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# Road User Behaviour and the Road Environment: A Framework for Analysis

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**OBJECTIVES**

- To study the interaction between road users and the road environment with the aim of identifying the conditions likely to improve this interaction.
- To see how the psychological approach can contribute to a safety diagnosis.

## ELEMENTS FOR THE ANALYSIS OF THE DRIVING TASK AND DRIVERS' ACTIVITY

### Generalities

An analysis of drivers' activity is taken here as an example. The theoretical framework of analysis described can, of course, also be applied to other categories of road users, as for example, cyclists or pedestrians, provided it is correctly adapted to take into account their particular characteristics.

Psychological research aims at developing knowledge on driver behaviour and consists in describing and categorising behaviour in traffic; identifying the internal and external variables likely to explain this behaviour (internal variables relating to the individual himself such as his driving experience, external variables relating to the technical and social environment in which the individual develops his activity); analysing the mechanisms that govern driving activity.

In the field of traffic ergonomics, psychological research contributes to identifying and assessing measures that aim at facilitating drivers' adaptation to the traffic system (design of road infrastructure, traffic management, or driver support devices). The questions raised when identifying these measures stem from complex situations, whose dimensions must be examined in research work and taken into account when validating the results and formulating the subsequent recommendations. The systems approach applied to road traffic focusses on interaction phenomena between the technical and organisational components (vehicle, road infrastructure, legislation, traffic management, . . .) and road users (drivers, pedestrians, etc.). It goes beyond a simplified view of causality in the analysis of the malfunctions that affect the system (Leplat and



Cuny, 1979; Hale and Glendon, 1987). From this standpoint, the study of road situations, tasks to perform and drivers' activity is a significant part of the search for solutions:

- In-depth analysis of road situations provides a way of specifying the nature of interactions (with the road infrastructure, with other users, and so on) and the demands (regulatory, structural, dynamic, etc.) to which drivers must adapt.
- Studying drivers' activity in these road situations calls for an examination of how they perceive and weigh the different demands and how they organise, perform and control the tasks required. This contributes to identifying the mechanisms that determine drivers' behaviour and the difficulties that they encounter when managing their journeys.
- Analysing drivers' errors is particularly useful in this respect (see, for example, *Ergonomics*, 1990, a special issue on driving errors). Errors may be considered as both a subject and a means of analysis (Leplat, 1986): a subject of analysis inasmuch as the mechanisms that produce them must be explained (several theoretical frameworks have been developed for use in this kind of investigation, see, for example, Rasmussen, 1982; Leplat, 1985; Reason, 1990); a means of analysis, in that they reveal the critical interactions within the system and direct research towards the situations that deserve specific investigation.

Analysis of driving task and drivers' activity requires in-depth knowledge of all relevant models, and of the methods available for the investigation of the particular phenomena to be studied. References to appropriate models are necessary to structure the analysis of complex phenomena such as divers' behaviour in traffic situations. These models govern the choice of observables and the methods used for studying drivers' interactions with the road environment. Furthermore, the analytical model chosen will influence the final recommendations and the type of solution advocated.

### Characteristics of the Driving Task

Research has identified some characteristics of the driving task that may serve as a general framework for analysing drivers' activity. Driving can be defined as complex and relatively unstructured task (Saad, 1975; Neboit, 1982).

*Complex*, as (De Keyser, 1988; Leplat, 1988; Woods, 1988):

- Drivers are required to constantly adapt to extremely diverse road situations and their variations; this adaptation is subject to temporal and dynamic constraints, resulting from the movements both of the driver himself and of other road users with whom he interacts.
- Drivers have to perform multiple and diverse tasks (Allen et al., 1971; Michon, 1985) and to manage the problems related to their organisation and control (Neboit, 1982).
- Drivers are facing uncertainty and 'risk' associated with multiple interactions, with his vehicle, with the road infrastructure, and with other users.

*Relatively unstructured* in that:

- the formal task (as prescribed by the Highway Code) only partially defines the conditions to be taken into account and the procedures to be applied,
- most of the information required for driving is informal (Neboit, 1982),

- in view of the content and duration of present-day driver training programmes (see, for example, Groeger and Grande, 1991), driving experience is mostly acquired through practice. Driving knowledge and strategies therefore build-up in an 'unsupervised' manner.

Drivers' adaptation illustrates their capacity to develop heuristic solutions to the complex dynamic problems they encounter when managing their journey. This adaptation can be conceived as resulting from their own structuring of the task (Saad, 1975), based in particular on:

- the acquisition and organisation of knowledge about the spatial characteristics of the road environment, the formal and informal rules that govern its use and interaction with other users, and the dynamical aspects of the various traffic situations encountered.
- the development of strategies for information taking and processing, and of 'rules of action' to be applied in various situations.

Errors, incidents and accidents reveal the limits of this adaptation whose determining factors must be identified and analysed.

## Models of the Driving Task and of Driver Activity

Several models can be found in road safety literature. They describe the various tasks to be performed and characterise the psychological activities involved. It is not possible to present here these models in detail. Only their main features will be summarised (for a more detailed review of these models see, for example, Michon, 1985; Ranney, 1994; Saad, 1989).

It has been underlined previously that the tasks of driving are diverse, and that some of them have to be performed simultaneously. Some models, for example, the model developed by Allen et al. (1971), structure the driving tasks in a hierarchical way, with three levels:

- Navigation tasks, related to trip management, route selection, time of departure, etc.; this is the highest level of the hierarchical structure.
- Situational or 'guidance' tasks needed for the drivers' adaptation to the various road situations encountered (going through junction, overtaking, car-following, etc.).
- Control tasks (speed and trajectory control); this is the basic level.

The model is interesting in that it characterises the goals and conditions to take into account for each specific sub-tasks and underlines the need to coordinate them. It has been formulated as a tool to define an information system for drivers: necessary items of information and their order of priority.

Driver activity models formalise the psychological processes brought into play when driving, the mechanisms by which the driver adapts to his environment and manages to perform the tasks. The models usually consider:

- Information taking and processing, which leads to the categorisation of the current situation.
- Decision-making: On the basis of road situation categorisation, and depending on drivers' own criteria, a procedure is chosen to control the situation.
- Implementation, which consists of carrying out the actions defined by the selected procedure.

These briefly listed processes interact closely and are functionally linked to the knowledge and representations acquired by drivers through training and experience. They also depend on drivers' motivation and attitudes. Some models put special emphasis on these last dimensions to explain driver behaviour in traffic (Wilde, 1982; Näätänen and Summala, 1974; Fuller, 1984; Van Der Molen and Botticher, 1986).



All the models stress the fact that driver behaviour results from complex processes and emphasise the active nature of driver/environment interaction. In short, driver behaviour in a particular situation is regarded at a given moment as a function of the information available, both from the road environment and from the driver's knowledge, of its processing, and of the decision-making criteria underlying the regulating action he takes.

## The Prescribed or Formal Task and the Effective Task

A final point concerns the difference between prescribed and effective tasks as emphasised by Leplat and Hoc (1983):

- The *prescribed task* is the task conceived by the designer of the system. It pre-exists the activity that it is intended to influence and determine to some extent. It defines the behaviour expected of drivers, what they should do. Analysing the prescribed task in a given situation will thus consist of identifying the demands and constraints imposed upon drivers. The task is determined essentially by the highway code, which defines the rules for using the road and for managing interaction with other users, by the design and layout of the road environment, and by traffic conditions.
- The *effective task* is the one individuals actually perform. It is related to the goals and conditions they effectively take into account. Identifying this task calls for the study of driver activity: how drivers react to the formal task demands, what their goals are, what information they select from the environment, what motives and criteria underlie their decision-making, etc.

Driver activity does not always correspond to the prescribed (or formal) task. Frequent deviations from the formal rules are observed with regards to, for instance, speed limits, or compliance with traffic signs. Understanding the reasons of these deviations, measuring their frequency, and identifying the conditions in which they appear, are necessary to devise ways of reducing their occurrence and/or their consequences. This calls for a joint analysis of situational variables and driver characteristics.

# METHODOLOGY

## Generalities

Analysis of the driving task and driver activity is based on very diverse methods and investigative techniques: interview or questionnaire surveys of drivers (in or out of traffic situations), behavioural observation in real traffic (on-site or on-board vehicles), or experimentations in controlled situations (on test tracks, in the laboratory, or on driving simulators). All these methods have advantages and disadvantages and have to be used in a complementary way when studying complex phenomena such as those involved in traffic safety. Selecting one or several complementary techniques depends on preliminary knowledge of the problem to be investigated, and on the objectives of the study. In practice, the choice will also depend on the time and means available.

Analysis of behaviour in real traffic is essential in any research dealing with traffic ergonomics. When identifying effective practice of drivers and/or designing or evaluating technical measures aimed at modifying it, such an analysis is absolutely necessary. Moreover, it is often a useful complement to in-depth analysis of accidents, and may compensate for the shortage of available information on this matter. It plays therefore an important part in safety diagnoses. This is why we will focus on methods of behavioural observation.

## Observation of Behaviour in Real Driving Situations

From a practical viewpoint, roadside observations are easier to implement and much more often used than observations on-board a vehicle.

Observations are made from one or several fixed locations on specific sites, such as entry to a built-up area, junction, etc. Data collection can be partially automated, depending on the variables selected (speed, time headway in car-following, respect of traffic lights, stop signs, etc.), and on the technical means available (radar, electromagnetical detectors, video-cameras, . . .). It has to be noted, that the number of parameters that can be observed from the roadside is often limited, in particular when technical means are restricted, and data have to be collected directly by observers.

Road situations are often complex, and events occurring there can be many and very fast. It is seldom possible to describe them all. The most significant events with regards to the research objectives and hypotheses need therefore to be selected for observation. Two pitfalls must be avoided: on the one hand, one must be willing to describe everything, an illusory endeavour; on the other hand, excessively narrowing the scope of observation could lead to the omission of important facts. This is why definition of the systematic observation procedure must be preceded by 'open' observations, aimed at exploring problems and providing a preliminary overview of the road situation to be studied.

The systematic observation procedure defines situational and behavioural categories, whose elements are organised in an observation grid. If data are to be recorded directly by observers, these categories must be specified in a clear and precise way: there should be no overlap between categories (any item of data collected must fall into one and only one category); categories should cover the whole scope of observation (any item of data should be categorised). The nature and quantity of data to be collected should be compatible with the capabilities of the observers. Finally, it is essential to train observers in the data-collection procedure by introducing them to the observation grid. Preliminary field-tests are needed to check feasibility of observations and reliability of observers. The observation programme should also define the time and duration of data collection, once again according to the research objectives and means available.

Data collected are usually treated through statistical methods in order to get a summary description of observations, and to identify significant patterns. In particular, statistical data treatment aims at establishing and weighing the links between the different variables defined in the study; for example, the effect of some infrastructure features on drivers' speeds.

## A Case-study in the Philippines: Contribution of Behavioural Analysis to the Safety Diagnosis

The study carried out in the Philippines was part of an extensive safety diagnosis requested by the Ministry of Public Works and Highways (BCEOM-RCG Consult, 1986). It was based on an integrated approach to road safety management (Muhlrad, 1987), which also included accident analysis, road inventory, etc. This study was aimed at analysing drivers' behaviour with regard to regulations, especially the road sign system (Saad, 1990). The purpose of the road sign system is to facilitate the driver's adaptation to a variety of road situations, and his interaction with other road users. It seeks to homogenise the operation of the traffic system, and thereby increase its reliability. It is therefore important to ascertain whether drivers actually comply with the regulations and understand their purpose and usefulness.

Two surveys were conducted in order to analyse drivers' compliance with stop signs at junctions, and with a ban on overtaking.

*Behaviour at stop sign regulated intersections:* Behaviour observations were performed at six junctions in open country (three cross-intersections and three Y junctions). An observation grid (Fig. 1)was defined in order to collect the following data:



Day: ............ Location: ....................

| Nr | H | Type of vehicle | Behaviour at stop sign | | | Manoeuvres | | | Traffic | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Full stop | Near stop | No stop | Straight on | Left turn | Right turn | Yes | No |
| | | | | | | | | | | |

**Figure 1** Observation grid for behaviour at stop signs

**Table 1** Behaviour at stop signs

| *Behaviour road users* | *Stop* | *Near stop* | *No stop* | *T* | *N* |
|---|---|---|---|---|---|
| Jeepney | 44 | 23 | 33 | 100 | 377 |
| Motorcycle | 27 | 28 | 45 | 100 | 121 |
| Motorbike | 32 | 28 | 40 | 100 | 25 |
| Bus | 25 | 42 | 33 | 100 | 103 |
| Truck | 44 | 27 | 29 | 100 | 100 |
| Light vehicle | 33 | 35 | 32 | 100 | 564 |
| Total | 36 | 30 | 34 | 100 | 1,290 |

(a) type of vehicle (jeepney, motorcycle, motorbike, bus, truck and light vehicles);
(b) behaviour at the stop sign (full stop, near stop, no stop);
(c) type of manoeuvre (passing through, turning left or right);
(d) visible traffic on the highway at the time when the observed vehicle arrives at the junction.

The main results (based on observation of 1,290 drivers) were as follows:

The majority of drivers (64%) did not strictly observe the regulations at the crossroads. Table 1 indicates the level of compliance for each category of road users.

Drivers' behaviour strongly depended on visible traffic on the highway: in the presence of traffic, most drivers came to a full stop (64%), whereas only 8% of them did it in the absence of any traffic. This was true for all categories of road users. However, bus drivers seemed to be less influenced by the presence of traffic than other categories of road users (it would seem that they tend to 'force' their passage at junctions). There was evidence, furthermore, of certain variations in behaviour according to the type of junction and its location, which indicates the need for in-depth studies to highlight the effects of environmental features on drivers' behaviour.

As a conclusion, the stop sign did not seem to be associated, in the minds of drivers, with a systematic unequivocal type of behaviour. In fact, they would seem to have behaved mainly according to their own evaluation of the traffic situation encountered, rather than according to the formal rules indicated by the stop sign.

Simultaneously to the observation programme, a survey was conducted in the same area on drivers' awareness of the meaning of the stop sign. It involved 140 drivers (55 drivers of light vehicles, 30 bus drivers, 30 truck drivers and 30 drivers of jeepneys). The findings indicate that most of the drivers interviewed knew what the sign meant (92%). Thirty two per cent of them, however, stated that, in the absence of any visible traffic on the highway, they usually only slowed down. This result would suggest that awareness of regulations is not the main factor explaining non-compliance. The attitudes of road users towards formal regulations probably play an important part.

*Observance of the no overtaking markings:* Observations were conducted at four sites where longitudinal road markings prohibited overtaking: one site located in an urban area, one in a suburban area, two sites in a rural area (before an intersection and before a bend). A grid was drawn up in order to collate the following data (Fig. 2):

(a) Type of overtaking vehicle
(b) Type of overtaken vehicle
(c) Apparent motives for overtaking (vehicle stopped on the carriageway, preceding vehicle slowing down or slower vehicle)
(d) Traffic visible in the opposite lane at the time when the observed vehicle begins to overtake.

Simultaneously, a traffic count was taken for each category of vehicle.

| DAY: ............ | | | | | | | Location: .................... | |
|---|---|---|---|---|---|---|---|---|
| Nr | H | Type of overtaking vehicle | Type of overtaken | Apparent motives for overtaking | | | Traffic on opposite lane | |
| | | | | Vehicle stopped | Vehicle slowing down | Slower vehicle | Yes | No |
| | | | | | | | | |

**Figure 2** Observation grid for overtaking behaviour

The results were expressed as a percentage of drivers committing violations out of global traffic going through the observed site. They indicate a significant proportion of violations (17%) of the regulations, in spite of the potential danger indicated by the road markings. Bus drivers were found to overtake against the rules the most frequently (28%), followed by drivers of private cars (21%) and truck drivers (18%). It will be observed that bus drivers account for the highest rates of violations on all sites, whereas drivers of jeepneys and trucks commit violations more frequently in urban or suburban areas than in rural areas (where traffic speeds are higher).

The highest rate of violations (22%) was observed at the site situated in urban area. It is related to the frequency of stopping manoeuvres on the carriageway, or to slowing down manoeuvres (particularly by public transport vehicles). The three other sites that were studied provided comparatively similar results



**Table 2** Frequency of violations of ban on overtaking

| Behaviour road users | Overtaking violations | Traffic count | Per cent |
|---|---|---|---|
| Jeepney | 53 | 597 | 9 |
| Two-wheelers | 7 | 644 | 1 |
| Bus | 168 | 608 | 28 |
| Truck | 121 | 689 | 18 |
| Light vehicle | 572 | 2,762 | 21 |
| Total | 921 | 2,762 | 21 |

(ranging between 15 and 17% of violations). Non-compliance was particularly dangerous at site 3 (a bend with reduced visibility).

Most violations were observed in the absence of on-coming traffic in the opposite lane (70%). These violations are, nonetheless, dangerous inasmuch as they may affect the safety of other road users (pedestrians in urban areas, for example), and on account of the hazards which the road markings are supposed to identify (bends without visibility, proximity of an intersection).

Frequent overtaking violations were partly related to the heterogeneous nature of the traffic involved (leading to significant variations in driving speeds), and, in urban and suburban areas, to the stopping of public transport vehicles on the carriageway. They also illustrate the importance given by drivers to maintaining their speed regardless of road regulations. More generally speaking, they raise the problem of drivers' perception of danger and risk-taking.

The survey on driver awareness of road sign meaning, referred to above, indicated that very few drivers did not know the meaning of road markings (5%), but most of them admitted to breaking the rules in some instances (e.g. in the absence of any immediate on-coming traffic, for overtaking much slower vehicles, or when there was little risk of being caught by the police). A road inventory, and a review of the current highway code, indicated that, due to historical reasons, three different types of markings were to be found on roads to indicate ban on overtaking. This probably introduced an element of confusion for drivers, and reduced credibility of the road marking system.

*Conclusions of the study:* The study showed the importance of non-observance of road regulations on the part of the various categories of road users. The survey conducted simultaneously and in the same area as the observations indicated was not due to a lack of awareness of the meaning of road signs and markings, but rather to the priority which drivers gave to informal rules. Improving compliance with traffic regulations was therefore a crucial objective to be reached and constituted a priority theme for information and training campaigns. Associated measures addressing infrastructure and traffic management, particularly in urban and suburban areas, should contribute to improve behaviour.

## POINTS TO REMEMBER

1. Road user behaviour results from the functioning of complex processes, which should be analysed and considered when designing infrastructure and safety facilities.
2. In order to influence road user behaviour through the design of the road infrastructure, it is necessary to get a basic understanding of the main determinants of this behaviour and to use precise methodologies to analyse the driver/road infrastructure interactions.

3. The analysis of road user behaviour and of its determinants should assist in the formulation of explanatory hypotheses on risk factors identified through accident analysis, and should supply the data required for the definition of safety measures.
4. In a safety diagnosis, relatively simple methods of behavioural observation can be designed to support accident analysis or provide backing information when accident data are not complete.

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