Urban Road Safety – Assessment of a Road Safety Measures Tool

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ABSTRACT

A just finished research project, "*IRUMS – Safer urban roads*", was aimed to develop a procedure for the explicit consideration of safety issues in the decision making process of urban transportation networks and in the allocation of resources for the physical renewal network. More specifically, the criteria of the selection of hazardous urban locations (areas or sections) were defined as well as the procedure of the selection of efficient infrastructure corrective safety measures was developed. Five years road accident records, data on road infrastructure characteristics and traffic and land use information were collected and were managed by a Geographic Information System. Integrated with this system is a developed analysis tool which can identify the type of accident (manoeuvres in the origin of each one) and connect the result to the definition of what to do in terms of the implementation of low cost countermeasures in the network. This paper focused on this analysis tool, describing the principles used, the main features, and what will be needed to achieve in order to have a full decision making tool.

Keywords: GIS integrated accidents databases, Urban Road Safety, Road Safety Measures, GIS analysis

INTRODUCTION

Knowing where accidents occur and in what circumstances contributed to these accidents is sometimes the key to finding solutions to minimize casualties and deaths on the road. Although there is information of accidents in urban areas in Portugal, this information is not georeferenced. The research project IRUMS - Infraestruturas Rodoviárias Urbanas Mais Seguras (Safer Urban Road Infrastructure), in collaboration with LNEC (National Laboratory for Civil Engineering) and benefit from a cooperation protocol between the Lisbon City Hall and the Police of Public Security of Lisbon, was able to collect and georeference four years of accidents (2004 -2007) in the town of Lisbon. With this database the project was aimed to the creation of a system to support the decision making in the implementation of engineering measures on road safety.

The georeferenced database was associated to the existing database of the Road Safety Authority in order to take advantage of all type of information available. This allowed a more effective analysis of each accident accumulation areas. Also a support tool was created that can complete the missing data that is necessary to enhance the full analysis of each situation and helps to link the analysis to the efficient corrective measures which are possible to implement in a given location in order to mitigate the number of accidents.

Finally, a model was created to help the decision making between several possible corrective measures, considering some common indicators usually used in this type of decisions. The model was applied to all areas analyzed and tested for different scenarios, allowing a wide set of options when making the final decision.

STRUCTURE, COLLECT AND ASSOCIATE DATABASE TO A GIS

When an accident occurs in urban areas in Portugal and it generates injuries, or when the parties involved in the accident do not come to an agreement, the Public Security Police is called to the accident scene. As a result of this movement, an official Accident Participation is drafted. A Statistical Bulletin of Road Accidents is filled- out, it is the official document for compiling statistics on accidents.

Accident Participation is the document registered by the police that enable to identify the maneuvers that preceded the accident and, at the same time, helps to identify the exact location where it occurred. So, it was requested to the Lisbon Public Security Police to consult the information on accidents that occurred in the city of Lisbon between the years 2004 to 2007 and, based on past experience (Carvalheira, 2002), the accident database used in this study was structured. This past experience was a project where a similar database was established to a medium size urban network also associated to a GIS. This experience allowed knowledge gather about police procedure when collecting data about accidents and also how to take advantage of a GIS software.

The aim of this database is, with the information collected, to identify the causes that have contributed to the accident occurrence. For each accident, this database can answer these fundamental questions: where (location), when (year, month, day, weekday and hour), injuries (deaths, serious and light wounded), weather conditions (to detect if a wet pavement could have been one of the causes) and how the accident occurred (through the accident scheme that is associated in the database). All this information has been associated to the Geographic Information System *ArcGis*, and analysis will be done starting from the cartographic evaluation of the information in database.

Carrying out such analysis with the use of a GIS is a remarkable advantage and this work shows that to insert data in a geographical information system can be a simple and quick process. In addition, georeferenciated data allows the association of another set of data needed for city management enabling to have information that allows more integrated decisions.

Type of Analysis

Using GIS, it is possible to obtain all possible analyzes, as much of the information is contained in alphanumeric database. Tables 1 and 2 show examples of possible outputs from alphanumeric database queries using GIS. Figures 1 and 2 show cartography queries, identifying where the accidents with specific characteristics occur.

Table 1 Total values for injuries and deaths recorded in years under review

Year	Total with Injuries	Deaths	Maximum p/Accident	Serious Injuries	Maximum p/Accident	Light Injuries	Maximum p/Accident
2004	2728	30	3	324	3	3001	20
2005	2671	42	3	310	3	2913	26
2006	2647	29	2	250	6	3082	9
2007	2447	21	2	169	4	2790	7

Table 2 Number of accidents with dead and/or seriously injured by type of accident

Type of Accident	2007	2006	2005	2004
Running over and getaway	6	4	9	7
Animal running over	1	0	0	0
Running over	64	89	127	108
Chain collision	3	2	2	6
Collision and getaway	1	1	3	2
Other collisions	11	3	2	1
Collision with vehicle or obstacle on the road	6	14	8	11
Frontal collision	14	20	22	25
Lateral collision with another vehicle in motion	19	31	43	39
Rear collision with another vehicle in motion	3	5	20	21
Going off the track with rollover	1	6	11	7
Going off the track with a collision with stationary vehicle or obstacle	8	8	12	19
Going off with retention device	2	3	5	2
Going off and transposition of the restraint lateral device	3	8	3	2
Going off without retention device	1	3	2	0
Simple going off	11	14	29	20

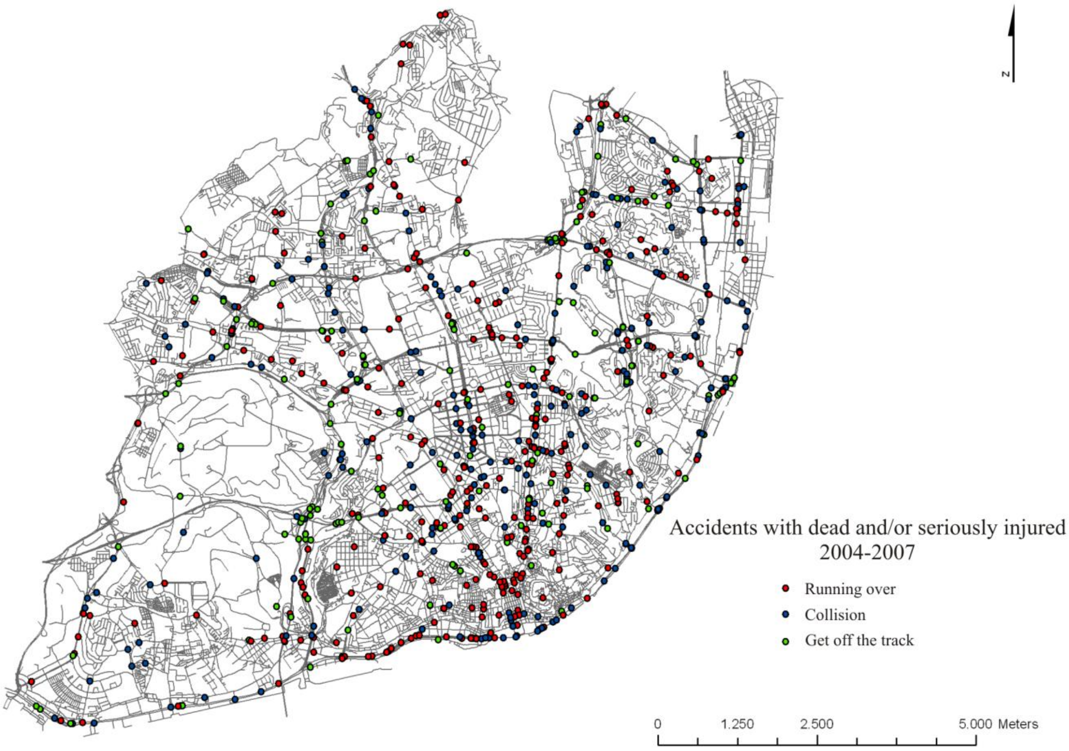


Figure 1 Accidents with dead and/or seriously injured by type of accident

Figure 2 Distribution of pedestrian accidents according to pedestrian actions

GIS TOOL USED FOR DATA ANALYSIS AND FOR SUPPORT OF CORRECTIVE MEASURES IMPLEMENTATION

One of the established and achieved goals was to attain a quicker and more efficient analysis of accidents contained in the database. For this, a tool was developed within the geographical information system which was used to allow, in a systematized way, the access to all information contained in the database for selected accidents, to complete information about the accident, associating schemes containing the maneuvers that have contributed to the occurrence of accidents and associating corrective measures to be implemented in the infrastructure for examined areas.

The tool “SIG Acidentes” ("GIS Accidents") is an executable file that produces a first window called "Summation", as shown in Figure 3, after being installed and activated in the geographic information system and, for a selected area (selected by user), and it contains the summary of the following points concerning selected accidents, namely:

- A sub-window with an accident scheme display;
- The sum of results of the field Type of the Accident;
- The sum of results of the field Description PSP (counting the running overs);
- Identification of the number of accidents per Day of the Week
- A summary of information related to each accident per year; the registration number, the hour, the information of only damage, the number of dead, serious injured and light injured
- The sum of results of the field “Weather conditions” (counting accidents with rain and with good weather)

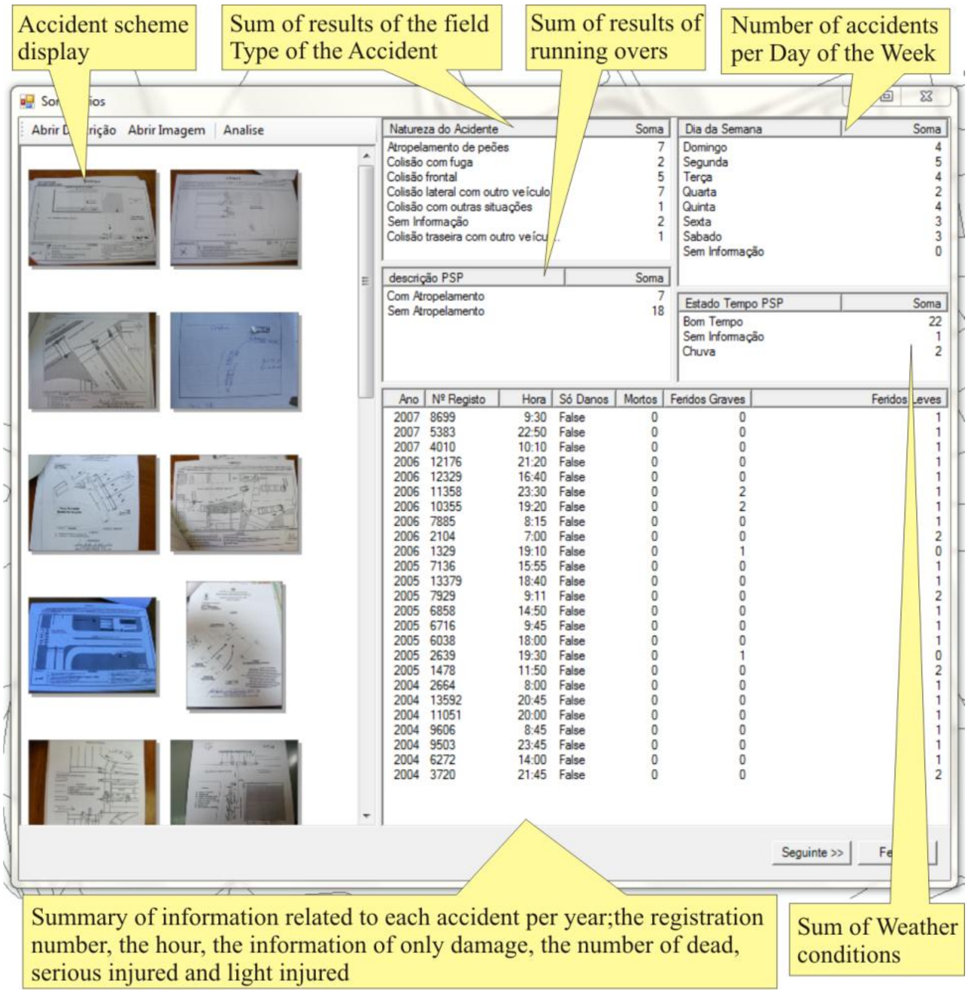


Figure 3 Window "Summation" with summary information of selected accidents

The following procedure in the use of this tool is filling-in, if necessary, additional information for each accident. Note that the structure of filling out this additional information is regarded to all the existing fields in the Statistical Bulletin of Traffic Accidents which contains information, possible to link directly to the database. Figure 4 shows the six tabs that compose the “Additional Information” window and each one of these tabs (numbered from 1 up to 6) allows adding the following information about accidents:

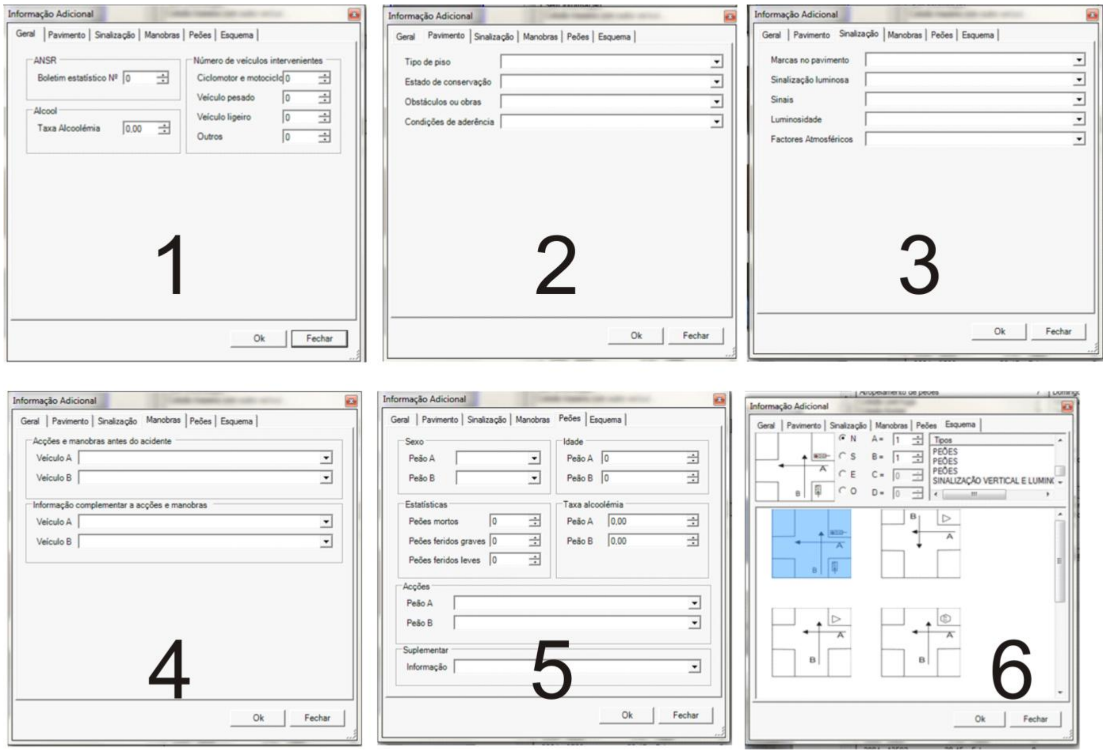


Figure 4 Tabs that compose the “Additional Information” window

Tab number 1 (General information):

- “ANSR” - number associated with the Statistical Bulletin (with the aim of subsequently making a direct link to the official database);
- Alcohol - driver alcohol rate;
- Number of vehicles involved in the process - filling in the information concerning the number and type of vehicles (moped and motorcycle, heavy, light and others) involved in the accident.

Tab number 2: (Pavement - Fields to be completed always in agreement with the options provided in Statistical Bulletin):

- Pavement type - dirt, tarmac, concrete, cement or stone pavement;
- Conservation conditions - in good condition, with regular condition or in bad conditions;
- Obstacles or works - non-existent, not signposted, insufficiently signposted and correctly signposted;
- Adherence conditions - clean, dry, wet, with accumulated water on the road, with ice, frost or snow, mud, with gravel, sand or with oil.

Tab number 3: (Signalling - Fields to be filled always in agreement with the options provided in Statistical Bulletin):

- Road markings - without road markings or little visibility, with separating transit lanes, and with separating transit directions.
- Light Signs - non-existent, to operate normally, intermittent and disconnected;
- Signs - stop, give way, prohibition, pedestrian crossing and others;
- Luminosity - in full light of day, with sunshine, dawn or dusk, night without lighting and night with lighting;

- Atmospheric conditions - good weather, rain, wind, fog, snow, cloud of smoke and hail

Tab number 4: (Maneuvers - Fields to be completed by vehicle user and always in agreement with the options provided in the Statistical Bulletin):

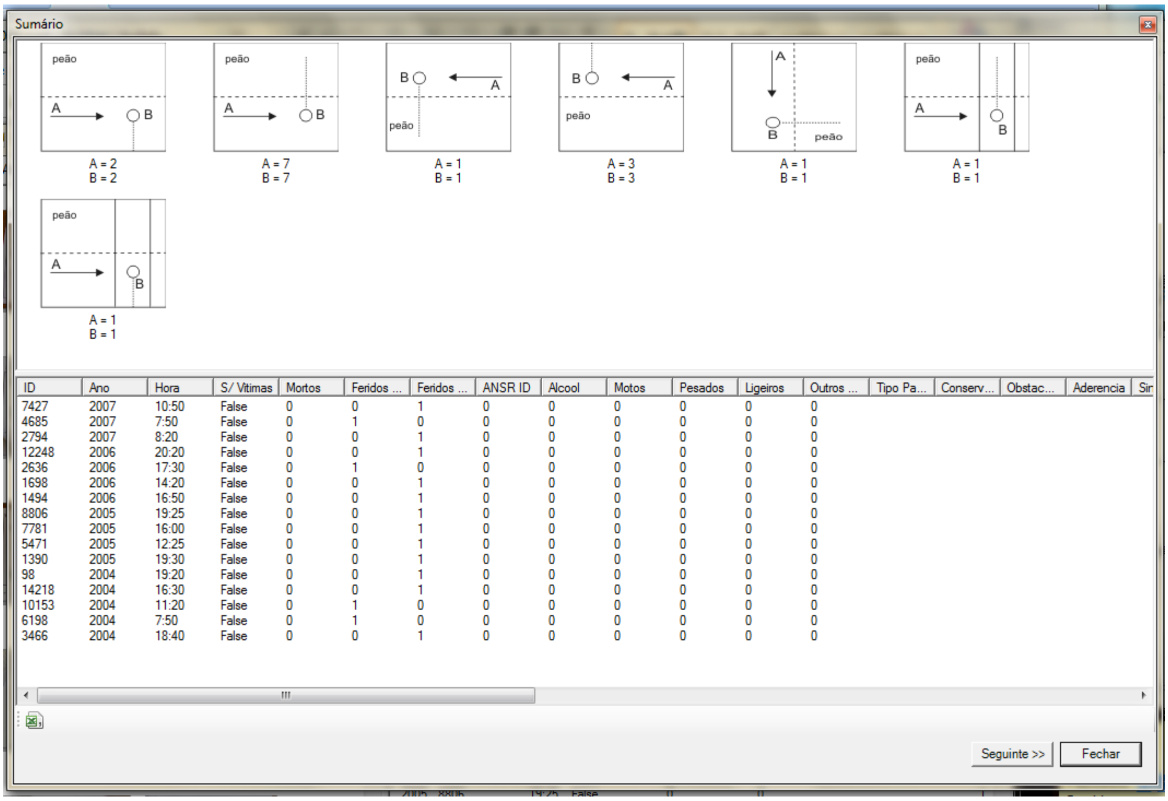
- Actions and maneuvers before the accident - beginning movement, exit parking or street, in normal movement, overtaking on the left, overtaking on the right, change of direction to the left, changing direction to the right and reverse.
- Additional Information for actions and maneuvers – disregarding vertical signs and disrespect of road markings, disrespect of vertical signalization, irregular maneuver, excessive speed the existing conditions, not signaling the maneuver, failure to comply with safety distances, movement away from road edge, tire bursting, mechanical failure of the vehicle, no lights when compulsory, unexpected obstacle on the road, door opening or glare.

Tab number 5: (Pedestrians information - Fields to be filled always in agreement with the options provided in Statistical Bulletin):

- Pedestrian sex
- Pedestrian age
- Number of pedestrian deaths
- Number of pedestrian with serious injuries
- Number of pedestrians with light injuries
- Alcohol rate of the pedestrian
- Pedestrian movements – Walking on the left side of the road, walking on the right side of the road, walking on curbside or on the sidewalk, appearing unexpectedly on the road, exiting or entering into a vehicle, crossing a signaled zebra crossing, crossing a signaled zebra crossing with disregard of traffic lights, crossing outside the zebra crossing and no zebra crossing closer than 50m, crossing outside a zebra crossing and with a zebra crossing closer than 50m, in refuge on the road, walking on right side of the road, in works on the left side of the road, walking on the sidewalk
- Additional Information – isolated pedestrian, pedestrians in group, leading with hand bicycles, children or handicapped cars, moving on skates, scooters or other.

Tab number 6 allows associating in a schematic form, the accident maneuvers, helping in the identification of the main causes of accidents occurring in an analyzed area.

There are still three windows left; the next one is the “Validation” window, the only purpose of it is to certify if the added information is right or if it is necessary to go back and correct something; the following window is called “Summary” and shows, as the name reveals, the summary of all added information, as evidenced in Figure 5.



ID	Ano	Hora	S/ Vitimas	Mortos	Feridos ...	Feridos ...	ANSR ID	Alcool	Motos	Pesados	Ligeiros	Outros ...	Tipo Pa...	Conserv...	Obstac...	Aderencia	Sir
7427	2007	10:50	False	0	0	1	0	0	0	0	0	0					
4685	2007	7:50	False	0	1	0	0	0	0	0	0	0					
2794	2007	8:20	False	0	0	1	0	0	0	0	0	0					
12248	2006	20:20	False	0	0	1	0	0	0	0	0	0					
2636	2006	17:30	False	0	1	0	0	0	0	0	0	0					
1698	2006	14:20	False	0	0	1	0	0	0	0	0	0					
1494	2006	16:50	False	0	0	1	0	0	0	0	0	0					
8806	2005	19:25	False	0	0	1	0	0	0	0	0	0					
7781	2005	16:00	False	0	0	1	0	0	0	0	0	0					
5471	2005	12:25	False	0	0	1	0	0	0	0	0	0					
1390	2005	19:30	False	0	0	1	0	0	0	0	0	0					
98	2004	19:20	False	0	0	1	0	0	0	0	0	0					
14218	2004	16:30	False	0	0	1	0	0	0	0	0	0					
10153	2004	11:20	False	0	1	0	0	0	0	0	0	0					
6198	2004	7:50	False	0	1	0	0	0	0	0	0	0					
3466	2004	18:40	False	0	0	1	0	0	0	0	0	0					

Figure 5 “Summary” window that shows the sum of information added in all tabs of “Additional information” window

After identifying all the types of accidents occurring in the analysis site, the following window named "Corrective Actions" allows the user to associate possible corrective measures for the different problems encountered, as well as add information about such measures, such as efficiency, costs, and other characteristics (Figure 6). In the left column of this window, it is possible to choose between the known corrective measures and each one of these measures that has been associated the bibliographic information with the respective description, costs and efficiency information. It is also possible to add new measures with particular information associated. One last window shows a summary of all selected measures, as well as all added data by each of these measures. This final window has the option of exporting it as a table, which is a final report describing the complete analysis for the selected area in study.

This “GIS Accidents” tool allows information analysis to be kept and it is always possible to seek and access the analyzes carried out. This can be useful, for example, to look for all the areas that contain a certain type of corrective measure as a proposal for implementation of all the areas that contain a particular type of accident that can be corrected with a determined corrective measure.

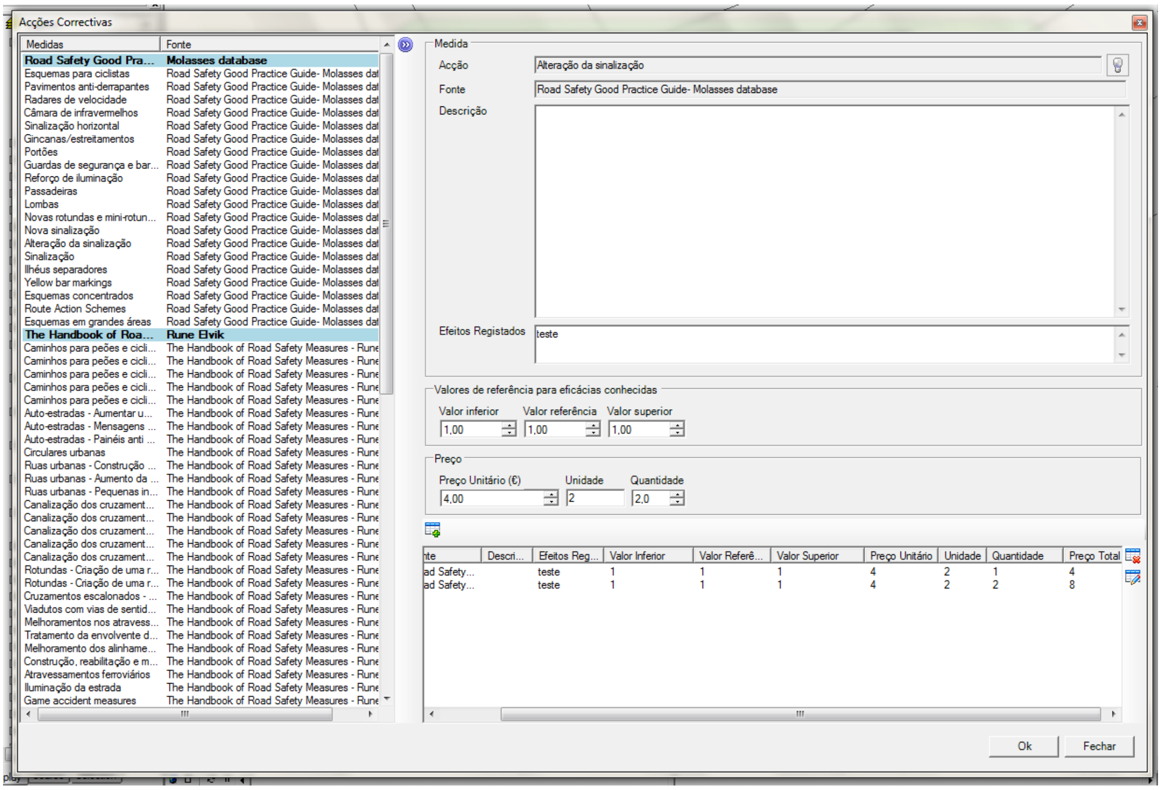


Figure 6 “Corrective Actions” window that allows to adding corrective measures for problems encountered

If the objective is to evaluate and prepare a road safety program in an urban environment, it must always be thought within a global urban network, otherwise there are only specific corrections, which can also be made with this tool, either way it allows comparisons to implement measures intending on the correction of problems only in selected areas.

It was prepared in such a way that it can be updated according to the new way of collecting information of accidents, however, for the moment, it is an analysis tool only for the available information for each accident and that makes it possible to strengthen the information by completing fields and presenting summarized and schematized the types of accidents.

Because it is a tool intended to support road safety analyses and decisions, for that reason a parametric model, in the sense that it is constituted by a set of definable parameters, was developed with the aim to rank the interventions between corrective measures in the same analyzed area and between analyzed spots in urban area whatever the priority measure may be in a specific area. This model will be, in a very near future, added to “Gis Accidents”.

SUPPORTING DECISION ON CHOICE ABOUT CORRECTIVE MEASURES TO BE APPLIED

The parametric model is, in each case, achieved in two stages, carried out in sequence (because the second stage uses results from the first one). In a first phase, it determines, among the areas in analysis, which are those that require more urgent interventions and, in a second phase, among the possible measures to be applied in a certain place in analysis, which is the hierarchy of its importance to the resolution of the problem. Please note that the final result of the two stages are joined together, in order to establish a prioritization indication among the measures proposed, which can be compared to different analyzed areas.

First Stage: Definition of the Hierarchy of Places to Intervene

The ranking of sites that require the most urgent intervention was established with the total number of accidents at each study site, the traffic volume corresponding to the peak time of the morning, and expressed in vehicles/hour and, finally, the registered severity of the accidents.

Used traffic values were designed from an existing work, Martínez (2006), where a model was developed for allocation of traffic to Lisbon. The information about the severity of the accident was gathered, including light injury (injuries that didn't require hospital internment), seriously injured (the ones that needed hospital internment) and fatal victims (accidents that had victims that died up to 30 days after the accident). Based on the value attributed to the costs of each one of these victims in Portugal Santos, (2007), it was defined a number of equivalent light injured (FLE), in which each seriously injured person is equated to 2.25 light injured and each fatal victim is equated to 12.5 light injured. Intervals between 1 and 5 were defined to achieve the level of seriousness for accidents at the workplace (Table 3).

Table 3 Intervals between 1 and 5 defining Severity Level

Nº of Equivalent Light Injured	Severity Level (*G*)
<= 12 FLE	1
<= 24 FLE	2
<= 36 FLE	3
<= 48 FLE	4
> 48 FLE	5

The Hierarchic Rank of the Site (*VHL*) in accordance with the priority of intervention is defined through the equation (1):

$$VHL = \frac{TAL}{VTL} * 1000 * G \quad (1)$$

Where:

- *TAL:* total number of accidents with victims registered on the site for the period of the study, assuming a minimum of 3 years (between 2004 and 2007 in the case of Lisbon)
- *VTL:* volume of traffic of morning peak hour (7am -9am) in vehicles/hour
- G: severity level of the accidents in the workplace as defined in the intervals of Table 3

In order to consider the variation between day and night traffic, as there is no traffic night counts, the calculation of *VHL* was considered for the traffic values known (the peak time of the morning) and the values of traffic night were assumed that the night time traffic (between 9pm and 7am) is 10% of the value of the traffic of the peak hour of the morning. The value was counted separately for the night time and for the daily time and the VHL was calculated for each one of the timetable, whereas the largest value of G is assigned to the total number of accidents in the area.

Second Stage: Definition of the Hierarchy of Intervention

Four key indicators are considered for the definition of the hierarchy of the intervention of corrective measures on road safety, namely Value Hierarchy of the Site (*VHL*), already defined in the previous section, Implementation Cost (*CI*), Ease of Implementation (*FI*) and Efficiency known (*Efc*).

The main criteria considered to choose between various possible measures was the Implementation Cost (*CI*). In order to implement a measure it is necessary, firstly, to ensure that there is financial availability, and, at the same time considering how many measures may be implemented with the available funding. All values were defined in intervals between 1 and 5 and *CI* is shown in Table 4.

Table 4 Intervals between 1 and 5 defining *CI*

Values for implementation (€)	*CI*
<= 30000	5
30000 - 90000	4
90000 - 150000	3
150000 - 250000	2
>= 250000	1

The Ease of Implementation (*FI*) of a measure considered as a determining factor in deciding which measure should correct or minimize the problem of road safety, especially in places where any intervention can be a problem, as for example, in historic areas with a high density of traffic, where any intervention in the infrastructure can significantly impair the flow of traffic and create congestion.

Thus, intervals for *FI* were defined especially considering the complexity of the intervention, in the infrastructure in terms of the allocation of public space during works for the implementation of the measure, as shown in Table 5.

Tabela 5 Definition of values for Ease of Implementation (*FI*) and their classification

Criteria to find values for Ease of Implementation	*FI*
Simple application (which can ease be carried out during the night period) without any allocation of demand and in which the infrastructure is low affected	5
Also without allocation of demand but intervention involving some logistical complexity with possibilities for small interference in motorized movements	4
Interventions in infrastructure imply assignment of demand, at least one route movement must be blocked	3
Besides allocation of demand, the implementation of the measures implies a greater amount of means for construction and replacement of traffic and public services in the zone of intervention. There is a need for a strong replacement of pavement.	2
Appreciable effect on daily experience in the area of implementation of the measures. Everything that implies major changes and strong intervention of replacement of all the affected area	1

The values of Effectiveness Known (*Efc*) were imported from other works, ADONIS (1998); Elvik e Vaa (2004); ROSEBUD (2006), and adapted to intervals between 1 and 5 in order to standardize data. This indicator was considered the less important in the analysis once there are no studies of the effectiveness of the measures carried out for Portuguese conditions. It is expected in a near future to achieve better values obtained from studies of the effect of the application of mitigation measures to some areas in Lisbon.

Among the possible measures, the Hierarchic Rank of the Measure (*VHM*) is the priority of implementation for the same area analyzed and comparable with the other areas with another location, and defined by *VHL*, *IC*, *FI* and *Efc*, through the equation (2):

$$VHM=VHL * x1+CI * x2+FI * x3+Efc * x4 \qquad (2)$$

Where:

VHL: the Value Hierarchy of Local
IC: the Cost of Implementation of the Measure
FI: the Ease of Implementation of the Measure
Efc: the known Effectiveness of the Measure
x1, x2, x3 and *x4*: the weights assigned to each of the considered indicators

The more reliable the value of an indicator is, the greater is the degree of confidence to give greater weight to this parameter.

For the analysis of the various possible measures to apply in a certain local, even if in some extent some of the measures are complementary to each other, the measure that should be consider for implementation should be the one that has greater value of VHM. Comparing VHM of a measure for different locals an administration could easily elected the locals where an intervention should take place with that measure and open a bid that included several interventions with the same measure which is more likable to produce a less costly answer by the contractors.

CONCLUSION

The analysis tool developed was tested in more than 50 places within the urban area of Lisbon and a qualitative interpretation of the results, based on the "engineering experience" of analyzing such situations, lead to the conclusion that the purpose of this work was substantially achieved, not only for the structure with the number of accidents in urban areas that is usually analyzed, but also with a methodology that could define the measures to be applied in the infrastructure in order to improve safety on the road network.

It is also important to underline that the overall process applied to the city of Lisbon was structured in such an open way to accommodate specificities of the site, and, therefore, can be transposed to any other realities of urban life.

The part of the work related to the validation of the "parametric model" that is proposed to support the decision of which countermeasures and where to implement them will be undertaken with a new program, that is starting, with the Lisbon City Council, established with the goal of solving the problems detected in some accidents accumulation spots in the city. With the implementation of the program it is expected to refine and strength the output of the aid-decision tool that the "parametric model" aim to be.

REFERENCES

ADONIS (1998) "Analysis and development of new insight into substitution of short car trips by cycling and walking - Best practice to promote cycling and walking", Copenhagen, A research Project of the EU Transport RTD Programme European Commission, Directorate General for Transport (1996 - 18 months).

Carvalheira, C. (2002) "Segurança Rodoviária em Meio Urbano: Metodologia para a Definição dum Sistema de Gestão." Departamento de Engenharia Civil, Master Dregree,Universidade de Coimbra.

Elvik and Vaa, T. (2004) "The Handbook of Road Safety Measures", Elsevier Environmental Systems Research Institute (Redlands Calif.) (2002).

Martinez, L. (2006) "TAZ Delineation and Information Loss in Transportation Planning Studies" Civil Engineer, Master Degree, IST.

ROSEBUD (2006) "Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making - Examples for assessed road safety measures - a short handbook ", Federal Highway Research Institute - BASt, Germany.