# Analysis of road safety conflicts. The case study of a road interchange in Guimarães, PT.

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***Abstract*—**This paper presents a case study to identify road safety conflicts in an interchange of the road network of the city of Guimarães, Portugal. For that an analysis using the SSAM (Surrogate safety assessment model) software was performed in order to identified and characterized the network points of conflict according their category and severity. To analyze traffic conflicts vehicles routes must be collected and inserted in SSAM software. To obtain vehicle routes a microsimulation traffic modelling was performed through the usage of PTV VISSIM software. Thus, a traffic and geometric data collection was done for the peak hour in the morning, and then the model was calibrated and validated using traffic volumes, travel time and queuing length using specific sections of the interchange. In addition, to identify and analyze three types of conflicts (rear end, lane change and crossings) with SSAM were evaluated two parameters the TTC (Time to Collision) and the PET (After Invasion Time) for all the vehicles, using their routes extracted from VISSIM. The location of the conflicts was analyzed in a GIS, which allowed the creation of maps of conflicts. The results shown that the most frequent conflicts are the rear end conflicts (1174), which occurs a little throughout the entire interchange and are more frequently in the entrances and exits of the freeway, which was also verified for lane change conflicts (107), but in a lower frequency. Based on these results it was also possible to conclude that the high number of conflicts should be a matter of concern for transport authorities, who may have to adopt measures to improve safety and reduce the potential for accidents, which may imply a reduction of speed in this interchange or a police reinforcement.

***Keywords*—**Traffic simulation, Traffic flow, Road safety, Traffic conflict, Surrogate Safety Assessment

## I. Introduction

THE driver behavior is directly affected by speed, due to changes of the characteristics that occurs in the visual field, peripheral vision, need to search for information at greater distances and the reaction time to unforeseen events. The practice of higher speeds does not allow drivers to make certain decisions, and many are unable to stop in time in the face of a conflict, resulting sometimes in accidents. Therefore, since changes of speed are associated with the physical and behavioral conditions of drivers, it is important and justify the involvement of designers and policy makers that can use this variable in the modelling exercises in order to promote mobility and traffic safety [1].

On urban highways, users want to run a stretch in the shortest possible time and in the safest possible way. To achieve this, it is intended that these road axes ensure, simultaneously, good levels of traffic fluidity and safety, which may not be easy, since minimal traffic disturbances can cause a significant variation in speed, creating a potential shockwave effect, affecting all users, slowing down the average speed, that will be one of the factors that can influence travel time.

The average speed is directly associated with the travel time, since it is impossible for a vehicle to always travel at the maximum speed allowed during the particular stretch of road, and it is very difficult to use it for travel time calculations. However, it is possible for the traffic to be fluid and safe by imposing a reduction of speed limits along different sections of a road axis, increasing travel time, but with a reduction of the risk of having an accident, thus increasing road safety.

In relation to the level of detail, traffic and transport models can be classified according to the capacity to reproduce certain traffic situations with greater or lesser detail for different territorial scales [4] [5] [6], such as:

• Sub-microscopic: models with a high level of detail, where the behavior of the conductors and the operation of parts of the vehicle are described;

• Microscopic: Evaluate traffic in detail by representing each vehicle individually;

• Mesoscopic: level of intermediate detail not distinguishing individual vehicles, but as platoons;

• Macroscopic: calculate the flow of traffic as a whole ("fluid"), not distinguishing between constituents, that is, traffic flows are treated.

Traffic simulation models offer a wide variety of solutions for a variety of problems, and can be evaluated first and foremost on the performance of the road network, which can also address environmental issues, to study and solve cases that affect and impact on footpaths, these being just a few examples of the wide diversity of micro-simulation applications.

The technological evolution allowed the appearance of various traffic simulation software, which permit the analysis of a road network, without the problems/ issues inherent to the

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actual functioning that involve changes in the operation of road networks. These simulations are a very effective tool for determining the benefits and impacts of projects in traffic circulation involving various modes of transport, where the use of these software facilitates the analysis of flow since they require less resources and can simulate situations without any risk to users of the transport system. Yet, they are a process of high complexity.

The use of microsimulation for traffic modelling serves to simulate the individual behavior of vehicles within a traffic flow. Thus, modelling at the micro level is related with the process of creating a virtual model for transport infrastructures, in order to simulate the microscopic interactions between vehicles, treating each vehicle as an entity with the possibility of interacting with other entities in the model [5] [6] [7].

Therefore, the main objective of this paper is modelling traffic behavior and vehicle interactions in a road interchange of the freeway of the city of Guimarães, PT, in order to estimate the main performance impacts in traffic and safety due to possible variations of speed limits in the highway.

## II. Procedure for Paper Submission

### A. *Modeling, calibration and validation*

Traffic modelling and calibration of a section of a road network includes the description and analysis of the different phases, such as, i) data collection (traffic counts and other traffic related variables) and introduction in modelling software, ii) calibration processes, iii) validation of the model (observed vs modelled values).

*Data collection*

Vilarinho [2] and Serra [3] used the traffic microsimulation to analyse the performance of a part of the road network of the cities of Porto and Guimarães, respectively, focusing on the improvement of the flow of traffic at various intersections, with the creation of scenarios. Vilarinho stated that although traffic volumes are easily collected, their impact in changing other variable values is reduced, while travel time is a more sensitivity variable to promote changes in other performance variables [2]. The variables that presented the greatest impact on the performance of the model were identified as speed, time of reaction and maximum acceleration.

However, the variables that are going to be collected are traffic volumes, speeds and the length of queues to be used in the Vissim software.

*Calibration*

The calibration process of a model involves the modification and correction of values associated to parameters previously defined by the software. The objective is to adapt the results of the simulation to the data collected in the field, improving the efficiency of the model in order to reproduce the behavior of the drivers and the performance through indicators as realistically as possible, by varying the parameter values.

The model is considered calibrated when, at the end of a sequence of iterations, the parameters meet the previously defined criteria. This process is strictly necessary, since no model is expected to fit all possible traffic conditions [2].

There are several indicators to measure the quality adjustment between modelled and real traffic values, and calibration can be done through any one, or all, of them, such as the Mean Square Error (RMSE), the Mean Square Error (RMSP) and the "classic" GEH index.

*Validation*

When the model is correctly calibrated, the validation process begins. This process intends to determine when the referred model accurately represents reality. This is an iterative process that involves the calibration of parameters and the comparison of the model with the actual behavior, i.e., actual traffic conditions. Then, to validate the model found it is necessary to use independent data for this phase, i.e., different points with traffic volumes than those used in the calibration phase. If there is no right procedure for this process, the best approach is for the modeler to find the best approach to the problem in question [2].

In this case, several points in the interchange will be selected and a sort of measurements will take place, especially in relation to traffic volumes, queues in congested stretches. Then, as in the calibration process, some indicators to assess the level of adjustment is done, though the calculation of the Mean Square Error (RMSE), the Mean Square Error Percentage (RMSP) and the "classic" GEH index for traffic volumes.

### B. *Traffic conflicts*

Hýden [9] defines conflict as an event involving the interaction of two or more users of the road system, where at least one user involved takes an evasive action, e.g., locking and/ or deflecting, to avoid a collision. The accident is necessarily preceded by a traffic conflict with failure or absence of evasive maneuver [10].

According to Robles [11], the most used technique for the study of accidents is the TACT, because it is where satisfactory results in terms of road safety can be obtained. Because, in order to analyze certain locations, data historical series are often not available. Thus, without access to this amount of information, the TACT allows setting the parameters needed to define an improvement in road safety conditions in a satisfactory way. Nevertheless, a TACT should be used as a supplementary tool to one of the other techniques as an auxiliary measure to identify possible road safety improvement measures.

According to Pietrantonio [12], a conflict is composed of four phases: i) the first individual performs an action; ii) the second individual is at risk of accident; iii) the second individual reacts to the action by locking and/ or bypassing; iv) the second individual follows his course in the lane.

One of the main objectives for traffic and transport engineers is to maximize the safety of the road network, either by improving the existing network or by creating new transport models. Ferraz referred that there are several factors, such as the driver, the infrastructures, etc. which influence road safety. In addition, he points out that the dynamic and complex combination of these factors introduces a level of "turbulence" in the traffic flow [12] [13].

Safety performance measures are defined as reflecting events with high risk relative to a projected collision point. Typically, these measurements are based on relationships between vehicle speed and space attributes. The measures are as follows [13]:

• Time to Collision (TTC) - defined as the time required for two vehicles to collide should they continue to run at the same speed and on the same path.

• Time to Accident (TTA) - time that elapses from the moment one of the road users reacts and begins an evasive maneuver until the time the user involved reaches the collision point if both road users continue to speed and direction unchanged.

• Post-Encroachment time (PET) - defined as the time difference between the moment the "offensive" vehicle leaves the area of potential collision and the moment the other vehicle enters that collision area.

It is possible to obtain a relation between TTC and PET in scenarios where there is persecution between vehicles.

### *C. Development of a case study*

In order to test the use of microsimulation tools (software) in the study of freeways, a case study of modeling an interchange in the urban area of the city of Guimarães will be developed, taking into account the availability of traffic demand data. With the results obtained with the VISSIM microsimulation software, these results will be used in the SSAM (Surrogate safety assessment model) software to analyze existing conflicts.

VISSIM is one of the most used worldwide software for microscopic modeling, due to its great level of microscopic detail, allowing the user to execute a realistic and quite effective model. This program can model urban and rural traffic and pedestrian flows, as well as the modeling of public road transport and private rail and transport [14].

The basic way to model a given network, or part of that network, is to connect points (intersections) with arcs and connectors (paths and path variation elements). The arcs can have one or more paths per direction, the connection between different arcs being carried out through connectors, thus building the model network [14]. The larger the network to represent, the greater the number of arcs and connectors needed for this construction.

It is in the arcs and the connectors that speeds can be limited and/or edit geometric parameters, such as track width, number of tracks, slope, conflict zones, etc., according to reality [14].

SSAM software currently identifies, classifies and evaluates traffic conflicts based on trajectories previously defined in microscope models, e.g., VISSIM software [16].

Microsimulation is normally required to generate and collect statistical data on the severity of conflicts and/or other measures that require detailed information, such as acceleration and deceleration of vehicles, among others, that function as a substitute to in situ studies [15].

### *D. Analysis of Results*

After the use of both simulation software in the road interchange, an analysis will be made on the results obtained, in order to perceive the reliability of the software used in traffic modeling, as well as, the factors that most influence road safety in highways, with focus on the influence of speed, intervals between vehicles and gap acceptance.

## III. Case Study

The case study involves the development of a microsimulation model of a road interchange of the freeway of the city of Guimarães, PT. A traffic model was developed in VISSIM, whose data later served to carry out a safety study through the analysis of some parameters that will allow to evaluate the number and the severity of the conflicts in this intersection. In the following figure 1 we see the drawing of the node made in VISSIM software.


Figure 1 – Interchange modelled in Vissim (*own work*)

Field data were collected in the network in order to ensure the reliability of the modelled interchange, and can be compared later with the results obtained in the software.

Data collection included traffic volumes, maximum and average queues and vehicle travel times.

The data collection was done at the morning peak hour (8:00 – 9:00). The traffic counts in the interchange of Fermentões included traffic counts in 8 points on the National Road – EN101, which crosses (unleveled) the freeway and the access to the freeway is made from 6 branches, and also in 4 points along the freeway [3].

In order to create a traffic model for the network under study, three types of motorized vehicles were taken into account: light, heavy and buses. After this data collection, the data obtained were processed and the main results introduced in VISSIM. The insertion of the traffic volumes in the simulation software was performed with the traffic counts for periods of 5 minutes that were converted into hourly rates.

The values used in the software for the calibration and validation stages will be presented below, where some of these values have remained unchanged, that is, they were already predefined by the software as default values and others were adjusted in order to get closer to reality.

Through an iterative process, the model was calibrated using the modelled traffic volumes in control points defined for calibration purposes, comparing these to the actual volumes observed in situ. The initial comparison mode was the GEH parameter and, afterwards, the remaining comparison parameters (Pearson's R, RSMP and RMSE) were used. In order to reach an optimal value, 28 iterations were performed, changing the values of some parameters previously mentioned.

For a GEH value to be acceptable, the ratio between observed and modeled traffic volume must be less than 5 (vehicles/hour) in each section that must be accomplished in at least 85% of the sections.

Table 1 – Observed and modeled traffic volumes (1st iteration)

| Traffic counting points | 1st iteration | | |
|---|---|---|---|
| | Traffic Volumes | | GEH |
| | Observed | Modelled | |
| A3 | 2415 | 1849 | 12.258 |
| A6 | 2455 | 2366 | 1.813 |
| Y2 | 1010 | 872 | 4.499 |
| Average | | | 3.095 |

After the first iteration, a series of measurements and changes of the modeling parameters were introduced in order to reduce the gap between actual values and modelled for the calibration points. To do this, the percentage of vehicles choosing routes where the modeled volume was higher than that observed was gradually decreased. After 28 iterations, the calibration process of the model for the interchange was concluded, with the results presented in table 2.

Table 2 - Observed and modeled traffic volumes (28th iteration)

| Traffic counting points | 28th iteration | | |
|---|---|---|---|
| | Traffic Volumes | | GEH |
| | Observed | Modelled | |
| A3 | 2415 | 2183 | 4,84 |
| A6 | 2455 | 2392 | 1,28 |
| Y2 | 1010 | 898 | 3,63 |
| Average | | | 3,25 |

As it is possible to observe the GEH values are less than 5.0 at all points used for the calibration and the mean of GEH is also below 4.0, i.e., it is possible to consider that the model is calibrated considering the variable of the traffic volumes. After calibrating using the assessment of the GEH parameter, three more parameters were used to test and confirm the calibration of the model, such as the Mean Square Error (RMSE), Mean Square Error Percentage (RMSP) and the mean correlation coefficient (r) – Paerson's R, that are presented in table 3.

Table 3 – Criteria used in calibration

| **Traffic counting points** | **Traffic Volumes** | | **GEH** | **RMSE (%)** | **RMSP (%)** | **r** |
|---|---|---|---|---|---|---|
| | Real | Modelled | | | | |
| A3 | 2415 | 2251 | 3395 | 8.191 | 7.176 | 1.000 |
| A6 | 2455 | 2327 | 2.617 | | | |
| Y2 | 1010 | 919 | 3.930 | | | |
| Average | 980 | 916 | 2.981 | | | |
| Difference | 823 | 792 | | | | |

In many cases vehicular volumes were only used to carry out the calibration and validation process of the traffic models, e.g., in Serra [3]. However, for the present case study and taking into account some specific characteristics of the interchange, such as slope of roads and visibility issues related with the horizontal curve of the roads, two more variables were used to calibrate the model: the average travel time and the average number of vehicle in queues at three specific points.

For the model validation it was necessary to use different points in relation to those that were used for the calibration. The traffic volumes used for calibration were selected from several outer points of the case study area (external volumes). In the validation, the objective is to prove that the model reproduces the reality and to show the maximum coherence in terms of traffic flows. Thus, it was selected some internal points of the study network (interchange), which are identified in the Figure 2.

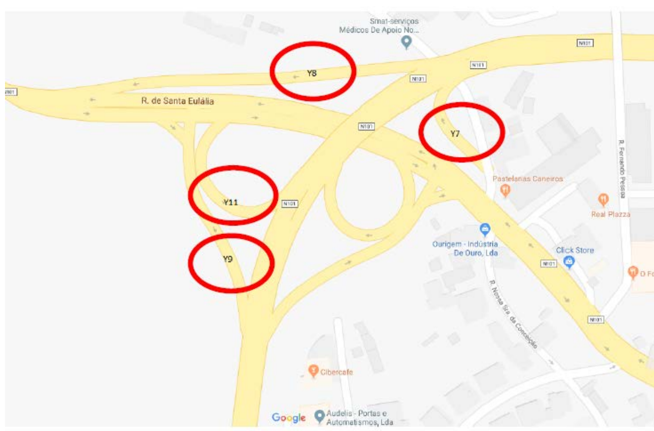


Figure 2 – Location of traffic counting points (*own work*)

The criteria used are the same as those used for the calibration, i.e., the GEH, the RMSE, the RMSP and the correlation coefficient (r), whose results are presented in the next Table 4.

Table 4 – Criteria used in validation

| Traffic counting points | Traffic Volumes | | GEH | RMSE (%) | RMSP (%) | r |
|---|---|---|---|---|---|---|
| | Real | Modelled | | | | |
| Y7 | 194 | 217 | 1,604 | 13,193 | 1,065 | 0,970 |
| Y8 | 440 | 436 | 0,191 | | | |
| Y9 | 644 | 566 | 3,171 | | | |
| Y11 | 342 | 298 | 1,604 | | | |
| Average | 270 | 252 | 1,238 | | | |

Traffic conflicts are then analyzed using SSAM software from FHWA. SSAM operates through a continuous analysis of all the photo frames of the trajectory file of the various vehicles used in a simulation. These trajectories result from the traffic model created in the Vissim.

The types of conflicts that were analyses were the rear end, lane change and crossing conflicts in order to evaluate and analyze the results of the Time to Collision (TTC) and Post-Encroachment time (PET). In the present study, TTC worked between 0.0 and 1.5 seconds because, so it only evaluates moderate or serious conflicts.

Once the conflict assessment parameters are defined, all the conflicts that occur in the traffic model are obtained. The following table shows the total number of conflicts for the traffic model of the Fermentões interchange, which potentially occur at peak time (8:15 - 9:15) of a regular day, which will be around 1303 conflicts, divided in three categories (Table 5).

Table 5 – Number of conflicts

| Total number of conflicts | | 1303 |
|---|---|---|
| Type of conflict | Rear end | 1174 |
| | Lane change | 107 |
| | Crossings | 22 |

According to the results presented in Table 5 it is possible to conclude that the most frequent conflicts are the rear end conflicts (1174) and that happen a little throughout the entire interchange and are more frequently in the entrances and exits of the freeway, as can be observed on the map of Figure 3. The same can be seen for the lane change conflicts, which also appear in the entrances and exits of the freeway, but much less frequently than the rear end conflicts. Yet, crossing conflicts occurred only in the National Road, in the movements from exiting the freeway towards Hospital for Azurém, for drivers who go to Braga, and at the entrance to the freeway for those who come from Guimarães.


Figure 3 – Types of road safety conflicts (own work)

The rear end conflicts are very high due to designing characteristics of the interchange, since it is a horizontal curve and with a high road gradient. Thus, situations where the pursued vehicle starts a braking will induce an evasive maneuver in the pursuing vehicle to avoid collision, and may need to brake, that is, if the pursuing vehicle is very close to the pursued, this braking action will count as a conflict. Since the period of analysis refers to the rush hour, where there are many users who drive aggressively, a very small space between vehicles has been defined in the model, and consequently there is an increase in the occurrence of rear end conflicts.

## IV. CONCLUSION

Through the work carried out it was possible to perceive the relevance of microsimulation models, to evaluate road traffic safety, especially in road interchanges.

In this work was used the PTV VISSIM software to carry out traffic microscopic models in order to study all vehicular interaction processes during morning rush hour of the case study of an interchange in the city of Guimarães, PT.

To evaluate traffic safety in the interchange was used the SSAM (Surrogate safety assessment model) from FHWA. It was assessed rear end, lane change, and crossings conflicts. It was concluded that the rear end number of conflicts between vehicles is largely superior to the other two types. In addition, with SSAM it was also evaluated the TTC and PET values of all the vehicles.

The location of the conflicts was analyzed in GIS, which allowed the creation of maps of conflicts. SSAM itself allows you to visualize the conflict map, but with much less graphical quality and possibility of interaction. Thus, when obtaining the results of the conflicts, it was possible to verify that the SSAM does not distinguish the trajectories of the vehicles that have an unleveled crossing obtained through Vissim, resulting in a high set of crossing conflicts. After perceiving this SSAM malfunction, these non-existent conflicts were manually removed.

Although an in-depth study is needed to understand the operation of both the software used in this work and the high volume of work associated with the field data collection, it was possible to conclude that the work was completed successfully and it was possible to develop a properly calibrated and validated traffic model that can be used to evaluate the future performance of road interchanges, namely the Fermentões. However, it should be noted that the objective of this work was not to assess the performance of the node in terms of traffic flow and congestion, but rather to evaluate the safety conditions using the results of microscopic traffic models, which has been achieved.

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