# SETTING SPEED LIMITS IN RURAL AND INTERURBAN TWO-LANE HIGHWAYS

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## ABSTRACT

Over the last years and mainly after the 1980's it has been assumed that the design of the road infrastructure should consider an integrated set of requirements such as the surrounding road environment and the presence and characteristics of its users. This change on the philosophy of road design has been accompanied by the increase importance with setting the most adequate legal speed limits for each type of stretch, having in consideration the lateral road occupation and the presence of vulnerable users. This concern is particularly relevant for managing inter-urban roads which cross differents environments.
The present paper presents an updated state of the art on this subject, namely on the approaches that have been pursuit by several countries for supporting their legal speed limits for each kind of road environment. The article continues by presenting an overview of setting speed limits in Portugal and presents two models recently developed by the authors, capable of objectively supporting the process of defining the adequate speed limit levels throughout the full length of a rural or interurban two-lane highway: (i) multiple regression model (ii) a multinomial logit (MNL) discrete choice model. The explanatory variables were collected to describe the functional and physical characteristics of the different stretches of the road and its surrounding environment. The practical application of this model is tested through its application in a case-study (a rural two-lane road), completed by a critical comparative analysis of the results of existing models.

*Keywords: speed management; speed limits; road safety; controlling speed.*

## INTRODUCTION

Speed is an important variable for describing the way the traffic system works. Due to its easy perception, speed is one of the most used parameters to assess the subjective quality of traffic management. Moreover the driver's behavior is affected directly by speed through changes in the peripheral vision, by the need to search for information as far as possible in our field of vision, as well as a decrease of the time available for processing and dealing with the information (together with a higher frequency of decisions) (TRB, 1998).

As research showed the speed is one of the most significant variables in explaining both the frequency as the severity of the road accidents (TRB, 1998). In 1997, Kloeden, et al. concluded that for speeds over 60 km/h, for each 5 km/h increase there is a double increase in crash risk. Stuster, J. et al. (1998) concluded that the increase in the percentage of traffic accidents with injuries doubles with the percent increase of the speed square, being this relation of 4 when we the fatal crashes are considered. More recently Aarts and Van Schagen (2006) concluded that small speed reductions (1 or 2 km/h) assume a significant effect on road accidents probability, being this effect a function of the reference speed. From another perspective, a report from the OECD/ECMT (2006) reaches the conclusion that in case of pedestrian crashes, the pedestrian has higher chances of surviving when the vehicle is going under 30 km/h, increasing drastically when the speed is increased for 50 km/h. It was also found that speed is related with the main cost components associated with travelling, namely environment, travel time and operations costs, which has motivated research for studying the optimal speed limits for each situation (Yang, & Daniel, 2004; Elvik, 2002; TRB, 1998; Austroads, 2005). However results are not consensual. For example, recently, Malyshkina e Mannering (2008) studied the effect of the increase in legal speed limits and road crash severity and concluded that this increase from 55 to 65 mph did not produce a significant increase in the severity indicators in interstate highways. Nevertheless the same study points for the existence of this causal effect in non-interstate highways (Kockelman, & Bottom, 2006).

Several methods have been adopted for defining these speed limits. These methods are supported by different approaches from which we may stand out the arbitrary judgment, the legal perspective or the more or less sophisticated engineering techniques (Farmer et al, 1999; Malyshkina e Mannering; 2008; Oei, 1996). Despite this fact and given the unsatisfactory results that have been obtained, this subject is still demanding complementary research (Agent, et al, 1998). Up until the mid 1980's the approach used for rural and interurban road design tended to put the emphasis on standardized geometric solutions with little consideration given to its integration with the surrounding environment (McMurtry et al, 2009). This led to the adoption of design and operational principles with the emphasis put on design speeds and quality of service, which was mostly associated with high average speeds, not really adapted to its surrounding environment. In many countries (namely in the USA and Australia), limits were set largely to reflect drivers' behavior and it was common practice to establish the speed limit near the 85th percentile speed, that is, the speed at or below which 85 percent of drivers travel in free-flow conditions at representative locations on the highway or roadway section (TRB, 1998; Austroads, 2005; Fitzpatrick et al, 2001). By that time, however, in many countries in Europe but also in the United States (DfT, 2006), Canada and Australia, the emphasis started to shift towards traffic safety and, progressively increasing its focus on environmental and quality of life related issues, particularly during the crossing of small urban areas and towns (Mackey, 2004).

Presently there is a widely accepted understanding that only through an integrated approach one is capable of taking into consideration in a coherent perspective the interests and needs of all the stakeholders (TRB, 1998) being these, on one hand, the vehicles' drivers and passengers who mainly want a fast and safe route and on the other hand, the needs and aspirations of the other road users, including the resident population of the areas which surround these infra-structures. This is even more important for rural and interurban roads where human occupation at the sides of the road is a reality, thus increasing the probability of interaction between vehicles and pedestrians or with other vehicles, exiting garages for example. This leads to the consensual acceptance of the great need to define coherent speed management strategies which can be applied to different traffic environments, serving as reference matrixes for the geometric and operational design of road solutions which, while being context-sensitive in each and every stretch, will also present adequate consistency and homogeneity throughout the length of each route.

In the case of two lane rural and interurban roads of a regional or national hierarchical level, the solicitations may vary greatly given that they tend to cross over many different environments. For these roads which go from the pure rural landscape with very little marginal accesses and interactions, to suburban environments where there is a non negligible level of lateral occupancy by human activities, to pure urban ones where the number of interactions is the greatest, there is still some work to be done in the development of speed management strategies which are at the same time efficient and can be applied in a standardized, widespread and systematic way.

In Portugal this aspects assume a reinforced importance. Recent data on road accidents show that 71% of the total number of accidents with victims and 47% of the total number of dead people occur on urban environments (PIARC, 2001). Along the last decade the country has seen a great expansion in its main free-way network which has captured the majority of long distance journeys, with the consequent hierarchical downgrading of the other roads. However this downgrading was not accompanied of the necessary geometric infra-structure adaptations to the new functions, being generally adopted the 50km/h speed limit regardless of the kind of urban occupation or the prevailing driving conditions. The traffic levels in these roads are most of the times extremely reduced, not justifying the use of sophisticated expensive techniques for speed limits enforcement. One of the basic problems related with this issue is the selection of the adequate speed limits, and consequently the positioning of the corresponding traffic signs, for the different stretches of these roads taking in consideration the functional and physical characteristics of the roads and also its users' expectations (Austroads, 2005).

Objectively this communication aims to face the question of establishing legal speed limits. There are present several philosophies which are followed internationally, making a reference to the Portuguese national perspective. Following this review there are present two statistical models recently developed to support the decision of which limits to apply to each two-lane highway segment having as main reference the different environments. Finally the models are applied to a segment of the Portuguese national roadway aiming to understand the suitability and easiness of appliance of the models, in a perspective of determining new lines of research.

# DRIVER CHOICE OF SPEED

In a normal state, drivers chose the speed which they prefer and find is safe, that is why generally they won't find that speed excessive at the moment of choice. The speed distribution characteristics (in space and time) for a given road segment are determined by the opinion which drivers have on the safe speed, thus it is a personal choice. The individual speed driver's choice is normally influenced by a variety of factors (Figure 1) (Oxley & Corben, 2002).

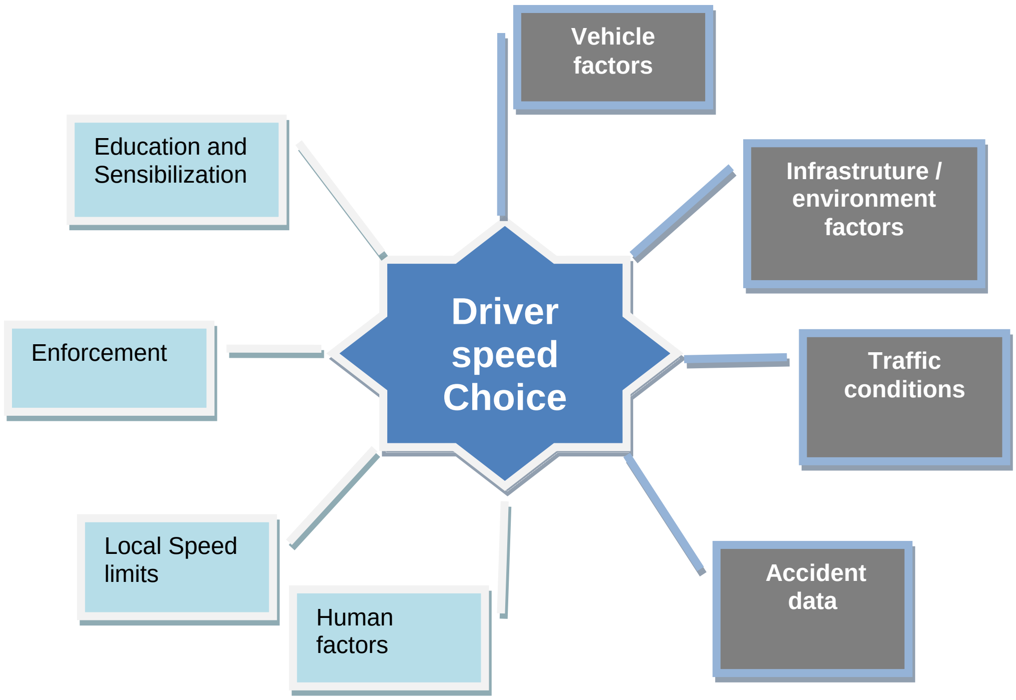


Figure 1 – Factors affecting speed choice

These may be grouped in 5 major classes: Driver's characteristics, road characteristics, traffic characteristics; type of vehicles and environment dependent factors. The influence of each factor is difficult to measure because of the high correlations between them and due to the impossibility of experimenting for univariate effects on speed choice. Nevertheless, from the different studies it is possible to take some conclusions on the most relevant.

The main factor which influences the driver, is the travel distance (total and left to be driven), while he presence of passengers, the age or the gender of the driver have a less clear influence. The type of road has a very direct relation with the speed choice (OECD/ECMT; 2006). The drivers have a tendency for maintaining the driving speed framed in an interval which they feel it's safe, not really adapting the driving to local variations of project speed.

It is possible to identify several variables linked to the road which afect speed (TRB, 1998). The curves radiuses, the frequency of intersections, number of lanes and geographic location are factors which have a great influence in the speed choice. By its turn, factors such as the longitudinal slope, visibility distance, pavement type, and lateral vision are factors which have a non negligible importance.

The traffic flow has an influence on speed, when it surpasses certain volume or density threshold values. The percentage of heavy vehicles, the relation between supply and demand of over passing opportunities, the opposite way traffic volume and traffic signaling are also variables to take into account (TRB, 1998; OECD/ECMT, 2006). In what respects to mechanical factors the type of vehicle and the relation between power and weight are the mist relevant. From the environment variables we may stand out the influence of the time of the day and the weather conditions, as well as enforcement operations.

By its turn, the speed enforcement would have its effect near the location and time of the enforcement activity. This is consistent with studies of visible speed enforcement that indicate the effects are limited in time and location (Hauer, Ahlin, & Bowser, 1982). Additionally, in situations where internal factors strongly bias speed choices up or down such as running late or fear of crashing, environmental factors may be less likely to impact on speed choice, compared to other situations or conditions.

Understanding the influence of these factors on speed choice is vital for devising effective strategies to manage speed. Speed limits provide a central footing for the management of speed, forming the basis of police enforcement and advising drivers of suitable and acceptable travel speeds. In these ways, speed limits can be used to enhance safety by mitigating the risks imposed by drivers' choice of speed (TRB, 1998).

# SETTING SPEED LIMITS – THE INTERNATIONAL OVERVIEW

The idea of regulating speed pre-dates the invention of the motor vehicle (in 1652 by New Amsterdam - now New York, prohibiting riding or driving horses at a gallop within the city) (Austroads, 2005). Until this time, speed limits are widely used to define acceptable speeds. They provide a basic indicator to road users of the maximum speed allowed under the law. In the 1960s limits were set largely to reflect drivers' behavior and using the 85th percentile speed – in effect saying drivers were making rational choices and only those in the minority 15% would be judged as 'speeding'. The analyses of crash data revealed a growing speed related problem. Therefore limits were set that took into account road design factors (sight distance, road curvature, etc) (Austroads, 2005). Up until the mid 1980's the approach used for road management tended to put the emphasis on standardized geometric solutions (Mackey, 2004, DfT, 2006) this led to the adoption of operational principles with the emphasis put on design speeds and quality of service, which was mostly associated with high average speeds, not really adapted to its surrounding environment.

These different views on the problem have been strengthening the need for developing decision support instruments for setting the most adequate speed limits for each specific case. The general practice of establishing a set of speed limits that reflect an appropriate balance between travel speed and the risk of crashing under favorable road conditions seems to be a prudent first principle in speed management. However, in setting speed limits is a complex set of trade-offs between the relative importance of crash and injury risks, enforceability, travel time, societal attitudes, environmental concerns and political considerations (Patterson et al., 2000; TRB, 1998). These trade-offs are normally reflected in a range of different philosophies. According to Austroads (2005) some major philosophical viewpoints are possible. It needs to be recognized that at least some of the different philosophies overlap and may share common factors (Austroads, 2005):

1) ENGINEERING PHILOSOPHY - Speed limits are most commonly set after conducting an engineering study of the road and traffic environment on the section of road and surrounding roads. In an engineering study information is normally collected on the traffic speeds, crash data, type and amount of roadside development, road geometry, and the number of type of road users. These factors allow engineers to designate a road design speed. The models of the family XLIMITS which have been developed in Australia (Austroads, 2005) are included in this approach. Also the mathematical models developed in Portugal (Seco et al, 2008; Correia and Bastos Silva, 2010) follow this methodology.

2) DRIVER SPEED CHOICE PHILOSOPHY - The philosophy of setting speed limits by drivers' choice of speed is otherwise known as the "basic law limit". This approach leaves it up to drivers to determine what constitutes a reasonable and safe travel speed. This has been an accepted speed limit practice because it is politically popular, appeals to road users and the general public, and is obeyed by the majority of drivers. In practice, most areas incorporating this philosophy post a speed limit based upon the majority of drivers' travel speed, which then allows deviant drivers to be prosecuted. However, speed limits arising from this philosophy often incorporate various engineering considerations which may result in modified speeds if the speed chosen by drivers were not appropriate. The 85th Percentile Speed methods, adopted in US (TRB, 1998) and Australia is one example of the application of this type of philosophy.

3) ECONOMIC OPTIMIZATION PHILOSOPHY - The foundation of the various economic optimization approaches is to set a specific cost value to all the costs associated with travel and to the burden of injury and death from motor vehicle crashes. The method relies heavily on the quality of the data used to determine the costs of each of the factors involved. The lack of a universally accepted method for determining the economic costs of each transport factor has limited the objectiveness of these approaches, which have been rarely used to determine speed limit policy. Nevertheless, the approach has gained some recognition by virtue of its emphasis on what mobility factors are actually costing society, particularly in terms of injury costs. The Optimum Speed Limits presented by Oppenlander (1962, cited in TRB, 1998) is one example of this approach. It uses a scientific procedure for setting speed limits at a level that is most favorable from the perspective of the society costs (costs per mile

related to four. factors: vehicle operation, travel time, crashes and service). It recognizes that drivers do not always choose a speed that accounts for the various risks and costs imposed on society.

4) HARM MINIMIZATION PHILOSOPHY - Economic optimization approaches assume that it is legitimate to put a fiscal cost on human injury. Some alternative approaches are based on the argument that life and health are beyond the monetary costs associated with safety and good health and beyond the other benefits of transport. These approaches recognize that while it may not be possible to eliminate road caused trauma, it may be possible to create a transport system that does not view casualties and fatalities as an acceptable and inevitable mobility cost. Two applications of these philosophies are described below. The recent Dutch Sustainable Safety and Swedish Vision Zero philosophies share many parallels and both share the idea of providing a transport system that minimizes harm to users of the system. Both philosophies describe speed management and the setting of limits as a part of the overall philosophy.

There are numerous other philosophies and strategies for determining and setting speed limits. Many of these have been at least partly incorporated in the previous philosophies and methods, like Variable Speed Limits (VSL) associated with dynamic message signs. This kind of signals allows changes in the maximum speed limit on the basis of real-time monitoring of the prevailing road and traffic conditions using dynamic information displays.

## SETTING SPEED LIMITS IN PORTUGAL

### The problem

In Portugal there is no technical documentation that considers the recommendations for supporting the selection of adequate speed limits, the reference is just the highway code. This flaw has been constraining the application, in Portugal, of adapted speed limits (dependent on, for example, the type of roads outside urban areas, or he type of lateral occupation) and this has even lead to a strong imprecision on the selection of these limits.

This situation has been reflected in a lack of coherence on the solutions and has hindered the creation, by the drivers, of a priori miss expectations jeopardizing the validity and credibility of the posted speed limits.

It was with that objective that FCTUC has elected this topic as a main research field, focused on the development of a mathematical model which could serve as an instrument for supporting the definition of maximum speed limits, having as reference a limited set of easy to measure explanatory variables which represent the infra-structure and the surrounding environment. It was our aim to develop a robust and easy to apply model, and that is why it is essential to make a good selection of the relevant variables. It was also fundamental at the same model would be capable of adapting to specific details and characteristics which are relevant for each road environment.

The next section presents in a summarized way, the evolution of the work that was developed to find such mathematical model, based in an engineering philosophy, as well as its application to a two-ways highway in Coimbra (Portugal) with a total extension of 17 km.

## Evolution of the model

### *Data Base*

The different versions of the model which were developed are based in a real database, which has 45 km of two-way road segments at a national and regional level in Portugal.
These roads were divided in a number of stretches of equal length for each of which a physical and functional evaluation was performed as was an evaluation by experts of the correspondingly adequate speed limits. After some consideration it was considered that 200 meters was an adequate length for the stretches of road since it was long enough to present intrinsic and observable characteristics and short enough to present reasonably homogeneous characteristics (Seco et al, 2008; Correia e Bastos Silva, 2010).

The physical and functional characterization of the different stretches of roads was done using a number of quantitative and qualitative variables. These variables were selected based on their perceived capability to directly or indirectly represent the different road related functions (motorized traffic or pedestrian related), infrastructure basic components (junctions, parking areas and spaces, pedestrian facilities,…), and surrounding environments (adjacent type of land use and level and proximity of the development to the road,…). A informação foi recolhida de forma desagregada em função do sentido de circulação (lado direito e lado esquerdo).

We have asked 4 experts to choose only one speed limit per stretch of road and only between three alternatives (90Km/h; 70Km/h; 50Km/h), which basically would represent rural, suburban and urban environments. They were also asked to disregard the existing speed limits and to also disregard the potential impact presented by eventual existence of driving limitation situations resulting for example from the existence of very localized below standard road geometric characteristics such as limiting bends or very localized road narrowing's (this recommendation is in line with what is normally accepted as referred in DfT, 2006). This database has allowed develop different mathematical models based in two different techniques: linear multiple regression (Seco et al, 2008) and logistic regression (logit discrete choice model) (Correia e Bastos Silva, 2010).

### *Multiple regression Models*

The different multiple linear regression models were developed with the simultaneous consideration of all the explanatory variables considered potentially relevant in each situation. The development of these models is presented in Seco et al (2008).
The initial models were based in disaggregated information for each way and expert. The obtained results were extremely consistent either in the statistical significant variables as to the importance of the coefficients. The $R^2$ values obtained were situates between 0.58 and 0.63.

The next stage of the modeling process consisted on evaluating the feasibility of reducing the number of explanatory variables by partially or totally aggregating those similar in terms of what they represent. Essas agregações incidiram na junção de variáveis que tendencialmente assumem efeitos similares (for example, diferent types of variables related with “Different Motorized Traffic Lateral Accesses, related with “Different Pedestrian Lateral Accesses”, etc.). Também a junção das variveis registadas no Near side e Off side foi testada. The obtained results shown to be very consistent, as the adjustment losses were very short ($R^2$ values between 0.54 and 0.60), overbalanced by a significant increase in simplicity and easiness to apply the model.

The final step of the modeling process consisted of the evaluation of the consequences, namely in terms of eventual reduction of prediction power, of the elimination of some of the explanatory variables, due to their potential reduced robustness. Incluem-se neste conjunto a existência ou não de passeios on a significant extension of each stretch of road e os sistemas de controlo de velocidade. Although being a potentially good variable to represent the existence of significant levels of pedestrian movements alongside the road, it has the potential problem of representing a physical element which is not always implemented, in Portugal, in accordance to precise and objective criteria. The speed control traffic lights in spite of having consistently proved to have statistical significance, was however considered to lack a strong capability to, even indirectly, represent either the roads’ functions, or their operational physical components or their surrounding environments. The main reason for their implementation is normally the fact that drivers are falling to understand and accept the imposed legal speed limit. The final model is presented by the following equation which has proven to explain 54% of the observed variance:

$$Sest = 85{,}327 - 3{,}042CROSS - 0{,}740NATER - 1{,}170BUS - 1{,}738NCROPR - 7{,}761REST \quad (1)$$

Where:

*CROSS* - – Number of intersections;
*NATER* – Number of vehicle accesses
*BUS* – Number of BUS stop
*NCROPR* – Number of crosswalks
*REST* – Level of Lateral Restrictions (Proximity of Buildings,…): 0 if low; 1 if medium and 2 if high

### *Logit model*

By selecting three speed limits for the experiment, 90 km/h, 70 km/h and 50 km/h one is intrinsically considering a discrete choice model. It would be unrealistic to calibrate a multivariate regression model since this would produce a continuous variable over a discrete dependent variable (Correia & Bastos Silva, 2010).
Comparing with the multiple regression model, we have opted for making the effect associated with the lateral restrictions (houses proximity and human activities) more robust, and this was done by using binary variables. These aim to include in the model, in a straightforward perspective, the effect of the surrounding road landscape, and as a consequence the proximity and density of the marginal occupation.
All the others variables do not vary between alternatives, thus and because only differences in utility matter, it had to be defined a reference alternative against which the other alternatives utilities were compared with. In this case we have considered that reference alternative to be 90km/h (56 mph) because it is the standard design speed for a rural two-lane highway in Portugal, hence, the coefficients of the explanatory variables will aim to translate why in some stretches the maximum speed cannot be applied, trying to identify highly significant factors for that reduction.
The systematic part of the utility expressions is thus defined as follows:

$$V(50km/h) = \beta_{50km/h} + \sum_{k=1}^{K_{50km/h}} \beta_{k\,50km/h}\, x_{k\,50km/h}$$
$$V(70km/h) = \beta_{70km/h} + \sum_{k=1}^{K_{70km/h}} \beta_{k\,70km/h}\, x_{k\,70km/h} \qquad (2)$$

$V(90km/h) = 0$ (Reference alternative)

with K being the number of significant variables in each utility function.

As it can be observed an independent coefficient is calibrated for each variable in the two utility specifications as also an alternative specific constant for each alternative in order to capture the weight of other factors not translated in the explanatory variables. One important analysis which should always be part of the calibration of such models is to analyze the correlation between the candidate explanatory variables. When these are highly correlated (usually a cut-off 0.8 correlation in module is used as this limit) one cannot measure the true effect of each variable on the choice which is being studied thus not allowing to measure their importance in the model. The correlations were computed for all variables and they have shown consistent low values in module, being the highest between the Pedestrian Paths Accesses at the NS and the number of Off-Road Individual Parking Accesses at the NS with 0.634 correlation, almost the same value is reached for the same relation for the Far-Side variables, this is coherent with the observed reality where most of the houses next to these roads have individual garages. Given this result we have decided not to exclude any of the variables based on their correlations.

The MNL model was calibrated through maximum likelihood estimation using the software Nlogit (Econometric Software Inc.). The number of statistical cases corresponds to 450 (stretches)×4(experts)=1800 cases. First all the variables in Table 1 were used, and then the variables with significance lower than a 5% level were gradually taken out of the model in order to increase its accuracy. The variables which remained in the final specification can be seen in the following table with their corresponding coefficients value and significance:

TABLE 1- Calibrated coefficients for the MNL model

| | 50km/h (31 mph) utility coefficients | | | 70km/h (31 mph) utility coefficients | |
|---|---|---|---|---|---|
| **Variable** | **$\beta$** | **P[\|Z\|>z]** | **Variable** | **$\beta$** | **P[\|Z\|>z]** |
| 50ASC | -4.875 | 0 | 70ASC | -1.734 | 0 |
| 50INTERR | 1.598 | 0 | 70INTERR | 1.117 | 0 |
| 50INTERL | 1.309 | 0 | 70INTERL | 0.928 | 0 |
| 50GARAGR | 1.389 | 0.0006 | 70GARAGR | 1.225 | 0.0022 |
| 50GARAGL | 0.809 | 0.0147 | 70GARAGL | 0.894 | 0.0062 |
| 50NATERR | 0.468 | 0 | 70NATERR | 0.268 | 0.0016 |
| 50NATERL | 0.670 | 0 | 70NATERL | 0.486 | 0 |
| 50NAPARR | 0.674 | 0.017 | 70NAPARR | 0.695 | 0.0133 |
| 50NCRO | 1.056 | 0 | 70NCRO | | |
| 50NAPEHL | 70NAPEHL | -0.168 | 0.0092 | | |
| 50NBUSL | 70NBUSL | 0.677 | 0.0006 | | |
| 50SIDEWR | 2.136 | 0 | 70SIDEWR | 1.542 | 0 |
| 50SIDEWL | 0.777 | 0.0008 | 70SIDEWL | | |
| 50AVCOR | 1.776 | 0 | 70AVCOR | 0.893 | 0.0001 |
| 50AVCOL | 1.069 | 0.0002 | 70AVCOL | 0.767 | 0.0003 |
| 50HICOR | 2.643 | 0 | 70HICOR | 1.607 | 0.0025 |
| 50HICOL | 2.623 | 0.0001 | 70HICOL | 2.405 | 0.0002 |

## Case study – Road N111 near Coimbra (Portugal)

The chosen road for applying the developed models was the N111 road localized between Coimbra and Montemor-o-Velho, with a total extension of 17 km's. The road is characterized by crossing a different set of road environments, associated to the crossing of small urban areas. In their major part the built environment is developed near to the road without having much interaction with it. The buildings are dispersed, and their majority is distanced over 30 meters from the road. Despite this fact, all urban centers have a clear marked sign of a town entrance, which, according to current legislation, impose a speed limit of 50km/h. The road design is extremely motivating for high speeds because it has rectilinear segments and large cross sections (see Figure 2). The inexistence of sidewalks or the presence of human activities lateral to the road causes drivers to adopt high speeds and generally disrespect local signals.


Figure 2 – Strech of N111 with 50km/h speed limit (a) km 4+800; (b) km10+400

The application of the referred mathematical models to this road has evidenced this miss adjustment. Figure 3 presents the results of applying the linear regression model to the N111. Results are presented in two ways: $S_{est\_MR}$: (estimated speed) the continuous variable which results from the equation and; $S_{aj\_MR}$ (adjusted estimated speed) which corresponds to the previous result but rounded to the nearest value of the set: 50; 70 or 90Km/h, which were the expert choices.

Thus we should underline the fact that the major part of the segments which were signalized with the 50km/h limit have a conflict level which could be compatible with a 70 or 90 km/h limit. One should also stand out that there was not even one road segment (200m) which the model pointed out that should be imposed with the 50km/h limit.

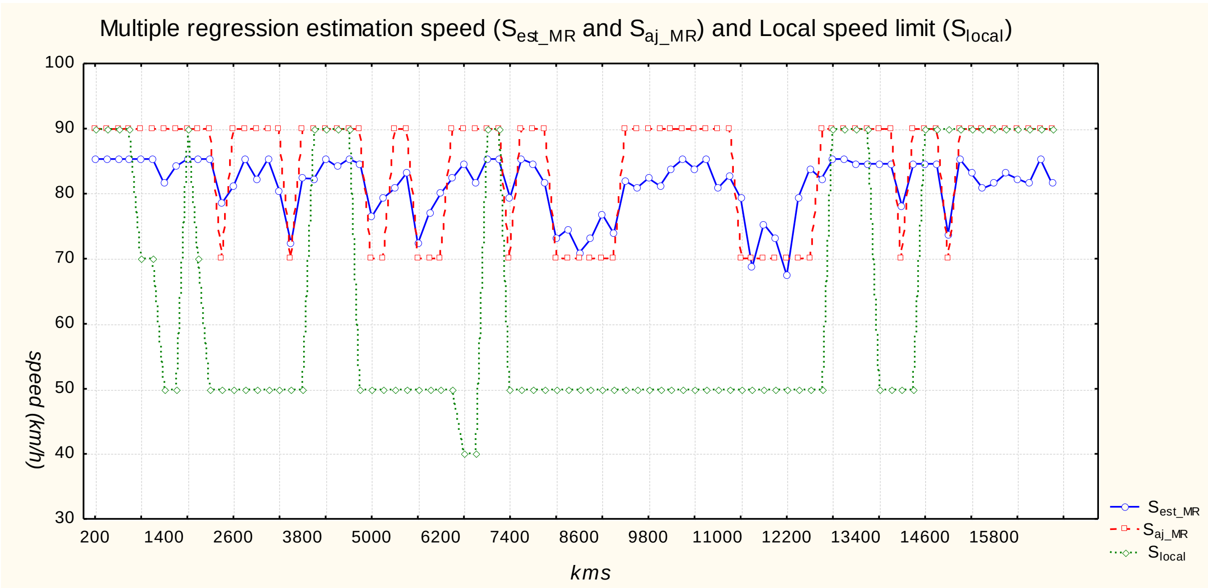


Figure 3 - Comparation of estimated speed limit (using multiple regression model) and local speed limit

We should however refer the difficulties which were felt regarding the final interpretation of the results, as the objective was to limit the choice of speed to pre-determined values the process of rounding to the nearest value is not adequate, because non significant differences may result in selecting legal speed limits which are very different. Which means that the estimated values of 79.9 and 80.1 would result in adopting a 70km/h limit in the first case and 90km/h in the second one. This type of conclusion has strengthened he need to use discrete choice models. Figure 3 presents the results of applying the logit model to the same data, using equation (2).

Some differences are evident between the results obtain using the two methods, moreover it is even more notorious the difference between the expert modeled speed and the local imposition. It is clear the tendency for having road segments which present some type of lateral urban occupation, which as we stated, have to be imposed a limit of 50km/h, when models are pointing to 70 or even 90 km/h.

Using as reference the logit model this difference is very notorious, we may conclude that only 26% of the analyzed segments the posted and modeled speed limits coincide. The comparative analysis of the results, shows that in their major part (41%) the segments are signalized with a 50km/h speed limit being the modeled speed of 70 km/h. Thus it is evident that there is the need for creating technical criteria which, in alternative or together with the road code, allow implementing differentiated speed limits, giving special importance to transition areas low density urban areas (typically compatible with the 70 km/h speed limit).

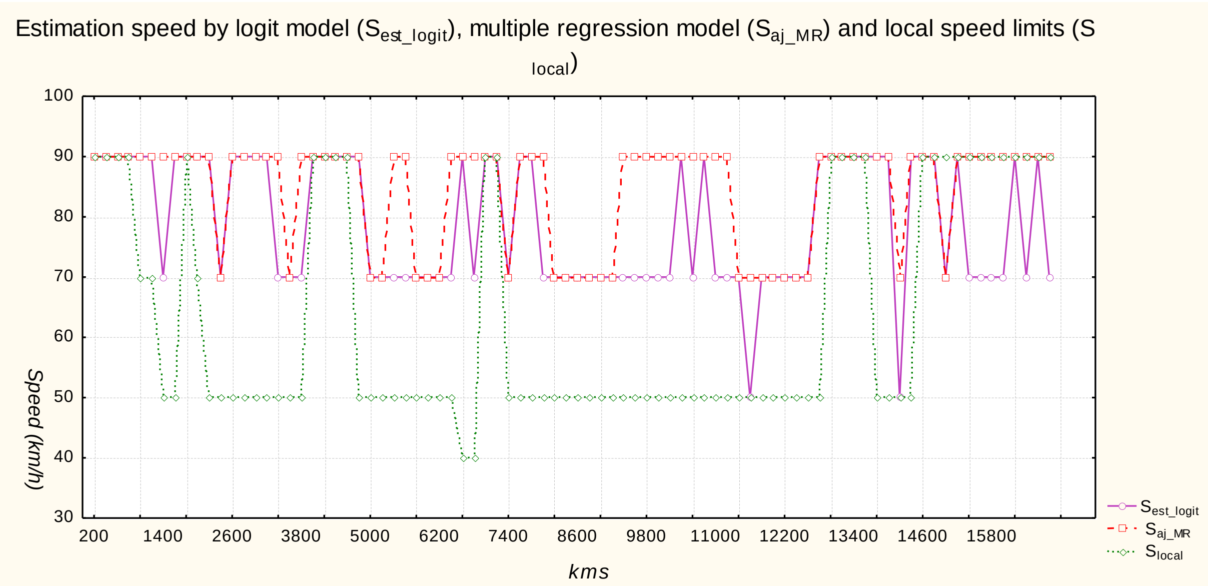


Figure 4 - Comparation of estimated speed limit (using logit model) and local speed limit

## MAIN CONCLUSIONS AND FUTURE WORK

This article aims to present an international and national, Portuguese, panorama on the theme of defining legal maximum speed limits. In an International level there have started to appear some informatics instruments for supporting this choice, however these need an ambitious set of data which may be difficult to obtain, and in the other hand they may not apply to all countries. In Portugal speed limits are still set as a result of applying the road code law, and the use of technical and objective criteria is scarce.

The methods herein presented aim to close this gap, making available a set of models, easy to apply and based in a set of limited information. Applying these models to a concrete case has evidenced the potential and defects of both of them and we may conclude that the discrete choice model, because of the fact that it points for the most adequate speed in a predetermined set of legal speed limits, is more adequate and robust.
Nevertheless some concerns and weaknesses were identified, and these should lead to new lines of research, namely:

- Refinement of the logit model through the sample increase and integrating new explanatory variables, e.g. optic with, presence of trees, systematizing automobile and pedestrian access, etc
- Defining an assessment process of the adequacy of each speed limit regarding the previous and following road segment. In fact this last concern should justify the analysis of the driver behavior and his reactions in face of speed limit variations, imposed in a more or less abrupt way, using a driving simulator.

It is however very clear that is only by using robust mathematical models that it is possible to contribute to the definition of adequate speed limits thus assuring the standardization of the solutions used throughout all the national road system, hence respecting and understanding the natural driver expectations.

It is therefore expectable that only a conjugate approach using the philosophies that integrate aspects related to the engineering, driver's expectations and operational characteristics can effectively contribute to the control of the accident levels. It is also necessary to recognize that without substantial, and often expensive, traffic calming measures speed limits without proper and effective enforcement usually results in ineffective speed management. Consequently, speed enforcement and sanctions will generally be needed to ensure compliance with speed limits.

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