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AN APPROACH TO ASSESSING DRIVER'S BEHAVIOUR AT ROUNDABOUTS

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Abstract

In urban traffic, roundabouts have been considered as an alternative traffic facility that can improve safety and operational efficiency, compared to un-signalized intersection. But in Morocco where roundabouts are relatively new, the concept is not rooted in the road culture of drivers. Moroccan drivers are used to the traffic lights telling them what to do. Roundabouts involve drivers using their own judgments at an intersection, so roundabouts negotiation can be confusing for drivers who are not familiar with their use. This fact has guided our research in this area to an approach that takes into account the Moroccan road context and human factors in this context. This article presents a detailed analysis of driving task to determine key functions performed by drivers as they approach and navigate through roundabouts. Our analysis aims to understand the mechanism of driving performance in roundabout's environments, to predict how drivers might respond , to identify roundabout elements that play a role in incorrect roundabout negotiation and therefore to suggest measures for improving drivers' abilities to properly negotiate roundabouts.

Keywords: roundabout, human factor, cognition, task analysis, human functional failure

1 Introduction

Moroccan experience with roundabouts is rather limited to date, but their numbers are increasing rapidly. For further discussion some consensus about terminology seems to be useful in order to avoid mixing things. A roundabout is a form of intersection design and control which accommodates traffic flow in one direction around a central island, operates with yield control at the entry points, and gives priority to vehicles within the roundabout, [1]. In Morocco, the new highway code (2010) defines the roundabout as "an intersection where all traffic merges into and emerges from a one-way road around a central island (impossible to cross) of circular shape, the circulation on this roadway is in a counterclockwise direction". The geometric configuration of roundabouts, as compared to others intersections, promotes the traffic safety. In fact numerous studies conducted in Australia and Canada [2-5], where roundabouts are common, and in the US, have found that roundabouts provide several benefits compared to standard intersections. A study was conducted in US [6], in 2003, on the safety performance of 23 roundabouts, the authors reported highly significant reductions of 40 percent for all crash severities combined and 80 percent for all injury crashes. In addition to traffic safety, other advantages of a roundabout have been studied extensively in the following areas: Capacity and quality of traffic flow [7], Traffic- calming effects, reduced delay and concomitant emissions. [8-10] Although roundabouts provide many benefits, there are some disadvantages as well. The primary drawback is that roundabouts have design elements that go against the common rule-of-the-road expectancy to yield to vehicles on the right, which can lead to

confusion and error for unfamiliar drivers. In order to properly address these questions, this article has been divided into four parts. After this introduction, the second section presents a detailed analysis of driving task to determine key functions performed by drivers as they approach and navigate through roundabout. Then from a literature review, we propose our driver error taxonomy at roundabout. We present in the third part our research approach and the primary findings of our study. The conclusion insists on the interest of our approach to understand better the difficulties that drivers encounter at roundabouts and how to address these difficulties in the context of improving roundabout safety.

2 Human factors issues in roundabouts

Negotiating roundabouts is one of the most complex and demanding tasks a driver faces. Even though roundabouts comprise just a small amount of the roadway surface area, they generally are more complex and difficult to navigate than most other road segments. 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.

2.1 Road user tasks and information requirements

Concerns for drivers at roundabouts include: confidence approaching the roundabout, navigating around the roundabout, direction of travel and yielding rules [11]. As driving involves complex interactions between human factors and system responses, the driver, through his senses can only selects what is significant for him, depending on his knowledge, on the situation and his objectives. While driving, many subtasks have to be performed at the same time, in an environment with many rules and complex interactions. Therefore, in order to determine exactly what a driver must do to consistently negotiate roundabouts safely a task analysis needs to be carried out. The technique of Hierarchical Task Analysis (HT A) is applied for collecting information on the tasks and procedures and for studying the working environment, the process of HTA is to decompose tasks into subtasks to any desired level of detail. Each subtask, or operation, is specified by a goal, the input conditions under which the goal is activated, the actions required to attain the goal, and the feedback indicating goal attainment, [12]. From an ergonomic perspective, the driver's behaviour in a particular situation is regarded as a function of information available at given moment (both information present in the road environment and information stored in the driver's memory); of its processing and of the decision-making criteria underlying the regulating action he takes,[13]. In the field of cognitive psychology, the notion of situation awareness (SA) can be formally defined as the "perception of the elements within a volume of time and space (Level 1), the comprehension of their meaning (Level 2), and the projection of their status in the near future (Level 3)", [14]. So each task encountered by the driver at roundabout involves a sequence of:(i) Perception or recognition; (ii) Decision making ;(iii) Execution or performance; and (iv) Real time system response by the vehicle, roadway and surrounding environment

2.2 Roundabout elements of concern to drivers

Roundabouts can be visually complex, requiring that drivers scan several different areas and keep track of several different elements to get the information they need to safely pass [15]. As a start point our research has been focused on the effects that traffic signs have on the driver performance and how to avoid distractions and human errors provoked by them.The objective of the road signs is to transmit an unambiguous message to the driver quickly and clearly, to minimize disturbance with the other users and to allow a sufficient time after recognizing the sign to make decision and control action. Drivers' perception processes are very important in understanding the effectiveness of a road sign. The principles that enhance perception and

reaction to signs are: conspicuity, visibility, maintainability, legibility , and standardization, [16]. According to this perspective, Andreassen [17] found that "...if any link existed between the sign and an accident, it might be due to the poor design, maintenance or placement of the sign ...". On the other hand, a study [18] conducted in Morocco in urban areas has shown that road signs led to several problems, It has been noticed in this study that " urban environment suffers from multiple dysfunctions, roundabouts are designed without rigorous standards, also roundabouts with the same features have different roads signs from one city to another and even within the same city". This finding justifies that research should be conducted to further knowledge about the influence of traffic signs on car drivers' behaviour, and it is one of the main objectives of our study.

2.3 Roundabout driving task analysis: a driver operating model

This article presents a detailed analysis of driving task to determine key functions performed by drivers as they approach and navigate through roundabout. The technique of hierarchical task analysis described above has been used to analyse the task of negotiating a roundabout. Our analysis underlies the assumption that to properly drive through a roundabout, drivers need competences more diversified than only the respect of the rules of Highway Code. Since this is a change from standard intersections, many drivers have difficulties in their first few encounters with roundabouts. In our frame we have combined the task analysis approach with the concept of situation awareness. Within each segment (approach, entry, within the roundabout, exit), we have identified individual tasks that drivers should or must perform to safely navigate the roundabout. Each task encountered by the driver involves information that needed to be obtained, decisions that needed to be made, or actions that needed to be taken. The steps, a driver must consider to correctly manoeuvres through a roundabout include the following

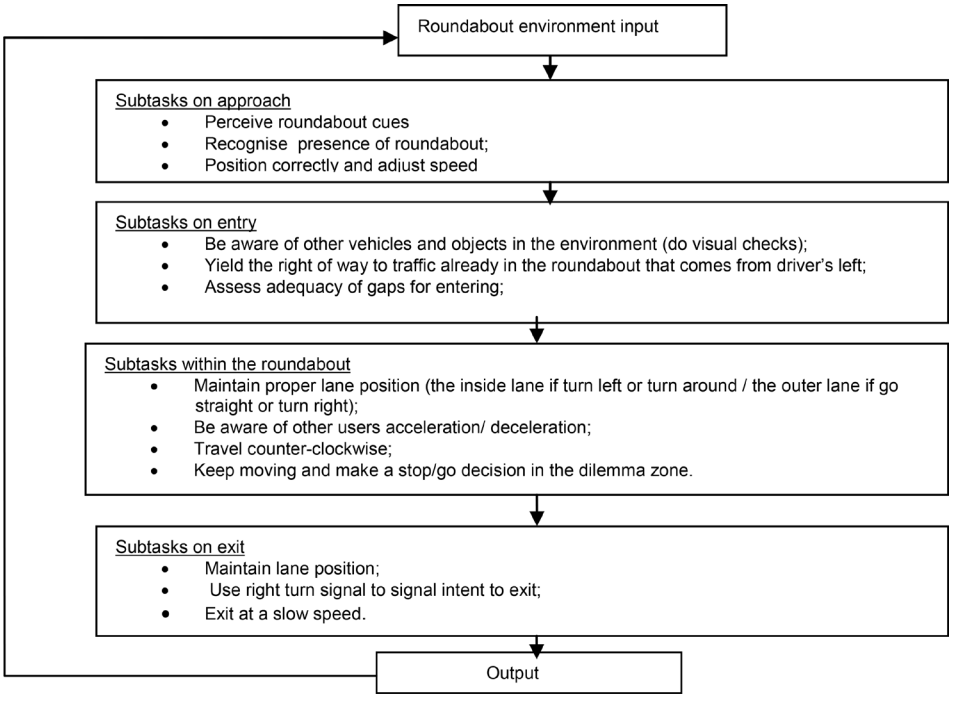

Figure 1 Frame of functional subtasks involved in roundabout negotiation.

This frame was used to construct the observation sheet of human functional failures for each of the task at roundabout, consistent with ergonomics concepts and specifically adapted to the roundabout driving task. Indeed, once correct driving behaviour at roundabout has been established, deviations from that behaviour can be defined as errors. Where an error occurs in any one or more of these steps, it may lead to an incident (such as a near miss) or accident (crash).

2.4 Literature review of driver error

Human error is a problem of great concern within complex system. One of the obvious consequences of assessing human error in roundabout is that, in understanding how and why it happened we may be able to prevent similar events. According to the literature [19], there have been numerous attempts at defining the construct of human error but no universally accepted definition exists. In order to avoid any semantic confusion, 'human error' will be considered in this article under the label of 'Human Functional Failure' (HFF), defined by Reason [20] such as following:"a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fail to achieve its intended outcome". There are also a number of different error classification schemes and error taxonomies avaible. A more recent study conducted by the American driver and traffic safety Education Association [21], describes driver errors in relation to the three driver tasks of perception, decision and execution: (i) Perception or problem recognition errors included: driver failed to stop for sign, delays in problem recognition (e.g. Improper lookout, internal distraction, delays in recognition, inattention, external distraction); (ii) Decision error included: Excessive speed, false assumption, improper technique /practice, improper maneuver, inadequate signal, tailgating, misjudgment of distance /closure, failure to turn, excessive acceleration ; (iii) Execution or performance errors that refer to : Improper evasive action, inadequate directional control, overcompensating, panic or freezing, critical non-performance(e.g. passing out, falling asleep). According to this study the types of drivers errors cited above are also influenced by a range of personal, environmental or infrastructure factors, which may contribute to drivers' error. These factors include: (Inadequate knowledge, skills, and training; Impairment due to: dysfunctions, disabilities; Willful inappropriate behaviour; Infrastructure, environment problems)

2.5 Proposed Human error taxonomy when crossing roundabouts

HAZOP (Hazard and Operability Study) is a classic tool of the industrial world that was developed for use in process design audit and engineering risk assessment. HAZOP involves analysts applying guidewords, such as not done, more done or later done, to each task step in order to identify potential errors that may occur.
In our study, a set of human error HAZOP guidewords were used, each guideword is applied to each subtask at roundabout. Once a description of error is provided, a cause and types of the error are described based on an orview of the literature which were interested to the sources of driver errors at roundabouts [21-28]. The driver error taxonomy is presented in table 1.

Table 1 The driver error taxonomy

N°	task	Domain	Internal error mode	Deviation	Psychological error mechanism	Errors types
1	**Subtasks on approach**					
1.1	Perceive roundabout cues	Perception	Miss see No detection (visual) See too late	User fails to perceive roundabout	Expectation Vigilance Distraction Overload Impairment due to dysfunctions	Recognition errors
1.2	Recognise presence of roundabout;	Memory	Forget information Miss recall information Wrong information obtained	User fails to recognise roundabout	Memory confusion Overload Misinterpretation Knowledge problem (user is unfamiliar with roundabout)	Recognition errors
1.3	Position correctly and adjust speed	Decision Action	Action omitted Action too late Action too early	Failing to formulate safe stopping strategy Failing to control speed on approach	Distraction Inadequate model mental Knowledge problem (user is unfamiliar with roundabout) Impairment due to dysfunctions	Decision errors And performance errors
2	**Subtasks on entry**					
2.1	Be aware of other vehicles and objects in the environment (visual checks)	perception	Miss see No detection (visual)	Failing to stop behind a queued vehicle	Expectation Vigilance Distraction Time pressure Impairment due to dysfunctions	Recognition errors
2.2	Yield the right of way to traffic already in the roundabout	Action	Action omitted Action too late Deliberate violation	Failing to yield the right of way to vehicles in the roundabout	Confusion Distraction Inadequate model mental Knowledge problem (user is unfamiliar with roundabout) Impairment due to dysfunctions	Decision errors
2.3	Assess adequacy of gaps for entering	Decision	misprojection poor strategy late strategy	Accepting an unsafe gap distance	Misinterpretation Knowledge problem Decision overload	Decision errors
3	**Subtasks Within the roundabout**					
3.1	Maintain proper lane position	Decision Action	Action omitted Action too late Wrong action	Failing to detect proper lane assign-ment when entering	Inadequate model mental Knowledge problem (user is unfamiliar with roundabout) Impairment due to dysfunctions	Decisions errors and Performance error

Table 1 The driver error taxonomy (continued)

3.2	Be aware of other users acceleration/ deceleration	perception	Miss see No detection (visual)	Failing to avoid conflicts with other users	Expectation Vigilance Distraction Time pressure Impairment due to dysfunctions	Recognition errors
3.3	Travel counter-clockwise;	Action	No performed action Deliberate violation	travelling clockwise	Confusion Time pressure Knowledge problem	Performance errors
3.4	Keep moving and make a stop/go decision in the dilemma zone	Action Decision	decision omitted decision too late Wrong decision	Stop at roundabout and refusal of priority	Confusion Distraction Inadequate model mental Knowledge problem (user is unfamiliar with roundabout) Impairment due to dysfunctions	Performance errors and Decision errors
4	**Subtasks on exit**					
4.1	Maintain lane position	Action	Action omitted Action too late Deliberate violation	Changing lanes incorrectly when exiting	Confusion Time pressure Knowledge problem Decision overload	Performance error
4.2	Use right turn signal to signal intent to exit	action	Action omitted Action too late Wrong action	Signal driving direction omitted Failing to use right turn signal to signal intent to exit	Distraction Knowledge problem (user is unfamiliar with roundabout)	Decision error
4.3	Exit at a slow speed.	Action	Action omitted Action too late Wrong action	Failing to control speed on exit	Confusion Time pressure Knowledge problem	Performance error

3 Methodology and summary finding

3.1 Study methodology

Our study was conducted at three roundabouts in Rabat. The three roundabouts met the primary characteristics of modern roundabouts: They had no traffic-control signals other than yield signs for entering traffic; circulating vehicles had the right of way. An observation sheet was developped for the field study. For each task involved in crossing roundabout, the observer had to chek if all subtasks required were accomplished by the subject and to mark missing, incorrectly or unrequired one. The observer also counted the frequency of different manoeuvres of the drivers, (e.g. lane-changing, overtaking). These measures served as basic exposure information so that error rates for different driving tasks could be calculated. In addition to the observation method described above, a questionnaire has been used to gather information about the reliability of drivers in the driving task under investigation. The following results will not draw upon the whole set of methods, but will mainly rely on the driver observation method.

3.2 Summary of finding

The roundabouts inspections that were carried out within the scope of this research had a rather exploratory character. The findings of the study can be summarized as follow in chapters 3.2.1 and 3.2.2.

3.2.1 Roads Signs

From a human factor perspective, some aspects of the current signage at roundabouts visited are not optimal, indeed:

- Roads Signs are not always conspicuous due to their size, colour and position;
- Warning sign which indicates the presence of a roundabout ahead wasn't always used at roundabouts visited;
- At some locations a mixture of road signs and other signs for the public could be seen as confusing or conflicting. An exemple is an "advertising sign"posted with a "yield sign"at one of the roundabouts visited;
- It was noted that "yield signs"were worded differently on each roundabout. The sign on one roundabout reads "give way", whereas the sign on another roundabout reads "you don't have priority". This discrepancy increases the ambiguity of the instruction.

3.2.2 Drivers' behaviour

The sample established was composed by 136 vehicles observed. Drivers' behaviour shown below represents the range of driver failure experienced at the roundabouts visited. These failures do not represent every possible error but represent easily identifiable deviation that can be related to incorrect roundabout negociation as previously defined. The analysis of the data collected shows that:

- Almost 88% of the drivers observed were judged to be at fault by failing to signal intent to exit;
- 79% of drivers omit signal driving direction;
- 72% of drivers fail to yield the right of way to vehicles in the roundabout;
- 42% of drivers fail to detect proper lane assignment while 34% change lane incorrectly;
- 54% of drivers fail to control speed on approaching roundabout.

Additionally, the results indicated that the least frequently reported aberrant behaviours at roundabouts visited were:

- Stopping at roundabouts and refusal of priority among 15% of drivers;
- Travelling clockwise among 5% of drivers.

4 Conclusion

The roundabout, with all kinds of traffic users, is too complex and it is extremely difficult to define a solid limit between correct and incorrect behaviour, 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 we have presented here represents an analytical approach. The interest of this approach is that it attempts to obtain an overview of drivers' behaviour in specific driving situation (e.g. roundabouts). The conclusions of the preliminary findings of our study indicate that the most common deviations occurring at roundabouts in this analysis were: lack of knowledge of priority rule and omission of signal driving direction. These results address that there is a general lack of awareness and understanding on the part of most drivers regarding roundabout. This is enhanced by inconsistencies in the road signs at roundabouts, which can be confusing and misleading. More generally it can be emphasized that roads signs at roundabouts need to be uniform from roundabout to another. This gives drivers the opportunity to gain experience

with roundabouts and at the same time develop mental schemata for managing roundabouts that help them safely negociate roundabouts, [29].
It is clear that there is much further investigation is required on the causal factors of errors and on the implications that these driver errors have on roundabout safety. The second stage is now to address the relationship between the elements of the roundabout environment and types of driver errors, this work is on progress by using questionnaires to make drivers precisely explain their perceptions of the facts, their decisions, actions and the difficulties they encountered, with the aim to suggest measures for minimising potential driver's errors and improving drivers' abilities to properly negotiate roundabouts in Morocco.

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