RISK, is there no REWARD?
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Abstract: The current preoccupation with risk and safety has created an industry which is principally concerned with anticipation and control of unintended undesirable events entailing loss to the society or the environment and harm to people. In the mean time, risk based approach to many aspects of engineering and public life have permeated the language and the regulatory landscape.

The great civilizations of the East developed holistic world views and philosophies which extolled the virtues of maintaining a balance between the two polar opposing forces in life. Alas this visionary and empirical perspective has been overshadowed by unilateral concern and aversion to risk and adversity in modern times.

This paper develops a systematic and unambiguous framework for the so called up-side and down-side risk and provides a practical illustrative case study for the new holism that it advocates. The case study is chosen from the rail industry where a complex decision based on the anticipated but generally unknown performance of a new technology has been facilitated through a scientific framework for bipolar assessment of up-side and down-side risks. This enabled the duty holders to arrive at a decision based on the balance of loss and gain rather than minimization of risk and adversity as advocated in legal frameworks today.

Key Words: Risk and Reward Analysis (RaRa), Holistic Approach, Axle Counters, Track Circuits.

1 Introduction

The re-signalling of a coastal region in the UK involved application of Axle Counters (AXC) as an alternative to the Track Circuit based Train Detection. However, due to the novelty of the technology in the environment of interest, the application safety case for Axle Counters faced challenges which are not atypical for complex multi-faceted changes in the safety conscious environment of the railways. The problems pertain to loss of a number of supplementary safety benefits provided by Track-circuits namely;

- Detection of a proportion of broken rails
- Use of track circuit operating clips for emergency protection
- Detection of failures in traction bonding
- Potential detection of obstructions on the line
This paper describes the process and depicts the outcome of a fast track safety study, initiated to tackle some of the complexities and consequent uncertainties in the Axle Counter application and pave the way for a credible and rational way forward in such circumstances.

2 Background

The author was consulted about an efficient and systematic approach to assist with the resolution of complexities associated with the safety justification of Axle Counter application in a resignalling project. To this end, a novel approach to the safety assessment, Risk and Reward Analysis (RaRa) methodology which was devised by the author in the past was proposed, adopted and applied to this study [1].

The risk and reward approach purports to represent a more realistic view of a change brought about by a product, process, system or undertaking. It is argued that any such change will invariably comprise detrimental (risk) as well as beneficial (reward) consequences. The mere focus on the detrimental facets as typified by aversion to risk is adversarial, blinkered and representative of a partial reality which is unsuitable and insufficient for rational and objective decision making. The approach therefore advocates and facilitates a holistic view and evaluation of the nature of change in any context including safety performance, through objective scrutiny and assessment of beneficial as well as detrimental impact. In view of its radical nature, the author assumes responsibility for providing rationale and justification for the adopted process whilst the essence of the knowledge captured belongs to the expert panel.

The study depicted in this paper relates to the systems safety aspects of Axle Counter Application in a resignalling project, aiming to identify the detrimental as well as beneficial facets to safety brought about by the application of this Train Detection technology in the project.

The principal aim of the study was to enhance understanding and find a way forward in the light of uncertainties and unresolved issues pertaining to broken rail related facets of the Axle Counter application. These had slowed progress in spite of an extensive safety study already conducted within the project. In this spirit, the RaRa study of Axle Counter application was designed as a fast track problem resolution exercise but with a larger scope for potential reuse elsewhere. The expert panel requirements were discussed with the project manager and the relevant experts were identified and invited by him.

2.1 Study Approach

A number of workshops were held to elicit expert knowledge in the context and provide the raw material for the RaRa analysis. These were chaired by the author who presented a number of alternative approaches and options for the systematic analysis of the risks and rewards associated with the application of Axle Counters in the resignalling project. The following options for the study were presented;

1. Full scale and independent study of Track-circuit and Axle Counter safety performance customised for the application with a view to contrast the risk profiles
2. Differential and full safety study of the Axle Counters risks and rewards baselined against Track-circuits
3. Detailed scrutiny of the loss of broken rail detection issue in the project

The panel opted for the second option, aiming to revisit the whole safety performance issue from a differential aspect in order to have a complete process and thorough coverage.

The outline plan for the study was elaborated as comprising three key stages;

a) Identification/review of the Problems and associated hazards
b) Identification of the Beneficial aspects and associated Opportunities
c) Qualitative yet numerical evaluation of the Hazards and Opportunities based on expert judgement

2.2 Methodology

At the first expert panel session, the chairman presented an overview of the Risk and Reward (RaRa) approach to the assessment of products, processes, undertakings and systems based on a new theory advanced by him. In this new paradigm, the detrimental and beneficial facets of any product, process or system are identified and assessed with a view to arrive at a balanced and realistic perspective on the net effects of introducing a change or enhancement. The RaRa methodology is universal and can be applied to any facet of performance including safety. The rationale being that whilst hazards arising from a product, process or system can cause accidents and various levels of harm to the exposed parties (risks), the beneficial technological or safety features are likely to reduce/mitigate the frequency or severity of undesirable accidents arising from the application of the existing technologies/solutions (rewards). Whilst rational, this is potentially radical within the adversarial framework of the law and current safety analysis norms and practice.

In the course of the study workshops, the chairman explained that after identification and equitable attention to the hazards and opportunities of the Axle Counters, the new holistic process for the evaluation of the effects of hazards and opportunities will be employed to establish the net impact of implementing Axle Counters in the project. In the absence of any counter arguments and alternative approaches, this was agreed and adopted for the whole study.

Two generic Hazard and Opportunity assessment models (Figures 1&2) underpin the process for expert knowledge elicitation and judgement in each case. Employing these generic models, expert knowledge about the escalation scenarios and probabilities associated with various aspects were elicited during the final session. To optimise the use of time and the available resource, the hazards and opportunities depicted in were prioritised in terms of their potential for accident causation/prevention and only the high potential cases have been evaluated in this study.
Fig. 1: Generic Opportunity Assessment Model
Fig. 2: Generic Hazard Assessment Model
3. The Study of Axle Counters

The study of the AXC in this context has mainly focused on the facets pertinent to the relative merits and demerits of train detection employing Axle Counters contrasted against Track Circuit based solutions. In this spirit, mainly the differential features of the AXC, when contrasted against the conventional UK train detection, have been scrutinised with a view to establish the incremental safety gains or losses arising from its application.

3.1 Problems - Definition and Scoping

At the outset, and given the history of the problem, the expert panel was asked to articulate the nature of the deficiencies that they perceived about the Axle Counters. Note that the problems are differential i.e. baseline against the conventional UK train detection. An illustrative sample of the core concerns comprising 18 classes of problem areas are depicted in Table 1 as follows:

<table>
<thead>
<tr>
<th>Ref</th>
<th>Description</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Discontinuous train detection</td>
<td>Track circuits are designed to continuously detect the presence of a train throughout its transition through the track section. In contrast Axle Counters merely detect the train entering and leaving the track section.</td>
</tr>
<tr>
<td>P2</td>
<td>Increase fixture of axle counter heads to the line</td>
<td>The additional need to drill the rail to affix the axle counter heads to it. This is countered to an extent by the removal of the need to make track circuit connections to the rail. See benefit B14</td>
</tr>
<tr>
<td>P…</td>
<td>Possession spanning across TC and AXC sections</td>
<td>There may be additional risk associated with the management of possessions which span the interface between track circuited and axle counter sections of line.</td>
</tr>
<tr>
<td>P18</td>
<td>Losing potential detection of major arcing</td>
<td>There is a potential for gross traction arcing to be detected by track circuits by the rupturing of track circuit fuses etc. This feature is lost when axle counters are introduced.</td>
</tr>
</tbody>
</table>

The list of identified concerns and problems were subsequently complemented with newly emerging issues arising from the scrutiny of the project’s hazard log or operational experience.

3.2 Hazard Identification

The expert panel was subsequently asked to focus on each real/perceived problem and identify the safety hazards which may arise from the stated deficiencies in the Axle Counter based Train Detection. The referencing adopted for each Hazard retains the problem aspect to which the specific Hazard relates e.g. P4/H2 signifying the second identified safety hazard arising from the fourth problematic feature when contrasted against Track circuits. An illustrative sub-set of 25 safety hazards identified are depicted in Table 2 as follows;
Table 2: The Hazards arising from Relative Deficiencies of AXC

<table>
<thead>
<tr>
<th>Item</th>
<th>Ranking</th>
<th>Ref.</th>
<th>Cause/Scenario</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>P1/H1</td>
<td>Train derailed and wreckage fouls the adjacent line, in a manner which would have caused a TC to operate</td>
<td>Obstruction not detected</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>P1/H2</td>
<td>WSF occurs (The differential hazard is that the WSF may be present for longer, as it does not have a tendency to self rectify as in the case of Track circuits)</td>
<td>Section shown clear when occupied for longer due to WSF of AXC.</td>
</tr>
<tr>
<td>…</td>
<td>L</td>
<td>P17/H1</td>
<td>Different procedures for AXC and TC (Ranked “L” on the basis of likely familiarity of staff with locality)</td>
<td>Some one not realising correct procedure, more staff present at track side to correct the error. (exposed to possibility of failure of protection)</td>
</tr>
<tr>
<td>25</td>
<td>L</td>
<td>P18/H1</td>
<td>Arcing damage to the rail is not detected – (Ranked “L” on the basis that although gross arcing may cause a track circuit failure through the blowing of fuses etc, the signalling staff called to rectify the failure are very unlikely to identify the site of the arcing. Hence in the track circuit case the likelihood of identifying the arcing damage is very low. Thus the differential between axle counters and track circuits is very low)</td>
<td>Traffic routed to broken rail section</td>
</tr>
</tbody>
</table>

The above hazards mainly relating to the design, application, operational and maintenance aspects of AXC were subsequently reviewed against the project’s Hazard Log to establish consistency and completeness.

3.3 Hazard Analysis

The data for the risk assessment for each hazard was elicited mainly during session 2 and reviewed offline by the expert panel, based on the requirements of the Generic Hazard/Risk model. The parameters against each hazard relate to the generic risk model elements evaluated bearing in mind the specific application environment. The standard scientific notation was adopted for the representation of the data in order to ensure clarity and consistency. The justification for the data and their relevance to the project environment was captured and recorded where appropriate.
3.4 Risk Assessment

The elicitation of the parameters for assessment of the risks arising from the Hazards identified in the study sessions 5 was mainly carried out employing the Generic Hazard Assessment Model (Figure 2) as the basis for elicitation of the requisite parameters. These were captured and shared with the panel for offline review, correction and enhancements. Note that these parameters are based on a consensus amongst the expert panel members after a number of reviews, taking the specific scenarios within the context of the project into account.

With the aid of the specific parameters pertinent to each hazard, the Generic Hazard Assessment Model was employed to compute the annual safety risks arising from each hazard. This process is principally based on the assessment of consequences and risks arising from hazards as advocated by Yellow Book III, the UK rail industry’s code of practice in change and safety management [Ref 3]. The risk figures have been computed per hazard and integrated to arrive at a holistic safety risk profile for the application of the AXC. The units of computation are annual safety risks per hazard and for the whole project. The Hazards were sorted in decreasing risk order and those which have been ranked as low impact have not been assessed and have null risk against them.

The annualised safety risk computations for all the hazards pertaining to AXC application are as follows:

<table>
<thead>
<tr>
<th>Total AXC Annual Safety Risks in</th>
<th>x.yE-05</th>
</tr>
</thead>
</table>

The risk forecast is in equivalent fatality units (a common currency derived from injuries and fatalities forecast) and is differential with respect to the level of risks associated with Track-circuit train-detection. This implies that the application of Axle Counters in the project will create an additional annual risk of equivalent fatality amounting to 4.5E-05 for Train-detection. These are further discussed under Conclusions section.

3.5 Beneficial Features - Definition and Scoping

The philosophy (RaRa) adopted in the course of the study necessitates that the all positive and beneficial facets of the product, system, process or undertaking are identified with the same systematic rigour applied to the adverse features. To this end, a Benefits and Opportunity identification exercise was carried out in the course of the second study workshop when, 21 classes of beneficial facets were first elicited from the expert panel. These are essentially contrasted against the standard UK Track-circuit based train detection and an illustrative sub-set is depicted in Table 3:
Table 3: AXC’s Classes of Beneficial Features Conductive to Better Safety

<table>
<thead>
<tr>
<th>Ref</th>
<th>Description</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Increased reliability</td>
<td>There is an expectation that axle counters will prove to be significantly more reliable than track circuits</td>
</tr>
<tr>
<td>B2</td>
<td>Removed IBJ</td>
<td>The elimination of track circuits will enable the removal of insulated block joints, which are an inherent weakness in the structure of the rail.</td>
</tr>
<tr>
<td>…</td>
<td>Rail break will not cause WSF</td>
<td>With track circuits, rail breaks in combination with other failures can cause wrong side track circuit failures.</td>
</tr>
<tr>
<td>B21</td>
<td>Short section of tracks fitted with AXC</td>
<td>There is no lower limit on the length of an axle counter section associated with spanning of the section by long wheelbase vehicles. With track circuits, such a lower limit exists.</td>
</tr>
</tbody>
</table>

These classes of perceived differential benefits over the conventional Track Circuit based Train Detection were reviewed during the second group study workshop in terms of their potential contribution to safety performance improvements in design, application, operational and maintenance aspects of AXC. These are ranked accordingly as H, M or L relating to High, Medium and Low. The expert panel identified a sub-set with the highest (H) potential in this context for detailed analysis. These were considered during the final evaluation group study.

In view of the nature of the creative knowledge elicitation processes applied to the identification of Problems and Benefits, these represent the best available expert knowledge and may be complemented with further analysis or during application with new emerging properties.

3.6 Opportunity Identification

Further to the identification of the beneficial classes of AXC design and construction and technology, the expert panel was subsequently asked to focus on each facet and identify the safety opportunities which may arise from each feature. Many Opportunities, i.e. circumstances with a potential to avert accidents and losses, were identified for each class of benefit in Table 6. The referencing adopted for each Opportunity retains the beneficial aspect to which the specific Opportunity relates e.g. B1/O2 signifying the second identified safety Opportunity arising from the first beneficial feature. An illustrative sub-set of the 29 Opportunities identified is depicted in Table 4:
Table 4: The Safety Opportunities arising from Perceived Benefits of AXC

<table>
<thead>
<tr>
<th>Item</th>
<th>Ranking</th>
<th>Ref.</th>
<th>Cause</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>B1/O1</td>
<td>Fewer failures of AXC, resulting in less degraded mode of signalling</td>
<td>Less human error through hand-signalling etc., security of interlocking preserved at all times</td>
</tr>
<tr>
<td>2</td>
<td>H</td>
<td>B1/O2</td>
<td>Fewer failures of AXC</td>
<td>Fewer staff at track side fault finding, and hence less red zone working (exposed to possibility of failure of protection)</td>
</tr>
<tr>
<td>…</td>
<td>L</td>
<td>B20/O1</td>
<td>Parallel bonding</td>
<td>Preserve the integrity of interlocking system</td>
</tr>
<tr>
<td>29</td>
<td>-</td>
<td>B21/O1</td>
<td>Short physical length of a scheme</td>
<td>Greater design flexibility</td>
</tr>
</tbody>
</table>

In a similar fashion to the hazards and for efficiency reasons, the safety opportunities with a High impact on the safety improvement of the operational railway have been assessed in the study.

3.7 Opportunity Analysis

The process for the knowledge capture and analysis of opportunities resembles that pertaining to hazards, as described earlier. This process, relates to an efficient, expert driven, yet quantitative evaluation of the impact of the identified opportunities. The supporting model for this essentially broad brush approach is depicted in Fig. 1. This model was mainly employed during the third group study session to elicit expert knowledge on the pertinent parameters for each element within the generic model.

In principle, the identified opportunities fall in two distinct classes namely, those hazards pertaining to Track Circuits which occur less frequently and those features specific to Axle Counters capable of preventing accidents which would otherwise occur. In view of their different nature, these classes have been assessed using the appropriate generic hazard or opportunity models.

3.8 Reward Assessment

The elicitation of the parameters for assessment of the rewards (accidents prevented/risks avoided) arising from the Opportunities depicted in Table 7 was mainly carried out during the third and final study workshop. The two classes of opportunities were assessed using both generic models since some were essentially less frequent hazards and more suitable for the generic hazard model and some specific new features better suited to the generic opportunity model.

The assessment of the opportunities relating to certain existing hazards occurring less frequently is best carried out against the generic hazard model (Figure 2) on a differential basis contrasted against the Track circuits.
The Generic Opportunity Assessment Model (Fig. 1) was employed as the basis for elicitation of the requisite parameters pertinent to the evaluation of opportunities relating to the specific features of Axle Counter within the application environment.

In the same spirit as the hazard assessment, the Opportunity evaluation parameters are based on a consensus amongst the expert panel members taking the specific scenarios and the application environment into account. With the aid of the specific parameters pertinent to each scenario, the Generic Hazard and Opportunity Models (Fig. 1) was employed to compute the safety rewards (accidents potentially avoided and lives saved) arising from each opportunity. Unlike the hazard assessment approach, this process has no public domain counterpart at the moment which is primarily driven by adversarial stance of the safety analysis and approvals regime in use today. The safety reward figures have been computed annually per Opportunity and summed up as general profile for each one of the two classes relevant to the application of AXC. The units of computation are annual risk avoided per opportunity for the whole project.

The safety reward computations for all the high impact Opportunities pertaining to the application of AXC are as follows:

<table>
<thead>
<tr>
<th>Total AXC Annual Safety Rewards (lives saved in Project)</th>
<th>e.1E-03</th>
</tr>
</thead>
</table>

Note that these results are only valid within the scope of the existing study and based on the perceived differential benefits of AXC against the standard UK train detection.

3.9 Discussion

The current perceptions of the risks associated with the Axle Counters have been subjected to systematic scrutiny, albeit with an adversarial safety perspective at first. The imbalanced focus on the detrimental facets has been redressed during the subsequent workshops, where many more beneficial as well as additional detrimental aspects were identified and captured.

It is worth emphasising however that the study has mainly been a process for the evaluation of the change brought about by the introduction of AXCs, as baselined against the conventional Track Circuit train detection. In this spirit, this study was principally aimed at a differential risk and reward analysis of the change and not initially intended to arrive at a risk profile for Axle Counters.

4. In Summary

4.1 Conclusions

The special study of the AXC was primarily initiated to establish an efficient and credible approach to its safety justification within the resignalling project. Whilst essentially qualitative in nature, the adopted approach renders quantitative estimates for risks hence capable of generating a holistic risk profile based on expert judgment. This is in sharp contrast with the traditional ranking matrices which are structurally deficient and often inappropriately applied to assess, determine tolerability and justify risks arising from individual hazards never knowing the total profile for the product or process.
4.2 The Balance

The safety rewards for the application of Axle Counters in the project demonstrated a net and a relatively large improvement in safety performance of the train detection in the project based on the RaRa analysis principally driven by the judgment of the experts participating in the study. Conventional safety assessment would have generated estimates for the risks arising from the identified hazards, potentially overlooking the beneficial facets and the overall impact of change. The Risk and Reward study of Axle Counters has generated the essential and holistic perspectives to support objective decision making.

4.3 Recommendations

The risk and reward analysis of the detrimental as well as beneficial features of Axle Counters, when contrasted against the standard train detection, as a potential alternative solution, has rendered a broad brush appreciation of the total risks, rewards as well as a net balance. These are computed in terms of safety risk i.e. likelihood of injuries and fatalities, annualised through consideration of train traffic and parameters pertinent to the operational environment.

However, the results of this study are treated as a component in the decision support process and per se are not suitable nor sufficient as the only criteria for deployment, should this be the ultimate judgement. In order to demonstrate compliance with the statutory requirements and the ALARP principle, consideration must be given to two classes of additional endeavours namely:

1. Review of significant hazards and consideration of costs & benefits of remedial/risk mitigation technical, operational or procedural measures
2. Design and deployment of a pertinent Safety Management System for the project to ensure operational risks will be managed competently

The process and outcome of this study and radical approach would constitute an essential input and a rational basis for the above activities which may be embodied within the project’s safety case.

References

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[3]. Engineering Safety Management (Yellow Book) Issue 3, Railtrack plc, 2000

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