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Human Behavioral Aspects of Level Crossing Safety with Special Reference to Indian Railways

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Abstract

Railway level crossings (LC) are the interface between roads and railway tracks, and as such are the potential site for vehicle-train collisions and incidents. About 95 % of accidents are caused by road users' misuse. Behavioural science is an academic and applied discipline involving the scientific study of mental process and behaviour. There is currently considerable interest being taken to better understand road users' behaviour at LC, and to implement additional controls and upgrades to improve LC safety performance. The present paper describes various parameters of behavioural science related to LC. The present study indicates that on Indian Railways, gate closure time on most of the L.C is unusually long and beyond the tolerance of the road users. About 30 % of the vehicle drivers have reaction time more than 2 seconds which results in delayed decisions and actions, sometimes resulting into accidents.

Keywords: Level Crossing (LC); Behavioural study; Road users; Reaction time

1. Introduction

Humans are the weakest link in any embedded system. Failure rates for humans as system components are several orders of magnitude higher than other parts of the system. Railway Level crossing gate operation requires involvement of a considerable no of persons. This results in more human errors and hence disastrous consequences [1].

A LC (also known as railroad crossing) is a crossing on one level ("at grade intersection") – without recourse to an over-bridge or under-pass. Early LC had a flagman in a nearby booth that would, on the approach of a train, wave a red flag or lantern to stop all traffic and clear the track. Manual or electrical closable gates that barricaded the roadway were later introduced. The gates were intended to be a complete barrier against intrusion of any road traffic onto the railway. In the early days of the railways, much road traffic was horse-drawn or included livestock. It was thus necessary to provide a real barrier. Thus, crossing gates, when closed to road traffic, crossed the entire width of the road. When opened to allow road users to cross the line, the gates were swung across the width of the railway, preventing any pedestrians or animals getting onto the railway line.

With the appearance of motor vehicles, this barrier became less effective. Many countries therefore substituted the gated crossings with weaker but more highly visible barriers and relied upon road users following the associated warning signals to stop.

In many countries, level crossings on less important roads and railway lines are often "open" or "uncontrolled", sometimes with warning lights or bells to warn of approaching trains. Level crossings without gates represent a safety issue; many accidents have occurred due to failure to notice or obey the warning. Railways in the United States are adding reflectors to the side of each train car to help prevent accidents at LC. In some countries, such as Ireland, instead of an open crossing there may be manually operated gates, which the motorist must open and close. These too have significant risks, as they are unsafe to use without possessing knowledge of the train timetable. Motorist may be instructed to telephone the railway signaler, but may not always do so.

The director of rail safety at the UK Railway Inspectorate commented in 2004 that "the use of level crossings contributes the greatest potential for catastrophic risk on the railways."

Fig.-1 shows LC risk weighed against the overall level of risk on the railway by the Safety Risk Model (SRM). It indicates that, excluding suicide, LC contributes approximately 6.2 % of the total risk. The right-hand pie chart shows that the majority of the risk comes from pedestrians being struck (57%), while the second highest risk arises from train collisions with road vehicle (35%). Of the risk at level crossings, over 95% is from human error and misuse; and less than 5% is caused by system failure. [2]

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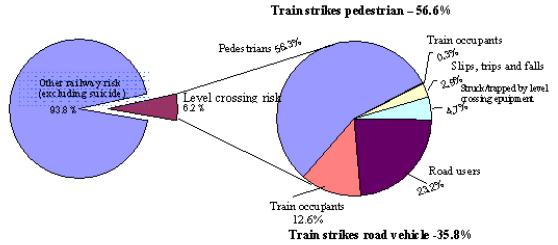

Figure 1: Level Crossing risk in context of overall railway risk. (Excluding suicide).

As on 31.03.2002, there were 21,792 unmanned and 16,549 manned LC on Indian Railway System. At present, 6446-manned LC is interlocked and 14,502 are provided with telephones. It has been found that around 80% accidents generally take place at those unmanned LC where traffic is low and visibility is clear. [3]

Recently in Australia there has been considerable recognition regarding the importance of human behavioural aspects of railway level crossing safety, particularly the ability to see a train and judge a safe gap to cross.

2. Level Crossing Safety Impediments

The Russian Federation Railways has identified the following factors as the main causes of LC accidents: [4]

- low level of public discipline and, as a consequence, mass violations by vehicle drivers of the rules relating to passing of LC;
- motor vehicle driver misjudgments concerning road conditions and the approach of trains on LC;
- motor vehicle driver misjudgments of vehicle speed and braking capabilities during the winter months.
- technical malfunction of road vehicles;
- non-compliance by highway authorities with the standards of road maintenance at the approaches to LC;
- poor maintenance of LC warning and protection devices;
- human error on the part of level crossing staff.

3. Behavioral Studies

An individual's observable response in a given situation with respect to a given target is known as behaviour. Ajzen [5] states that behaviour is a function of a compatible intentions and perceptions of behavioral control. The perceived behavioural control is expected to moderate the effect of intention on behaviour, such that a favourable intention produces the behaviour only when perceived behavioural control is strong.

Founded by John B. Watson and extended by Edward Thorndike, Cark L. Hull, Edward C. Tolman, and later B.F Skinner studied the mind via. 'Introspection'. The behaviourists (e.g. Watson) argued the contents of the mind were not open to scientific scrutiny and that scientific psychology should only be concerned with the study of observable behaviour. Behaviourism differs from other perspectives in a number of ways. Behaviourists focus on behaviour-environment relations and analyses overt and covert behaviour as a function of the organism interacting with its environment. [6]

95 % of accidents are caused by the road users including vehicle drivers and pedestrians. Therefore, there is a need to conduct behavioural studies for the road users to find out suitable methodology to educate them in order to minimise accidents at LC.

3.1. Road user psychology:

Road user psychology is young, expanding and wide field in psychology. It is primarily related to the study of the behaviour of road users and the psychological process underlying that behaviour as well as to the relationship between behaviour and accidents, individual and social factors in the movement of people and goods and travel demand management [7]. There is no single theoretical framework in road user psychology, but, instead, many specific models explaining, for example, the perceptual, intentional, cognitive, social, motivational and emotional determinants of mobility and traffic behaviour. One of the most prominent behavioural models divides the various tasks involved in traffic participation into three hierarchical levels, i.e. the strategic, the tactical and the operational level. The model demonstrates the diversity of decision and control tasks which have to be accomplished when driving a vehicle. However, until now, most of the psychological models have had a rather heuristic nature, e.g. risk theories such as the risk compensation hypothesis, Fuller's task capability model, and thus are not sufficiently precise to allow for concrete behavioural prediction and control.

3.2. Road rage:

It is aggressive or angry behaviour by a driver of an automobile or other vehicle. Such behaviour may include rude gesture, verbal insults, deliberately driving in an unsafe or threatening manner, or making threats. Road rage can lead to altercations, assaults and collisions which result in injuries and even deaths. It can be considered as an extreme case of aggressive driving [8].

3.3. Behavior and accident:

This is particularly in relation to different groups of road users (age groups, modes of transport), but also in relation to road design and motor vehicles. Explaining and predicting road user behaviour depends on the development of valid and reliable models about the role of human factors in mobility behaviour, and, especially, driver performance. Psychological traffic accident and behaviour research deals with matters such as: analysis of the driving task, changing conceptually from a traditionally rather sensory-motor task to a task with high monitoring impact, perception, cognition and attentiveness when driving, driver information processing and expectations, the driver's state, workload, alertness and fatigue.

- driver personality, risk-taking, attitudes, motives for driving, excited ness and emotion,
- interactions and the social psychology of driving,
- the relationship between the personal and environmental background of behaviour, overt behaviour, emerging conflicts and accidents,
- work on risk compensation theory.

3.4. Accident prevention and improvement of road users' safety:

This comprises education and information, above all following the "4 Es": enforcement, education, engineering, encouragement/economy. The main goal is promoting safety in influencing and modifying behaviour. [9]

3.5. Research and counseling:

This includes differentiation between transportation needs of special groups and main topics are:

- mobility needs and travel demands, choice of means of transport,
- travel behaviour research, above all activity-based approach,
- altering mobility behaviour and modal split, problems of habituation and resistance to change, car dependence,
- design and acceptance of travel demand management, above all of road pricing measures [10]
- psychological aspects in road design and traffic environment,
- quality management, especially quality of service, usability and well-being.

3.6. Psychological assessment and counseling:

This kind of assessment and counseling is for drivers who display irregular behaviour. It involves driver assessment, training and rehabilitation.

4. Total Reaction Time

Total reaction time of the driver is the time taken from the instant the object is visible to the driver to the instant the brakes are effectively applied or any other decision is finally executed. During this time the vehicle travels a certain distance at the original speed. With increase in reaction time of the driver, the stopping distance increases or final decision is prolonged. [11]

4.1. PIEV Theory:

According to this theory the total reaction time of the driver is split into four parts, viz, time taken by the driver for:

- Perception.
- Intellection.
- Emotion.
- Volition.

Perception time is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system and spinal chord. Perception involves the process of not only detecting an object in a general sense, but also comprehension of its significance. [12]

Intellection time is the time required for understanding the situation completely. It is also the time required for comparing the different thoughts, regrouping and registering new sensations.

Emotion is the complex psycho-physiological experience of an individual's state of mind as interacting with biochemical (internal) and environmental (external) influences. In humans, emotion fundamentally involve s "physiological arousal, expressive behaviours, and conscious experience" [13]

Emotion time is the time elapsed during emotional sensations and disturbances such as fear, anger or any other emotional feelings such as superstition etc. with reference to the situation.

Volition is the cognitive process by which an individual decides on and commits to a particular course of action. Volition time is the time taken for the final action. [14] It is also possible that the driver may apply brakes or take any avoiding action, even without thinking, i.e. under reflex action. Reflex actions are instinctive and require the shorter time as they involve no thinking [15]. Most driving does not involve reflex action. However, when a strong unexpected stimulus is presented to a driver, a reflex action may result. Such reflex actions are usually wrong and can be disastrous. The PIEV process has been illustrated in fig. 2 [16]

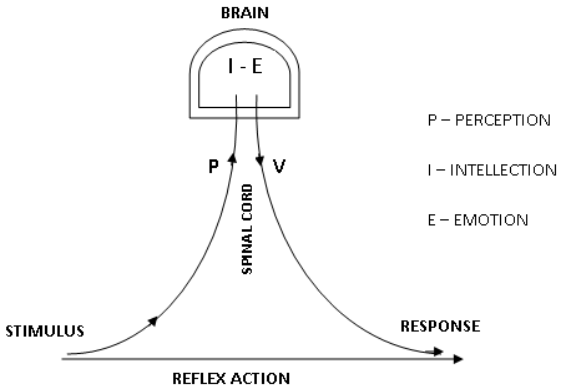

Figure 2: Reaction time and PIEV process.

The PIEV time of a driver depends on several factors such as physical and psychological characteristics of the driver, type of the problem involved, environmental condition and temporary factors (e.g., motive of the trip, travel speed, fatigue, consumption of alcohol, etc.). Thus, it may be concluded that the total reaction time of a driver is an important parameter for the study of drivers' behavioural characteristics.

Perception and volition times of the driver combined together can be satisfactorily measured by a simple arrangement of time measurement as observed by a vehicle driver between changes of light signals observed. This measured time may be called as reaction time of the driver

and is a convenient measure for comparing the efficiency of the drivers.

5. Level Crossing Elements

The components of railway level crossing safety have been illustrated in fig.3. Principally there are two agencies contributing to rail-road accidents at level crossings i.e. (i) train driver, and (ii) road users. It is almost impossible for a train driver to stop and prevent the collision even if he notices a road vehicle on the crossing from a distance of 500 to 600 meters nor is it possible to change the course of a train similar to that of road vehicle.

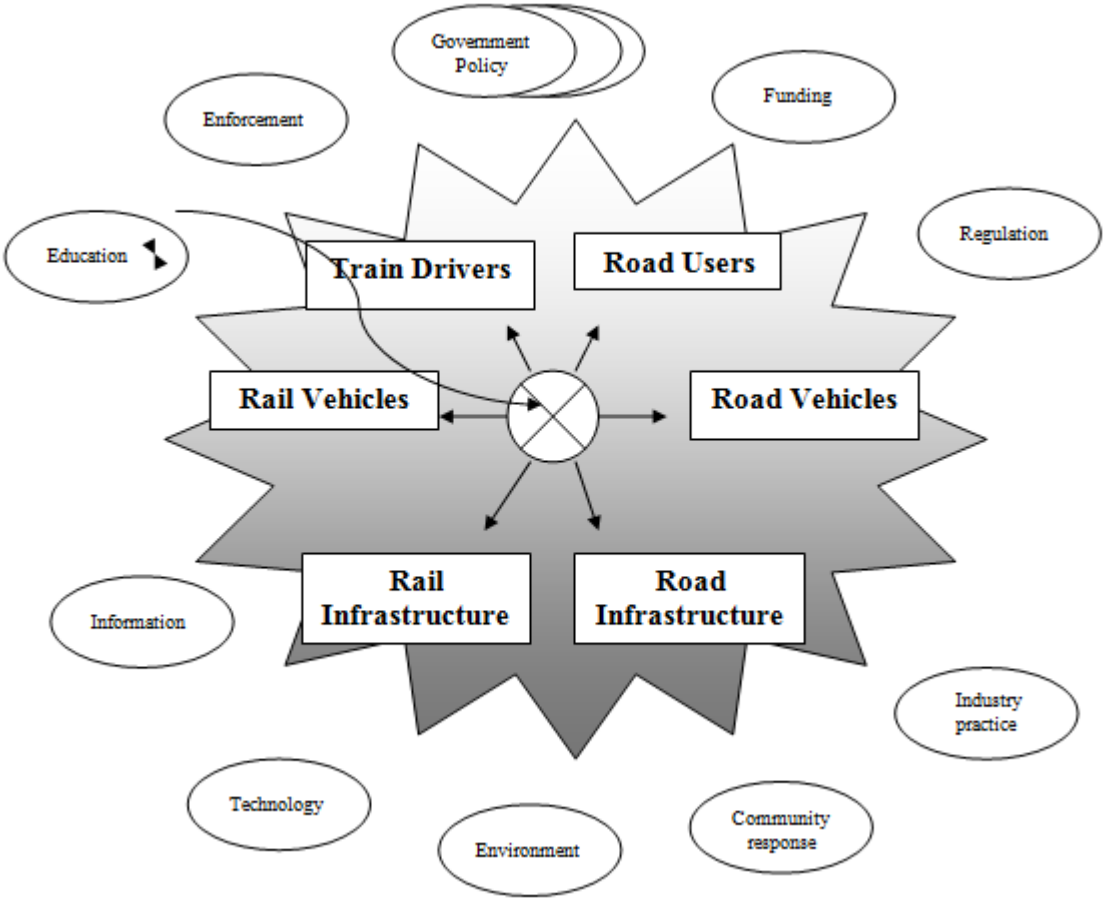

Figure 3: Components of railway level crossing safety.

The road users in India comprises of:

- Trucks and heavy vehicles,
- Cars and light vehicles,
- Motorcycles and scooters,
- Animal driven carts,
- Cycles,
- Pedestrians.

At the level crossings with barriers, motor cyclists, scooterists, cyclists, and pedestrians have major contribution to the accidents; whereas all types of road users contribute equally at uncontrolled L.C. This clearly indicates that the behaviour of road users including pedestrians is of prime importance in accident control.

6. Present Study

The present study was aimed at exploring some human behavioural aspects responsible for the accidents at LC in the context of Indian Railway. At 5 nos. of manned and 3 nos. of unmanned LC gates on main line and branch line of E.C Railway, the gate closing time, train crossing duration, gate opening time and approximate no of stranded three and four wheeler vehicles were observed. During the gate closure period, some of the vehicle drivers were interviewed to know their reactions on the obstruction due to the gate closure. The purpose was to assess the status of their minds when obstructed or crossing LC. The questionnaire included name, age, educational qualification, marital status, number of children, other liabilities, origin, destination, purpose of journey, How they felt while crossing a LC, and what they felt when obstructed with a closed LC gate? The behaviour of other

occupants of the vehicle influences the mental status of the driver.

During the present study, the reaction times of 150 drivers at LC were measured by the method stated above and are presented in Table-1.

Table 1: Total no of drivers tested for reaction time: 150.

S.N	Reaction Time Range (in millisecond)	No. of drivers & Age group (in years)					Total	%
		< 25	25 - 40	40 - 50	50 - 60	> 60		
1	< 0.20	5	9	3	1	-	18	12.0
2	0.20 – 0.40	7	12	4	3	-	26	17.3
3	0.40 – 0.75	3	7	4	2	2	18	12.0
4	0.75 – 1.00	4	8	5	1	2	20	13.3
5	1.50 – 2.00	2	5	7	4	7	25	16.6
6	2.00 – 3.00	2	4	4	6	10	26	17.3
7	>3.00	2	2	3	5	5	17	11.3

6.1. Observations at manned level crossings:

- The gate closing time varied from 3 minutes to 15 minutes at a time, whereas the actual time consumed by a train to cross LC varied from 20 seconds to 1 minute 30 seconds.
- The number of four wheelers being stopped on both sides of the LC gate for one closure on national highway- rail road crossing ranged between 50 and 100, besides a good number of two wheelers.
- It was observed that not a single pedestrian or cyclist stopped at the crossing due to closure of the gate; they generally stopped about 2 m away from the track when the train was crossing the LC.
- Most of the two wheelers also attempted to sneak the closed LC gate and stopped along with pedestrians only when the train is actually crossing the gate.
- As the four wheelers had no option but to stop at closed LC gate, they stopped without any exception but instead of stopping in their own lane only, they had no hesitation in occupying the full width of the highway. This created utter confusion and chaotic situation when the gate is lifted for the passage of the traffic resulting in much more delay.
- The number of vehicles at the state highways / other roads-rail road crossings varied between 5 and 30 per LC gate closure. However, this number was 20 to 50 in and around a city. Alertness of the cabin / gate men on branch line LC was observed much less than those on main line.
- About 80 % of the truck and car drivers felt annoyed and obstructed by the LC gate closure. They were quite pessimistic in estimating probable waiting time at the gate. Most of the drivers were illiterate or had education up to primary level and had neither knowledge of railway working nor the safety consciousness. They thought gate closure as an obstruction on the road. The rest 20 % of the truck / bus and car drivers understood the importance of the gate closure but they were quite worried about the probable delay in reaching their respective destinations.
- The two wheelers had a different concept altogether about a closed LC gate. 90 % of them thought that the gate closure was not meant for them and they can proceed further by sneaking the closed LC gate.
- Pedestrians and cyclist considered themselves to have more freedom and flexibility over two- wheeler drivers while crossing a closed LC, though they contributed to good number of accidents while crossing a forbidden railway track.
- The average reaction time of the drivers is 1.51 seconds and it has a tendency to increase with age after attaining an age of 50 years [Table -1].

6.2. Observations at unmanned level crossings:

- The unmanned LC are generally provided on unimportant roads having very little traffic in order to save the expenditure of installing and maintaining the LC infrastructure.
- During the present study the drivers of the vehicle were interviewed at several railroad crossings. About 85 % of the drivers were illiterate and unconscious about the safety requirements. About 30 % of the tractor pulled trolley drivers had no valid driving license even.
- Each and every driver was found to be in great hurry while crossing the LC.
- The capability of the drivers to estimate the speed of the train, distance of the train from the crossing and expected travel time of the train up to the crossing were far from being accurate. In other words it can be said that 'Reaction time' for most of the vehicle drivers were quite more and were prone to misjudgment.
- The behaviour of the two-wheelers and pedestrians were no different than those at the manned level crossings.
- Animal driven carts have some special problems. Their drivers had to face and tackle the erratic behaviour of the animal(s) occasionally at the LC gates besides other factors.
- Most of the unmanned LC in India has no alarm/light system for the road traffic which makes the situation 'Free for All' at unmanned LC.

6.3. Analysis of the Observations:

The variation in gate closure time is quite considerable and unpredictable on Indian Railways. This makes the road users impatient and uncomfortable. The study shows that drivers frequently take unnecessary risks at the LC and are placing themselves and their passengers in situations of high risk and that there is a need to focus on factors to improve driver safety performance. It may be further analysed as follows:

- The ignorance and poor education among majority of the drivers make them unconscious about the necessity and safety requirements at LC.
- The poorly designed LC or unauthorised constructions along the track do not provide sufficient visible distance of the railway track to the road traffic at many places.

- At most of the manned LC the light signals have been provided for the road traffic but sound alarms are missing.
- There is no light or sound signal at unmanned LC in India. Only danger sign posts have been placed on either sides of the LC which do not give the desired effect to the road traffic.
- The purpose of journey can also make vehicle drivers impatient at times.
- The vehicle drivers/pedestrians give priority to false time saving exercises over the safety rules. Some of them have higher 'Reaction Time' which can lead them very close to the accidents.
- A good number of vehicles are not worthy of running on the road.
- Animal(s) driven carts require much more time to cross LC. The unpredictable behaviour of the animal(s) may add up some more time to the above. If the cart driver is not aware and alert about these contingency situations, sometimes he may be trapped in an accident.
- The drivers of long distance vehicles are most of the time over fatigued due to long hours of continuous driving without reasonable sleep/rest. This makes them irritated and frustrated when they are stopped at LC.
- To overcome the mental stress on any count, at least 10-15 % vehicle drivers are addicted to alcohol or some drugs and this brings behavioural change and this is not conducive to safe driving and observance of safety rules.

The author summarises the scope for the study of behavioural characteristics of road users in the fig. no. 4 with special reference to railroad crossings.

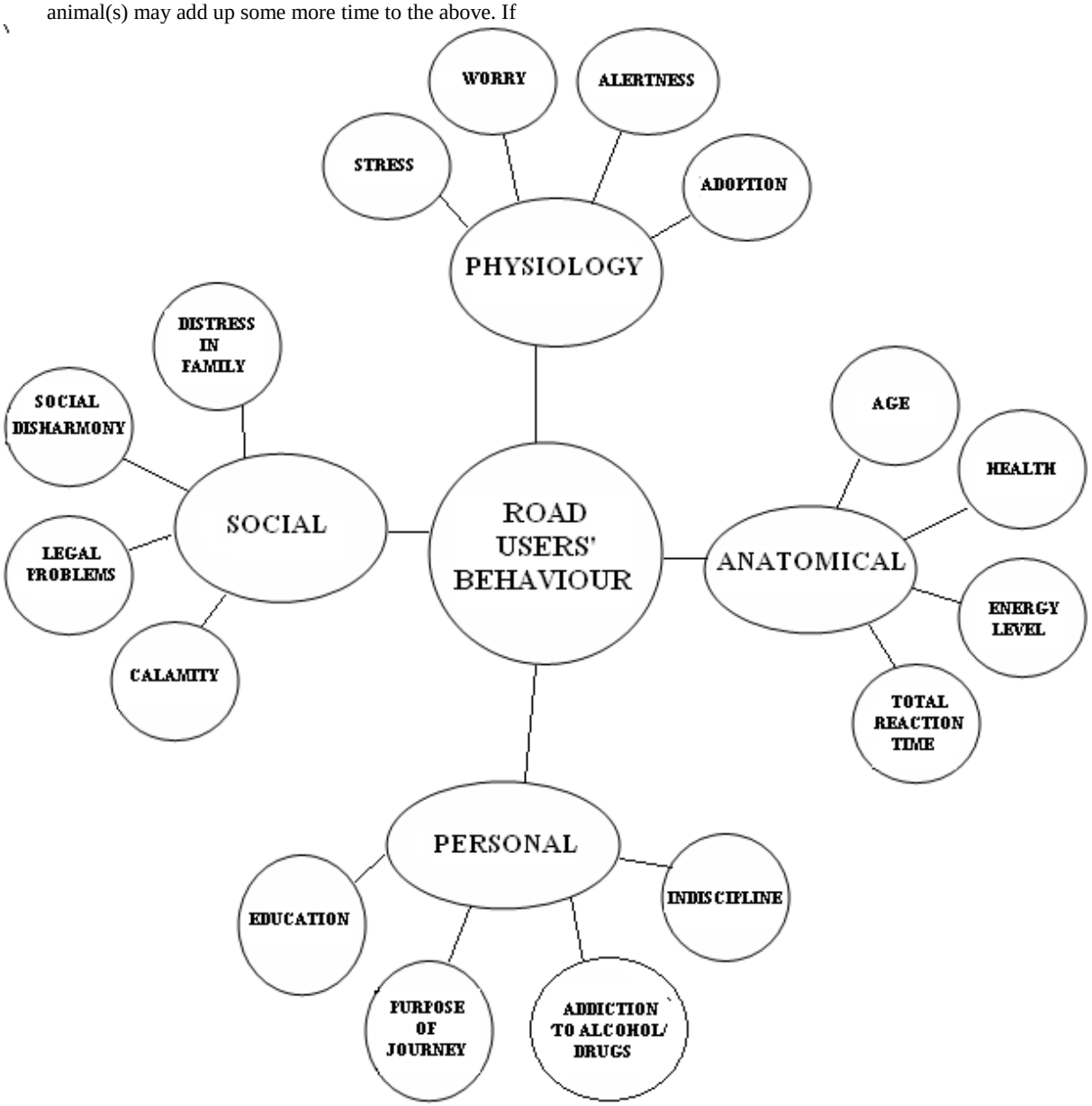

Figure 4: Scope for Behavioural Studies of Road Users.'

7. Conclusions and Suggestions

- On the Indian Railways system the barrier closure time on some level crossings is unusually long. Such closure times are much longer than those which would normally be tolerated by the road users. Excessively long barrier closure times tend to be a feature of the Absolute Block System as this system requires barriers to be closed immediately after a train's departure from a neighbouring station.
- 29.6 % drivers have reaction time more than 2 seconds indicating their delayed decisions and actions, which may sometime result in to accident.
- The 'deliberate risk taking' behaviour results in major risks, particularly where heavy, long or slow vehicles are involved. It is more prevalent in the people who know the site well, young people and truck drivers.
- Sometimes drivers fail to identify that a train is approaching.
- Some drivers fail to judge a safe gap to cross in front of an approaching train at unmanned railway crossings, particularly as operational train speeds are increasing.
- There are a range of options available for improving safety at level crossings and their implementation requires integrated, tailored solutions involving both the road and railway authorities. However, economic requirements put restrictions on the implementation of these.
- Even if all the safety measures are adopted at LC, the number of the accidents is likely to be considerable unless the road users become quite responsive. To understand the psychology and limitations of the road users there is no other way but to conduct behavioural studies on them regularly and in accordance to the findings the remedial measures are undertaken.
- In issuance and renewal of driving license, in addition to driving skill tests, behavioural competence of the driver including reaction time determination need be conducted.

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