	F	S	R	F	S	F	F	S	R	F	S'	R
PEOPLE																		
–NZR	6	4	24	3	6	18	3	4	12	2	4	8	2	4	8	1	3	3
–PUBLIC	6	2	12	3	6	18	3	4	12	2	6	12	2	2	4	1	2	2
RISK SUB TOTAL			36			36			24			20			12			5
ENVIRONMENT	6	1	12	3	1	6	3	5	30	2	5	20	2	5	20	1	3	6
PROPERTY																		
–NZR	6	4	24	6	6	18	3	2	6	2	3	6	2	2	4	1	3	3
–PUBLIC	6	2	12	3	6	18	3	4	12	2	5	10	2	1	2	1	1	1
RISK SUB TOTAL			36			36			18			16			6			4
CUMULATIVE IMPACT			6			2			2			2			2			2
TOTAL RISK SCORE			90			80			74			58			40			17

RISK SCORE [R] = FREQUENCY [F] x SEVERITY [S]
TOTAL RISK SCORE = RISK SUB TOTALS + CUMULATIVE IMPACT

LEGEND

ACCIDENT FREQUENCY	*SCORE [F]*
VERY LOW [<0.5%]	*1*
LOW [0.5 – 2%]	*2*
LOW TO MED [2 – 5%]	*3*
MEDIUM [5 – 10%]	*4*
MED TO HIGH [10 – 50%]	*5*
HIGH [>50%]	*6*

SEVERITY	*SCORE [S]*
NEGIBLE	*1*
LOW	*2*
MODERATE	*3*
MODERATE –HIGH	*4*
HIGH	*5*
VERY HIGH	*6*

CUMULATIVE IMPACT	
NEGLIGIBLE LIKELYHOOD	*1*
LOW	*2*
MODERATE	*3*
MODERATE –HIGH	*4*
HIGH	*5*
CERTAIN	*6*

** ENVIRONMENTAL RISK SCORE IS MULTIPLIED BY A WEIGHTING FACTOR OF 2*

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Ray Ryan
M. R. Hughes

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WELLINGTON URBAN TRAIN SERVICE

RISK ASSESSMENT SCOPING STUDY

A Presentation to International Railway Seminar
at British Rail October 1991

R S Ryan
Executive Manager
Quality and Safety
NZRL

M R Hughes
DMR Consultants Limited
Wellington NZ

NEW ZEALAND RAIL LTD

WELLINGTON URBAN RAIL SYSTEM

RISK ASSESSMENT SCOPING STUDY

INTRODUCTION

The Wellington urban area is served by an Electric Multiple Unit Rail System which leads into the city in 3 principal "arms".

The routes converge in the Wellington Railway Yard where Depots, freight handling Interisland ferry terminal activities are performed. The city station is on the end point of the converged routes. A schematic layout in illustrated in figure 1.

Two serious accidents occurred in the yard area; one in 1979 resulting in 44 injuries and the other in 1980 resulting in 2 deaths and 77 injuries.

In 1990 a risk assessment study was embarked upon with the principal objective of identifying the elements in the whole operating system that needed to be addressed for the maintenance of safe operation. The 1st stage of the assessment was a scoping study. The study proceeded by initially undertaking a pilot study on one line, Wellington to Trentham (near Upper Hutt).

The scoping study's aim was to set the foundations for obtaining measurable and comparable values of the risk to passengers, staff, other persons and property in the Wellington Urban area. In addition the work led to a better understanding of the safety issues affecting the risks associated with Rail Transportation and the factors affecting railway incidents and accidents. In order to undertake a risk assessment it is necessary to develop a quantified procedure, or model, that can be used to evaluate the effects of specific factors on the level of safety of the system. Any such procedure, or model, uses expected frequencies or rates of incidents, and consequently must be based around the concepts of probability theory.

Of the modelling techniques available for the quantification of the incident frequencies, the Fault Tree methodology was chosen as being the most suitable for this study.

FAULT TREES

The Fault Tree analysis is deductive in nature and is used to trace back the causes of a complex event to simpler events, ultimately to basic failures for which appropriate data exists or can be generated.

The data is usually supplied as failure rate. That is, expressed as failures per unit time, typically failures per year or failures per million hours.

Components, which are called upon to act infrequently eg. emergency equipment, alarms etc, have their failure rates expressed as a probability of failure per demand.

Human failures are also expressed as a probability, and have two aspects:

- introduction of incipient faults designed into the system
- the failure of humans to carry out required duties or functions

All probabilities are input into the lowest level of the fault tree and the overall probability of the undesired complex top event is calculated.

The main objective of this scoping study was to derive fault trees for the Wellington Urban Rail System that could then be used during the Pilot study to undertake a Quantified Risk Assessment of the Wellington to Trentham line.

In undertaking a Fault Tree analysis it is important that:

- the boundary and function of the system are well defined and understood
- the undesired top event is well defined

To satisfy both of the above criteria, the study proceeded by first undertaking a hazard identification exercise and then the preparation of a checklist of safety issues.

HAZARD INDENTIFICATION STRATEGY

For this scoping study the hazards were identified by examining the operation from the broadest viewpoint possible in a structured and documented fashion. The methodology used attempted to maximise both direct and indirect experience and involved:

- On Site Inspections

  The Consultant and Railway project representatives travelled on the units between Wellington and the Hutt Valley in the cab of the unit with the driver. Note was made of any hazards observed, or pointed out by the Loco Engineer and Train Manager

- Interviews with NZR Personnel

  A questionnaire was prepared then and train crews, signalmen, supervisors, maintenance, management and design staff were interviewed.

  The scope of the interviews was not limited to the Wellington to Trentham line, but encompassed the whole Wellington Urban Train Service. This served to identify:

  - common and specific safety issues that could be dealt with immediately, -- for all lines

- any differences, in relation to safety issues, that may exist between Wellington/Trentham and the other two routes

The personnel were chosen for their experience and knowledge of the Wellington Suburban Rail System, and NZR operations in general.

In conjunction with these interviews, a separate study was commissioned to:

- identify all events which pose potential threats or hazards to the rail route between Wellington and Trentham and;
- identify potential threats arising out of the rail usage to property and population located along that route.

A survey of land uses along the rail corridor was undertaken which gave a broad spectrum of these potential hazards.

Aerial photographs were used as the base for the survey and a further assessment carried out on the ground by travelling along the route both in the multiple unit and by car/foot.

Following the hazard identification a checklist of rail safety issues and concerns was prepared. This checklist formed the basis of the fault tree construction. Discrepancies and omissions identified were investigated further and a final list issued.

HAZARD IDENTIFICATION RESULTS

Personnel Interviews

Immediate safety issues arising from the interviews were dealt with immediately through the normal management channels. Briefly, the issues raised were:-

- Internal Carriage Communications

  Communications through the length of the unit was not always possible due to the necessary switch being incorrectly set. Confusion existed amongst some Train Managers and Loco Engineers as to whose responsibility it was.

- Debris

  Poor housekeeping results in stones, debris, lengths of rail, fish plate bolts etc being left on the side of the track which subsequently find their way onto the track and into the switch blades of turnouts.
- Reporting Procedures

  Confusion over the correct procedure for reporting faults or repair and maintenance requests

- Radio Communication

  Some interference in the train radio system from taxis, trucks, Speedlink vans around the Plimmerton to Pukerua Bay areas. (Paraparaumu route)

- Track Side Phones

  Johnsonville line phones not always working or poor quality.

- Ambulance Boxes and Fire Extinguishers

  Are being vandalised and are not being repaired.

All personnel interviewed were co-operative and forthcoming. Common concerns and issues raised by different personnel led to the belief that the comments were true and honest.

In general terms the personnel believe that the Wellington Suburban Rail System is a safe mode of transport, and that the greatest risk of injury or death is not to the passengers or staff, but to trespassers on the line, especially in the Hutt Valley and Porirua areas.

External Impact Assessment

The survey along the rail corridor identified major land uses such as residential housing, schools, community centres, racecourse, level crossings and influential topographical features such as seismic fault lines (earthquake potential) and flood plains along a 100 m corridor each side of the rail route. In addition a brief appraisal of events within a 200 m corridor was made.

For the pilot scheme, Wellington to Trentham, the major hazards to the route were identified as:

- Heavy Industrial Areas

  (a) Pomare - Taita Eastern Hutt Road
  (b) Taita - Wingate Peterkin Street
  (c) Petone - Wellington

- Level crossings (4) and major river bridges (3)

- Isolated service stations with a LPG facility

- Geological Feature:

faultlines (earthquake potential) and flood plains of the Hutt River

The major hazards created by Rail operation to property and population located on route were identified as:

- Derailment in residential areas particularly where the track is elevated above housing (Silverstream, Pomare)

- Derailment near facilities which attract large concentrations of people eg; schools, racecourse, shopping centres.

The report also identified areas considered to require more detailed research.

Checklist of Operating Safety Issues

The results of the investigation were formed into a check list of which the main headings were:-

- Rolling Stock

  Primary Structural Crashworthiness
  Non-Structural Crashworthiness
  On train fire safety
  Inspection and Maintenance

- Track and Structure

  Inspection Maintenance practices

- Overhead Traction

  Inspection and Maintenance practices

- Right of Way Security

  Trespassing and Vandalism
  Level Crossings

- Operations

  Signals and Train Control
  Organisation and Communications
  Emergency Response
  Training and Supervision
  Miscellaneous Issues

FAULT TREE DEVELOPMENT

The undesired top events were defined as being passenger, other person, and staff casualties. "Casualties" can be either fatalities or injuries: the same fault trees can be applied to both.

The fault trees are constructed so that separate measures can be obtained for passenger, other person, and staff casualties.

For ease of understanding, the fault trees for all 3 categories (passenger, other person, staff) follow, as far as possible, a common format and layout. For example, Figure 2 shows the major possible causes of passenger casualties. These are shown in the seven boxes in the lower level and are casualties due to derailments, collisions, overhead traction, on-unit incidents, incidents at stations and structures, and other. The third box is empty, as this is reserved for casualties due to other persons and staff on the right of way, shown in Figures 3 and 4. Passengers should not be on the right of way. If they are, then they are classified as other persons, or more specifically trespassers, hence this cannot be a cause of passenger casualties. Similarly, Figure 3 has its fifth box empty as this is reserved for casualties due to on-unit incidents which cannot affect other persons, so is only filled in Figures 2 and 4.

Figure 5 gives the logic by which the probability that a particular passenger will be a casualty can be calculated, given a derailment. The possibility would be dependant on the effectiveness of:

(a) Crashworthiness
(b) Emergency systems and procedures

The combinations of (a) and (b) being OK and NOT OK are shown in the four lower boxes. The eight boxes below these are where the data will be input and are dealt with in the next section.

Figure 6 is the fault tree that gives the probability of a major train being involved in a derailment. The five major causes of a derailment and the relative contributing causes to each are also shown. The fault tree branches for the other major categories follow similar format and logic, as do the fault trees for Other Person and Staff casualties.

PROJECT DEVELOPMENT

The development of the fault tree structures was the significant output from the scoping study. The quantified risk assessment phases were to follow as more specific data was obtained. This work has not proceeded to date, however notes on issues to be addressed are:-

Fault Tree Data Requirements
Sensitivity Analysis
External Impact Assessment

Fault Tree Data Requirements

In order to determine the data requirements for the Fault Trees, it is first necessary to decide how the results should be presented, that is, what final major measures need to be produced.

One measure that is commonly used is a single number eg; the Fatal Accident Rate (FAR) or the probability of fatality per trip or per kilometre. Another measure is an overall annual fatality, or injury, rate.

However, society views multiple fatality accidents more severely than an equal number of single fatal accidents. Regulatory authorities and companies assent to this view. A method of displaying societal risk is shown in Figure 7. This shows on a log-log scale, the estimated frequency (F) of incidents causing N or more fatalities.

Both the FAR and F/N plots have their use, whether for setting management targets, obtaining a number for comparison with other rail operations or transport modes, or for using in a cost/benefit study.

The fault trees as constructed here, can be used to provide both of the above measures, provided that the breakdown into passengers, other persons and staff is retained in the form of Figures 2, 3 and 4.

Probabilities must therefore be input into the lowest levels of the fault trees.

Sensitivity Analysis

Traditionally single numbers based on either historical data or estimates have been input at the lowest level, and a single result then calculated for the top undesired event. Sensitivity analyses are then used to attempt to give an overall range for the undesired event.

If the project had proceeded further, it was intended that use be made of a computer simulation package to ensure that the probability profiles of all the input variables are used to arrive at a true profile of the top undesired event.

Generally, analyses combine simple point estimates of a model's variables to predict a single result. Estimates of model variables must be used because the values which actually will occur are not known with certainty. In reality, however, there are variables, some estimates may be conservative, others may be optimistic. The combined errors in each estimate often lead to a real-life result that is significantly different from the estimated result. Uncertainty can explicitly included in estimates to generate results that show all possible outcomes ,if a simulation package is used.

With the simulation technique all the uncertainties identified in the modelling situation can be combined. The results are no longer restricted to a single number estimates, but give far more information about a variable including its full range of possible values and a measure of likelihood of occurrence.

Historical data may provide a continuous probability distribution for a variable and this can be used directly. Alternatively estimates may have to be made, by the most suitable and experienced personnel, on a variables value, in which case at a minimum, that person should provide.

- the most likely value, say once in 10 years
- the minimum value, say once in 100 years
- the maximum value, say one a year

Whichever is the case, the simulation result will provide a true graphical profile of the undesired event in which greater confidence can be placed than any result produced by simple sensitivity analyses.

External Impact Assessment

The fault trees as constructed only deal with casualties within the NZR land boundaries. A scoping study on all events and threats to and from the rail operation on a 100 m and 200 m corridor either side of the route was completed.

The report identified areas that required further research before their impact can be included in a Qualitative Risk Analysis (Q.R.A). These areas included:-

- Evaluation of the industrial activities identified and the risk their activities posed or could be impacted on by rail operations. This information is particularly important in hazard identification, given the potential for an industrial accident.

- The data requires demographic analysis to gauge population trends, age, structure, and size of households, and the exposure of residents in terms of their movement patterns in relation to the rail corridor, ie, how often do they come into contact with the rail corridor.

- An analysis of land use trends to determine any likely effect on the railways. Pertinent issues include:-

    - Pressure to permit multi-unit dwellings to locate on established sites;

    - Whether shifting of heavy industry from the Petone/Lower Hutt Valley will reduce risks;

    - Industrial encroachment onto residential land may increase risk.

- The identification of conflict between the adjacent roading network and the rail route has not been explored.

- The threat posed to the rail route by the Hutt river and its tributaries in the event of major flooding has not been appraised. The topographical information collected to date is scant and requires further identification of potential hazards. Further work on this aspect would be undertaken in parallel with the next step of quantifying the fault trees.

CONCLUSION

The Wellington Urban Rail System has the highest level of public involvement of any of the Companies activities. It operates in the right-of-way sharing tracks, signalling and traction power with long distance passenger and heavy freight trains. Like most urban passenger systems, revenue generated does not cover full operating or financial costs. Local authorities subsidies contribute to funding (by way of contract) but economic pressures from many quarters contribute significantly to lengthening the negotiating process.

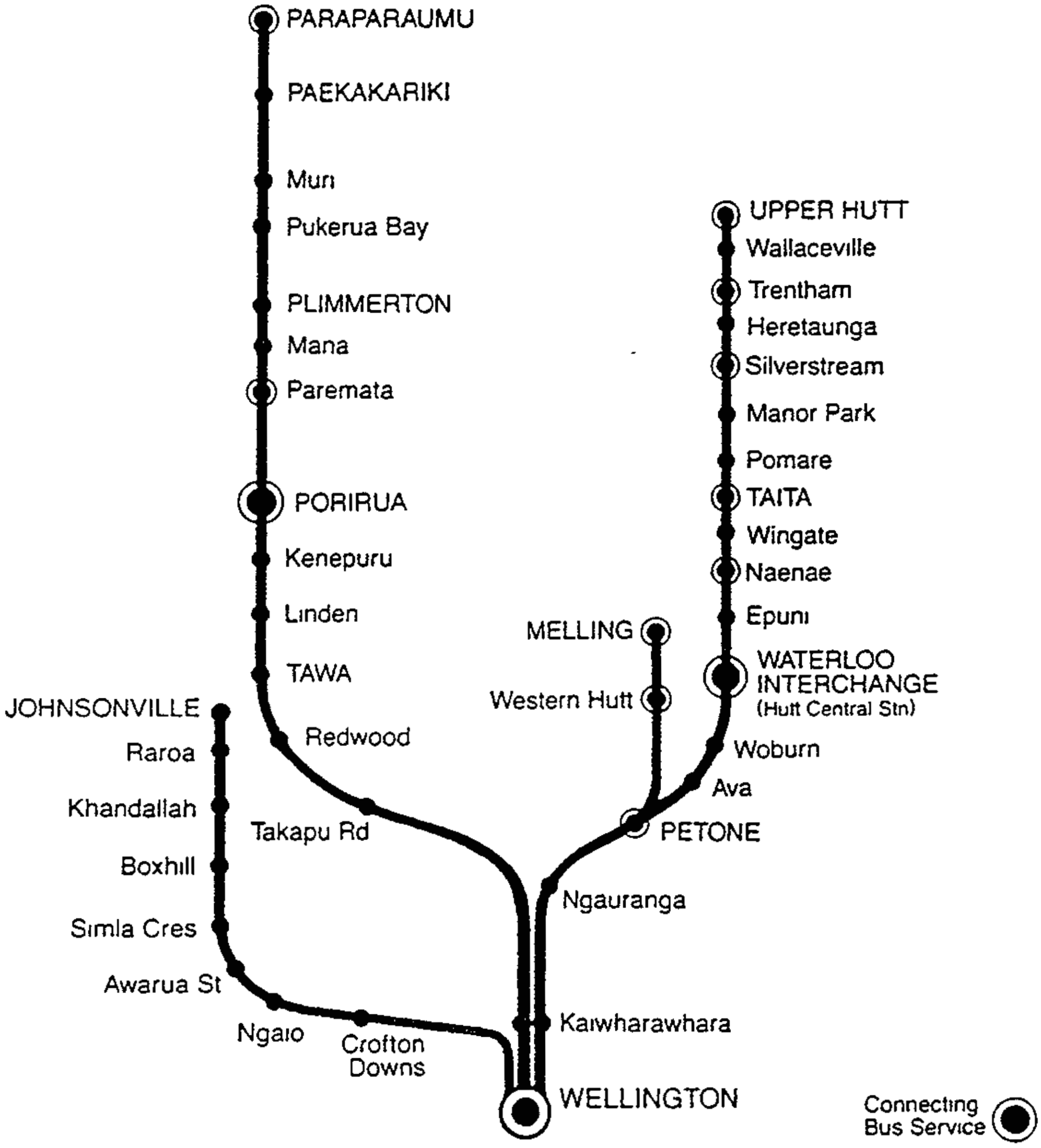
Public expectation of safety performance of the system is high. The Wellington Urban Rail System has a history of train accidents albeit small both in number of incidents and consequent fatalities, and especially small in comparison to urban road deaths. It is therefore important for the company to be vigilant by understanding safety issues and the impact resources have on the maintenance of safety performance.

Although this risk assessment project has not progressed beyond the scoping study phase, value from the work has been gained by obtaining better understanding of hazards and mechanism of failure that can lead to impacts on people on, off and adjacent to the system. It is therefore a useful aid in decision making for resource allocation.

Cityrail

PASSENGER NETWORK

SUBURBAN TRAIN SERVICES TO – JOHNSONVILLE, PARAPARAUMU, MELLING AND UPPER HUTT



Cityrail ELECTRIC UNITS operate frequently between Wellington city and –

- The Northern suburbs (Ngaio, Khandallah, Johnsonville).
- Tawa, Porirua, Plimmerton, and Paraparaumu.
- The Hutt Valley

Cityrail CARRIAGE TRAINS link the Capital and Hutt Valley with Featherston, Carterton and Masterton. Just ask for a free timetable or guide to services at your nearest attended railway station or local public relations office, or phone 725-399 for timetable information

FIGURE 2

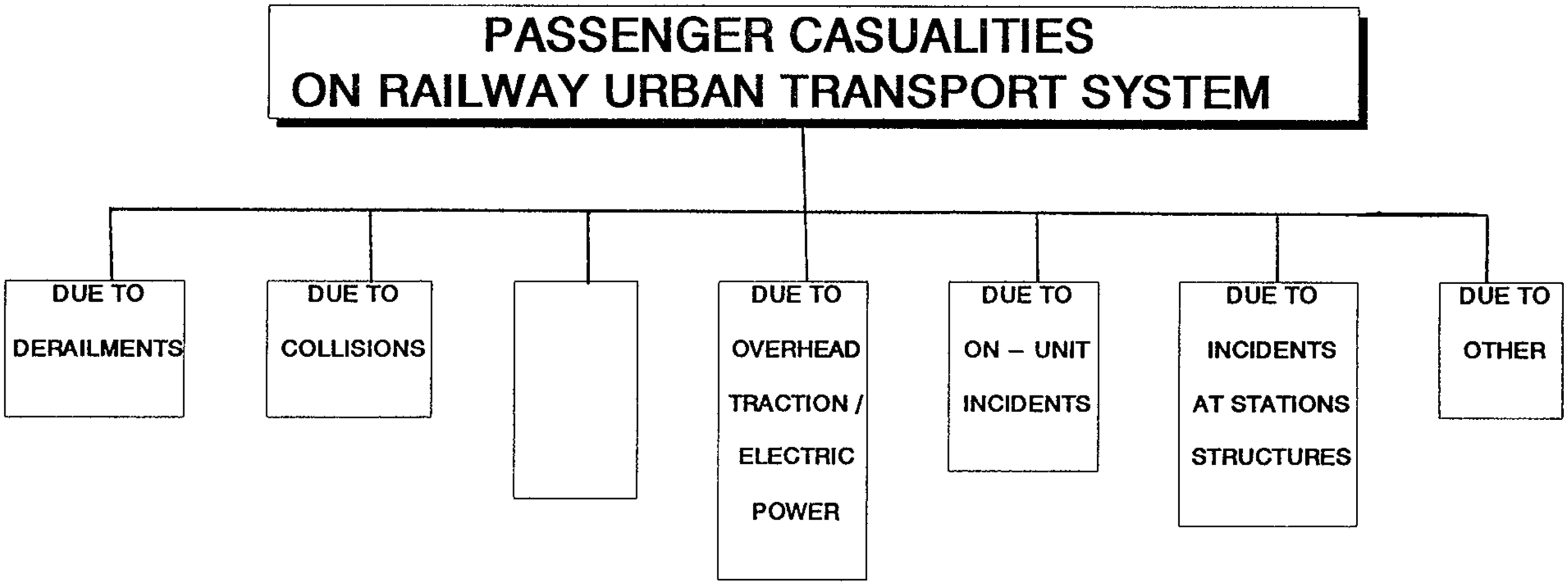

PASSENGER CASUALITIES
ON RAILWAY URBAN TRANSPORT SYSTEM
DUE TO DERAILMENTS
DUE TO COLLISIONS
DUE TO OVERHEAD TRACTION / ELECTRIC POWER
DUE TO ON – UNIT INCIDENTS
DUE TO INCIDENTS AT STATIONS STRUCTURES
DUE TO OTHER

Figure 3

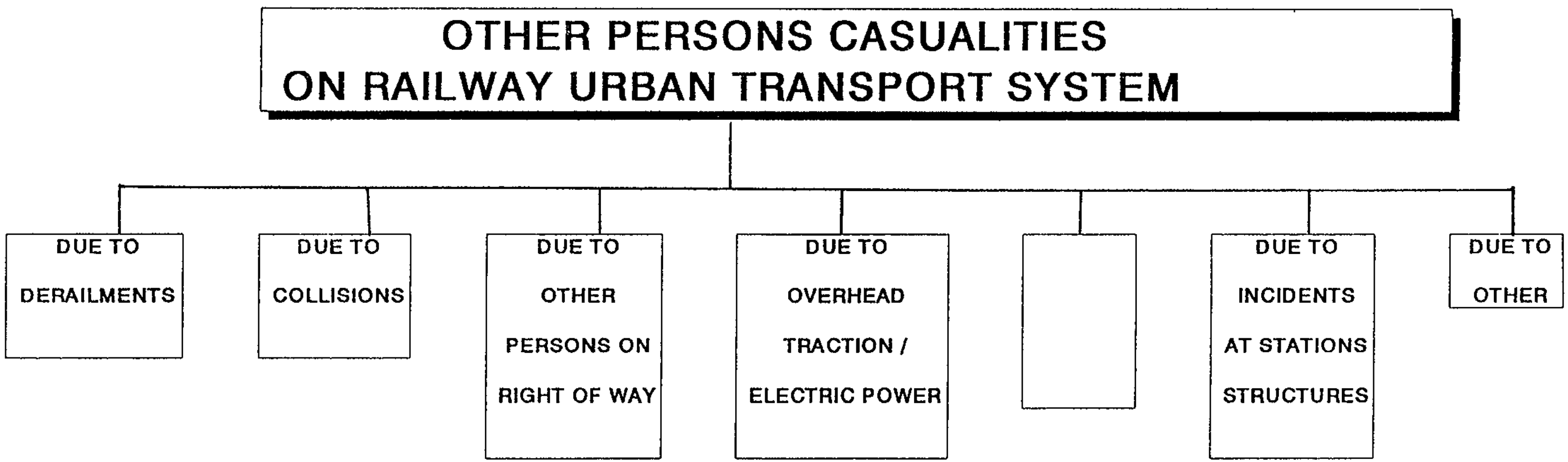

OTHER PERSONS CASUALITIES
ON RAILWAY URBAN TRANSPORT SYSTEM
DUE TO DERAILMENTS
DUE TO COLLISIONS
DUE TO OTHER PERSONS ON RIGHT OF WAY
DUE TO OVERHEAD TRACTION / ELECTRIC POWER
DUE TO INCIDENTS AT STATIONS STRUCTURES
DUE TO OTHER

Figure 4

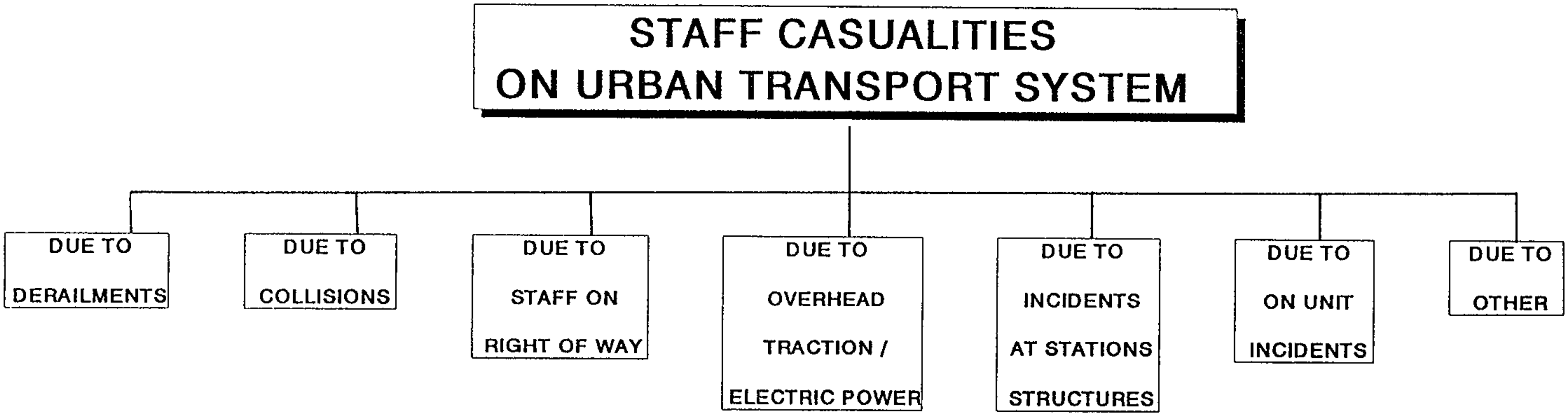

STAFF CASUALITIES
ON URBAN TRANSPORT SYSTEM
DUE TO DERAILMENTS
DUE TO COLLISIONS
DUE TO STAFF ON RIGHT OF WAY
DUE TO OVERHEAD TRACTION / ELECTRIC POWER
DUE TO INCIDENTS AT STATIONS STRUCTURES
DUE TO ON UNIT INCIDENTS
DUE TO OTHER

Figure 5

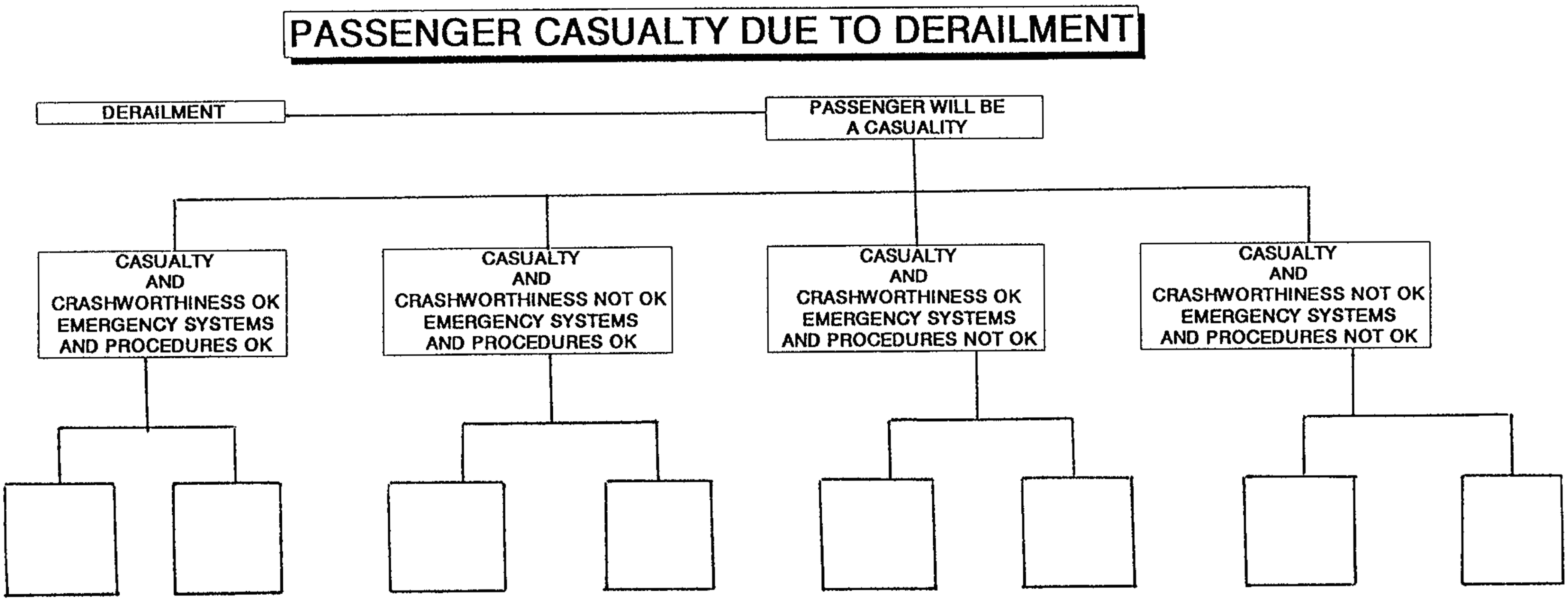
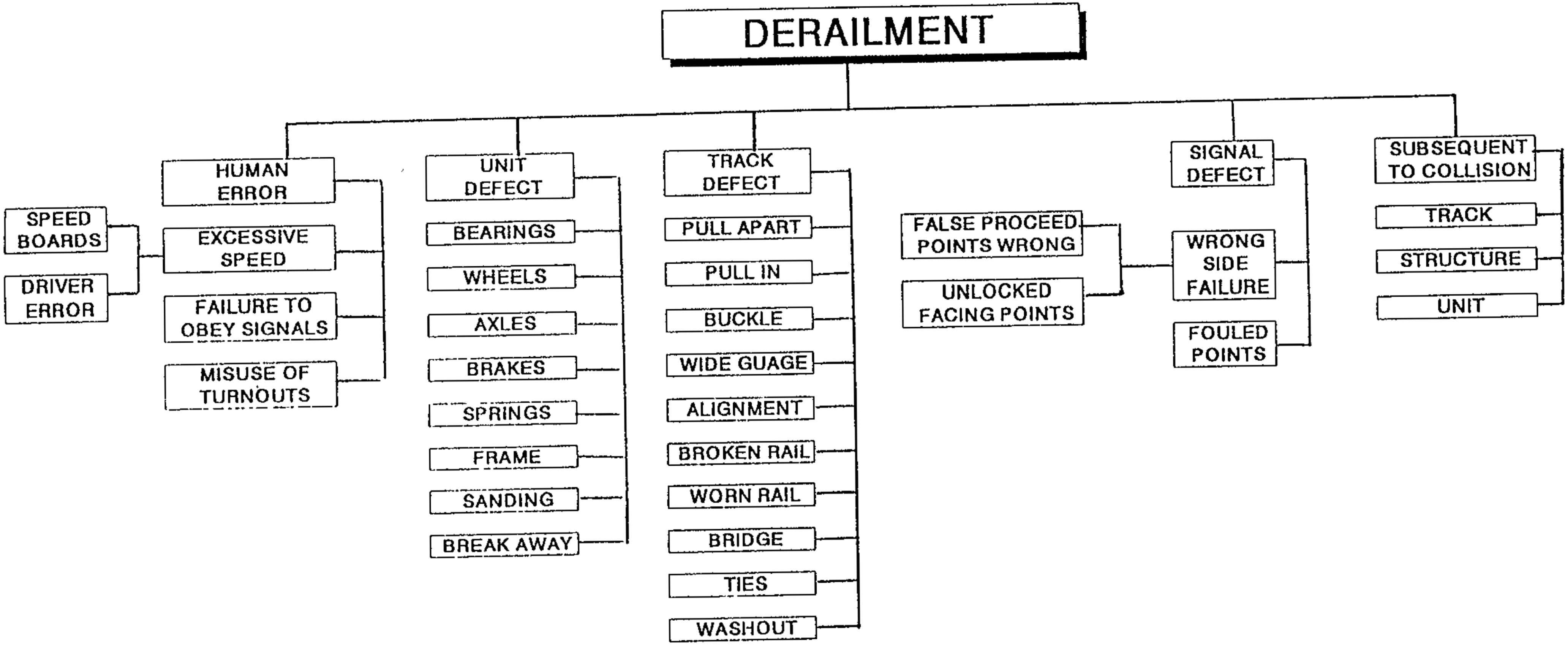
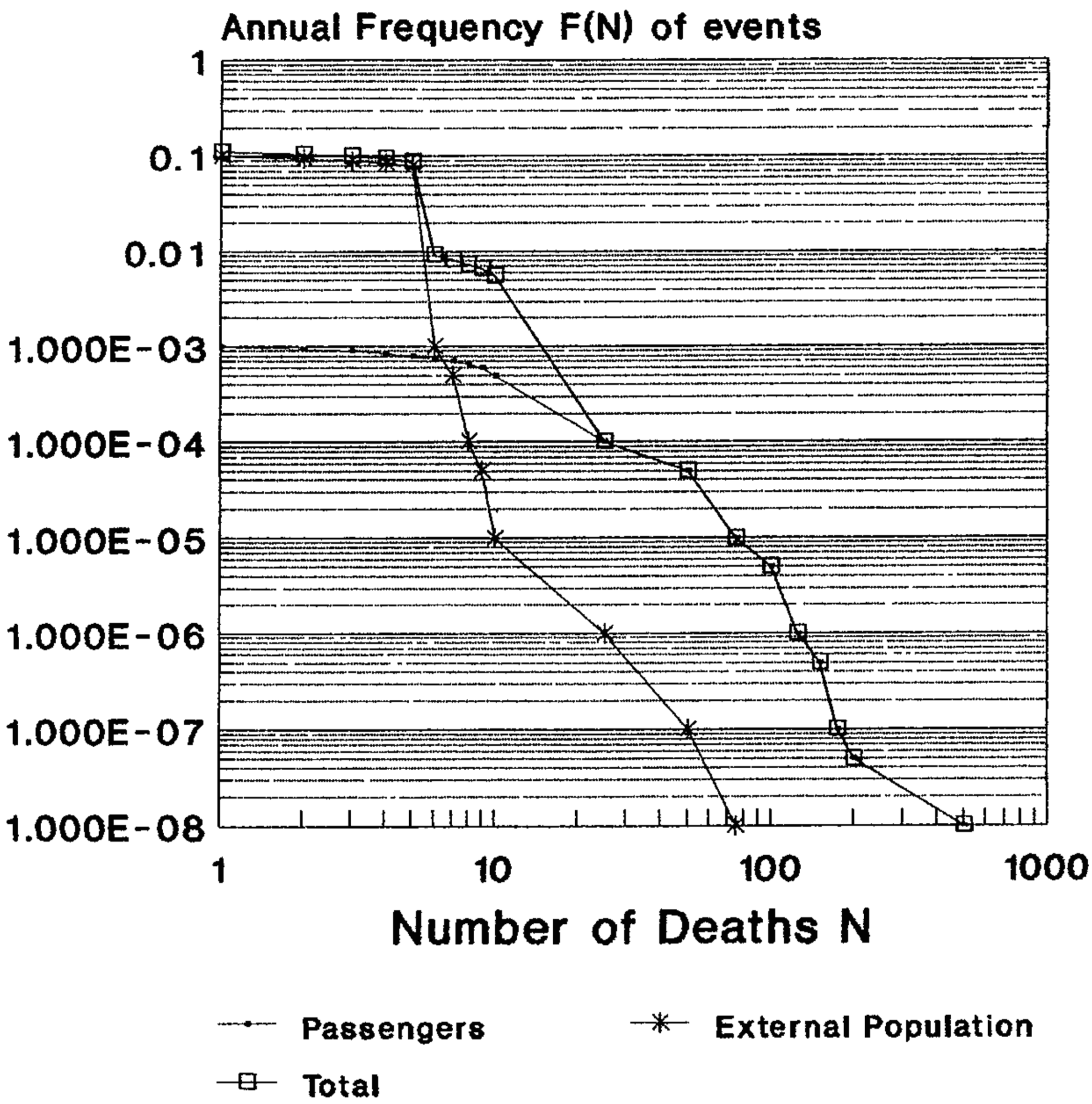

PASSENGER CASUALTY DUE TO DERAILMENT
DERAILMENT
PASSENGER WILL BE A CASUALITY
CASUALTY AND CRASHWORTHINESS OK EMERGENCY SYSTEMS AND PROCEDURES OK
CASUALTY AND CRASHWORTHINESS NOT OK EMERGENCY SYSTEMS AND PROCEDURES OK
CASUALTY AND CRASHWORTHINESS OK EMERGENCY SYSTEMS AND PROCEDURES NOT OK
CASUALTY AND CRASHWORTHINESS NOT OK EMERGENCY SYSTEMS AND PROCEDURES NOT OK

Figure 6



DERAILMENT
HUMAN ERROR
EXCESSIVE SPEED
SPEED BOARDS
DRIVER ERROR
FAILURE TO OBEY SIGNALS
MISUSE OF TURNOUTS
UNIT DEFECT
BEARINGS
WHEELS
AXLES
BRAKES
SPRINGS
FRAME
SANDING
BREAK AWAY
TRACK DEFECT
PULL APART
PULL IN
BUCKLE
WIDE GUAGE
ALIGNMENT
BROKEN RAIL
WORN RAIL
BRIDGE
TIES
WASHOUT
SIGNAL DEFECT
WRONG SIDE FAILURE
FALSE PROCEED POINTS WRONG
UNLOCKED FACING POINTS
FOULED POINTS
SUBSEQUENT TO COLLISION
TRACK
STRUCTURE
UNIT

F-N Plot
Societal Risk



International Rail Safety Conference

1991 LONDON

30 October - 1 November 1991
Latimer House, London, United Kingdom

Paper 9117

Author Unknown

British Railways Board, Safety Programme Prioritisation

Publisher
2000 International Rail Safety Conference

British Railways Board

Safety Programme Prioritisation

17 October 1991

BRB/Safe/10/01

The purpose of this presentation and discussion are ...

- To inform the Board of progress on the prioritisation of projects put forward for the Safety Programme;
- To overview the results of prioritisation and to agree how they will be used;
- To examine the use of F-N curves as an aid to safety policy making at British Rail;
- To agree a way forward for safety investment prioritisation in the long term at British Rail; and
- To confirm the steps to be taken for formal discharge of the Board's responsibilities on Hidden 48

There are five parts to this presentation ...

Method & Process	Use of results	F-N Curves	The Way Forward	Hidden 48
• Outline of method • Application of method • "Post-hoc" factors	• Observation of results • "Enabling" projects • Hidden & Fennell projects • Major projects (e.g. ATP) • Fire projects	• Using F-N curves to aid policy setting • F-N curves for BR • Effect of safety programme on F-N curve	• IFR • Line of route identification of risks • Integration of safety and business investment appraisal schemes	• Short term actions • Longer term actions

Method & Process

The prioritisation scheme is an effective aid to implementing safety improvements at British Rail

- We have structured a robust method which has been proven in practice
- The method has been applied using an iterative process with review and revision to improve the quality of submissions
- The scheme has enabled us to highlight important "post-hoc" factors, which we can now address
- Our activities have been scrutinised and endorsed by DTp, SMG and the Safety Panel

The method provides a common basis for safety project prioritisation for use throughout BR

Inputs

Authorised and not yet authorised project submissions :

S&T	61
DOCE	39
M+EE	102
Ops	7
D Safety	22
Projects	5
Other	21
Total	**257**

(at 1 October 1991)

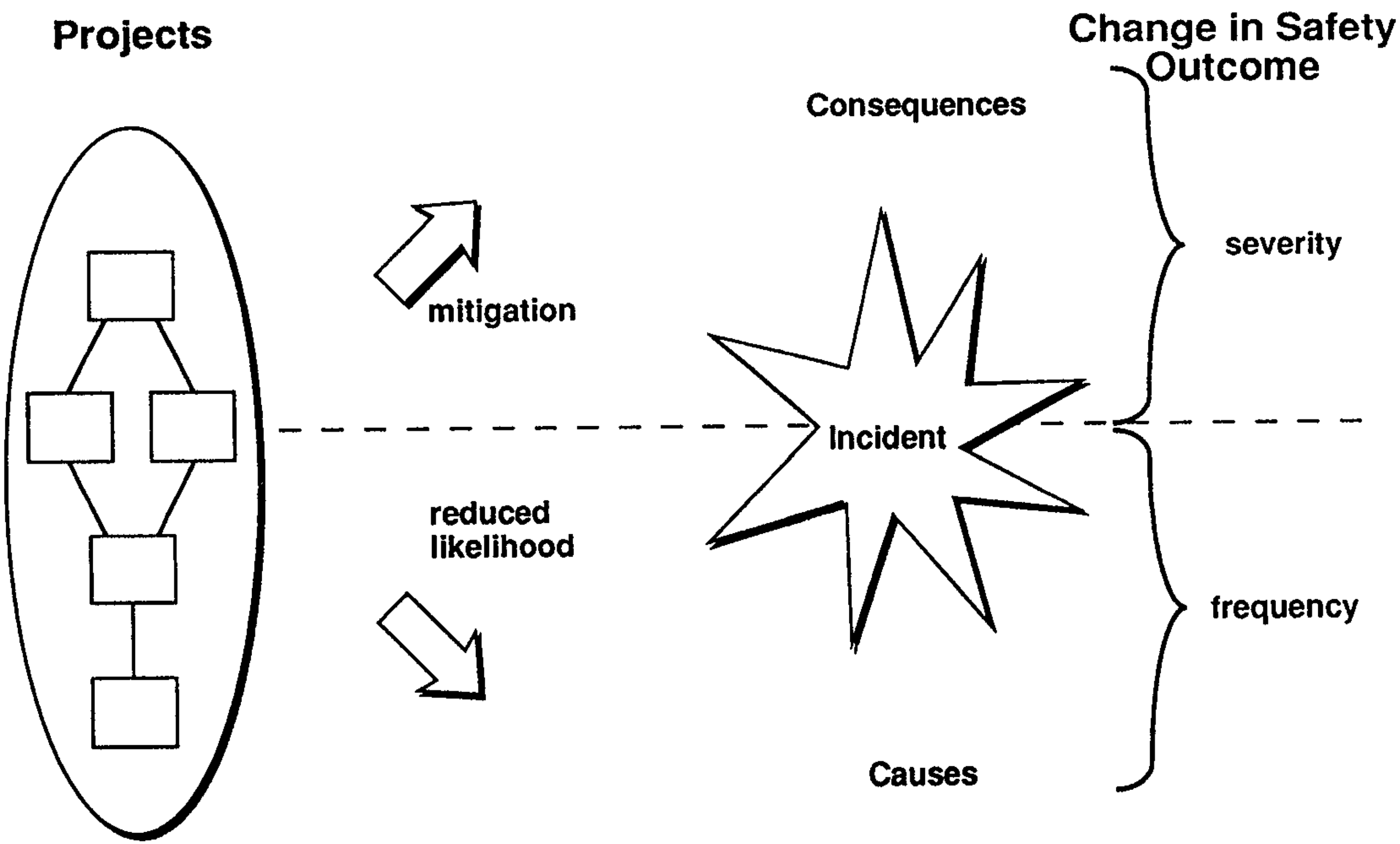
The "Short-term" prioritisation method

Inputs

- Project priority listing by : safety benefit per £ spent
- Key "post-hoc" factors

- Project submissions are assessed for their contribution to safety objectives in a clear and concise manner
- The method is structured to expose key assumptions to expert scrutiny

The method focuses on the reduction of fatalities and injuries (safety outcomes)



To prioritise the proposed projects we identify key factors which are combined to give a priority rating

These factors are ...		... and we can assign ratings to each :
i) The importance to overall BR safety improvement of the incident(s) which the project addresses	→	Incident rating (which is a measure of safety outcomes) = ISOi
ii) The effectiveness of the project in reducing the outcome arising from the incident(s) it addresses	→	Effectiveness rating = PEi
iii) Project cost (annualised net present cost)	→	Project Cost = Cp

- ISOi x PEi = Safety Benefit = the extent to which the project satisfies safety objectives
- Safety Benefit + Cost (Cp) = Priority Rating

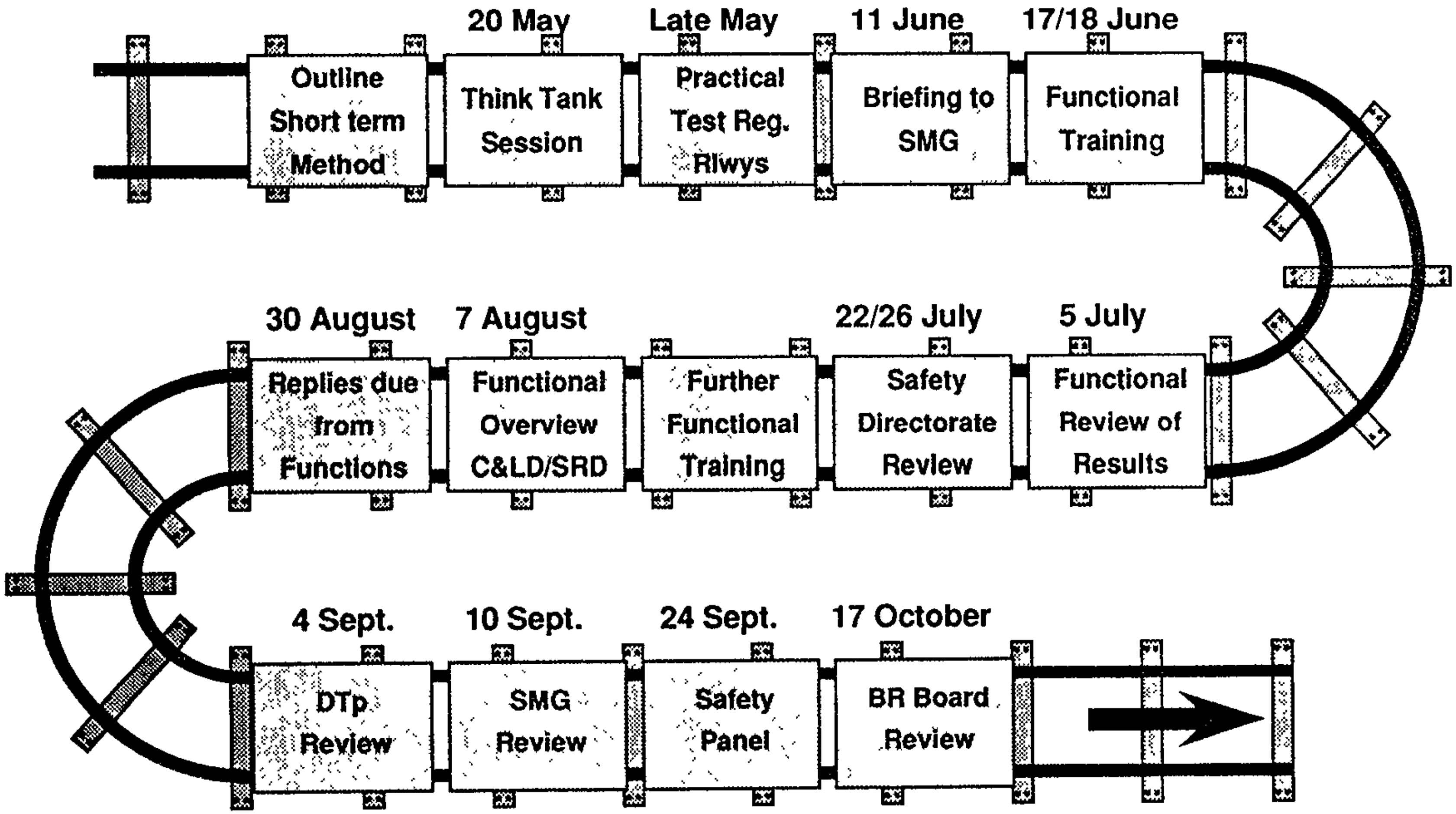
Safety outcomes have been translated to a common basis

- In the short term we have only considered human safety
- We have used the following relative weightings …

	BR Method	DTp	(DTp note)
Fatality	1	1	(600)
Major Injury	0.1	0.03	(18.2)
Minor Injury	0.005	0.00067	(0.4)

… which increase the relative importance of injuries relative to road figures and thereby implements the BR and DuPont human centred approach to safety

In developing and applying the scheme we have focussed expertise, experience and data on the method, results and interpretation



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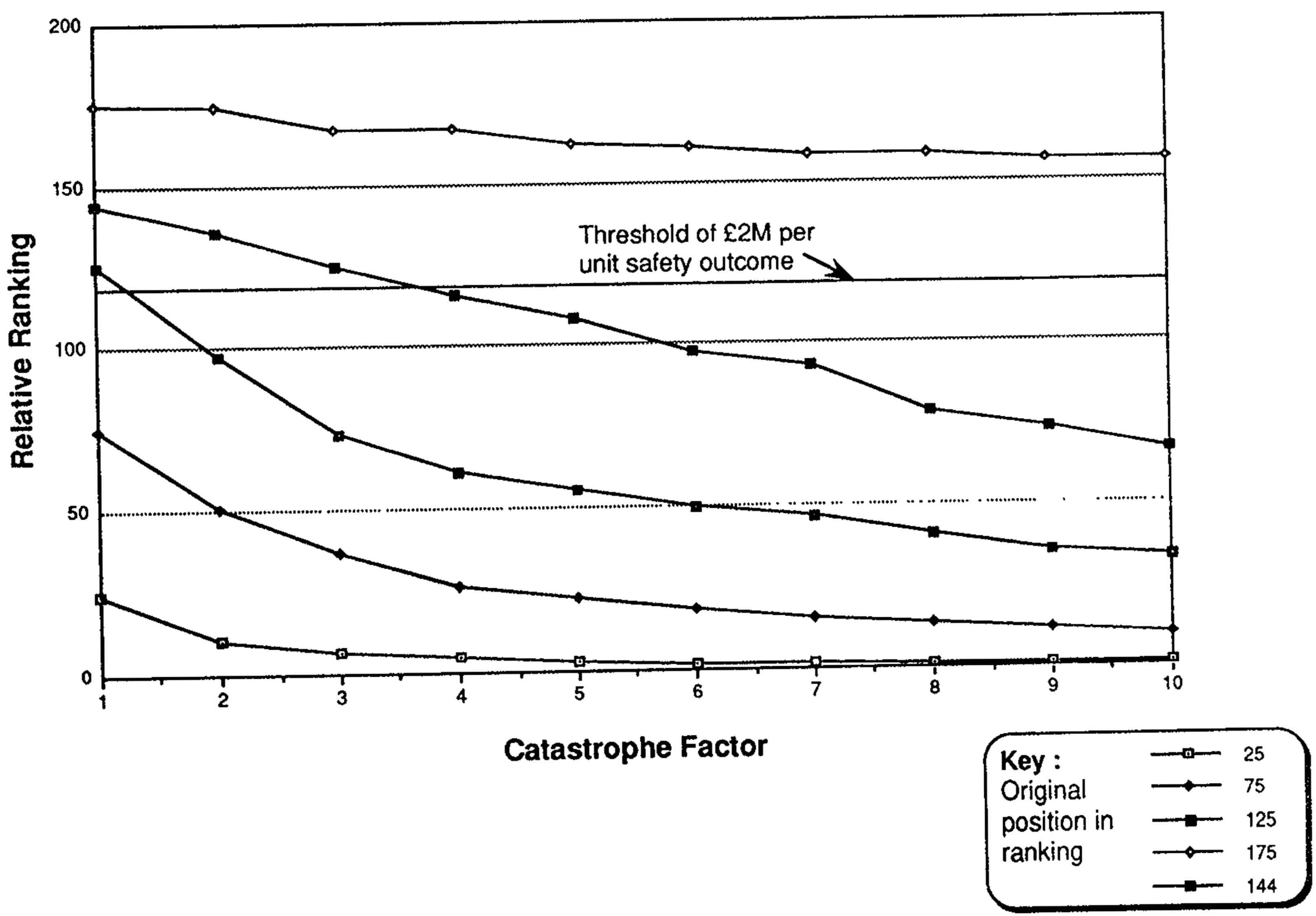
Important "Post-hoc" factors which we need to consider include ...

- Treatment of catastrophe prevention/mitigation projects
- Potential over emphasis on projects addressing trespass/suicide
- Requirement to meet all Judicial Inquiry recommendations
- Funding of legally required projects, e.g. fire certification
- Inclusion of full business benefits in prioritisation scheme
- Status of spend on projects

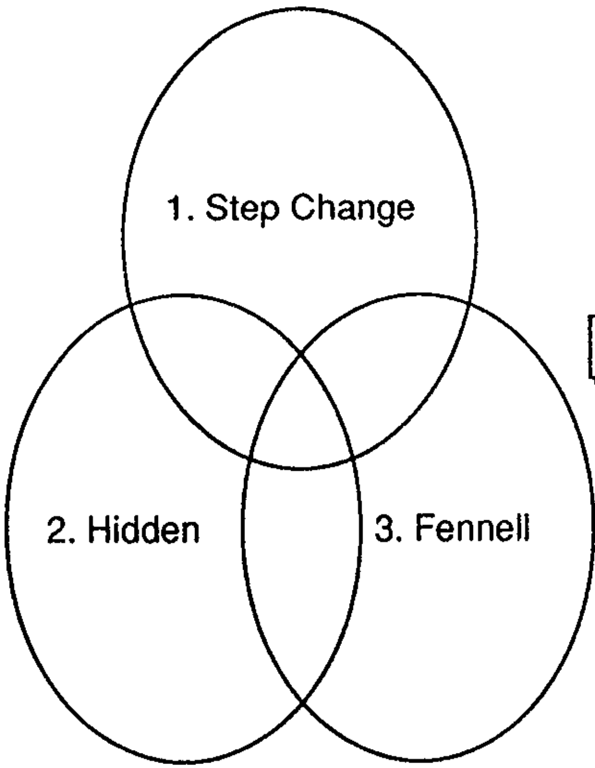
Weighting for catastrophe particularly affects the middle ranking projects



Use of results

Key objectives can be identified for the safety programme ...

Aims



Objectives

- Minimisation of passenger injuries
- Minimisation of injuries to public on BR premises
- Minimisation of "lost time" injuries to BR staff and contractors
- Avoidance of catastrophes
- Conformance to legal requirements
- Conformance to judicial requirements

To meet the aims and objectives of the safety programme a portfolio of projects has been put forward

Project Assessed to 1st October 1991

Origin	No.	91/92 Request £M	92/93 Request £M
S&T	61	28.3	33.8
DOCE	39	36.6	49.0
M+EE	102	45.3	19.8
Ops	7	24.6	17.1
D Safety	22	30.8	26.7
Projects	5	10.0	10.0
Other	21	3.2	1.7
Total *		**250.0**	**267.0**

* including slippage and not yet prioritised projects

Characteristics of Priority List

Quarter	Priority Rating Range	Median	Comments
Top	45.5 - 2.77	5.9	• Small engineering investments
Second	2.7 - 0.93	1.33	• Emergence of people related projects, good house keeping, DuPont schemes
Third	0.88 - 0.14	0.47	• Some large engineering projects
Fourth	0.13 - 0.0	0.01	• Fire certification projects • Some large engineering projects

- plus approximately sixty "enabling" projects

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A group of important "enabling" projects has emerged from the prioritisation scheme

These projects include, for example :

- Safety Audit
- Development of safety management infrastructure
- TQM
- Risk identification and analysis

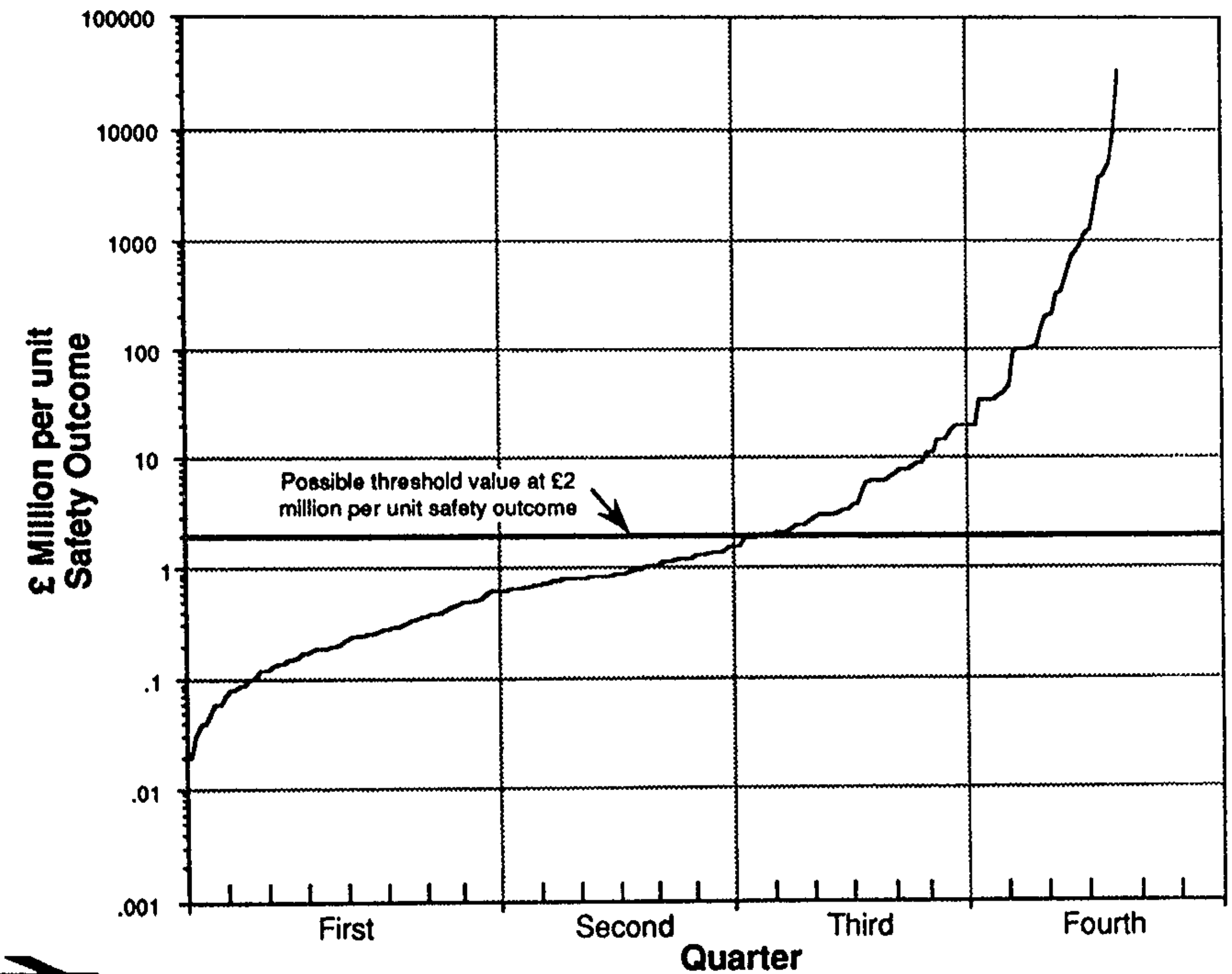
Individually, and as a group, enabling projects may significantly enhance the effectiveness of other, more specific, projects

Enabling projects have been grouped separately for review and Safety Panel has endorsed their importance to meeting overall safety policy

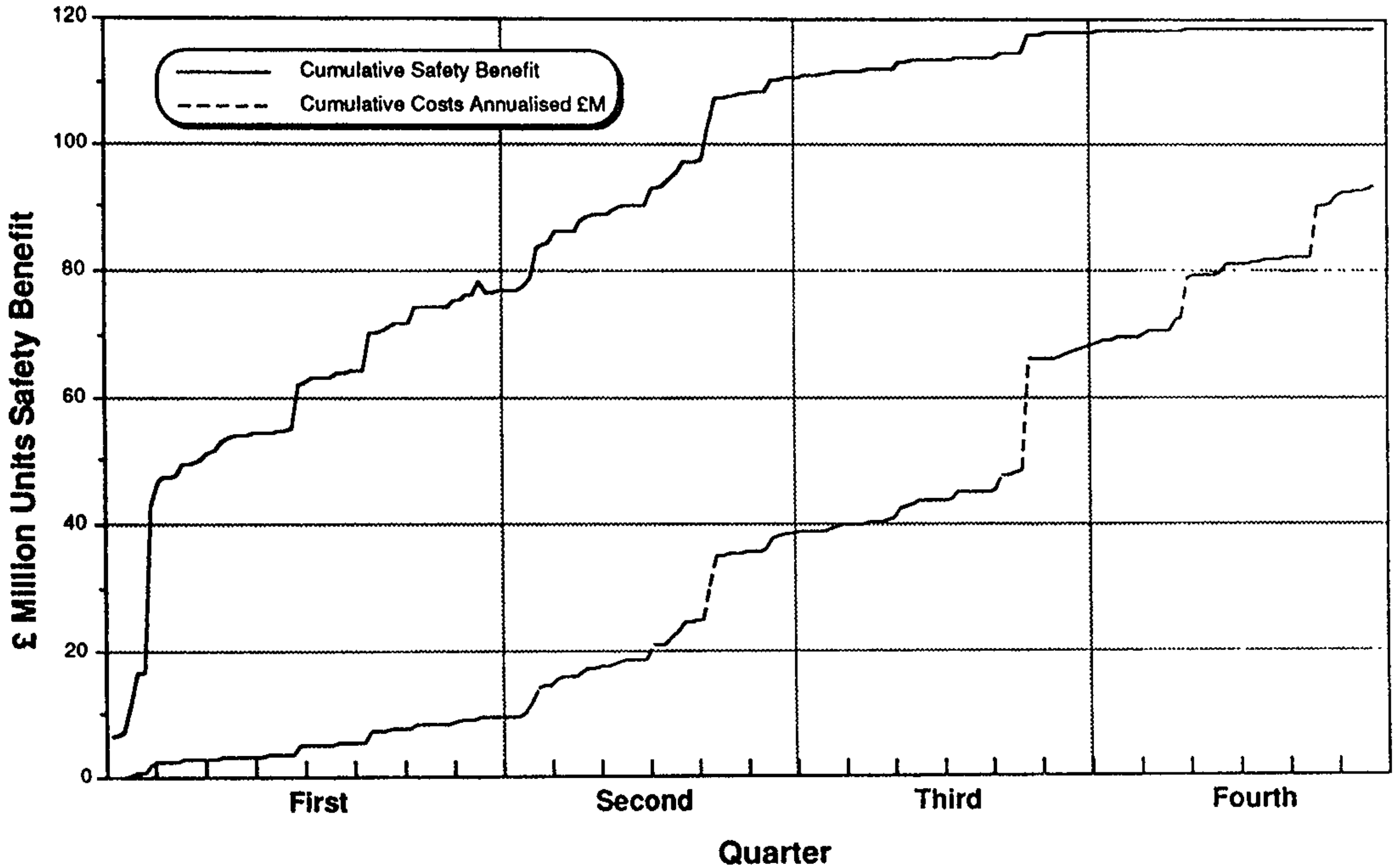
- Enabling projects in the current portfolio account for requests of £42M in 1991/92 and approximately £60M in 1992/93

A threshold value of £2M spent per unit safety outcome has been put forward in discussion with DTp

- This value corresponds to a priority of 0.5
- The threshold has been endorsed by SMG and Safety Panel



Cumulative Benefits & Costs



Approximately 60% of projects are within the threshold, but there are some notable exceptions ...

Hidden & Fennell Projects

Project	Ranking	Request 1991/92 £M	Request 1992/93 £M
ATP Development	144	9.0	3.0
Excessive Hours Hidden Recommendation 18	169	7.5	0.0
Birmingham New Street Fire Precautions	175	4.1	10.2
On train data recorders	189	4.1	3.4
Charing Cross improved access	191	2.3	0.5
Waterloo General Offices fire certification	192	6.2	4.8

Other Major Projects

Project	Ranking	Request 1991/92 £M	Request 1992/93 £M
Improved supervision of traincrew	140	2.5	3.5
Corrosion pitted rail (WR)	164	0.6	1 8
Paddington Station roof	167	1.5	0.0
Improving clamp lock points	168	0 8	0 6
Fitting of new chokes	179	0.6	0.5
North Wales sea defences	193	3 0	5.0

- We recommend a more full assessment of these major projects including more detailed risk analysis

Fire certification projects all have low priority ratings due to the very low safety benefits which they offer

12 out of 13 direct fire projects appear in the fourth quarter

Range of safety benefit per £M spent :

0.32 (rank 135)

to

0.00 (rank 198)

However, most of these projects are required to meet fire regulations

The results of the prioritisation provide very practical information ... it is now necessary to consider where we go from here

Policy

- Safety projects provide a means for practical expression of safety policy ... their impact on safety performance can be viewed through F-N curves

Methods for long term use

- The portfolio of projects has largely arisen "bottom-up" ... a "top-down" view of priorities is important
- in the longer term the method should be integrated with business investment prioritisation

Hidden 48

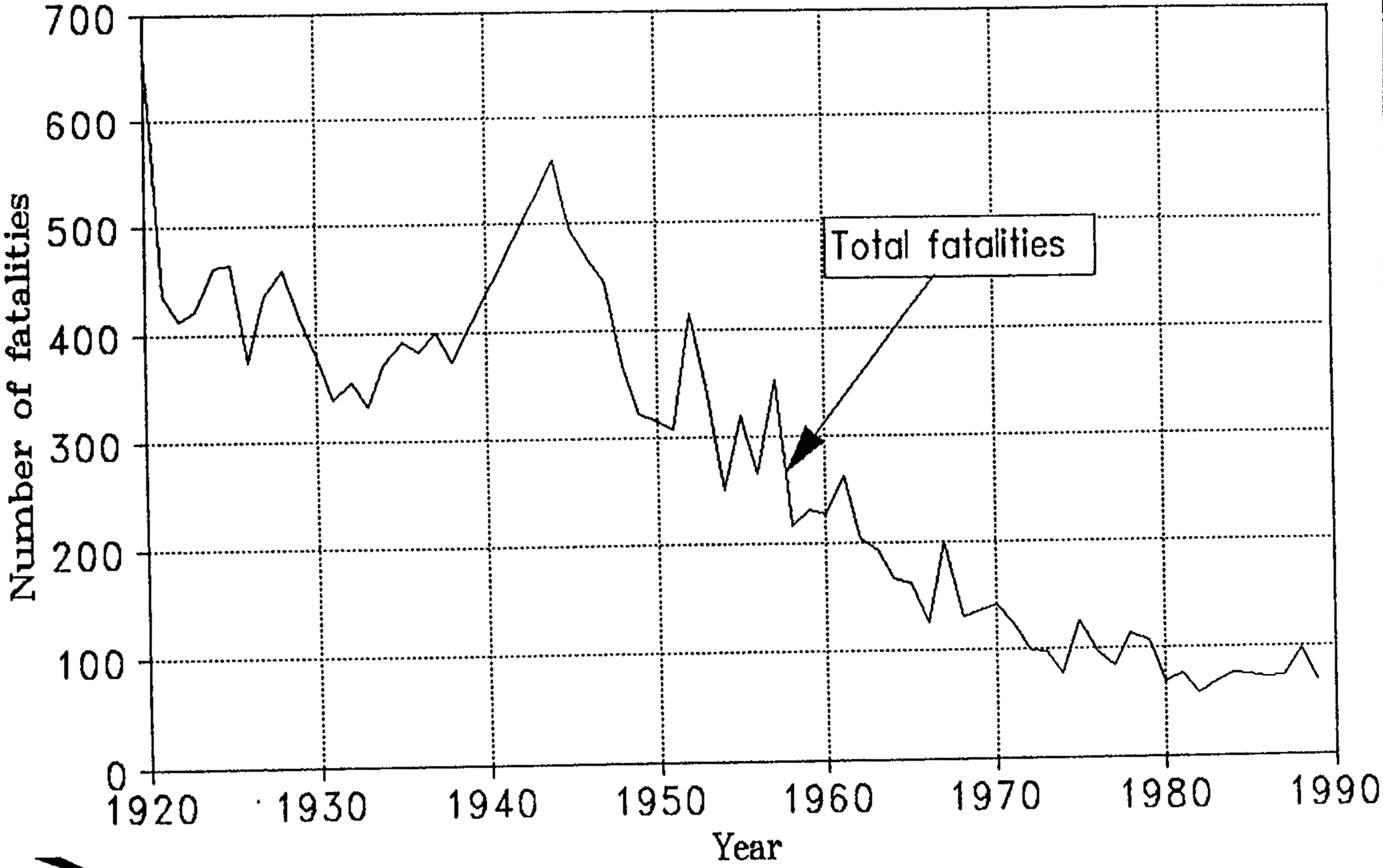
- Formal discharge of responsibilities is required

F-N Curves

BRB/Safe/10/23

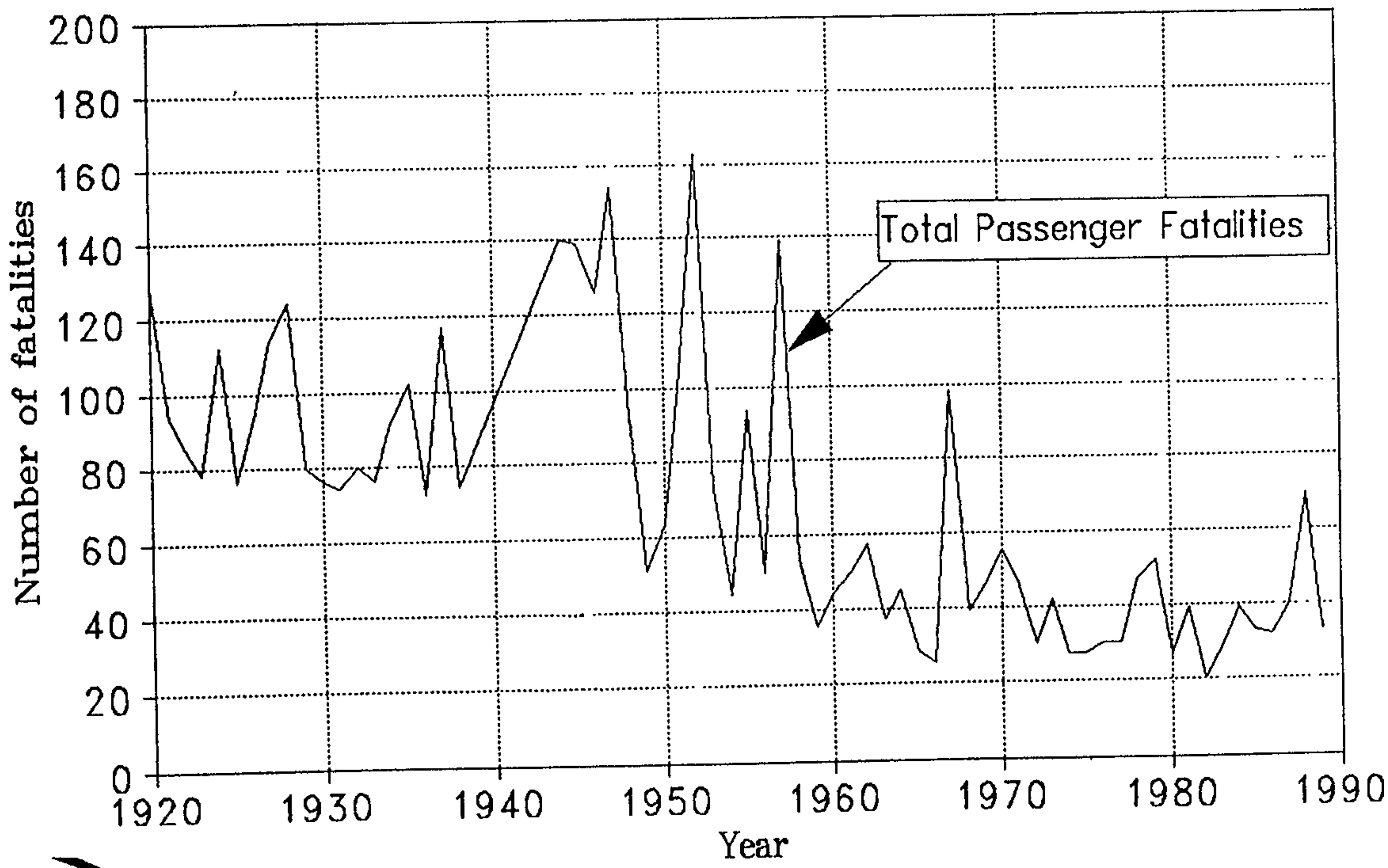
Total fatalities excluding T & S

1920 - 89 TOT2089



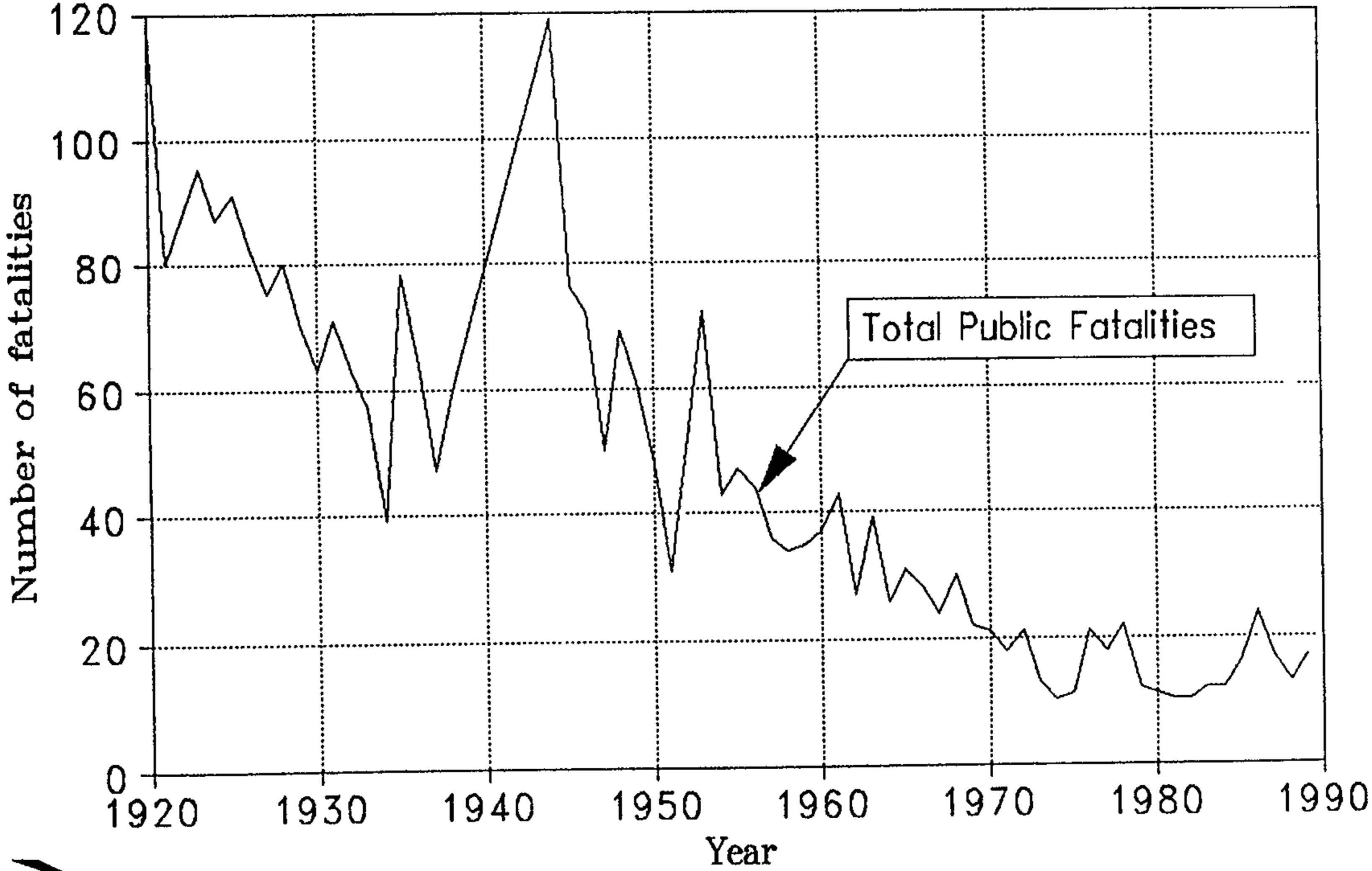
Total Passenger Fatalities 1920 –1989

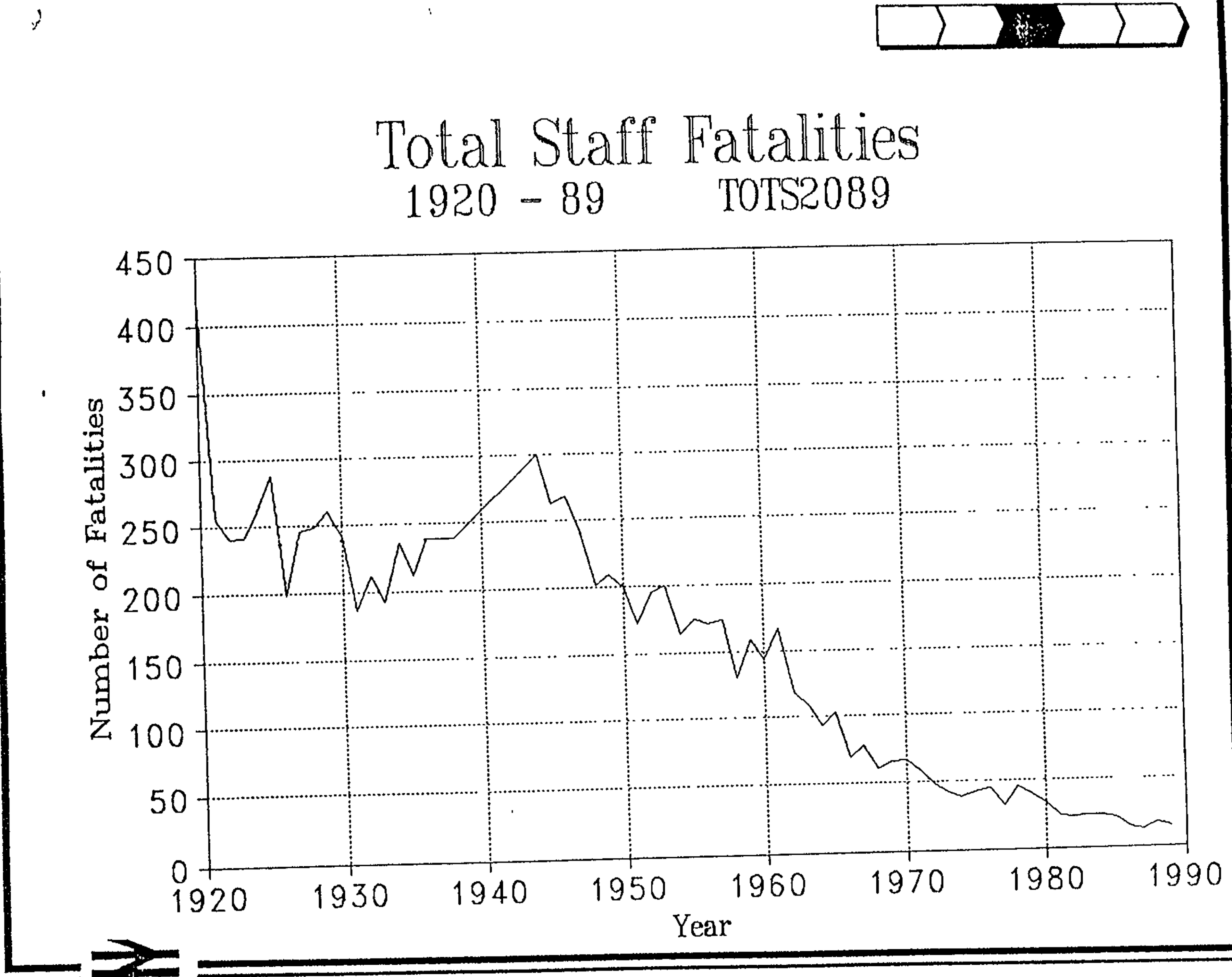
TPD2089



Total Public Fatalities

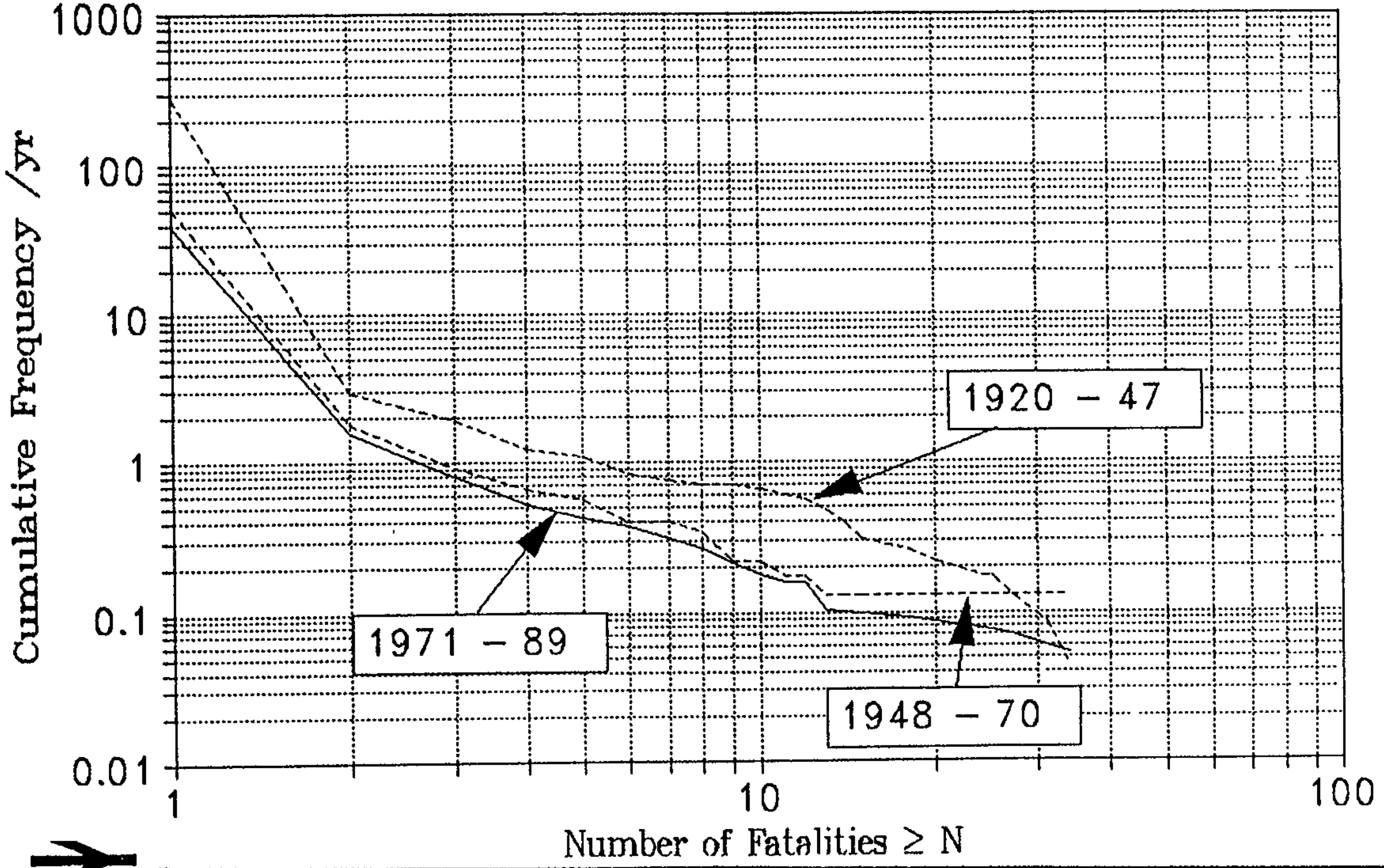
1920 - 89 TOPU2089




Total Staff Fatalities
1920 - 89
TOTS2089
Number of Fatalities
450
400
350
300
250
200
150
100
50
0
1920
1930
1940
1950
1960
1970
1980
1990
Year

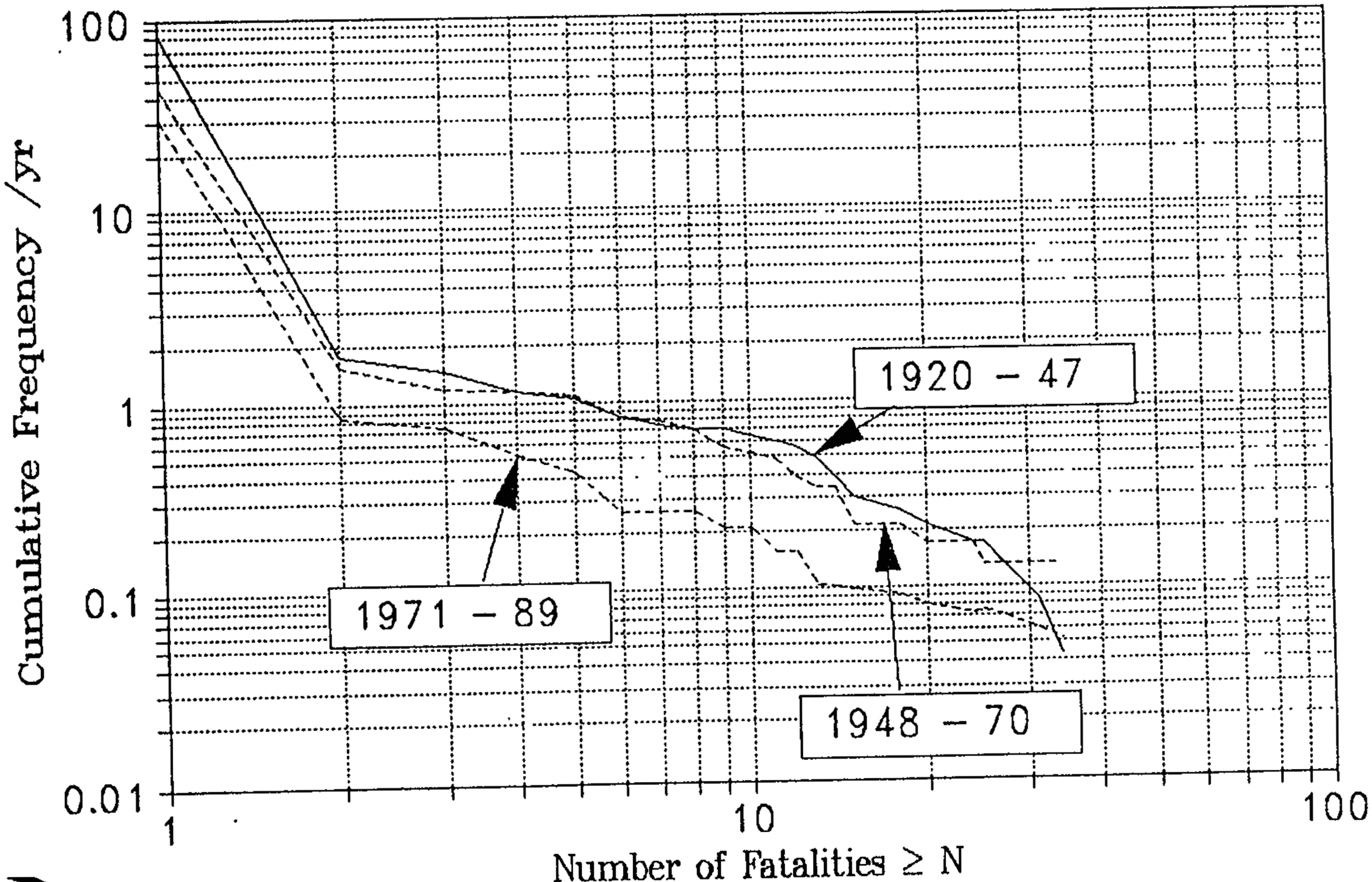
F/N Curve Total Fatalities 1920 -1989

Cumulative TFC2089C



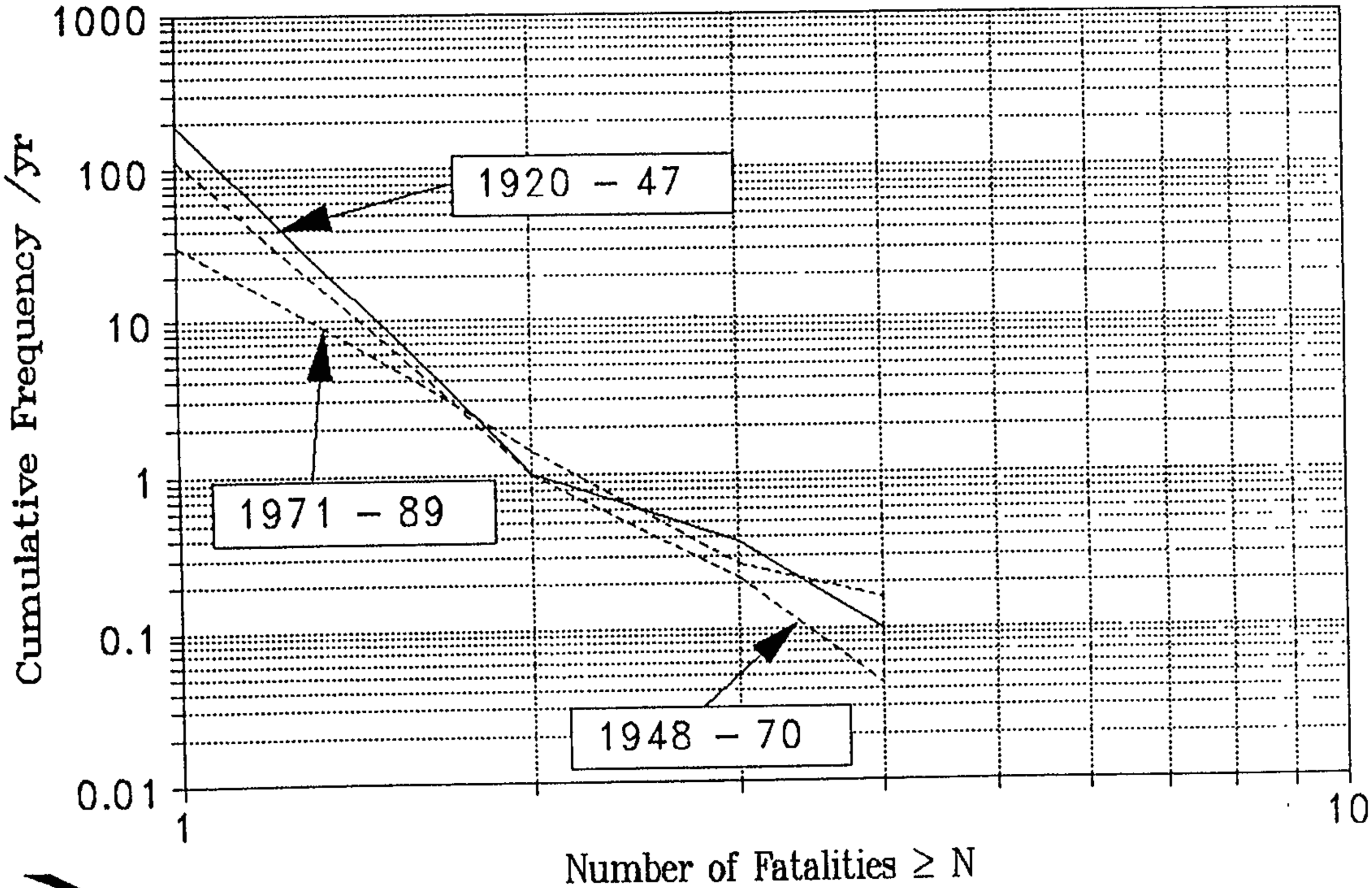
Total Passenger Fatalities

Cumulative TPC2089



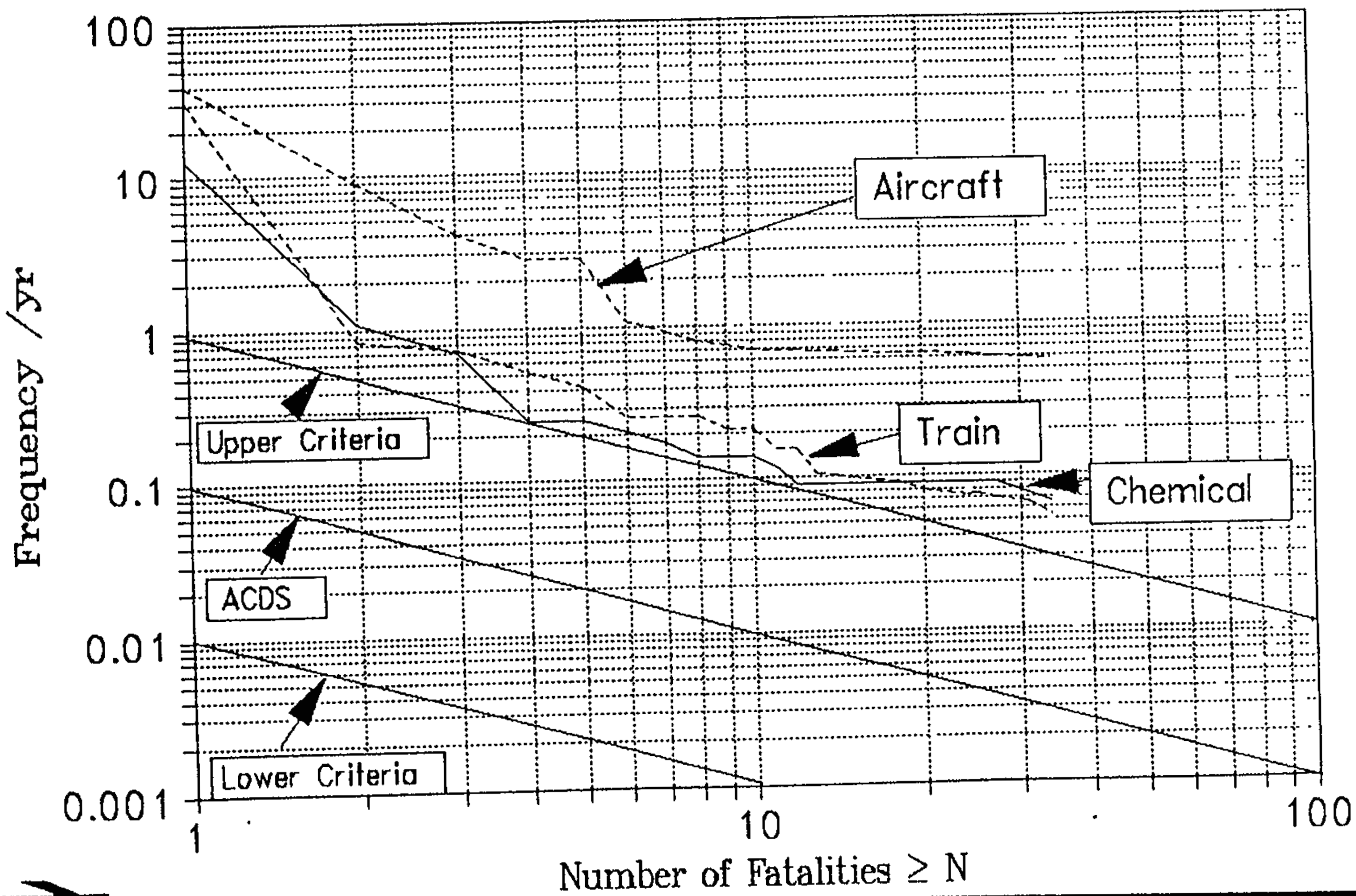
Total Staff Fatalities 1920 - 89

TSC2089

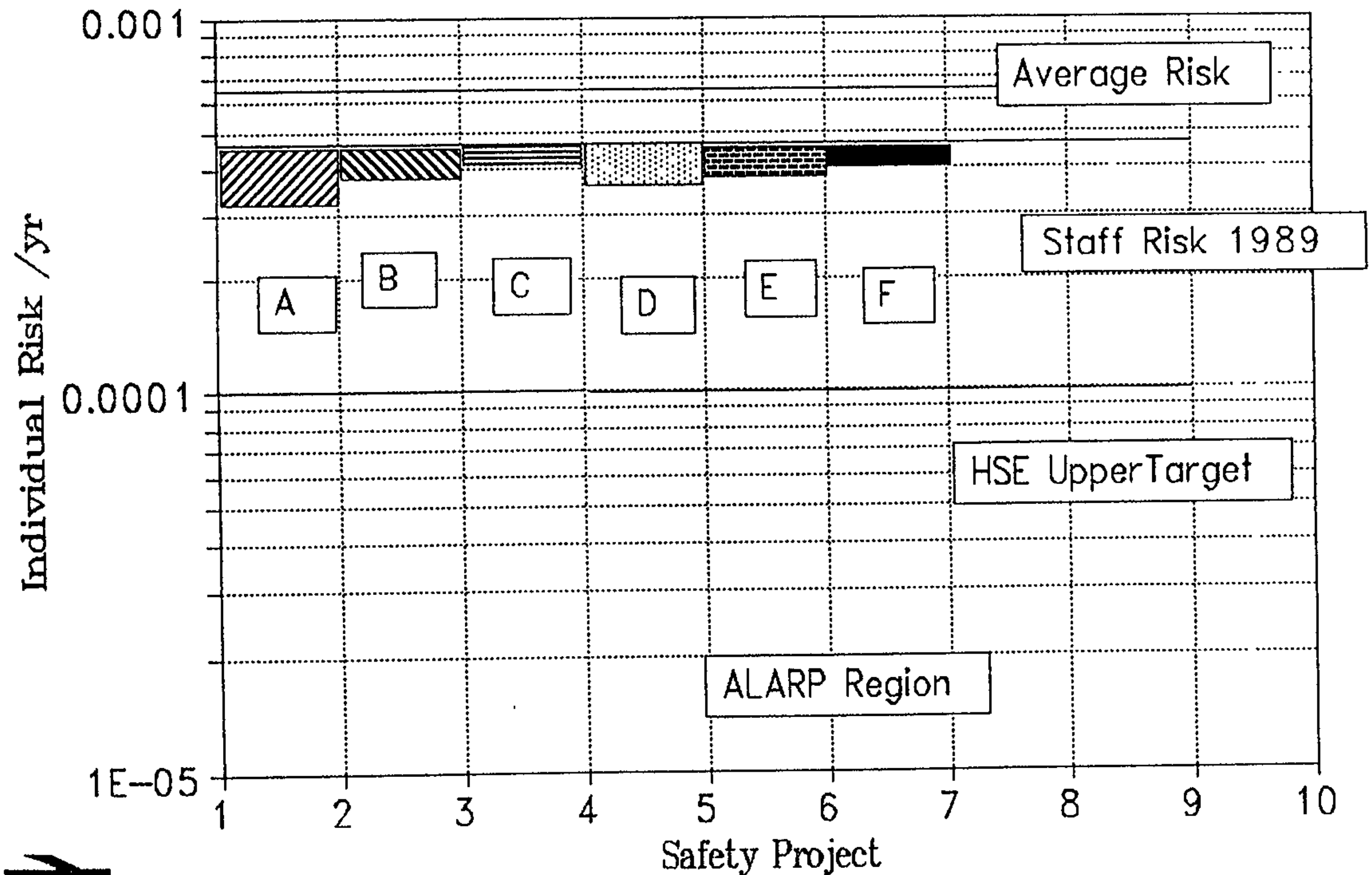


F/N Curve Comparisons Circa 1966 – 89

Cumulative FNTCOMP

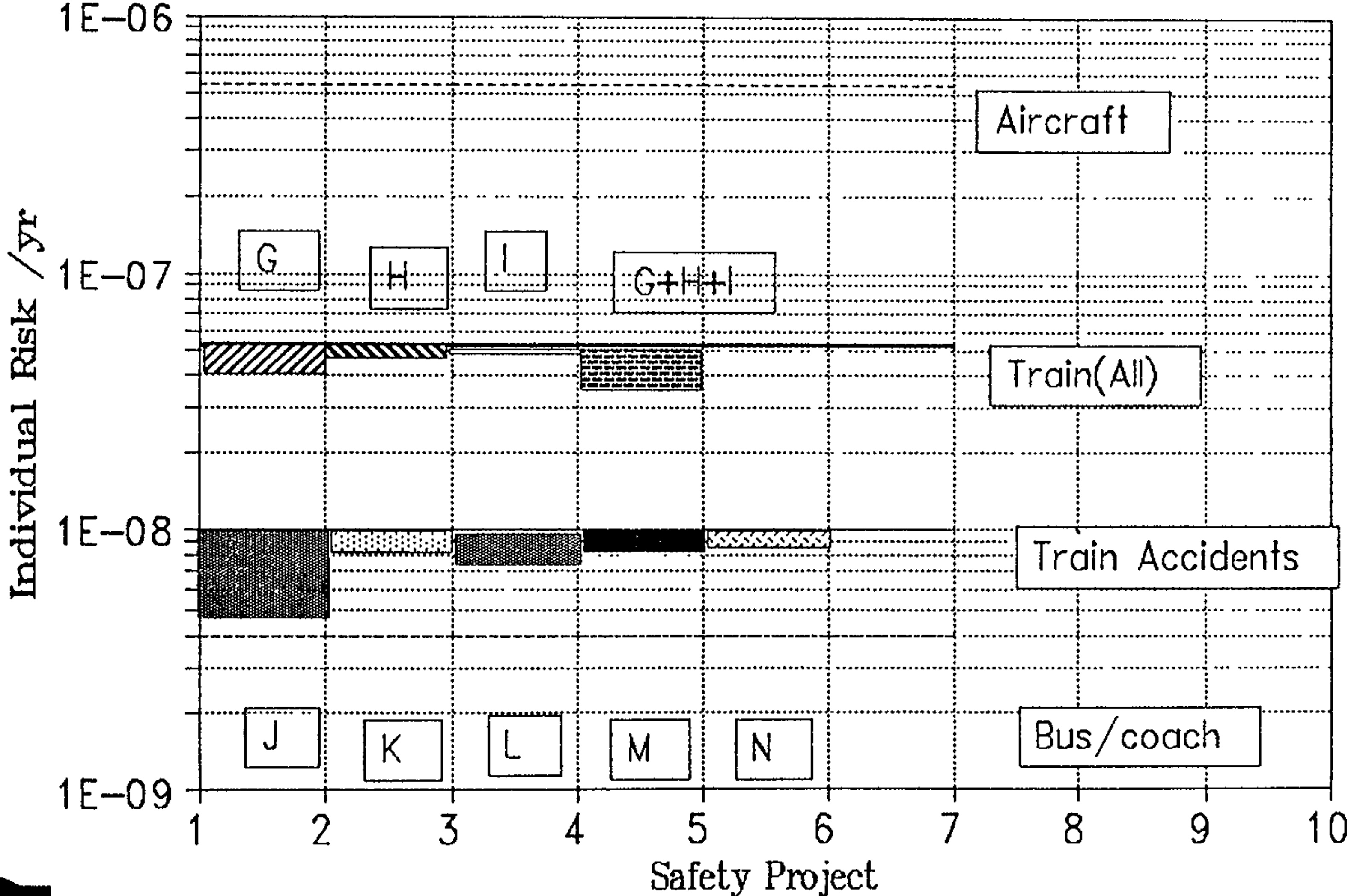


Effects of Safety Projects
on BR Staff Risks



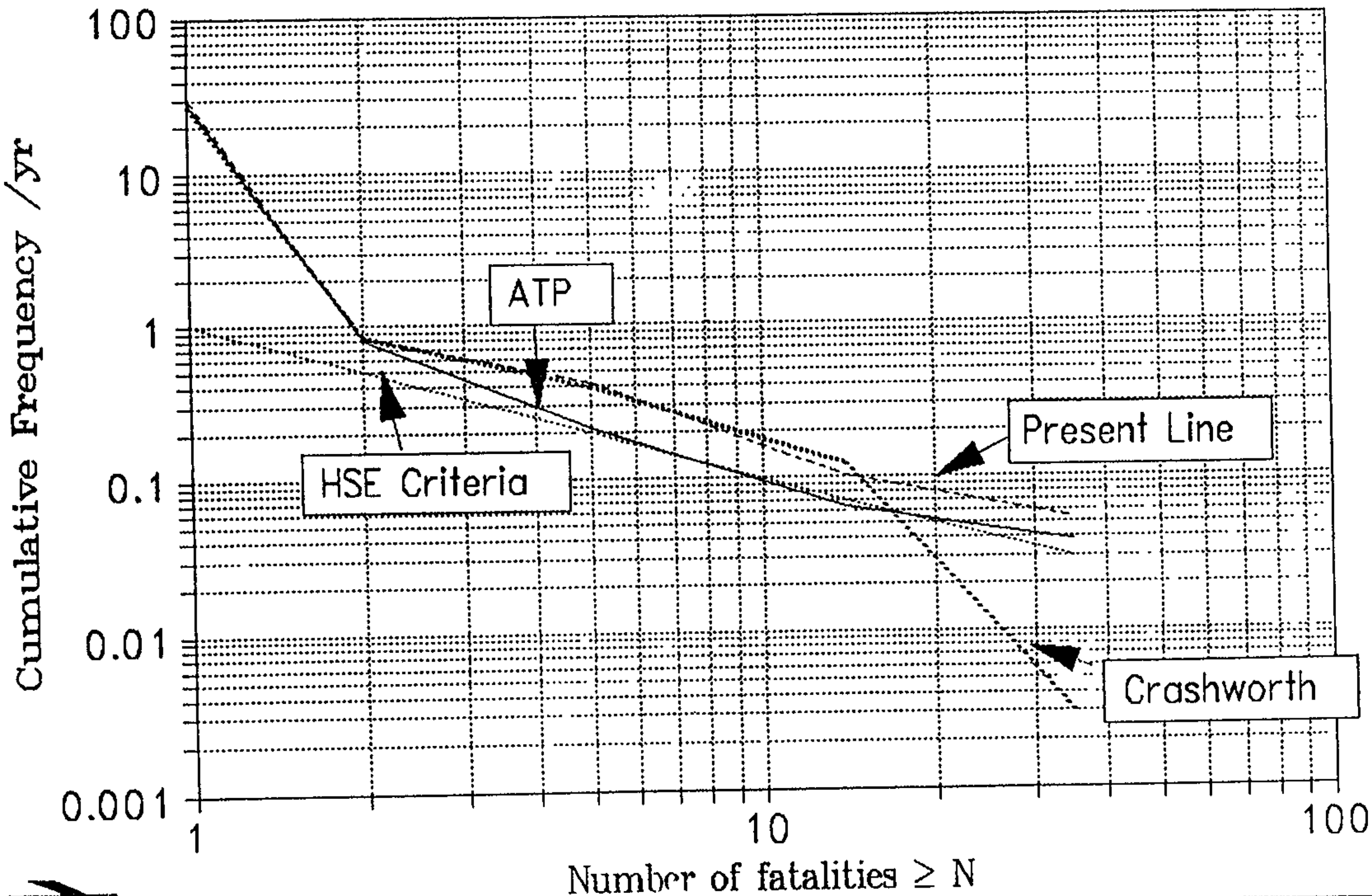
Effects of Safety Projects

on BR Individual Passenger Risks



Passenger Safety Projects

Cumulative TOTPSP7189



The Way Forward

In considering the way forward, there are three important issues to explore

1. How the results of the scheme fit into the IFR process

2. The development of a "top-down" process for identification of safety needs

3. Integration of the prioritisation scheme for safety expenditure into business investment appraisal

The IFR bid for 1992/93 will amount to £277M in <u>project</u> costs *

Classification	Authorised projects £M	Not yet Authorised projects £M	Totals
Priority 1 Enabling Projects	22.2	38.0	60.2
Priority 2 Top ranked projects > 0.5 SB	32.2	54.8	87.0
Priority 3 Below 0.5 SB but Hidden/Fennell/ Legal	63.6	41.9	105.5
Priority 4 Other Projects	1.8	22.4	24.2
Grand Total	119.8	157.1	276.9

* excluding slippage, leakage, contingency and interest

The IFR bid for 1992/93 will amount to £278.8M in total costs

Classification	Authorised projects £M	Not yet Authorised projects £M	Totals
Priority 1	22.2	38.0	60.2
Priority 2	32.2	54.8	87.0
Priority 3	63.6	41.9	105.5
Priority 4	1.8	22.4	24.2
Reduction (slippage & adjustments)			(52.0)
Leakage (91/92)			9.9
Contingency			20.0
Interest			24.0
Grand Totals			278.8

The development of a "top-down" analysis of safety needs can be effectively carried out through the "line of route" approach

- Route and traffic vulnerabilities should be identified and prioritised
- Effect on risks of business policy and safety schemes to be measured
- Collection and analysis of safety performance data to be linked into a risk management tool for business Managers
- ECML portion of route selected as pilot study :-
  - Joint team approach
  - ECML line management
  - Director Safety
  - Research
  - Consultants

Hidden 48

BRB/Safe/10/30

Formal discharge of the Board's responsibilities under Hidden 48 will proceed in two stages ...

... this year ...

By November 1991 an interim report on completion of the short term method will be prepared for the Secretary of State for Transport.

... next year ...

By November 1992 a Final Report on completion of Hidden 48 will be prepared to demonstrate how safety and commercial investment can be integrated.