A Critical Study of Issues Pertaining to Fatigue & Alertness of Crew in Rail Transport System Through Analysis of Data of Vigilance Control Device Installed in the Locomotive

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Abstract
Transportation is a 24x7 Industry. 'Rail Transport' amongst all four prime modes of transports (i.e. Road, Sea, and Air& Rail) is unique particularly for transportation of freight in view of 'open roster system for crew'. There have been many accidents in Railways indicating impaired performance of crew. In most situations it is difficult to establish any other possible reason for his impaired performance other than that being fatigue related. Study on fatigue has been rather almost a forbidden topic on most industries including the transport industry. However off late there has been significant research globally to understand the role of fatigue on performance of crew. Through this study an attempt is made to understand the complex cause of fatigue in rail crew with an aim to evolve possible counter reasons. Till date commonsense knowledge has been guiding the analysis of crew impairment. There has been a growing concern due to very adverse outcome of crew fatigue. In this paper, attempt has been made to analyze the data of vigilance control device installed in the locomotive for better understanding of the crew impairment.

Keywords
Crew , Fatigue, Alertness, Vigilance Control Device, Loco Pilot, Master Controller (MP), Brake Controller (A9, SA9).HOER.

I. Introduction

Fatigue is one of the more pervasive yet under reported causes of human error related accidents & incidences in 24/7 transport industries. Institutional responsibility provides me a unique opportunity for getting the in sight of an accident. Most time the investigation concludes with identification of cause or assumption of probable cause. However, the true investigation should aim at finding the causes for the cause. In most incidences the truth remains circumstantial with majority of findings remaining intriguing. Truth is often unfortunately buried with the painful and sad demise of the front line operators. It is undoubtedly essential that every attempt through scientific study is made to unravel the hidden truth. Fatigue a rapidly emerging as one of the greatest single safety risk now facing the transport industry. Though study of fatigue and its impact on transportation has a long history, still less is a known and more remains unknown in this area. For most organization fatigue is a forbidden subject and under evaluated. However in view of its being cause of many serious consequences and tragic accident, it is essential to assess the role of fatigue more logistically and objectively.

An attempt has been made through this study to identify the causes and identify its counter measures. With this subjective, issues of crew alertness and fatigue are studied with available information and data. In recent past all the locomotives of Indian Railways have been equipped with Vigilance Control Device (VCD) a safety device, as a counter measure against the risk of crew inattention / failing. In this paper an attempt has been made to analyze the data of VCD to identify various issues which till now have been considered as common sense knowledge. The analysis, however, revealed information contrary to the accepted common knowledge thus compelling for continued study in this direction.

Aims of Study

The study intends to focus on freight crew.

To reveal the extent of risk with subjective evaluation and recommending counter measures that could be a part of over of a modern rail transport safety management system.

1. The contributing factors for onset of fatigue
2. Evaluate the impact of fatigue on performance impairment with possible consequence of mishaps/accidents and incidents.
3. Existing protection in the rules being presently expected and the system of work.
4. Areas of conflicts/violation and clarity of objective with ever growing needs of transport.
5. Drawing the limit of balancing act between demand and operational safety
6. Role and responsibility of organization and individuals to handle to the risk.

II. Approach

The study of science of fatigue till now has not revealed a definite method to be used to reduce/eliminate its effect on performance. Till now "commonsense" approach being widely noted to address the issue of fatigue and its likely impact on impaired performance. Freight crew being the most critical/important front line staff to be affected by fatigue, a comprehensive study is made. The working of freight crew are governed by

Provision in Hours of employment rules (HOER). The very nature of job makes their duty cycle variable on day to day basis. There can be no fixed roster/shift. The unique features of their working make them stand out amongst all safety critical front line staff Transport is a 24/7 industry "Rail Transport' amongst all the four prime modes of transport is unique for its 'operational system for freight crew'.

A. Job Requirement freight crew

1. Variable duty cycle
2. Variable working hours
3. No fixed time of start/end of duty
4. No fixed weekly rest
5. No fixed time for rest, rest period rather varies from 6 hrs to 24 hrs.
6. No regular time for taking food, attending to nature call, bathing, sleeping etc

B. Physical Requirement

1. Dynamic working environment
2. Serious influence of weather and external factors in working.
3. Ever changing condition of work
4. Different type of locomotive, wagons loads, etc.
5. Every day is a new day for him

6. Everyday a new partner at work

Nothing is static except his resolve to accomplice the job safely Freight Crews are subjected to most unpredictable work/Rest cycle in entire transport industry. Hence 'Fatigue' is common to the entire population of freight crew. They often struggle to fight 'fatigue' to do their job. It has been established through research that even a moderate level of fatigue produce impaired performance similar to allotted (Dawson & Rail 1997). The effect of shift length is exacerbated by the start and end time of the shift. Main cause of high fatigued life is long shift duration accompanied with uncertain shift start time. The ability of a crew to exceed driving skills depends on their level of arousal. Arousal is a general physiological stage ranging from coma, asleep drowsy to alert. Different level of arousal affects task performance in form of inverted U, with optimal performance at an intermediate level. Further the optimal value of arousal is inversely related to the difficulty of the task.

Low level of arousal is mostly caused by facts such as

- Inadequate sleep
- Sleep debt
- Sleep loss
- Sleep quality
- Shift start time
- Time of day
- Driving duration
- Perception of tasks
- Physical health
- Climate and environment of work.

The low level arousal can cause a decline is person's ability to sustain probability of distraction. "During period of low arousal it is still possible to respond automatically even though task awareness is lost". This is often is found in case of a mishap while driving. This often therefore remains "illusive" and intriguing to explain the untoward incidence during otherwise a safe journey so far. Attention relates to the allocation of mental resources that are available (capacity) and the mental operations that must be performed. This remains as a unique demand on the crew's job.

III. Job Demand

The expectation of a flaw less performance from start to end obviously cannot be compromised in the job of crew. This brings in many challenges to find and train a crew. If one is called upon to design the specification of a crew who needs to work as a perpetual machine from "start to stop" with universal efficiency, the following need deep consideration with the focus that Crew's job is defined as Life Critical Job (LCJ)

The following are unique features working and environment

- Poor working condition
- Irregular working time
- To work under perpetual motion
- No fixed duty hours
- Too many parameters to watch at a time under motion
- Responding to silent signals
- Excess heat/vibration, noise, pollution, cold rains/fog/ weather
- Deprived of social commitment
- Deprived of personal commitment
- To meet the requirement of modern life
- Perpetual fear to loose
- Continued Present Mindedness being naturally unsustainable

IV. Crew Alertness

Alertness is a readiness to detect stimuli in the environment requiring a response and to react to them quickly and approximately. Alertness declines during period of little or no stimulation. An unchanging stimulus or repetition of the same or similar stimuli will also induce loss of alertness. One's loss of response to continued or repetitive stimuli is called "adoption" Foremost amongst his many skills, the crew must demonstrate vigilance on capacity to be affective to all critical, information inputs throughout a trip. Within a confined work place of loco cab the alertness to be always at its peak. Strange that loss of alertness can occur on a job as complex and demanding as freight train driving. If the train is dynamically balanced to cruising at a required speed, and no events occur in the external environment to affect the trains progress than there is very little in the job to stimulate the crew. Distribution of activity is such that there were long spells (5 min to 20 min) during which the crew had little to do or care about. Even in undulating terrain there is fair possibility that the inactivity period may range from 30 to 50 percent. Many of the stimuli that are present are essentially continuous such as sound of locomotive back ground noise etc. The passage of track, the wayside one masts or km posts, the visual experience are rhythmic in nature and rapidly adopted to as un-simulating back ground. All night light passing in the visual along side track may be irregular, but they flew by at a constant speed that is also lulling. These "soporific effects" are aggravated at night by a natural daily cycling of human activity. The knowledge that one is rushing along track in front of an enormous mass of metals, difficult to control create stress that continually constitute a mere or less. Steady drains on the crew's capability to perform. Fatigue of crew arises not always from overload of the human system but also sometimes from underload or monotony and boredom due to inaction, combined with stress. This is essentially a special feature in working of freight crew. Alertness improves when, in a complex vigilance task, there is a decreased amount or novel stimulations to the sense organs not involved in the vigilance task. For single tasks, alertness improves with increased stimulation of other sense.

A. Only Stimulus for Crew is Signals

The principle of "expectancy" and 'inter signal distant' suggest the use of a regular spaced signals and crew is used to its locations. But the principle of complexion and novelty suggest some value for unpredictable alerting task. The paradox needs even further deep study.

B. Physiological Response

There is continuous decline in physiological response of the crew during the course of journey. The change in brain was (EEG) of loco crew, heart rate sometimes can reliably predict the change in response accuracy. However, doing this is not possible in present set up. Simulator for driving fails to provide accurate field standard.

C. Behavioral Response

Rate of eye blinks, frequency of eye moments, bodily achieving or response latency reliability predict changes in response accuracy. As long as monotonous work continues, general physical response and behavior tend to slow down. Frequency of eye blinking, extent of eye movement, frequency of body movements, reaction time are difficult to scientifically evaluate at present. With regard to the later variable, the elapsed time between the onset of a signal and beginning of a crew's response to the signal – There is always

response latency. Whether there can be measure and trigger for working with diminishing alertness needs further investigation.

D. Loss of Alertness

There is a distinct difference between 'alertness' and attention. A crew must be alert to be able to focus upon external events. An awake driver may still be inattentive and fail to perceive a crash treat due to " mind wondering"."Mind wondering" is a distractions internal and external to vehicle and situation or improper lookout. Divided attention could lead to loss of attention. Loss of Alertness also occurs when a person works for extended period of time or gets insufficient sleep, and or work during period when circadian rhythm are at their low points. Loss of Alertness can compromise mental, physical or physiological elements.

Partial Loss of Alertness plays a larger role when Loss of Alertness (asleep at wheel) leading to unforced mental error or judgmental error. Fitness for duty, rest and recovery readiness to perform is individual assessment. However these aspects could be counter measures to alleviate Loss of Alertness.

The Laws of attention (ref. ix)

1. Attention is a limited resource crew to expect the unaccepted is the general view.
(i). Attention is not free
(ii). It is zero sum game
(iii). More allotted to non significant event less shall be allotted to significant event.
2. Attention is selective
3. Consciousness require attention
4. Attention does not require consciousness
5. All tasks require definite degree of attention although the amount is different.
6. Directing attention to automation behavior can be highly disruptive.

Basic features of the job for a freight crew-

1. 1sthr to last hr of work sustained alertness
2. Driving skill/driving attitude with perpetual efficiency
3. Rail Rage control
4. Patience/Decision making
5. Alertness to stimuli
6. Attention to distraction
7. Fatigue free body
8. Sustained situational awareness
9. Emergency response
10. Emergency Communication
11. Safety Communication
12. Written Communication
13. Instruction understanding
14. Application of Knowledge
15. Interpretation
16. Communication
17. More than one function at a time
18. Constant vigil being not supportable, guarding against.
19. Working in abnormal situation
20. Prediction of risk
21. Realistic risk assessment
22. Risk averse behavior
23. Risk behavior suppression
24. Guard against assumption
25. Complacency and familiarity overlook
26. Life style issues effective management
27. Discipline
28. Dedication
29. Devotion
30. Unmindful in the abnormal working
31. Slow decay of safe working practices after long spell of safe operation.
32. Situational Awareness/Concentration
33. Stress management, struggle with stress anxiety, depression.
34. Fatigue issue
35. Safety behavior
36. Self Awareness
37. Diligence - systematic and strong attention

Being diligence, recognize the importance of checking information/ actual being diligent reduces the potential for complacency and assumption.

38. Personal responsibility to remain motivated to deliver a good job in time. There is no room for bad work.
39. Recognizing own ability and limit
40. Not being over confident

In order to get somebody to accomplice the above job demand, one needs to design a perpetual human machine. Hence the following is an overview of specific requirement. The true appreciation comes from making an attempt to design this perpetual human machine. This leaves always a challenge for the organization. An attempt is made here to list out the specific requirement under the exciting heading of design a driver (DAD).

E. Design A Driver (DAD)

- Psychological autopsy i.e. ever ready for above compliance
- General driving behavior Inventory
- Rail Rage resistant
- Self Assessment of Driving Skill ensuring perpetual efficiency
- Behavioral competency – driving in hostile condition
- Driving Attitude
- Driving Experience
- Dust, heat, vibration, noise resistant
- Hourly and continuous rating
- Fatigue free body
- No Wear and Tear/ Quick rest and recovery
- Compatible to variable opportunities for physical activities (Eat, Sleep, Bath, Nature call etc)
- Social factors
- Fear of loss
- Continuous Present Mindedness – unsustainable (CPM)
- Error resistant

Present Approach

The factors controlled by organization are

- Rostering
- Hours of work
- Working on rest days
- Work/rest management to minimize the condition of fatigue.
- In addition Railway Organization urgently needed to counter and safeguard against risks arising out of such issues of momentary lapse of attention of crew.
- Vigilance control devices were inducted and installed in the loco cab during last few years. This is perhaps one of the most critical safety tool introduced in recent time to safeguard against the possible risk arising out of crew's loss of alertness. A holistic analysis of the efficiency of this equipment has been assessed in this report with an objective to learn the complex issue of crew alertness decrement.

V. Vigilance Control Device (VCD)

- Monitoring alertness / in case of incapacitated of the engine crew through a multi-resetting system which gets reset by specified normal operational activities of the crew, in addition to acknowledgement of the vigilance check by pressing a pedal switch or push button provided for driver and assistant driver respectively for this purpose. Preventing accidental operation of locos, by anyunauthorized persons also can be accomplished.

A. Basic Principle

VCD is a Microprocessor base Multi resetting device. Its Main control unit consists of mother board called CPU which senses digital inputs signals from locomotive and activates output appropriately, resets the unit accordingly for next vigilance cycle.

Main functions of Vigilance System:

- Activating the VCD
- Vigilance / delay cycle
- Action cycle / Warning cycle
- Audio-visual warning
- Penalty brake cycle
- Penalty brake release
- Vigilance reset
- Vigilance suppression

B. Vigilance cycle / Delay cycle

The cycle has a preset period normally set at 60 seconds. This cycle is automatically re-started whenever the vigilance unit detects one of a number of external inputs derived from other vehicle control functions under the driver's control from the active cab, the presence of which automatically infers that the driver has taken some positive action and is therefore vigilant. The control function includes:

- Notch up /notch down by the master controller (MP) or EEC
- Operation of sander, horn, Train brake (A9), Loco brake (SA9), MPS-1
- Operation of the vigilance foot (pedal) switch

If, the driver fails to perform such an action within the cycle period, the cycle period shall be completed. When such an event occurs, a second time cycle shall be initiated and audible and visual warnings shall be given to the driver.

C. Action cycle / Warning Cycle:

This cycle is initiated whenever the delay cycle runs to completion indicating that no positive driver action has been detected for the length of the delay cycle period. During this cycle, VCD shall begin flashing a Yellow warning light for a time period 8±2 seconds. If by the end of this period, an acknowledgement by crew has not been actuated, an audible alarm for a time period 8±2 seconds shall begin in addition to yellow flashing light.

If for any reason, the action cycle expires without being reset, the brake cycle is initiated to make an automatic brake application and regression of GR.

D. Penalty Brake Cycle

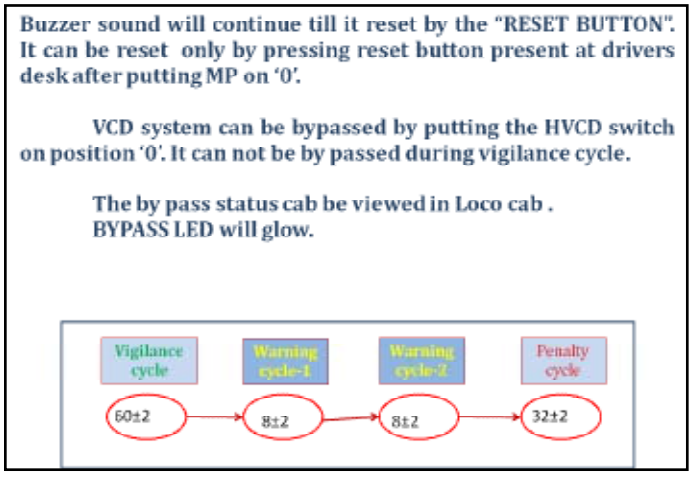
The brake cycle is initiated if the driver fails to respond to the audible and visual warnings before the expiry of the action cycle. A brake application is immediately initiated with regression of GR. This ensures that the vehicle is brought to a complete standstill. VCD initiates penalty brake, which will remain applied for a period 32±2 seconds and cannot be reset once applied during this period. Only after the expiry of the brake cycle period and then only after the master controller has been set to the off position i.e. '0' position, VCD can be reset by using the reset push button provided at driver desk. The brake application then gets released, the audible and visual warnings are cancelled and normal vehicle operation can be re-established.

E. Function of VCD

VCD unit is connected with 110 v DC. When HBA turned 'ON' a self test is performed by the unit by flashing of LED and a buzzer sound. After few seconds VCD becomes in vigilance cycle and check for the input vigilance signals from the following operations.

- Progression / regression through MP /EEC
- Sander
- Horn
- Pedal switch for acknowledgement
- Operation of Shunt 1 i.e. MPS-1
- Acknowledgement push button by ALP
- A9/SA9

When none of the above function is performed by the loco pilot within 60 sec. a visual indication of yellow warning light will blink. It continues for 8±2 sec. If then also, it is not acknowledge , an audio indication is also given along with visual indication for another 8 sec (with buzzer sound). If no activity is performed with in this last 8±2 seconds, QVCD will energize and BP will drop. Hence Penalty brake will be applied. Auto regression will also take place through NO interlock of QVCD, by feeding the 110 DC supply to SMGR regression coil. This remains activated for 32±2 seconds and can be reset only by reset button only.



VCD system shall get suppressed and by passed in following cases:

- Vehicle is stationary / speed is less than 2 kmph
- In trailing loco in the MU operation
- Application of A9 / SA9 and
- Manual control of GR
- Bypass VCD from HVCD bypass switch provided in switch board panel in healthy condition of VCD. Green and red LED shall glow to show healthy ness and bypass condition, VCD cannot be by passed during vigilance cycle

F. LCD Display

16×2 LCD display is provided to display of current status and alarming message 2 no Frs. Up/Down buttons are provided to study the Logged messages by pressing up/down. 2 nos USB interface ports are provided for data uploading and down loading(one

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is for pen drive USB interface and another is for lap top USB interface).

Logged Events (sample)

Logged Events

Vigilance Control Device Events

User ELS/BN Loco No: 27727
From : 24/02/2012 10:40:10 VCD SrNo:BL305M FW Ver: 2.006 To : 05/09/2012 08:48:02

Sl No.	Date	Time	Message	Remarks
1	24/02/201	10:40:10	POWER ON	
108	02/05/201	10:47:00	IP PROBLEM	
1118	05/05/201	15:45:46	VCD SUPPRESSED A9 APPLIED	
131	02/05/201	11:02:58	FOOT SWITCH 1 OPERATED	
132	02/05/201	11:03:08	ACK P/BSW1 OPTD	
14	01/05/201	17:59:14	VCD BYPASS BUT HEALTHY	
24837	06/07/201	22:54:13	PB APPLIED	
24839	06/07/201	22:54:56	RST P/BSW2 OPTD	
2609	07/05/201	14:06:25	FOOT SW2 CNTPR5	
35496	05/09/201	01:27:45	CAB2 ACTIVE	
36090	07/09/201	05:04:07	MP OPERATED	
36104	07/09/201	05:16:24	FOOT SWITCH 2 OPERATED	
36155	07/09/201	05:55:26	HORN2 OPERATED	
4	27/02/201	10:58:35	WARNING CYCLE	
8	27/02/201	11:00:12	POWER OFF	
95	02/05/201	10:43:23	SANDER OPERATED	

G. Data

Data recoded in the microprocessor of VCD installed in Diesel Locomotives were collected and analyzed. In total data 210 VCD application data over a period of nearly two years was obtained from as many locomotives. These data were collected randomly to ensure universality.

H. Data Analysis

VCD (Diesel Loco)

Table 1:

Application Time			No. of VCD Applications
0	-	1 hr	5
1	-	2 hrs	10
2	-	3 hrs	9
3	-	4 hrs	6
4	-	5 hrs	7
5	-	6 hrs	5
6	-	7 hrs	6
7	-	8 hrs	10
8	-	9hrs	11
9	-	10 hrs.	11
10	-	11hrs	14
11	-	12hrs	14
12	-	13 hrs	10
13	-	14hrs	15
14	-	15 hrs	20
15	-	16hrs	15
16	-	17 hrs	12
17	-	18hrs	4
18	-	19hrs	4
19	-	20hrs	2
20	-	21hrs	4
21	-	22hrs	7
22	-	23hrs	5
23	-	24hrs	4
TOTAL			210

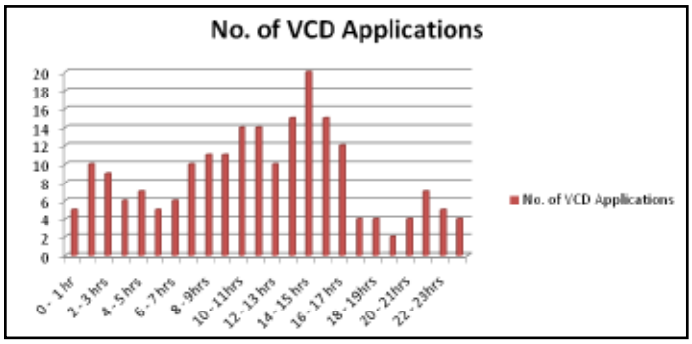


Table 2:

Application Speed	No. of VCD Applications
0-20 Kmph	56
20-40 Kmph	67
40—60 Kmph	48
60-80 Kmph	20
80-100 Kmph	**19**
TOTAL	**210**

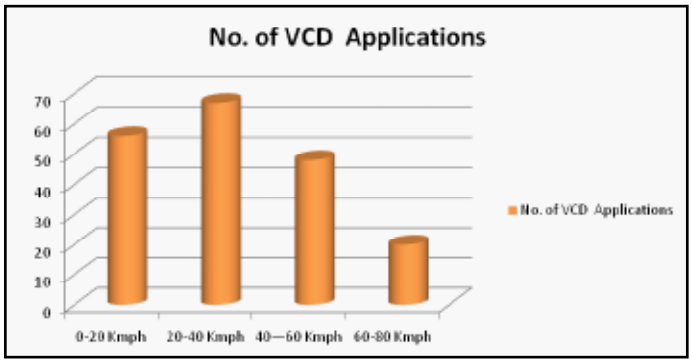
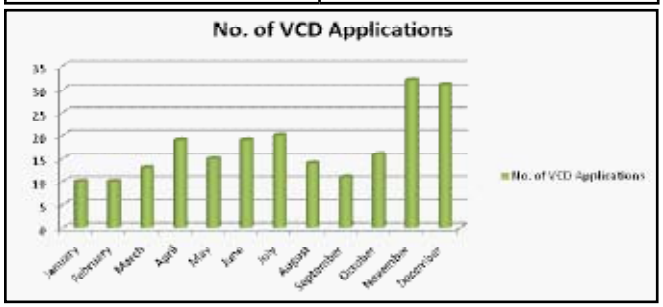


Table 3:

Month	No. of VCD Applications
January	10
February	10
March	13
April	19
May	15
June	19
July	20
August	14
September	11
October	16
November	32
December	31
Total	210



VI. Conclusion

From the above data analysis the following inferences are drawn

1. Crew alertness could be poor during 14hrs to 17 hrs. This period is therefore needed to be recognised as vulnerable period along with the commonly acknowledged vulnerable period of 2 to 5 hrs.
2. Majority VCD applications were at low speeds, indicating alertness decrement happening primarily at low speeds
3. Crew alertness could also be impaired at higher speeds of 80 to 100 kmph.
4. Crew alertness decrement could be prominent in winter months of NOV to DEC.

These inferences however need further corroboration in form of real time incidence and evaluation of supporting data and information before being finally accepted for strategizing counter measures

VII. Further Study

Evaluation of factors responsible for contributing to crew fatigue along with quantification of their impact on safety is complex. While knowing all shall be a challenge. Hence knowing little more than what is known today is perhaps could be a realistic objective. The more is known in this area, the more counter measures can be evolved. With this objective further study is planned.

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