A critical analysis of signal passed at danger (SPAD) events of Indian railways

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Abstract. SPAD i.e. "Signal Passed At Danger" is defined as an event when a train passes a signal at danger (stop) without any authority. It is a frightening event for any Railway system in view of its potential disastrous outcome. Every railway system in the globe advanced and not so advanced are extremely concerned about this safety risk. Hence there is a need to manage the risk. As present reasons for SPAD, has not been a guarantee for its non occurrence, it is essential to relook at the entire gambit of issues related to SPAD with use of scientific model (MODEL FOR ASSESSING AND REDUCING SPAD) MARS to gather further in depth and true knowledge on the issue so essential for any future strategies of SPAD reduction and mitigation. Indian Railways also grapple with the perennial vulnerability of their system from SPAD.

Keywords: Signal Passed At Danger (SPAD), Model for Assessing and Reducing SPAD (MARS), Train Protection Warning System (TPWS), Vigilance Control Device (VCD)

1 Introduction

'Red signal' is a common status in rail transportation. Rail crew encounters mailing of 'Red signals' in their service carriers rather uneventfully .However, passing a signal at danger is a frightening event, in view of its serious adverse impact and catastrophic outcome. Every railway system in the world is struggling to cope up with this frightening event however less in number it may be .Indian Railways also have been cautiously taking action not only to reduce the number of incidences of SPAD but also to reduce its severity and very adverse consequence. However, despite the effects being taken on a continuous manner there are still large numbers of incidences occurring annually. SPAD rate for millions of red signal encountered has not been assessed truthfully. Assessment of Human Reliability perhaps does not answer the entire gambit of issues related to SPAD. Train driving requires undivided attention observing all information and controlling the train accordingly.

There has been extensive research globally on SPAD. Still whether SPAD is a random human error that is typical of rail crew is not fully researched and established .Induction of advanced technologies (i.e. Train Protection Warning System, Automatic Train Protection etc) only aim at managing the consequence of SPAD while remaining totally clueless about the cause for occurrence of SPAD. Every research takes expert from their own system, assimilate the generic issues. In most cases of SPAD, prima facie reporting holds crew guilty without details being obtained and analyzed. Crew becomes instant culprit. Despite this approach the incidences of SPAD is happening with equal impunity. There is apparently no explanation for this paradox. Though induction of advanced technology has started (provision of TPWS, ATP etc) it may take considerable time and money for complete implementation. From evolution of rail transport system, the rail industry looked forward for a cost effective solution to mitigate this possible error. Against this back ground the SPAD incidences are critically reviewed with a scientifically proved model (MARS) to evaluate present method of mitigation and identify gaps so that a mere comprehensive mitigation strategy can be evolved to deal the menace called SPAD. The paper has been organized as follows. Section 2 reviews literature on Railway accidents, SPAD, its causes & Remedy. In Section 3 SPAD is analyzed in Indian Railway sector where as section 4 represent the collected data and its further analysis. In Section 5 MARS is applied to reduce SPAD. Section 6 discusses how SPADS can be observed and tackled efficiency in the long run & Section 7 concludes paper.

2. Literature Review

Several factors like- population, overcrowding trains, carelessness of passengers and drivers towards railway norms are highlighted to be the major causes of railway fatalities. Hence Railway authority and people both should take preventive actions through awareness, maintenance and enforcement of strict laws to reduce the number of accidents [1]. An effort is made to diagnose faults in fixed block railway system where single train is allowed in a block and driver has to pay attention for the signal for the next track. Petri net and DES approach used to design model to diagnose faults and prevent collision [2]. Study on optimizing railway sector by improving its traffic control process carried out. A Model developed which consists of two methods heuristic resolution and optimization solution to resolve the conflict. Heuristic resolution which is greedy algorithm solve conflict in short span of time taking only local decision criteria whereas optimal solution take all the possible decision criteria using branch and bound technique and search tree method. Results of the model from these two methods were analyzed by conducting different tests. Tests revealed that results were optimal with in feasible time limit [3]. Work reported on optimization of railway traffic globally. Computerized dispatching rule (ROMA) is used to reschedule the disturbed network. Computational result showed effective performance in reducing delay as compared to local dispatching procedures [4]. A survey carried out in two countries passengers' those are 200 Korean Train Express passenger and 150 France TGV passengers to develop conceptual model of ride comfort. Model further analysed using structural equation modelling. Result showed that although there is difference in cultural environment, preference still both the models possessed similar critical factors but difference of loading factors in 1.5 to 2 times [5]. Based on the past studies, one may think that there is no common list of factors that are applicable in all countries [6] .In other words, each country having their unique factors from the other countries due to their capital availability, technological advancement, expertise of work force and top management vision. Hence it is concluded that railway accidental factors and its solution may vary from one country to another [7]. Causes of railway accidents and railway safety in Great Britain, Europe Union and U.S. are studied. Best cited examples are automatic train protection system and level crossing safety and further cost benefit analysis carried out [8]. Majority of accidents were due to derailment -broken rail was stated. So through proper welding, number of accidents could be significantly reduced. Cost effectiveness of this strategy compared with others to select the best one which maximize safety and minimize risk [9].

3. Analysis of SPAD in Indian Railway

Indian Railway is adopting a traditional method of SPAD analysis. The comprehensive analysis of primarily done with crew focus. A recently analysis of 239 cases over last five yrs, reveal the following.

- Out of 239 cases, 22 cases (9.2%) SPAD led to consequential accidents.
- The distinctive of share of SPAD cases traction wise ie Diesel and electric are almost same.
- SPAD cases involving passenger train and freight trains are almost equals 51.5% and 48.5% respectively.
- Majority of cases of SPAD occurred with crew availing HQ rest.
- The no of SPAD cases done during i.e 6 a.m to 18 p.m and night 8 pm to 6 am are almost equal.
- Maximum no of SPAD cases happened during the time period 10 hrs. to 12 hrs. followed by 4 am to 6 am, 2 am to 4 am.
- In most of cases (70%) crew had completed 6 hrs. of duty or less.
- Passing of 'starter signal' & 'Home signal' are almost equal 45% and 44% respectively.
- Maintenance no of SPAD cases occurred in DEC followed by FEB.

- Maximum number of loco pilot involved in SPAD cases were between ages of 40-45, followed by age group of 50-55.
- On 15% of loco pilot involved were of 'C category'

This exhaustive analysis believes the common perception with the revelation of above facts. The common knowledge vis-a-vis the findings is tabulated for better appreciation.

Table 1 represents the common knowledge vis-a-vis the findings

Common knowledge	Findings
1. All cases of SPAD is a catastrophe	1. Only 9.2% cases led to consequential accident
2. SPAD incidence are more with freight train	2. SPAD incidences are same for freight & passenger train
3. SPAD cases more in diesel traction	3. It is same for both diesel and electric track.
4. SPAD cases happen mostly during night	4. Incidences are equal during day and night
5. Worst time from SPAD between 2 hrs. to 4 hrs.	5. The maximum number of cases happened in 10 to 12 hrs
6. Long hours of working result in SPAD	6. 70 % cases are with loco pilot duty hrs is less than hrs.
7. Loco piloted promoted departmentally are more involved.	7. The cases are evenly distributed between RRB SPAD

These revelations prove the traditional knowledge of SPAD was misconstrued. This should be a serious cause for concern. Moreover the incidence analysis in this format does not lead to a conclusive finding so that appropriate preventive strategy can be formed. Every preventive action taken till now appears to be like whistling in the darkness.

Against this backdrop, a different method of analysis of SPAD cases using MARS model to facilitate a better understanding of this frightening unsafe occurrences and there by assess correct preventive measures. Prior to that the, relevance of each factor needs a close look.

4. Data Collection and Analysis

Total number of 468 cases of Indian Railways over span of last 8 years was critically analyzed with application of the above model. The total number of cases has been further divided into two categories according to their severity. A total of 53 cases are having severe consequences out of the total 468 cases (nearly 11%) while balance 415 cases have minimum/ nil consequence.

4.1 Analysis of 415 cases with minimum/nil consequence

Table 2 represents errors in total Incidence

Type of Error	Nomenclature	Total No. of Incidence
Error and Detection	D	146
Error in Decision/ Interpretation	I	142
Error in Response/Action	A	122
	Total	415

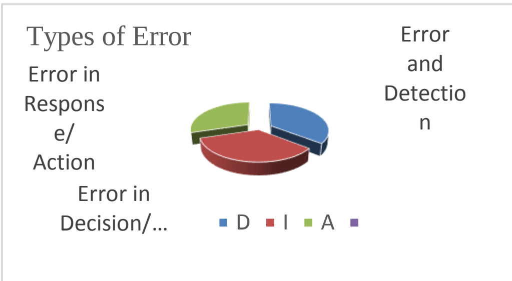

Figure 1 pie chart shows type of errors

Observation: Number of detection error and interpretation error are almost equal while error in response is marginally less. Broadly error in all the three stages is found to be almost equal. Hence the preventive measures need to be equally focused on all stages of error

Table 3 shows type of signals in total no of Incidents

Type of signal	**Total No. of Incidence**
Starter	158
Advance Starter	18
Home	175
Shunt	76
Automatic Signal	8
Total	415

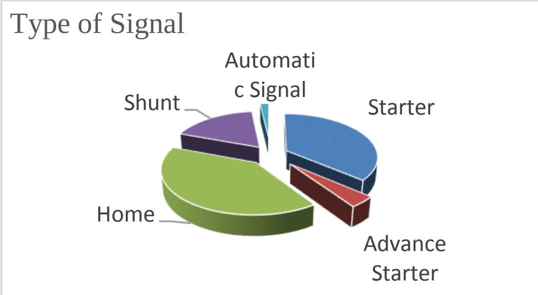

Figure 2 pie chart shows type of signals used

Observation:
The number of incidences of passing starter and advance starter signals at danger vis-à-vis home signals at danger is almost equal confirming error in detection and error in response to be at par. There is large number of incidences of passing shunt signals at danger. Passing automatic signals at danger is rather very less (hardly 2%).

Table 4 shows type of Trains

Type of Train	Total No of Incidents
Passenger	115
Freight	132
Locomotive	98
EMU	55
Track Machines	15
Total	415

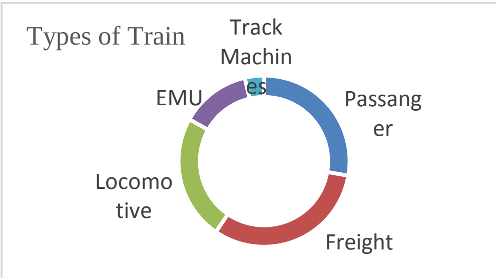

Figure 3 pie chart shows type of Train

Observation:
The number of incidences involving freight trains is more than passenger trains. There are almost 11% cases involving EMU i.e. single man crew. There are nearly 4% cases involving track machines which would be mostly due to conflicting instructions.

Similarly 53 cases having severe consequence are further analyzed. From where it is observed that

- The number of incidences due to detection error is almost equal to incidences caused both due to error in interpretation as well as error in response. Incidences due to error in interpretation and response are almost equal.
- The number of incidences involving passing of starter signal at danger and home signal at danger are almost same. Almost 10% of incidences are due to passing shunt signals at danger i.e. at low speed
- Incidences involving locomotive alone is a quite high indicating lowering of alertness during driving of light engine.
- The number of incidences leading to collision and derailment are almost same. Protection to be planned for both with equal focus.

5. Application of MARS [MODEL FOR ASSESSING & REDUCING SPAD]

Getting at the underline systemic causes of SPAD – A new approach
Working with rail track and number of train operating companies, human reliability associates had developed a model to inform SPAD investigation through analysis of systemic cause. This has become known as MODEL for assessing and reducing SPAD (MARS).
The MODEL consists of three categories of information processing. These represent the normal stages through which crew must progress when responding to a signal while working a train.

Detection :
Acquisition of information
Detecting the presence of a signal and identifying the signal aspect.
Decision/ Interpretation:
Interpreting the meaning of the Signal Aspect & developing an intention to act in formulate a braking strategy – normally this is performed without conscious thought.
Response/Action:
Executing chosen course of action physically.
In every stage there is possibility of commission & omission.
At all the above stages human performance may be influenced by factors that are not always under the direct control of the individual.

6. Discussion

With application of MARS all the incidences have been classified according to the influence diagrams. From these diagrams inferences are drawn for identifying causal factors. Such analysis aims at providing a broad frame work for allocating resources to address the most critical contributors to risk. The MARS model also provides an in built route cause analysis.

A higher level consistency and conformity can be achieved with application of this model. This in turn allows underlying systematic patterns and trends in the factors giving rise to SPADS to be observed and therefore tackled efficiency in the long run. In addition to the above SPAD reports can be generated with details as indicated below for facilitating categorization of causal factors. SPAD Reports finally considers the following. (i)Rolling Stock (ii) Crew (iii) Station .For better appreciation of SPAD analysis/ deliberation on existing signaling system is considered essential. Each of these ideas needs exhaustive evaluation and implementation to ensure SPAD protection / redundancy in design, erection, operation and maintenance. However detailed explanation of each of these strategies mentioned under the primary heads is excluded from this report in view of space limitation. Exhaustive deliberation of issues is separately attempted in an extended study to prepare the mitigation strategy framework.

7. Conclusion

SPAD is considered a Random Human Error (RHE).Every human error leading to rail transport accident is in that way a 'random human error'. Then how SPAD is different? From other human errors often revealed in rail transport accident. SPAD is unique i.e. that it is both mental and physical at the same time and defy all logic. It is an unusual event so close to a usual event. Crew passes of signals safety every day, day after day, and year after year uneventfully, unnoticeably .The man machine interface in sighting a signal remains always dynamic. Hence no lapses / failing are predictable. The randomness of the SPAD event makes the analysis on the basis of crew criteria, rolling stock criteria, signal criteria, environment criteria, situational criteria, often futile. Railways have always tried to search for a pattern and then strategic mitigation. However with practically no fixed pattern, the search for mitigation remains always elusive. SPAD is not the sickness the system suffers due to a single virus attack. Hence complete quarantine may not be possible. However the systems resilient &Can be upgraded to withstand any passive harmful effect of SPAD with minimum consequence.

To this objective, the mitigation strategies being implemented in a systematic manner shall definite make the risk less fatal and thus inconsequential.

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