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DISCRETE EVENT SIMULATION AS AN INNOVATIVE APPROACH TO SUPPORT EDUCATION AND AWARENESS STRATEGIES IN ROAD SAFETY AND PREVENTION

[1] KHADIJA OUAZZANI TOUHAMI, [2] SALIHA ASSOUL, [3] NISSRINE SOUISSI

[1]Mohammed V University in Rabat, EMI-SIWEB Team, Rabat. Full Professor, Computer Science Department, Ecole Nationale Supérieure des Mines de Rabat, ENSMR. Morocco.

[2]Mohammed V University in Rabat, EMI-SIWEB Team, Rabat. Full Professor, Computer Science Department, Ecole Nationale Supérieure des Mines de Rabat, ENSMR. Morocco.

[3]Mohammed V University in Rabat, EMI-SIWEB Team, Rabat. Full Professor, Computer Science Department, Ecole Nationale Supérieure des Mines de Rabat, ENSMR. Morocco.

E-mail: [1]ouazzani@enim.ac.ma, [2]assoul@enim.ac.ma, [3]souissi@enim.ac.ma

ABSTRACT

Nowadays, a large part of African countries, and all over the world, don't cease to make considerable efforts, especially in recent years to advance and predict possible strategies and policies for more effective road safety and prevention. Indeed, the number of accidents and victims continues to increase, in the world and in Morocco, this despite the efforts undertaken by the competent institutions, knowing that the reasons in question are generally related to human factors and behaviors, which justifies the relevance of interest to this case. At our level, we believe that the use of new technologies in this area, as well as some techniques of decision support, can be of a great contribution, and thus contribute largely to the development of the countries. So far, the Moroccan Ministry of Equipment, Transport, Logistics and Water, is generally based on statistical studies to decide on points to focus and awareness strategies and education in prevention and road safety. In this article, we propose to use discrete event simulation, as a tool to help road education in the perspective of better occupation and sharing of road space. The principle of this approach would be to compare, through simulation, different scenarios or policies to prevent traffic accidents, and to measure the impact of the variation of a risk factor, or a combination of factors, concerning the behavior of drivers, on the improvement of road safety. This could have a real impact on the mastery and regulation of road traffic. The results of these simulations could be the subject of didactic bracket, which can be used in support of road user awareness and education workshops, for better prevention and road safety.

Keywords: *Discrete Event Simulation, Didactic Approach, Prevention and Road Safety, Risk Factors, Driver Behavior.*

1. INTRODUCTION

How can countries reduce the number of road deaths more efficiently and faster? A question that each country in the world seeks to answer every day for a better sustainable development.

Morocco is among the lowest ranked countries in the world in terms of road safety, in several respects [1]. The current vision of managers is to develop responsible driving and a safe road network, with the aim of significantly reducing the number of deaths, injuries and accidents in general in the years to come.

Statistics on the rate of traffic accidents in Morocco show that it is constantly rising. The reasons for this increase can be classified in two main axes. The first concerns problems related to road infrastructure, such as the state of the roads and the signaling system. The second axis concerns the behavior of certain drivers, which can sometimes be problematic, and this in spite of the changes made in 2010 on the Highway Code by the

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Ministry of Transport, as well as the various awareness campaigns conducted regularly.

Regarding the first axis, considerable efforts are made, and the road network, inter and intra Moroccan cities, is in recent years an open-air yard, this for the purpose of its improvement and upgrade.

In this article, we are interested, more particularly, in the 2nd axis, namely, the problems related to driver behavior, compared to many risk factors, among which, the distraction that can be caused by the use of the phone when driving, for example, drunk driving or drowsiness, speeding, non-compliance with the Highway Code, traffic light or priority, etc.

In fact, Traffic crashes represent a significant cost for Moroccan society [2]. In 2017, it was estimated that crashes cost more 2 billion of USD. Based on estimates from the World Bank, crashes account for 2% of Morocco's GDP (gross domestic product).

Otherwise, the behavior of road users is an important determinant of a country's road safety performance. Inappropriate speed in particular is one of the main causes of road crashes [2]. In Morocco, about 9% of all road fatalities in 2016 were caused by speeding.

An increasing problem for traffic safety in Morocco is distraction [2], for instance through the use of mobile phones while driving. The use of hand-held phones while driving is forbidden. The use of hands-free devices while driving is authorized. A survey conducted in 2017 among 3031 car drivers, revealed that 75% of drivers admitted having used a mobile phone while driving in the last twelve months.

The idea in this article is to answer the following questions, what are the risk factors involved in the majority of road accidents? Are they always well identified? And what is the share of human behavior of drivers [3]?

The article will study the idea of using simulation in this context. In fact, the studies generally conducted by the Ministry, in this sense, are statistical, compared to measurements made in the field. But would not it be even more interesting to base on these studies to make estimates for the years to come? Can we consider a certain risk factor and study different scenarios of its evolution according to different possibilities of improvement or association with other factors, in particular those related to driver behavior?

The contribution of such simulations would be, in addition to the vision of the past provided by the statistical studies, to give an estimate, for future years, in relation to the measured indicators. This will allow decision-makers to have an idea of how the numbers will evolve in relation to one risk factor or another, and some possible improvements. This will then allow the development of prevention, education and road safety strategies based on scientific forecast studies.

The challenge, from this simulation study, would be not only to focus on the drivers of tourist vehicles, but can extend to other categories of road users, in particular, heavy truck drivers, two wheels, and even pedestrians. Indeed, the heterogeneity of road users, because of their behavior, as well as their vulnerability, when moving in road space, requires studying and analyzing observed practices, and the gap with those expected, by category of users.

This article is organized in six sections. Section 2 presents the problem of traffic accidents, at the international level, as well as at the national level, by presenting some numbers. Section 3 then provides an overview of the situation in Morocco with regard to the causes of traffic accidents, particularly those related to driving behavior. In section 4, we identify the most common risk factors related to accidents, particularly those related to driver behavior, and propose the use of discrete simulation to measure the impact of certain risk factors on road safety. In section 5, we begin by defining the discrete simulation and in which cases it is used. Then, and to consolidate our choice to use this technique in the field of road safety, we present two examples of work, taken from the literature review, and interested in simulation in road safety. Finally, we highlight the interest of using simulation to measure the impact of certain risk factors on road safety and prevention, and we present the approach to follow to carry out a simulation study of this kind. And in section 6, we finish our article with a conclusion and perspectives.

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2. PROBLEMATIC

Internationally, the numbers of the World Health Organization (WHO), in terms of traffic accidents, are without appeal [4], [5], namely:

• More than one million 250 thousand killed a year, worldwide. Three-quarters are men, compared to a quarter of women;

• 23% of those killed on the road are motorcyclists, 22% pedestrians and 4% cyclists;
• More than 25% of deaths are in Africa;

• Over 90% of deaths are in low- and middle-income countries;

• It is the No. 1 cause of death among young people aged 15 to 29.

At the national level, and according to statistics from the Ministry of Equipment, Transport, Logistics and Water, the numbers are equally worrying. Thus, and for the period from 2007 to 2016, which is the subject of a statistics miscellany of the Ministry [6], we note that:

- The number of accidents, both in agglomeration and outside agglomeration, as shown in table 1, continues to increase from one year to the next;

Table 1: Evolution of the number of accidents outside and in urban areas from 2007 to 2016

	Accidents outside agglomeration	Accidents in agglomeration
2007	16 940	41 984
2008	18 555	46 160
2009	19 048	47 910
2010	17 361	48 100
2011	18 960	48 122
2012	18 949	48 202
2013	18 341	49 585
2014	17 149	51 130
2015	21 027	56 976
2016	21 638	59 042

Figure 1 below illustrates this increase even more.

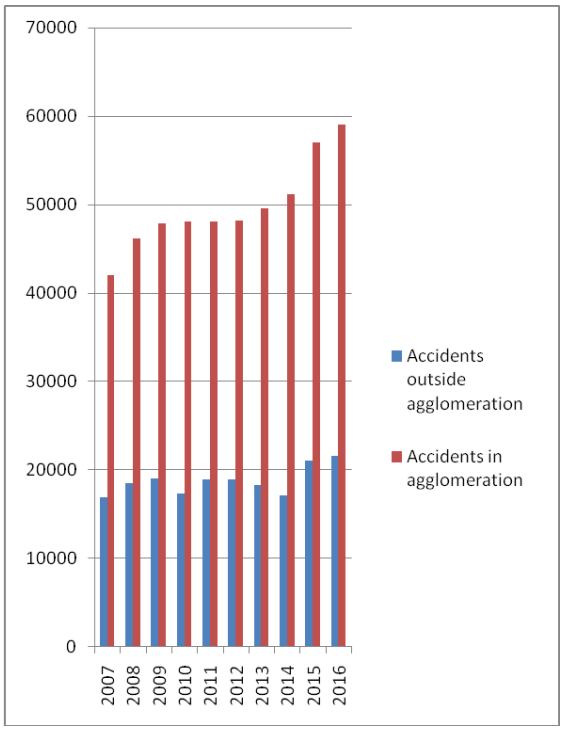

Figure 1: Number of bodily accidents

- The number of fatal accidents, as well as the number of killed, varies in saw tooth, as shown in Table 2 below, with a slight decrease in recent years;

Table 2: Evolution of the number of fatal accidents and the number of people killed between 2007 and 2016

	Fatal accidents	Number of killed
2007	3 252	3 838
2008	3 546	4 162
2009	3 489	4 042
2010	3 181	3 778
2011	3 636	4 222
2012	3 531	4 167
2013	3 265	3 832
2014	3 021	3 489
2015	3 365	3 776
2016	3 317	3 785

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The variation of these 2 criteria is illustrated in Figure 2.

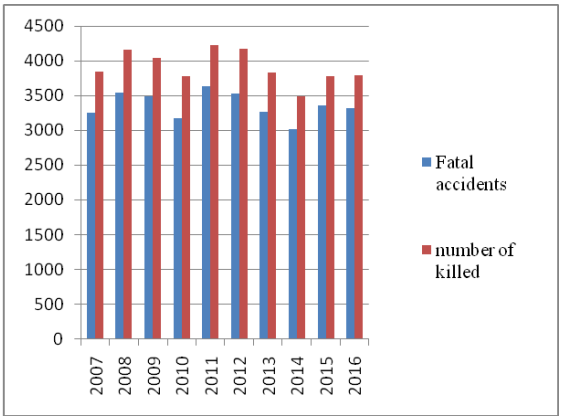

Figure 2: Number of fatal accidents and number of killed

- The total number of accidents, as well as the number of wounded, light and severe, continue to increase over the years, as shown in Table 3 below, especially during the last two years of the period studied.

Table 3: Evolution of the total number of accidents and the number of wounded from 2007 to 2016

	Total Accidents	Number of wounded
2007	58 924	89 264
2008	64 715	98 907
2009	66 958	102 743
2010	65 461	98 472
2011	67 082	102 011
2012	67 151	102 350
2013	67 926	102 040
2014	68 279	101 242
2015	78 003	115 042
2016	80 680	119 162

The steady increase, even accentuated toward the end of the studied period, is even better seen in figure 3.

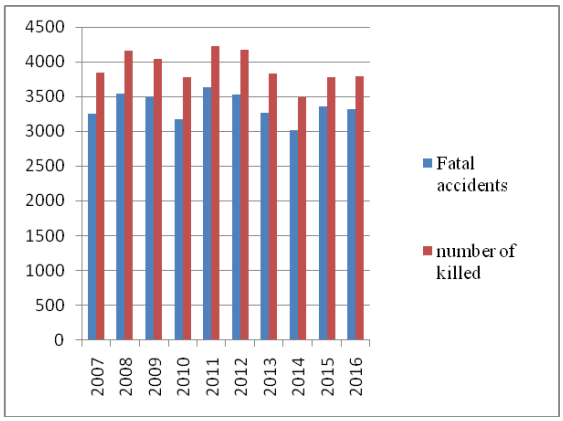

Figure 3: Total number of accidents and number of wounded

3. AN OVERVIEW OF THE SITUATION IN MOROCCO

The majority of statistics concerning the number of accidents and the number of victims, all categories combined, continue to increase, this despite the measures and efforts undertaken for a number of years, namely:

• The change of the regulations in 2010, which introduced the driving license to points and saw the majority of sanctions strengthened;

• Awareness campaigns regularly conducted, which consider various factors, such as speed, wearing seat belts, respect for priority and stop, driving while under the influence of alcohol or when drowsiness, etc. The media used in these campaigns are just as diverse, including TV spots, posters, radio information bubbles, songs, and so on.

Breakdown of driver's faults, by type, and still according to the 2007 to 2016 Accident Handbook, of the Ministry of Equipment, Transport, Logistics and Water [6], is made according to two types:

- Driver-specific faults, including speeding, non-compliance with priority, careless driving, etc. We note, moreover, and as shown in Table 4 below, that at least 35% of the faults in this category, those grouped under the name "Other", are due to unidentified factors;

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Table 4: Breakdown of drivers' own faults according to their nature

Nature	Percentage
Traffic light or Stop	2,83
Priority	9,59
Irregular overtaking	2,34
Irregular maneuver	3,32
Circulation without precaution	36,76
Speeding	8,51
Traffic in prohibited area	0,82
Stop / Stationing prohibited	0,61
Other	35,23

The following figure 4 shows this distribution of faults due to driver behavior according to their nature.

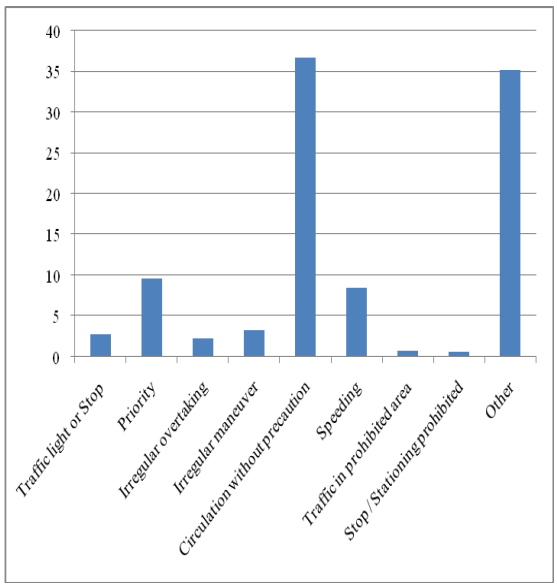

Figure 4: Driver-specific faults (by percentage)

- Faults related to physical factors, including driving while under the influence of alcohol or narcotics, drowsiness or fatigue, etc. Except that, again, and as shown in Table 5 below, we find that more than 95% of the faults due to driver behavior, those grouped under the name "Other", are due to undefined factors.

Table 5: Distribution of faults related to physical factors according to their nature

Nature	Percentage
Infirmity	0,39
Alcoholic beverages	2,05
Narcotics / Medicaments	0,06
Slumber	0,18
Fatigue / Sudden malaise	1,86
Other	95,47

The distribution of these faults due to physical factors is represented by the figure 5 below.

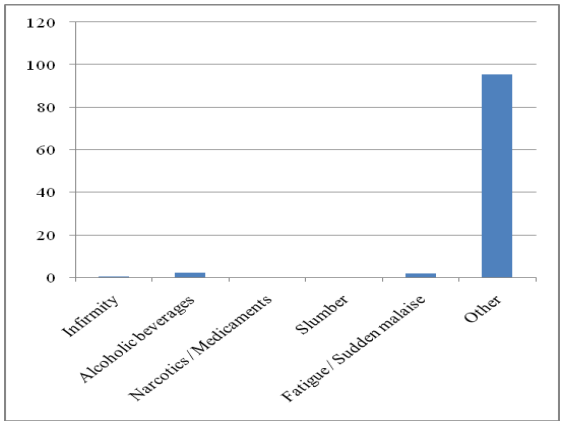

Figure 5: Faults Due to Physical Factors (by percentage)

Thus, it is clear that, according to Ministry's statistics, many of the risk factors, largely those related to driver behavior, remain unidentified, the thing that makes any attempt at prevention or road education incomplete. Indeed, if all the risk factors are not well identified, how to warn drivers, or even control them compared to these factors.

4. RISK FACTORS AND PROPOSED APPROACH

Exposure to road risk [7] is not limited to a simple quantitative count of traffic accident opportunities; it also includes a qualitative dimension. Indeed, in the literature review [8], [9], [10] risk factors are widely discussed.

These risk factors are generally classified into two main types:

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• Quantitative factors [9], those that are measurable or observable in a binary way, such as speeding, respect or not of priority, traffic light or stop, traffic or parking in prohibited area, etc;

As already mentioned in the previous section 3, a good part of these quantitative risk factors, more than 35%, are of unidentified origin. Figure 6 below clearly shows it.

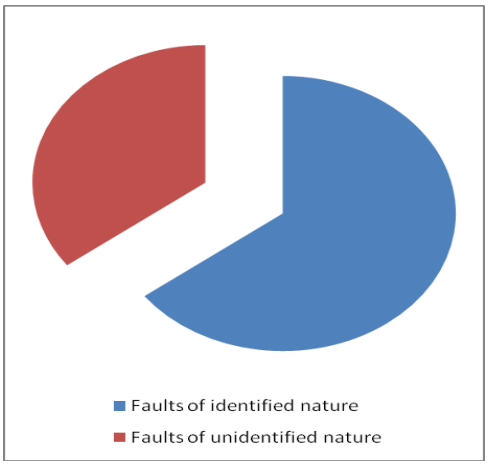

Figure 6: Breakdown of faults due to qualitative factors

• Qualitative factors [10], those that are not necessarily measurable, and that are generally related to driver behavior and alertness [8], such as driving while tired or drowsy, driving under the influence of alcohol or narcotics, etc;

Once again, Section 3 above mentioned that the vast majority of these qualitative risk factors, more than 95%, have an unidentified origin. This is clearly highlighted in Figure 7 below.

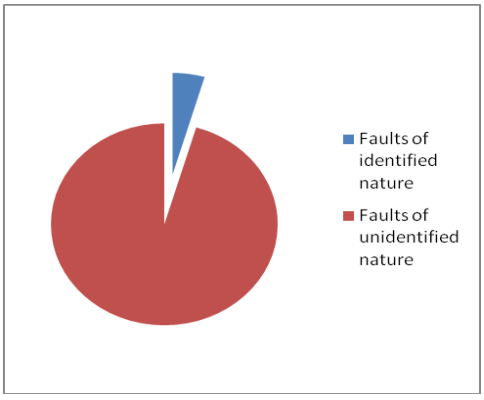

Figure 7: Breakdown of faults due to quantitative factors

These studies have identified new risk factors, mostly of a qualitative nature, and therefore related to driver behavior [11], [12], especially:

• Driving at night, a thing that increases risk and reduces alertness, visibility, etc;

• Driver distraction, using the phone while driving, handling the radio or other gadgets on the dashboard, interacting with other passengers in the vehicle, etc;

• The driver's state of mind, nervousness, stress, etc;

• Interaction with other road users, inattention, aggression, revenge, etc.

Our proposal, in this article, is to integrate these new factors identified in the studies and statistics of the Moroccan Ministry especially that according to the current numbers of the latter, a good part of the faults committed by the drivers remains of undefined origin, more particularly those related to driver behavior (see Figure 5). Then, and following the impact of each of these new factors, integrate it into pedagogical and road education campaigns. But to do this, which factors to be considered?

The proposed approach is to use discrete event simulation to measure and predict the impact of a certain risk factor, or combination of factors, on the number of accidents and the number of casualties. The results of the simulation can thus serve as a didactic support for road safety education and prevention.

5. USE OF SIMULATION

We propose, therefore, to resort to simulation, more precisely, discrete event simulation. The simulation's studies and predictions can be used to support policies and strategies for education to road prevention and safety.

5.1 Definition of Simulation

Simulation is a decision support tool. It allows to building an abstraction or model of a system or a reality, then to make experiments on this model, and to possibly make evolve the model in the time [13].

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The objective of the simulation is, generally, to study the behavior of a system to better understand it in order to improve it, to study the behavior of the system for different situations, to compare different scenarios, etc.

An illustrative example would be to consider a toll area of a highway, with 4 toll lanes, and an average waiting time $\overline{W}$, then to look at the impact of adding, for example, 2 more Toll lanes, so go to 6 lanes in total, on this waiting time $\overline{W}$. Indeed, this time would certainly decrease, but by how much?

Simulation can answer this kind of question. This would consist of studying the scenario with 4 lanes, and the scenario with 6 lanes, measuring each time the average waiting time $\overline{W}$, and comparing.

Discrete or digital simulation, or discrete event simulation [14], is concerned with systems whose states or characteristics can change over time, but at separate times, and not continuous. In our example, if we are interested in the number of lanes out of service, each time, it can change over time, and go from 0 lanes off, to 1, to 2, and after solving the problem, go back to 1 and 0. Thus, this number would vary in time, but in a discrete and non-continuous way, and the curve that would represent it would be a discrete curve.

In this article, we propose the use of discrete event simulation.

5.2 Example of Existing Work on Road Safety and Simulation

In the literature review, a number of research works, was interested on simulation in the field of road safety [15], [16], [17], [18], [19]. As an indication, we cite the following two examples.

5.2.1 Using the phone and handling other objects while driving

This is a study, conducted in Belgium [15], on some distracted behavior of drivers at wheel, especially the use of the phone while driving, eating at the wheel, smoking, handling the dashboard, trying to catch an object, etc. This study was therefore interested with certain qualitative risk factors, such as those discussed in section 4 above.

This is a study that uses a sampling method to measure, for certain factors, for example the proportion of telephone use, compared to certain indicators, namely:

• Direct use of the phone or via a hands-free kit;

• The type of vehicle in question, car, truck, bus/coach, etc;

• The type of road, 70 km, 90 km, highway, etc;

• The region, Wallonia, Brussels, etc;

• The presence or absence of passengers in the vehicle;

• Gender, man or woman;

• The period of traffic, peak or not, mid-week or weekend;

This study also combined some of these indicators, for example:

• Use the phone with or without a hands-free kit, and depending on the type of vehicle, car, truck, van, etc;

• Using the phone, with or without a hands-free kit, depending on the region and gender.

This sampling study conducted for the use of the telephone, was also lead, in the same way, and according to the various indicators, for other risk factors, namely:

• Hold a cigarette by hand while driving, depending on gender, area, etc;

• Holding an object by hand, a drink, glasses, food, etc., and again, depending on the gender, type of vehicle, etc;

• Manipulate the dashboard, depending on the gender, region, type of vehicle, etc;

The study in question also spread to the aggravated consideration of several of these factors combined, and according to the different indicators, for example, driving using the phone directly or via a hands-free kit, holding or not a cigarette in the hand, and at what time, rush hour or not, weekend, etc.

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This study was limited chiefly to statistical sampling and the measurement of the potentially distracting behaviors observed in drivers. And it is in the recommendations formulated that the authors propose to make simulation studies, to measure and predict the impact of different forms of distraction on the performance of the road driving.

5.2.1 Multi-agent simulation applied to urban road traffic

This is a study conducted in France [16], with the collaboration of the IFSTTAR (French Institute of Sciences and Technologies of Transport, Laying out and Networks), which focuses on a simulation of urban road traffic, considering a behavioral approach based on multi-agent or multi-actor systems.

Multi-agent simulation is used in the case of complex systems, to model interactions between different agents or autonomous actors.
In the case of this study, the agents considered concern:

• On the one hand, the different actors of the environment, namely, the number of physically marked lanes on the ground (2 or 3), traffic light, crossroads, vehicles traveling on the various lanes, etc;

• On the other hand, drivers of different vehicles, two-wheelers, etc., involved in road traffic by their behavior.

It is therefore a double cross simulation, in which the author has tried to reproduce:

• The parameters of road space, and infrastructure, such as, lane markings on the ground, parked vehicles, a vehicle parked poorly or blocking a lane, etc;

• Driver behavior, especially for contexts of very dense traffic in urban areas, such as:

- A motorized two-wheeler that sneaks or practices a climb up a lane;

- Drivers of vehicles which, sometimes to move, and depending on the occupation of marked lanes on the ground, the size of vehicles, their respective speeds and positions, etc., create and use virtual lanes, which are not really marked on the roadway, and which can vary in number, which is sometimes high and critical;

- A vehicle trying to reclaim a space on a lane or a crossroad because it is in an emergency or to exceed an obstacle or a vehicle parked poorly, etc.

And, these different behaviors of drivers can, sometimes, not be safe, and lead to conflicts or collisions, Hence the interest of studying and understanding these practices.

In this study, the author proposed to endow agents with an ego-centered representation of the environment, enabling them to make decisions in terms of space occupancy. It is a representation of the driver in relation to what he perceives in front of him, on his left, on his right, etc., with the possibility of considering, in the environment of each driver, up to one hundred objects, dynamic or not, for example, another vehicle that is rolling or is in a state of parking, a sign, a traffic light, etc.

Driver behavior is represented by a model, interacting with the environment, based on the concept of affordance [16], according to which, to act, an agent is led to identify the possible actions offered to him, and this according to, on the one hand, his ego-centered perception of the road environment, and on the other hand, his individual characteristics, namely, his level of vigilance, his conformity with normative actions etc.

Thus, in this study, the author was based on an ego-centered representation of the agent, based on affordances.

For the validation of this model, it has been implemented in the ArchiSim traffic simulation tool.

The evaluation and validation of this approach has been done at two levels:

• A first assessment, based on different scenarios, to test particular cases where the drivers considered are put in situations for which a specific behavior is expected. Evaluation consists in observing individual behaviors, and comparing them with practices observed in reality;

• The second level of evaluation focuses on a simulation of traffic for a real circuit, for which the

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author has data measured in the field. The simulation data is then compared to the actual data.

The central idea of this project consists on simulate a complex and realistic traffic, based on the results of work in psychology of the conduct, according to the model of behavioral simulation ArchiSim, whose decision making mechanisms are essentially based on algorithms of conflict resolution.

The author emphasized, however, the presence of two types of difficulties in this kind of simulation:

• The difficulty of having real data, for lack of the existence or deployment of sensors;

• The difficulty of validating the behaviors generated in the simulation, which must be developed in collaboration with psychologists, or even, on analysis and opinion of the drivers themselves.

5.3 Simulation Process

Apart from the sociological, psychological and educational dimension that is generally associated with this problem of pedagogy and road safety, and, in addition to statistics developed and published regularly, by the Ministry of Equipment, Transport, Logistics and water, which effectively provide information on a certain number of indicators measured against various risk factors, it is time for Morocco, and like other countries, to tackle this problem in the context of scientific and university research.

In this article, we propose to use discrete event simulation, in order to:

• Better understand and analyze the current situation;

• Test some scenarios that would allow studying and analyzing new situations, possibly considering new risk factors;

• Projecting for the future, and predicting accident numbers for the years to come, until 2026, for example, a deadline for CNPAC (National Committee for the Prevention of Traffic Accidents), which hopes to halve road mortality by that date [20]. Even make estimates beyond 2026.

This simulation usually consists in reproducing the behavior of the system by a model, which is in turn implemented by a simulation program, as shown in Figure 8 below.

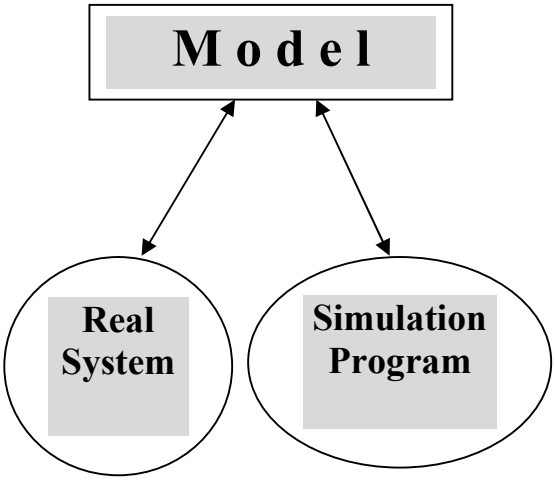

Figure 8: Simulation process

The interaction between these 3 entities, system, model and program, makes it possible to take into account the parameters and assumptions considered each time during the different simulations.

More precisely, and according to a rather simple vision, a project of simulation in road safety can be elaborated in 4 great stages [21]:

Step 1: Analysis of the problem.

This stage covers the following phases:

• Specify the need behind the simulation, by determining the risk factors that we are interested in, which may be quantitative or rather qualitative, among those already identified and measured by the ministry, or those not yet defined and newly identified in the literature review;

• Determine the objectives to be achieved by this simulation, the indicators to be measured, the significance and relevance of each compared to road safety, as well as to road safety education and prevention;

• Collect the data needed to parameter the simulation. These data can be of different types or origins, namely:

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- Data collected from the statistics of the Ministry of Equipment, Transport, Logistics and Water;

- Data based on those published internationally, in the event that these data are missing or not measured at the national level;

- Parameters corresponding to the different scenarios to be simulated, for the different situations to be studied.

Step 2: Model elaboration.

It consists of elaborating a logic model representing flow mapping, as well as a mathematical model representing the different logical variables to be considered or measured, and validating these models.

Step 3: Implementation.

It's about implementing the model as a simulation program, using a standard or specialized programming language, and validating it against the model and the real system.

Step 4: Experimentation.

The experimentation of the program and simulation model is summarized by the following phases:

• Execute the different scenarios specified during the analysis step and follow the various associated performance indicators;

• Analyze and interpret the results generated, in different forms, tables, graphs, etc;

• Study the different possible proposals, and make decisions;

The results of the simulation can thus be exploited for 2 purposes:

• Elaboration of new road prevention education and training policies or strategies, using the results of simulation studies as a didactics support;

• On the light of the scenarios studied, and trends identified or confirmed, readjustments of the road regulations can be made.

6. CONCLUSION AND PERSPECTIVES

Improving and securing road traffic is a fundamental pillar of sustainable development of countries, especially those under development.

In Morocco, according to a literature review conducted in the field of road safety [3], [9], [10], [22] and a collaboration with CNPAC (National Committee for the Prevention of Traffic Accidents), road accidents are generally caused by risk factors of two types, quantitative factors and qualitative factors. These risk factors, especially qualitative factors, are for the most part of unidentified origin. Qualitative risk factors, such as drowsiness, fatigue, drunkenness, drug or narcotics, are the cause of many road accidents. However, the majorities of these factors (95%) is not currently identified, and remain not covered by departmental statistics and outside the fields of treatment or improvement. In particular, we are thinking of some distracting factors that are becoming more common nowadays [11], [12], at their head the use of the smart phone while driving, or other dashboard gadgets while driving.

In our next works, we count:

- To further elaborate the specification of these factors, in particular qualitative ones not yet defined, with a view to their integration into the Ministry's statistics and better consideration in prevention policies;
- Carry out a simulation case study, following the process proposed in section 5, to measure, in the case of Morocco, the impact of certain risk factors, to be identified, on the evolution of the accident report.

In the literature review, the majority of simulations conducted in the field of road safety are based on existing statistical studies or fundamental mathematical or physical resolutions. In this paper, we propose to use discrete events numerical simulation which, based on existing data or even random data generated by a stochastic process, allows doing experiments to estimate numerically the results or values of certain indicators which we are interested in to determine, this for different situations and different scenarios, and for an extended period in the past, but also and especially in the future. This makes it possible to propose an innovative approach of decision support in this field of prevention and road safety in Morocco. The implementation of a simulation case study in our future work will further demonstrate the

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effectiveness, relevance and innovation of the proposed approach.

The development of a simulation model remains a time-consuming activity, and the model developer must use his skill and experience to produce an algorithmic description of the activities and events of the project.

Nevertheless, the simulation remains a technique that allows experimenting, at a lower cost, the different driving systems, according to the scenarios studied. Indeed, the simulation allows considering the extreme cases, where all the drivers have irreproachable behavior, and the cases where they have an irresponsible behavior, without causing real accidents, nor requiring additional material or human resources in the road space.

Thus, the simulation in road safety field constitutes an innovative approach to road pedagogy and education.

The ideal perspective on which this proposal could lead, would be the effective realization of a simulation study, at the national level, in which different scenarios can be elaborated, considering, each time, a risk factor, or even a combination factors, and measuring the necessary indicators.

Given that in Morocco, the consideration of the human aspect is weak compared to other types of risk factors, this study will be based more particularly on the qualitative risk factors relating to human behavior [13].

The simulation results can be used to support the various pedagogical and educational approaches to road prevention and road safety. They can also serve and help readjust the outstanding regulations for better prevention and safety road.

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