Study of Safety Awareness at Railway Level Crossing

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ABSTRACT

Despite the fact that the number of railway crash fatalities has fallen in recent years, level crossing accidents constitute a significant proportion of the rail toll. With many level crosssing fatalities and injuries resulting in coronial inquests, litigation and negative media publicity, the actions of rail and road infrastructure providers and the behaviour of road users and rail users, come under close scrutiny. Research in this area has been plagued by the rail/road interface and the separation of responsibilities between rail and road authorities reflecting the social and political context in which they are contained.There is a need to better understand the scope and nature of road users'behaviour at level crossings, in order to develop and implement more effective countermeasures for unsafe human behaviour. Safety awareness is an important factor in understanding human behaviour at level crossing. Being aware of what is happening around level crossings users and understanding what the information means to them, now and in the future, is the basis for safety awareness.Inthe present study a model has been developed to evaluate awareness of road users' and a method to calculate Individual Awareness Index and Average Awareness Index at the level crossing.

Key words: Safety Awareness; Level Crossing; Awareness Index; Human Behaviour.

1.0 Introduction

Road/rail grade intersections are unique in the world of transport in as much as they present the only case of two different infrastructures placed under different responsibilities and travelled by vehicles with considerably different performances which converge and meet during their normal operation. The result is that these intersections constitute high-risk spots on all railways in the world. The potential for accidents is made higher as the railways only control only half the problem. The other half, meanwhile, cannot really be said to be controlled by one entity as, even though traffic rules and road design standards supposedly exist, the movements of road users are not organised and monitored by one specific entity as rigidly as rail movements. Each year, accidents at level crossings not only cause the deaths of or serious injuries to many thousands of road users and railway passengers, but also impose a heavy financial burden in terms of interruption of railway and road services and damage to railway and road vehicles and property.

The accidents at level crossing take place, primarily, because the road users do not respect the right of way of the railways.Even, when the barrier is down, trespassing at level crossing is a common sight. Road users continue to cross the track even whenthe train is visible and approaching. In a majority of cases accident takes place because the road user fails to judge the speed of the train correctly.

LX accidents not only dominate in terms of frequency, but can be more severe in their consequences than other types of railway accidents, simply because they can involve injuries and fatalities to railway passengers, as well as, to road vehicle occupants and other users of LXs. Increasing road construction and road vehicle population create greater opportunity for LX accidents to happen. High speeds will place new requirements on the standards and quality of construction and maintenance of level crossing infrastructure.[1]

Every year more than 300 people are killed in 1200 level crossing (LX) accidents in Europe.[2]Similar figures of deaths are noted all over the world. Level crossings are thus considered to be a major weakness in rail transport infrastructure and a safety threat for ground transportation, Current safety measures taken at LX do not meet people safety expectations, because they dread the heavy consequences that may results from a train colliding with a vehicle or pedestrian using the level crossing.

2.0 Classification of Level Crossing

(i)Passive crossings

Control of the movement of vehicular or pedestrian traffic across a railway level crossing by signs and devices, none of which are activated during the approach or passage of a train, and which rely on the road user detecting the approach or presence of a train by direct observation. [3]

(ii)Active crossings

Control of the movement of vehicular or pedestrian traffic across a railway level crossing by devices such as flashing light signals, gates or barriers, or a combination of these , where the device is actuated prior to and during the passage of a train through the crossing.

In India, the result of one year survey indicates that 80% of all level crossing accidents occurred at passive crossings (i.e. unmanned level crossings)[3]

3.0 Level Crossing Impediments

The Russian Federation Railways has identified the following factors as the main causes of level crossing accidents. [4]

- (i) Low level of public discipline and, as a consequence, mass violations of vehicle drivers of the rules relating to passing of level crossings;
- (ii) Motor vehicle driver misjudgments concerning road conditions and the approach of trains on level crossings;
- (iii) Motor vehicle driver misjudgments of vehicle speed and braking capabilities during the winter months;
- (iv) Technical malfunction of road vehicles;
- (v) Non-compliance by highway authorities with the standards of road maintenance at the approaches of level crossings;
- (vi) Poor maintenance of level crossing warning and protection devices;
- (vii) Human error on the part of level crossing staff.

4.0 Human Factors

So far, most efforts for increasing safety at level crossings have considered mainly actions aiming at modifying and improving some LX technical aspects. The human factor has been, however, identified to be the driver of 90 % of LX accidents. Study about possible technological solutions to reduce the number of accidents at level crossings and giving recommendations on how to increase the human awareness and respect of the level crossing safety system connected with proposed technical solutions. [5]

In order to cross a LX safely, the road users must stop, look, listen and think. They should stop to read carefully traffic signals indicating the status of the LX which will give them enough information to decide whether to cross or not. Before crossing, they must look in both directions for approaching trains. Simultaneously, they should listen to the noise of approaching trains or their whistles. Finally, road users should always think and obey all the warning signs. Finally when the road users are sure that LX is clear from any trains, they should cross the LX straight ahead. Level crossing technologies should make sure to help the road users stop, look, listen and think. Although level crossings are designed to be safe if crossed correctly by road users, 90 % of LX accidents are due to human errors. This can be explained by recognising that it is natural for humans to make mistakes. Thus level crossing technologies should be enhanced in order to help the road users and all other human actors at LX avoid making mistakes and thereafter prevent the occurrence of deadly and costly collisions. It is imperative to understand and define human features that describe people who are interacting with LX.

Human factors involve the study of all aspects of the way humans relate to the world around them, with the aim of improving operational performance and safety. Human factors are defined to be sets of human specific physical, mental and behavioral qualities / limitations which either may interact in a critical or dangerous manner with technological systems, human natural environment and human organisations. These human factors should be taken into consideration in the design of ergonomic human-user oriented equipments. The choice / identification of human factors usually depend on their possible negative or positive impact on the functioning of human – organisation and human machine system. Other human factors can be based on psychological or sociological factors. Human to Human interaction is based on psychology, while sociological factors such as group dynamics can be culturally or ethnically based.

Mental limitations of LX human actors should be considered while introducing new LX technologies aiming at increasing safety. The psychological human factors that may affect road users' compliance to warning signs need to be considered. The present study introduces the concept of situation awareness and justifies its relevance for safety at LX. Further several important design aspects of new technologies are considered that promote situation awareness.

5.0 Situation Awareness at Level Crossings

Embedding new technologies on board of trains or vehicles or around LX will certainly bring useful information that may help human users assess danger level at LX. These new technologies should give the users the ability to identify process and comprehend the elements of information about what is happening at the level crossing. In other words, the new technologies should provide their users with an accurate awareness of the situation when crossing a LX.

What is situation awareness (SA) and how can it be used to enhance safety at level crossings and taken into consideration while designing new technologies for LX?

Being aware of what is happening around level crossings users and understanding what the information means to them, now and in the future, is the basis for situation awareness.

A generic definition of situation awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future".

Although the elements of SA vary widely between domains, the nature of SA and the mechanisms used for achieving SA can be described generically and applied to LX safety domain.

Situation awareness knows what is going on around you. Inherent in this definition is a notion of what is important. SA is most frequently defined in operational terms of the goals of a specific application, for example crossing safely at Level Crossing. The LX user does not need to know everything, but needs to know a great deal of information related to the goal of safety crossing the LX. Figure 1 shows a model of situation awareness identifying its role in human cognition and factors affecting SA.

The model indicates that human decision making revolves around situations awareness at three different levels, namely perception, understanding and projection.[5]

- Perception of important cues is fundamental for forming a correct picture of the situation.
- Understanding is beyond simple perception; this level promotes an accurate current understanding of the environment through the integration of multiple pieces of information and a determination of their relevance to the person's goals.
- Projection refers to the ability to foresee accurately future situation events and their dynamics.

SA is a precursor for decision making and for taking actions which may change the environment itself. The model insists that SA is also the product of different components including the environment which is also driven by feedback from the human action and also by the human cognitive workload, which affects directly decision making and actions and finally by a number of factors intrinsic to the human user.

5.1 Information handling zones

According to Tustin [6]the situation feed by a driver of any vehicle at a crossing occurs in three areas or zones. Information handling zones are particular areas of the road that vehicle drivers take decisions about the level crossing ahead. The three zones include:[6]

- **Approach zone-** This zone is the area of the road in which the vehicle driver begins to formulate actions needed to avoid colliding with trains. Scanning trains or signals, recording any hazards, and deciding the proper course of action, are behaviours that vehicle driver use in this zone. The driver must be aware of the crossing ahead, with information usually provided to him by an advance warning sign or pavements warnings. The driver must make notice of the crossing through visual observations, control devices or sounds from the train whistle. Advance warning systems should be placed in an area that provides sufficient warning to drivers to alter their speed and take appropriate driving action as required.

- **Non-recovery zone-** This zone begins at a point along the road where vehicle driver must make a decision to stop, if a train is approaching. If the stop/go decision is delayed beyond the beginning of the non-recovery zone, the amount of road remaining will be insufficient to avoid collision with an oncoming train. The non-recovery zone ends at the beginning of hazard zone, and starts at the stopping sight distance required by the vehicle speed. Proper design and installation of warning systems and control devices will provide the majority of drivers with information needed to make the decision in time to stop, if required. Provided with such information, the vehicle driver must operate their vehicle as required by the prevalent conditions (e.g. visibility of an approaching train).

- **Hazard zone-** This one is the rectangle formed by the width of the road and distance measured along the road on either side of the tracks. This zone is the area where stopped or approached vehicles are capable of colliding with approaching or stationary trains. The objective of this zone is for the vehicle driver to cross the tracks safely. Obeying warning signals and protection systems is crucial for crossing safely in this zone.

5.2 Important design aspects of new technologies that promote Safety Awareness

Human factors research has proven that moulding the technology to the human is more effective than moulding the human to the technology. New technologies introduced to prevent accident at LX, should present audible and visual information that will increase situation awareness and thereafter enable dangerous situations in order to act in atimely manner and avoid them safely. It is thus imperative to understand how to beat code and displays. There are a number of environmental design aspects that will assist in providing the appropriate information.

5.3 Types of information to be provided

Current information available to the users at the proximity of is usually static and includes for example signs indicating proximity to. New technology aims at presenting users with dynamic information reflecting the current or actual status of the LX within a volume of time and space. Dynamic information can be classified as:

- Quantitative—presenting specific numerical values (e.g. train coming in 2 min),
- Qualitative—indicating general value or trend (e.g. foggy weather conditions at LX),
- Status—reflecting one of a limited number of states (e.g. LX gate open/close),
- Warnings—indicating emergencies or unsafe conditions (e.g. obstacle detected at LX or train coming now),
- Alphanumeric—using letters and numbers,
- Representational—using pictures, symbols, and color to code information. Coding should ideally be standardized,
- Time-phased—using pulsed signals varying in duration and inter signal interval(e.g. blinking light)

It should be noted that one information display may incorporate several of these types of information simultaneously (e.g. a video feed of a LX with the presence of obstacle is a dynamic warning sign using both alphanumeric and a representational type of information).

5.4 Display Modality

Since vision and hearing are by farthe most developed senses and most used for receiving information, the choice of display modalities is generally limited to them, The choice of which of the two to use depends on a variety of factors, with each sense having certain advantages as well as certain disadvantages. If follows that technological solutions to be used for increasing safety at LX at relies on these two display modalities.

5.5 Redundancy for critical situations

Combining several dimensions in a redundant manner, leads a more likely correct interpretation of the information sent. Using two different modalities will improve the response as compared to two different dimensions. For instance if visual display of LX is reinforced with an audible warning signal along with a red colour in the visual display will improve the response of the train driver to the dangerous situation at the LX.

5.6 Design aspects that may hinder situation awareness

Situation awareness may be reduced if different negative aspects are introduced in the design of new technologies. Below is several well-known design aspect which may reduce Safety Awareness.

- Attention tunneling refers to situations where the user of new technologies fixates on specific elements of the information presented to him while becoming blinded to other elements. For example, if we present a car driver constantly with video feed about the LX, he may neglect paying attention to the road.
- Some design tax working memory to the point where SA is decreased due to workload. This is referred to as Requisite memory trap.
- Physical and psychological stressors can have a negative impact on the information intake by making it less systematic and more subject to error. This is usually referred to as Workload, Anxiety, Fatigue, and Other stressors.
- Data should be organised and presented to the user in a way that avoids data overload.
- Salience is usually placed on important pieces of information that the user should use promptly. Misplaced salience may on the other hand hinder SA, because it puts emphasis on less important information.
- The user of new technologies should be able to correctly interpret the information presented to him, thus it is important to present to him simple and non complex information.
- Mental models play a key role in how information is interpreted, comprehended and used to make projections. Designers should adhere to standardization in order to avoid activating errant mental models in the users minds that may cause them to misinterpret the meaning of the cues presented to them.

6.0 Human Factors affecting compliance of road users to warning signs around LC

Warning signs are an important means to promote safety among road users as they approach a level crossing. The warnings should alert the road users of the danger they may encounter at the LX, describe the nature, and explain what will happen if the user fails to comply. The problem with warnings is that they often fail to work. In order to be effective, the road user must process the warning in a series of mental operations: The user must first notice the warning, and then the warning must be perceived, next the road user must properly understand the meaning of the warning in order to finally comply with it.

Warning signs around level crossing are usually noticed, seen, understood but unfortunately ignored, sometimes, by road users. Road users who view warning signs around level crossing use a mental model to perform a cost-benefit analysis which may lead to compliance failures for warnings. First, road users have a general knowledge about level crossings and how they work; they may also have a set of beliefs and expectations based on experience with the same or similar LX environments or technology. Finally they enter the LX with a goal and strategy for achieving the goal e.g. ("I want to cross the LC as soon as possible")

The three main components that constitute the cost-benefit analysis performed by theroad user to decide to whether or not comply with the warning sign are: cost of compliance, perception of danger level and personal and social and cultural decision- making factors.

6.1 Cost of compliance

Many studies have found that warning signs are more likely to be ineffective if the cost of compliance is high. Reducing compliance costs is a very effective way to increase safety, but it is necessary to understand where the road user's costs arise. For road users intending to cross a LX, the cost relate to their ability to cross to the other side as safely and quickly and as easily as possible. The main cost of compliance of road users with LX signs is waiting time.

6.2 Perception of danger level

Perception is the organization, identification, and interpretation of sensory information in order to fabricate a mental representation through the process of transduction, which sensors in the body transform signals from the environment into encoded neural signals.[7]All perception involves signals in the nervous system, which in turn result from physical stimulation of the sense organs.[8]

Danger perception has a strong influence on the result of the cost-benefit analysis performed by the road user before complying or not with warning around

LX: the greater the perceived risk and hazard, the greater the likelihood road of compliance. Several factors may influence the level of perceived risk including road users'familiarisation with level crossing systems, dilution of important warning signs in the presence of other non-safety relevant signs,(i.e. the presence of an advertising sign), finally the physical appearance of the warning sign (size, color, shape, location…) may inadvertently communicate hazard severity.

6.3 Personal, social and cultural decision-making factors

Decision making is regarded as the cognitive process resulting in the selection of a course of action among several alternatives. Every decision making process produces a final choice. [9] The output can be an action or an opinion of choice.

It is important to differentiate between problem analysis and decision making. The concepts are completely separate from one another. Traditionally it is argued that problem analysis must be done first, so that the information gathered in that process may be used towards decision making. [10]

Some road user may ignore a sign asking them to be cautions as they approach a LX zone not because they view the cost of compliance as high or because they underestimated the danger but because they have a high tolerance for risk which makes them prepared to engage in risky actions, e.g. ignore the warning signs or the train siren and chose to engage in the LX danger zone. In fact, the presence of danger may decrease their compliance because their goal might involve courting danger. These risk takers are less likely to comply with warnings signs and regulation of LX.

Some other road users may acknowledge the presence of danger (i.e. train is approaching) but attempt to control risk by behaving in a "safe" manner, e.g. cross the LX at high speed as the barriers are on their way down. These people are trying to perform a "partial compliance "or compromise, where their behavior is modified as a tradeoff for more safety. Partial compliance is also increased when the road users believe that he has a good mental model of the function of the LX. More specific warning reduces like hood of partial compliance.

Society affects individual notions of norms, standards and acceptable behaviour. It is not surprising that a road user's compliance to a warning sign near a LX is affected by whether other road users are complying with the warning signs or not .furthermore seeing other people ignore warning can also reduce perception by people in – person or on video or any other dissemination methodology.

6.4 Sight Distances.

The sight of an approaching train may be obscured from a motorist's view for a range of reasons. Limited sight distance along the tracks compounds the motorist's difficulty in detecting an approaching train and the estimation of its rate of approach. Objects in the driving scene, signs other than the crossing signs, vegetation, buildings / structures, are all possible visual distractions that may take a drivers attention away from an approaching train. [11] Failure to detect a train by a motorist is largely the result of sight distance, particularly at passive crossing.

6.5 Approach speed limits

A field study was undertaken to compare motorist approach behaviour between day and night – time conditions. All observations of approach behaviours were conducted without the crossing signals being activated. Day and night observation periods were made within the same level crossing and in close temporal proximity to minimize confounding and any migration of motorist characteristics (Ward and Wilde, 1995). This study concluded that approach behaviour to the crossing examined was far more conservative at night than during the day. [12]

6.6 Visibility of trains

There is no doubt that under certain conditions, the failure of a motorist to detect an approaching train is a major contributing factor in a vehicle – train collision. Passive crossings without flashing lights or boom barriers make it difficult for motorist to detect a moving train and correctly estimate its time of arrival to the crossing. With the majority of level crossings being passively protected, it can be difficult for motorist to detect a train at night. One important factor in the failure of motorist to detect an approaching train is the lack of properties on the train, other than its standard headlight (Carroll et al., 1995).[13]

7.0 Awareness index at Level Crossings

The following flow diagram has been developed in Figure 2 during present study (with observations at several passive and active LXs in India) which exhibits the awareness of road users' at LX and guides to calculate Individual Awareness Index as well as Average Awareness Index:

The behaviour of individual road user can be observed under each stage of the flow diagram and evaluation is made on the basis of marking scale provided (with each stage in the flow diagram). Thus, the total score obtained by the individual is termed as Individual Awareness Index (IAI). The average of a good number of individual Awareness Index at a LXbe termed as Average Awareness Index (AAI).

It is suggested that if the value of IAI is less than 50, the road user is prone to the accident; if this value is more than 50 but less than 75, the road user is less prone to accident; and the value more than 75 indicates that the road user is in the safe Awareness zone. Similarly, the value of AAI at a LX indicates the degree of vulnerability of the LX to accident.

8.0 Means to gain compliance

To gain compliance the road user must be convinced that there is a real personal benefit. Several methods are being used by different organisations to influence human' behavior and increase their compliance with respect to warning signs:

- Overstate the risk (using cell phones increases car accident risk by a factor of 5 seconds)
- Institute penalties for noncompliance
- Appeal to lower economic cost ("tax money saving")
- Appeal for social welfare ("human lives will be spared") or good citizenship.

These are specific conditions where warnings have a greater ability to modify behavior, including behavioral consequences with greater magnitude (high penalties), with lower threshold (i.e. they apply as a reaction to a small violation), with lower response time (i.e.they occur immediately after the non compliance).

It should be noted that experiments should be conducted to check whether the suggested solutions lead indeed to higher compliance from the road users at level crossings.

9.0 Conclusions

(1) Human factors research has proven that moulding the technology to the human is more effective than moulding the human to the technology. So far, most efforts for increasing safety at level crossings have considered mainly actions aiming at modifying and improving some LX technical aspects. The human factor has been, however, identified to be the driver of 90 % of LC accidents.

(2) Human factors are sets of human specific physical, mental and behavioral qualities / limitations which either may interact in a critical or dangerous manner with technological systems, human natural environment and human organisations.

(3) A generic definition of situation awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future".

(4) Situation awareness may be reduced if different negative aspects are introduced in the design of new technologies.

(5) Sometimes, the cost of non-compliance to the warning signals can be more expensive than investing in compliance activities.

(6) During the present study a model has been developed to evaluate awareness of road users' and a method to calculate Individual Awareness Index and Average Awareness Index at the level crossing.

10.0 References

[1] Safety and Security in Indian Railway, Fifth Report of Standing Committee on Railways, 2004, 14thLok Sabah.

[2] E. Schnieder and R. Slovak, SELCAT Objectives and Expectation, Safer European level Crossing Appraisal and Technology, Institute for Traffic Safety and Automation Engineering, Pockelstrasse 14, Braunschweig, Deutschland.

[3] Australian Standard (SA1742.7 – 1993), Manual of uniform Traffic Devices – Part 7: Railway Crossing (Standards Australia, 1993)

[4] Economic and Social Commission for Asia and the Pacific, Evaluation of Cost – Effective Systems for Railway Level Crossing Protection, United Nations, New York, 2000.

[5] A. Cherkaoui andA. Berrado, A Promoting Human Awareness in New Technological Solutions for Improving Level Crossings Safey, "Safer European Level Crossing Appraisal and Technology".

[6] B.H.Tustin, H. Richards , H. McGee and R. Patterson (1986). Railroad-highway grade crossing handbook (2nded.) Virginia: U.S Department of Transportation.

[7] Schacter, Daniel (2011), Psycholog, Worth Publishers.

[8] ^ abcdef Goldstein (2009) pp. 5–7

[9] J.Reason, (1990),Human Error ,Ashgate.ISBN 1-84014-104-2.

[10] Kepner, H. Charles ,Tregoe,B. Benjamin , (1965). The Rational Manager: A Systematic Approach to Problem Solving and Decision-Makin, McGraw-Hill.

[11] J. K. Caird,J. I Creaser , C.J. Edwards , and R. E. Dewar (2002). A human factors analysis of highway – railway grade crossing accidents in Canada. Calgary: Transportation Development Centre, Transport Canada.

[12] N. J. Ward and G.J.S. Wilde G.J.S. (1995), A comparison of vehicular approach speed and braking between day and nighttime periods at an automated level crossing, Safety Science, 19, 31 – 44.

[13] A. Carroll , J. Multer , and S. Markos (1995), Safety of highway - railroad grade crossing : Use of auxiliary external alerting devices to improve locomotive conspicuity. Cambridge: U.S. Department of Transportation.

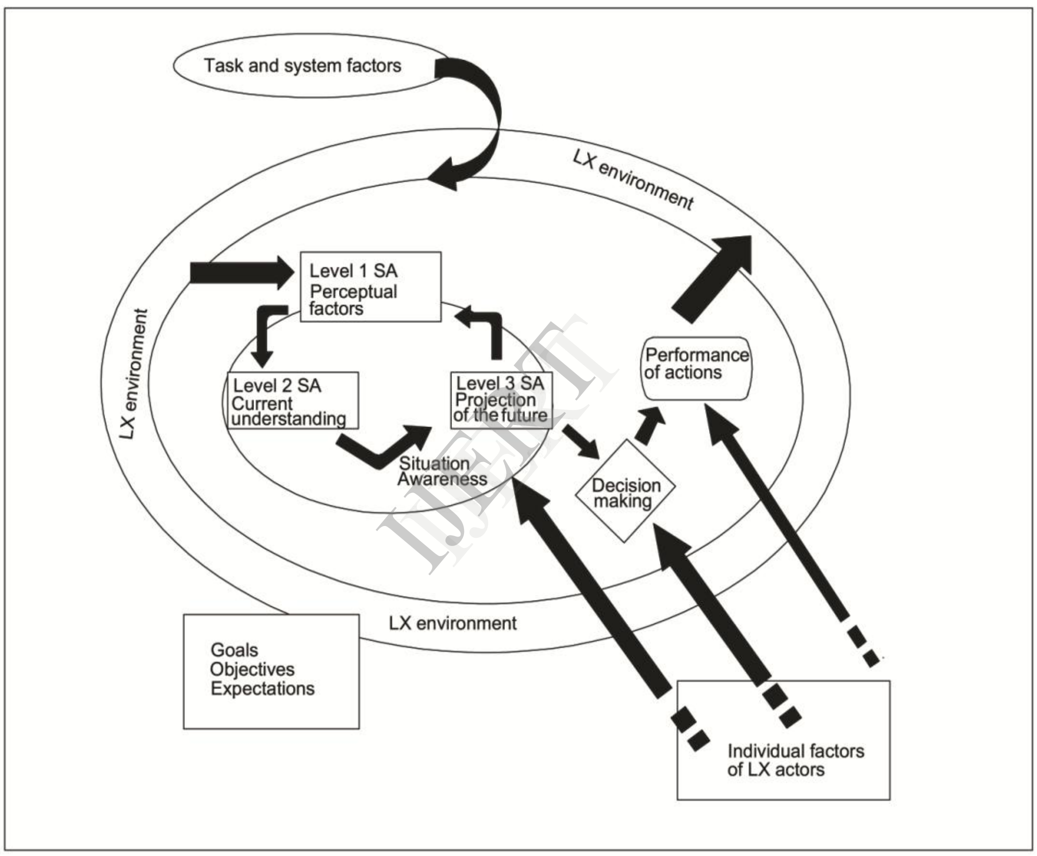

Figure 1 : A situation Awareness model

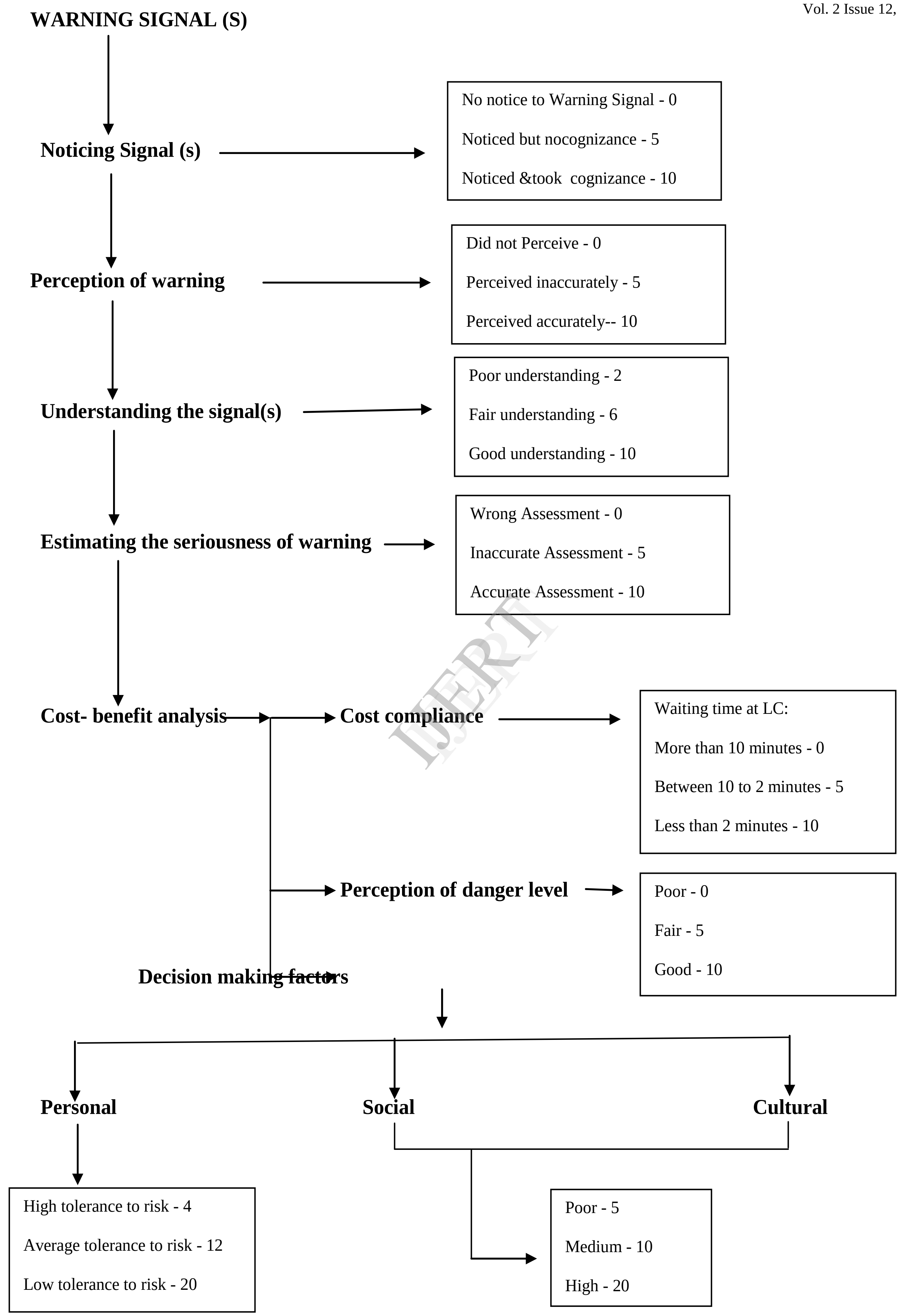

Figure2. Flow diagram for assessment of safety awareness at a LX