Human Factors in the Analysis of the “Tram-Car Drivers” at Intersections

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Abstract: The modern tramway has resurfaced as the cure to today's urban transport problems such as pollution, road congestion and uneven access to transit. However, trams at intersections often experience frequent and extended delays due to vehicles crossing the tram tracks. There is an increased potential for conflict between trams and vehicles at these locations and crashes are common. The question of the effects of human factors on trams crossroads safety has been little dealt with in literature. The general aim of this article is to further knowledge about the influence of tramway and surrounding environment on car's driver behavior at intersections. Understanding these influences, involve conducting a systematic review of the cognitive tasks related to driving and identifying the hazards that can arise at each task, and what factors can make these more or less likely to arise, considering the environmental design at intersections and behavioral factors. To achieve that, the HAZOP (Hazard and Operability Study) approach is conducted for this study. Concerning data collection, the methodology includes site visits to record user behavior and questionnaires to determine the opinion, concerns and knowledge of car drivers in interaction with the tram environment.

Key words: Tramways, intersections, human factors, road safety, cognition.

1. Introduction

In response to growing problems of road safety related to travel, the road transport network in Morocco has been modernized with the implementation of Rabat-Sale tramway since April 2011. The Moroccan government carried out this project to connect Rabat and Sale, twin cities located on either side of the mouth of the Bouregreg River. After Rabat, the city of Casablanca also launched the realization of this Tram project, whose railway length is almost 30 km. Even though the achievements are few, projects are there and therefore it is logical that Morocco is particularly concerned with the road security strengthening.

For further discussion some consensus about terminology seems to be useful. For the purposes of this paper, a tram system, tramway or tram is a railway on which streetcars or trolleys run. It is

typically built at street level, sharing roads with traffic, but may include private rights of way especially in newer light rail systems [1].

The modern term “Light Rail” embraces tramways but goes further and faster than traditional tramways. However, there is no definite border line between “tram” and “light rail”—they merge gradually from one to another, and as a tramway system gets upgraded it becomes light rail.

In Morocco, road users are not qualified enough to adapt to the current situation of modern and advanced developments in the road traffic system. In fact, a study [2] conducted in Morocco in urban areas has shown that in comparison with the multitude of dysfunctions observed the accidents are few. In this report, the road traffic is distinguished by the local customs of behavior acquired over time with the evolution of the complexity of traffic. This finding justifies that research should be conducted to further knowledge about the influence of tramway and surrounding environment, (specifically at crossroads)

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on car’ drivers behavior, and it is the general aim of this article. Understanding these influences, involve conducting a systematic review of the cognitive tasks related to driving and identifying the hazards that can arise at each task, considering the environmental design and behavioral factors.

The first part of the article seeks to investigate the interaction between trams and cars within the road network, the authors also discuss problems that drivers have to face with at crossroads. Then from a literature review of driver behavior psychological models, the authors propose their framework to study the interaction tram-car driver. In the third part, the hypothesis and research approach will be presented. The conclusion insists on the interest of this approach to understand the drivers’ behavior and the interface between tram environment and car driver.

2. Car-Tram Interactions within the Road Network

2.1 Some Broad Issues

Cars and trams are at opposite in terms of size, mass and speed but they share the same road network. Both trams and cars may have parts of a roadway set aside for their specific use. However, specific issues of visibility and manoeuvrability are likely to occur at intersections. The interaction between cars and trams on the road system will have three major types of consequence on:

- Infrastructure capacity requirements: in terms of damages to the infrastructure and rolling stock that can occur during an accident and which may be heavy in terms of economic damages and number of victims. Indeed as a mode of public transport, the accidents involving tram with other road users may involve a large number of victims. However, as of now there is comparatively little information about the background of the involvement of trams in crashes in Moroccan urban areas, but the media side on accidents involving public transport (in this case a tram) should be noted, even though they are few, they are totally

unacceptable to the public opinion;

- Operational performance, in terms of safety and travel time: conflicts between cars and tramway can have negative impacts on both trams and cars in different ways, causing tram delays and inconvenience;
- Perceptions, particularly by the car driver, which lead to changes in travel behaviour.

2.2 The Effects of the Tramway on Urban Transport

In all countries, the fight against pollution and congestion has been tackled in urban areas through the promotion of tramway as they have been considered the optimal option for fostering public transport patronage and also for getting a sustainable mobility for the growing urban population [3]. Tramways provide fast, regular, safe and comfortable services. At the same time, they provide a modern image of the city.

In spite of the growth in the interest of this urban rail system, it is well known that the tramway line implementation leads to changes, both in terms of the urban shape as on the overall functioning of the city. Indeed, the place occupied by the tram on the roadway is directly taken from the car. More specifically, most tram-car interaction within the road network takes place in the context of existing road infrastructure, which has physical limitations and implicit, sometimes explicit, limitations on additional capacity provision. But beyond the physical dimension of this competition for space, there is also a misunderstanding of the rules relating to this mode as of its constraints of traffic. The rule “tram has priority over all users” is explained by the fact that the tram is a vehicle on rails, it cannot avoid an obstacle but it is also explained by the big braking distance necessary to a tram to stop. More generally, tram priority is assuring the tram movement through an area without the potential detriment of others users of this area. These will often be where traffic volumes are high, traffic speeds are low and vehicles movements are

complex (e.g., intersections).

2.3 Crossroads Problem: Understanding Human Behavior

Crossroads navigation is a particularly hazardous component of driving. Even though crossroads comprise just a small amount of the roadway surface area, they generally are more complex and difficult to navigate than most other road segments. More specifically, crossroads can be visually complex, requiring that drivers scan several different areas and keep track of tram and several different elements to get the information they need to safely pass [4].

Specific issues of visibility and manoeuvrability are likely to occur at crossroads. So great attention is paid nowadays to the meaning of the space the driver is moving in. This area of research and action is known as the “road readability”.

“Road legibility”, “road readability” and “self-explaining roads” all raise the question of how the road infrastructure could support drivers’ activity. The concept of the “self-explaining road” is defined in terms of the processes by which drivers’ expectations are structured. “Self-explaining roads” are roads with a design that evokes correct expectations from road users (...). This means that drivers are given direct information about the type of road they are driving along and the type of behavior required [5]. Therefore, for a safe situation it is important that every road user can see all the other road users and that everyone knows what is expected of him.

In practice, however, the actual safety and convenience of road use depend heavily on driver’s perceptions of both the road and traffic conditions and of other users.

In Morocco, traditional methodologies mostly focus on single effects of causing parameters to traffic unsafe situations. For example, in most of the statistical reports on traffic safety in Morocco [2], it is written “speeding behaviour has the highest percentage in all causes of traffic conflicts and/or accidents”. However,

to explain the accident, one should not seek to blame a single and last element, but to see how the interaction system broke down. Many researchers have considered that the problem is not unsafe drivers or unsafe road users, but the unsafe complex system. Drivers, pedestrians and other road users will continue to make errors as long as the road system exists. It was concluded [6] that rather than focusing entirely upon removing road user error, effective error management in road transport should focus on increasing the capacity of the road transport system to tolerate error. This fact has guided our research in this area to an approach that takes into account the Moroccan road context and behaviour of the driver in this context.

3. State of Knowledge on Human Behavior in Driving

3.1 Human Functional Failure

The specific role of human factors inside the traffic system has to be stressed in order to go further than the usual view on accidents factors. It is important to be aware of the very specific role of the human element: It is both a component and the principal actor [6].

When a driver fails to avoid an accident because the situation exceeds their limitations, it is often called “human error”. Safe and efficient driving requires the adequate functioning of a range of abilities including vision, perception, cognitive functioning and physical abilities, and loss of efficiency in any of these functions can reduce performance and increase risk on the road [7].

It is consequently the same processes which allow the drivers to adapt to the difficulties of the environment and which sometimes may fail and lead them to the error. As the costs of human error can be very high, it is important to find out why human error happened and how it can be prevented in the future [8]. For this purpose, the cognitive approach is especially suitable for analyzing higher order functions such as problem solving and decision making.

3.2 Human Behavior Models

There is a great wealth of literature dealing with analysis models, giving preference in one way or another to the description of functional sequences such as: information acquisition, processing, decision and action. This type of model is aimed at understanding the malfunctions. Other model types are built up using the description of driving task [9].

Two theoretical models that originate from cognitive psychology and are frequently mentioned in the literature on road user behaviour are Endsley's model of information processing, and the hierarchical structure of the driving task as described by Michon. The reason for mentioning these models and not others, is that the models listed are all considered to be relevant for describing traffic behavior [10-12], and, more importantly, because they are complementary.

Endsley's model of information processing [13], serves as a starting point. Endsley proposes a model of human decision-making related to SA (situation awareness). The concept of situation awareness focuses on the mental picture of the situation that people find themselves in and how this picture can be distorted or improved by internal and external factors. Endsley's model illustrates three stages or steps of SA: perception, comprehension and projection.

The first level of SA, involves the processes of perception, cue detection and simple recognition, which lead to an awareness of multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions). At the second level of SA people combine, interpret, store and retain the collected information. The third and highest level of SA (called projection) involves the ability to project the future actions of the elements in the environment. These characteristics make it a suitable model for studying the formal stages involved in unsafe or undesirable situations.

We also borrowed from Michon [14] the distinction he makes in the driving task between the strategic, tactic and operational level. On the strategical level, driver makes decisions related to planning and executing a trip from origin to destination. The task on the tactical level requires taking decisions about driving speed and how to handle specific traffic situations such as crossing a crossroad. In this situational context, he plans manoeuvres that suit the navigational objectives. Finally, at the operational level, the driver takes decisions that relate to vehicle control [15].

It is obvious that other aspects of driver behaviour, such as experience, intentions, attitudes, emotions and spatial properties including location, size, separation, connection, shape, landmarks, and movement also play an important role in modelling driver behavior. Consequently, it is vital to be aware of how spatial knowledge and beliefs are acquired and developed over time, and how aspects of spatial knowledge and reasoning are similar or different among individuals or groups. This approach gained insight from the work of Lynch [16], a planner who argued that “images” of cities guide people's behaviour and experiences of those cities [17-19]. In fact, there is a growing need to include spatial cognition explicitly in models [20].

With this in mind, the articulation of models presented before seemed to authors particularly interesting to fully understand human behaviour in typical driving situations. The authors also combine notions of cognitive mapping to their analysis to suggest how cognitive mapping might be employed to help us better understand and predict driver behaviour. The authors therefore set out to develop a driver behaviour framework to generate and test hypotheses about the specific causes of unsafe driving behaviour in crossing crossroads that pass through tramway line. Fig. 1 shows the interaction and indicates variables moderating the hypothesized relationship to be tested in the field study.

Fig. 1 Diagram for the tram-car driver interaction assessment

4. Hypothesis and Research Method

4.1 Research Hypothesis

Several research work [21-23] have helped to affirm that road design elements play a role in the driving circumstance difficulties. These different studies have led the authors to formulate the general hypothesis of research, which can be defined as follows: Driver behaviour at tram crossroads will depend very much on what is seen or “not seen” by the driver, in the road scene and how he “reads” the situation.

Briefly speaking, our analysis aims to answer three questions:

(1) How (how often) do people behave at specific

crossroads crossed by tramway line;

(2) Why do they behave that way;

(3) What are the results of such different behaviours.

4.2 Research Methodology

To meet the research hypotheses, the methodological proposal is largely based on the functional and dysfunctional approaches which are consistent with the goals of this study. Among them are such techniques as HAZOP. In the study, failure constitutes the limits of cognitive functions engaged by the driver in a context of driving activity at crossroad. For each failure that refers to a function of the driver’s mental model in degraded mode, a quantitative and qualitative assessment will be

conducted to identify potential accidents that can result from the deviations, to determine the cause of the deviation and to find the safeguard which helps to reduce frequency of problems encountered by drivers in crossing tram crossroad.

HAZOP is a classic tool of the industrial world, the authors tried to adapt it to the context of the study by simplifying it to facilitate its ownership by stakeholders. At this level, their work joins several studies HAZOP in the road sector including one conducted by a research program initiated by “Rail safety standards and Board” and whose results were published in the report “Understanding Human Factors and Developing” risk reduction solutions for pedestrian crossing at railway stations [24].

To validate the hypotheses and the methodological proposal, a particular attention is paid to the data collection. Observational surveys will be used to record user behaviour and a questionnaire to determine the opinions, concerns and knowledge of users. The observation is based on an analysis grid to carry out the assessment, and to examine whether it would be possible to identify characteristics of crossroads that coincide with a higher likelihood of unwanted events. To guide the choice of elements to be included in this grid, the authors were inspired by the work of Millot [21] taking care to adapt the reading points to the field of study and to their specific questions. To complement those observations, a face to face interview using the existing situational questions, will be conducted to encourage drivers to express their opinion and share their experiences which will contribute significantly to gathering information for hazard identification and prevention of traffic accidents and congestion.

4.3 Validation

As a first step, a validation exercise was carried out to assess the feasibility of the methodology. Two crossroads at Rabat city were selected according to the number of collision and related incidents that occurred

there in the last year 2012.

During the validation exercise, observations were carried out. This involved spending periods of time at each crossroads and observing the behavior of users. A review of the physical aspects of each crossroad and its surrounding were made. An assessment of the driver’s behavior during a journey within the vehicle itself was also used. At varying intervals during the crossing, the participants were asked relevant questions about the scene in order to determine their knowledge and their representations of the driving situations studied, in addition to this a detailed explanation of the driving process was provided by the drivers as they progressed through the sequence of each roundabout, this technique allows previously unknown parameters to be found and enables driver to make comments about his behavior, especially as regards to the environmental conditions which influenced him and came into play in the various situations he encountered.

4.4 Preliminary Findings

The following list highlights a number of human factors and design features at each crossroads that can have an influential role in unwanted events and contribute to unsafe conditions. The list can be supplemented by further observations and interviews:

(1) At crossroad united nation street at Rabat

- A high traffic volumes and pedestrians movement due to shops, this requires car drivers to be alert for pedestrians and tram approaching;
- A stop line is not demarcated, either with a white line or appropriate pavement marking, to help drivers identify safe stopping location;
- Tramway signs are not always conspicuous due to their position relative to other signs;
- Parked cars before and after the tramway line may result in vehicle drivers slowing and being caught on the tracks while a tram approaches;
- Non compliance with traffic signal encouraged sometimes by police due to problems of traffic

congestion;

- The sequence of lights is believed to be confusing to car drivers;
- The crossing being completed without the necessary caution increases during rush hours and on working days.

(2) At crossroad street IBN ROCHD

- At some locations there is considerable visual clutter from surrounding infrastructure, which can detract from the primary safety messages “give way to tramway” and “beware of tram”;
- Text in association with trams signs can be hard to read due to car driver’s speed;
- Some users failed to fully understand the meaning for various trams signs and are not aware of the rules and procedures for correctly using trams crossroads;
- Drivers can be distracted from scanning for trams while they seek an appropriate gap in traffic on main road;
- A stop line is not demarcated, either with a white line or appropriate pavement marking to help drivers identify safe stopping location;
- Vehicles waiting or queuing across the tram tracks due to traffic congestion;
- The curvature of the intersection creates a difficult angle from which to observe on-coming trams;
- The desire to pick gaps generated by traffic platoons can result in crossing being completed without the necessary caution, indeed the amount of time the users expect to wait at trams crossroads may influence their risk taking behavior.

5. Conclusions

There is very little literature concerning the interaction between tram environment and the drivers’ behaviour. To address this issue we are therefore oriented towards the methods used in urban development, and human cognition.

While moving, the driver evolves—particularly in

crossroads—in a complex and extremely dynamic environment, hence the need to set up developments which allow the driver to discern, to identify and to choose easily in this environment, the indices for the effective regulation of its activity.

The methodology the authors have presented here represent an analytical approach. The interest of this approach is that it attempts to obtain an overview of drivers’ behaviours in specific driving situation (e.g., crossroad crossed by tramway line) and the variables likely to explain them using complementary indicators: site visits to record user behaviour and questionnaires to make drivers precisely explain their perceptions of the facts, their decisions, actions and the difficulties they encountered.

The conclusions of the preliminary findings of the study has identified a number of problems associated with tramway crossroad and has explored some of the road design and human factors that contribute to the difficulties experienced by drivers at these intersections. It is clear that much further investigation is required on the causal factors of errors and on the implications that these driver errors have on tram crossroad safety. The second stage of the study is now to address the relationship between the elements of the tram environment and types of driver errors, this work is on progress, with the aim to provide suggestions for minimizing potential conflict between cars and trams and for enhancing error tolerance at crossroads that pass through tramway line and within the Moroccan road transport system in general.

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