Traffic Noise Impact in Road Intersections

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Abstract**—**In the framework of urban environmental control, acoustical noise is considered one of the most important physical polluting agents. In particular, urban area are strongly affected by noise coming from vehicular traffic. Nowadays traffic noise models are mainly used to predict traffic noise in urban general environments and don't takes into account conflicting points, such as intersections. Only some models consider the addition of a constant penalty due to the presence of a road intersection. In this paper the authors summarize the classification and the choice criteria of different intersections typologies, and then investigate the noise impact of different road intersections both on a review plan and on a software aided performance. The introduction of graphical elements for designers and engineers, able to furnish hints for the choice of intersection typology and geometrical features, based on the acoustical impact on urban environment, is pursued. Noise maps, easy to be read by final user, are produced for different intersection typology and compared by means of contour lines or areas.

Keywords**—**Noise Control, Acoustical Traffic Noise, Road Intersections, Predictive Software.

I. INTRODUCTION

NOWADAYS the control of vehicles traffic flow in an urban environment is of a fundamental importance in the framework of the development of infrastructures in new residential and/or industrial zone of a growing city. If one wants to control the environmental impact of the new constructions, many physical polluting agents should be taken into account, such as noise and air pollution. A wide specific literature presents many suitable procedure to monitor these parameters. In particular, for the noise problem, we refer to Harmonoise and IMAGINE projects (*Improved Methods for the Assessment of the Generic Impact of Noise in the Environment*) [1, 2], funded by the European Community, which present an exhaustive description of the noise calculation, measurement and mapping problems. Moreover, in the Harmonoise project, there is the final and ambitious aim of producing an European common standard criterion for the characterization of noise sources and for the evaluation of their impact on the human being life.

Very often, the noise problem is not well considered in the design of a new infrastructure, since only in the late years, most of the European countries are issuing a formal reference regulation on the noise control matter. Moreover the noise problem is not felt very important for human health with respect, for example, to air pollution or electromagnetic fields. This is probably due to a low perception of the risk and of the possible damages of noise, especially before the problem occurs, i.e. before the noise source is operating. More on this topic can be found in [3], where some of us proposed the definition of an overall Health Quality Index (HQI), based on the evaluation and on the monitoring of some physical polluting agents, such as noise, electromagnetic fields, fine dust and other air components, temperature and humidity.

In general, scientific literature and law regulation consider road traffic as one of the main noise source in an urban area, together with railways, industrial areas and airports.

It is quite evident that noise coming from vehicular traffic is strongly influenced by some "intrinsic" parameters (coming from the noise production and propagation processes), such as traffic volume, traffic flow, velocity, road features, etc., and other "specific" parameters (dependent on the particular area of interest), such as kind of vehicles, speed limits, vehicles maintenance duties, law emission thresholds, driving skills, amount and typologies of road intersections, etc..

All these parameters can be implemented in a so-called Traffic Noise predictive Model (TNM), which, in general, has the aim of predicting the noise equivalent level once the traffic flow is given. A review of the most used TNMs can be found, for example, in [4], where the authors performed a careful comparison and exploited the features that make the models to produce results eventually different from each others. The general expression of a TNM can be formulated in a three parameters formula as follow:

$$L_{eq} = A \cdot LogQ\left[1+\frac{P}{100}(n-1)\right]+b \cdot Log(d)+C \qquad (1)$$

where L_{eq} is the acoustic equivalent level (defined later), Q is traffic volume in vehicles per hour, P is the percentage of heavy vehicles, n is the acoustical equivalent and d is the distance from observation point to center of the traffic lane. The A, b and C coefficients may be derived, for a fixed investigated area, by linear regression methods on many L_{eq} data taken at different traffic flows (Q,P) and distances (d). The acoustical equivalent, n, (defined as the number of light vehicle that generate the same acoustic energy of an heavy

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one) can be estimated both by regression method or by single vehicle emission measurements.

Besides these models that work on the prediction of noise level, there are many models able to predict the traffic volume on a given road or on a given network. A wide literature in this direction is present and it is mainly divided in two classes: one more oriented on regulation and engineering issues, the other focusing on physical and dynamical aspects of the traffic problem, which, for example, can be implemented with graph theory (scale free schemes, cellular automata, etc.) or, more in general, with complex network theory.

To the first class, for example, belongs the *Highway Capacity Manual* [5] or [6], where the evaluation of a road or network typology is performed on the basis of the calculation of its capacity and level of service for individual elements of the surface transportation system and also for systems which contain a series or combination of individual facilities.

On the other hand, one can find very deep investigations on traffic phenomena, for example, in [7, 8, 9, 10], where modern techniques are applied to this field.

The integration between these complex dynamical traffic model and an innovative TNM will be the aim of forthcoming investigations.

In this paper, instead, the main idea is to focus the noise control problem on the intersection issues. The comparison between noise impact from different intersection typologies is performed, after a brief discussion on the classes and the criteria that lead to the choice of a particular junction. The prediction of noise level is calculated in the CadnaA software framework.

We remind that the results are given in term of the acoustical equivalent level, L_{eq}, defined as:

$$L_{eq} = 10\,Log\left(\frac{1}{\Delta t}\int_{t_1}^{t_2}\frac{p^2(t)}{p_0^2}\,dt\right) \tag{2}$$

with $\Delta t = t_2 - t_1$, which can be easily related to *SEL*, defined as:

$$SEL = 10\,Log\left(\frac{1}{t_0}\int_{t_1}^{t_2}\frac{p^2(t)}{p_0^2}\,dt\right) \quad with\ t_0 = 1s \tag{3}$$

If one defines: $\tilde{p}^2 = \frac{p^2(t)}{p_0^2}$ and considers $k = 3$ categories (motorcycles, light and heavy vehicles), we can write:

$$\int_{t_1}^{t_2}\sum_{k=1}^{3}\left(\sum_{j=1}^{N_k}\tilde{p}_j^2\right)dt = \sum_{k=1}^{3}\sum_{j=1}^{N_k}\int_{t_1}^{t_2}\tilde{p}_j^2\,dt = \sum_{k=1}^{3}\sum_{j=1}^{N_k}10^{0.1SEL_j}$$

where N_k is the number of vehicles belonging to the k-esim category. Multiplying and dividing for Δt, one can relate L_{eq} with *SEL* :

$$\left[\frac{1}{\Delta t}\int_{t_1}^{t_2}\sum_{k=1}^{3}\left(\sum_{j=1}^{N_k}\tilde{p}_j^2\right)dt\right]\Delta t = 10^{0.1L_{eq}}\ \Delta t = \sum_{k=1}^{3}\sum_{j=1}^{N_k}10^{0.1SEL_j}$$

In the end, we find:

$$10Log10^{0.1L_{eq}} + 10Log\Delta t = 10Log\left(\sum_{k=1}^{3}\sum_{j=1}^{N_k}10^{0.1SEL_j}\right) \Rightarrow$$

$$L_{eq} = 10Log\frac{1}{\Delta t} + 10Log\left(\sum_{k=1}^{3}\sum_{j=1}^{N_k}10^{0.1SEL_j}\right) \tag{4}$$

which is the required relation.

II. INTERSECTIONS CLASSIFICATION

The “road intersection” is defined as the area obtained by the convergence in the same point of three or more road branches.

The intersections, wherever they are localized, constitute a critical point for a road network because of the crossing of different traffic flows. They are divided into three main categories:

- *Planar Intersection*, subdivided in *linear intersections* and *roundabouts*, where the converging roads are coplanar, with consequent interferences between transiting and curving currents.
- *Traffic Light Controlled Intersections*, which are still coplanar crossings, but there is a periodic and alternate stop of the traffic currents. They are used quite exclusively in urban and suburban ambits.
- *Not Planar Intersections*, in which the separation of the different transit currents is obtained through overpasses, while the connection between the two streets is given by one or more exchanging ramps.

In the following, we will briefly report a description of the main planar intersection typologies, including the traffic light controlled ones.

A. Linear Planar Intersection

To this category belong all the Linear Planar Intersections without traffic lights, with three or four branches, that are the roads converging in the conflict point. If the number of branches is five or more than five, it is preferable to adopt the roundabout solution.

These intersections are particularly suitable for secondary or local roads, where, in general, flows and velocities are not extremely high. Depending on reference velocities and on vehicles flows, one could find different configurations for the intersection, from the simplest to the most complex ones. For example, in the local road ambits, one can have the standard simple “cross configuration” (see Fig. 1), with smooth borders and a radius ranging from 6 to 8 meters, in order to allow turnings, also in low speed regime.

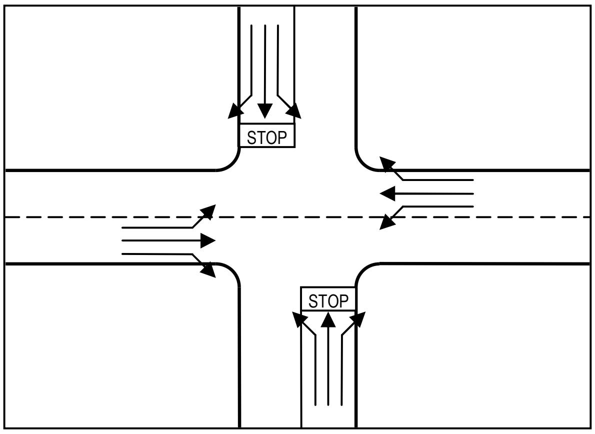

Fig.1: Example of simple cross intersection.

Moreover, if velocity and traffic volume grow, in order to improve safety and functionality of the intersection, one could insert special lanes of deceleration, acceleration and accumulation (waiting), or one could realize shaped island to favour the regulation of flows.

The regulation is made on the basis of national laws, but, in general, is achieved thanks to priority signals for some currents and STOP signals for others, with the additional rule that a STOP on the principal road is predominant to a STOP on the secondary one. In quite all the intersection schemes, the central part of principal road is devoted to waiting (accumulation) for vehicles turning on the left (see Fig. 1), while acceleration and deceleration lanes, that help exit and enter actions, are present on the principal road only in more complex schemes. The insertion of these special lanes is decided on the basis of a deep evaluation study, in which one should take into account the interfering flows entity and the frequency of conflicting turning actions by vehicles engaging the intersection. An overview of the criteria that help these evaluations can be found in the next section, while, for a deeper description, one can refer to literature, for example to [5, 6].

B. *Roundabout Intersection*

The roundabout is a planar intersection constituted by a ring drivable only in one direction, from vehicles coming from different branches.

During last years, roundabouts design has evolved from a starting planning scheme where the priority was assigned to entering flows with respect to vehicles running on the ring. This scenario resulted in the disadvantage that an increase in entering flows could bring to a congestion in the area between two following branches of the roundabout, i.e. the exchange area. Thus, in order to guarantee the functionality of these intersections, too large dimensions where required, especially for ring diameter, with consequent higher building costs.

Subsequently, in order to avoid these problems, the design evolved towards a more efficient scheme, giving priority to vehicles running on the ring, respect to the entering ones. This brought to a sensible lowering of the ring diameter and to the introduction of the “*compact roundabouts*” instead of the first ones. In the compact roundabouts, the central island is not drivable. Nowadays, in urban ambit, designers are preferring smaller dimensions for the central island, resulting in a kind of “*mini roundabouts*”. In these element, the island is drivable, so that heavy vehicles are not prevented from transiting in that intersection.

Many states are installing roundabouts instead of traditional intersections because of clear evidence that roundabouts dramatically reduce the incidence of severe injury and death for vehicle occupants involved in crashes at intersections [11, 12, 13]. It also often occurs that traditional intersections are replaced by roundabouts in some critical situation, where the traffic flow needs to be better reorganized.

In the past, the principal design element of roundabouts was the length of exchange zones, that were calculated according to theoretical models based on the “*critical interval*” concept, which is the minimal time interval needed to perform an action (entering or exiting the intersection, turning) [5].

Models used nowadays for the calculation of modern roundabouts parameters, are based also on experimental issues [6]. This is due to the need for a rigorous description of users behavior, which is a really difficult issue. From a general point of view, the user approaching the roundabout should wait a suitable gap before entering the ring, but, very often, this does not happen and the driver enter the ring using a lower interval with respect to the critical one. This leads to a slow down in the ring current, with a significant growth of the accident risk.

In general the roundabout design main criterion consists in the assignment of geometrical features able to satisfy the traffic demands and in the verify of the relative level of service and safety.

Finally, we can summarize the principal advantages coming from the adoption of a roundabout intersection.

- Easiness in turning and global reduction of waiting times, which become equilibrated between different currents, since it doesn’t exist a hierarchy between different flows.
- Better managing of traffic fluctuations with respect to traffic light intersections with fixed time.
- Consequent reduction of acoustic and atmospheric pollution.
- Growing, in general, of the safety level [11, 12, 13].
- Efficient connection from non urban fast roads to suburban and local ones.
- Possibility to invert the direction without dangerous actions.
- Easiness of insertion in urban sites, where many squares are already configured in a ring scheme.

Moreover, it is important to remark that the adoption of roundabouts is not recommended where some particular conditions, here briefly reported, occur.

- Small intersection, which results in lack of space for the installation of a suitable roundabout. The roundabout, in fact, needs much more space with respect to standard intersections.
- Not equilibrated flows. When there is a strong difference between the currents converging to the conflict point, it could be more functional to realize an adaptive traffic light controlled intersection.
- High speed traffic currents. If one current, usually the principal one, has not a strict speed limit, the roundabout could lead to a unnecessary reduction of velocity.
- High volume of public transportations connections, that cannot use dedicated lanes.
- Contemporary presence of heavy vehicles and motorcycles. In this case, the roundabout is more dangerous than a standard intersection.
- High flows of pedestrians, that are not favoured from this configuration.

C. Traffic Light Controlled Intersection

The Traffic Light controlled intersections are probably the most used intersections in the big cities, where the traffic flows need to be carefully organized and merged with the pedestrian ones. In the previous subsections, in fact, it has been explained how one can improve the circulation in proximity of a critical node of the road network, but the pedestrians issue is quite always neglected in a traffic optimization process. The traffic light helps to improve pedestrian safety, especially in urban environment, because it can have a cycle which provides a time interval totally dedicated to pedestrian crossing.

One can distinguish three main classes of traffic lights.

- *Fixed cycle traffic light*, characterized by constant time intervals of the cycle; they are particularly used where the flows are almost stable during all functioning time.
- *Adaptive traffic lights at the node level*, which can change their time intervals for each intersections. They are equipped with some sensors, placed along the various branches of the intersection, that allow the traffic light to adapt cycle’s phases depending on the traffic demand of each road.
- *Adaptive traffic lights at the network level*, which are similar to the previous ones, but which adapt their cycles on the basis of data coming from the overall road network.

The calculus of traffic lights cycle consists in defining the number of phases in which the cycle itself has to be divided and which currents can have the green light in each phase. One can find a more exhaustive description of these calculations in literature, for example in [6].

III. INTERSECTION CHOICE CRITERIA

The design of a new road corresponds, in general, to the insertion of new road branches and nodes in the actual road network. The choice of a given path fixes the choice of the nodes position, i.e. the position and the typology of the intersections.

Once the position has been fixed, the choice between the three different kind of intersections described above comes from the different kind of roads that converge in the node, in particular from the network in which the intersection has to be inserted.

In this section we will refer in particular to the Italian “*New Road Regulation*” (“Nuovo Codice della Strada”) which has been issued in 1992 and updated in 2009 [14].

In this regulation, roads are classified as follows:

- A: Highways (urban or not)
- B: Primary extra urban roads
- C: Secondary extra urban roads
- D: Urban road with continuous flow
- E: Urban road
- F: Local road (urban or not)
- F-bis: Cycle-pedestrians route

Starting from these categories, four levels of networks can be introduced.

1. Primary Network

It is the network of class A roads, that are supposed to provide national or inter regional connections. This network serves long distance connections and has to be designed with high average speed features; this network is forbidden to some components of traffic, such as pedestrians, light motorcycles, etc..

2. Principal Network

B and D road categories belong to this network and their role is to distribute flows from the Primary Network to the secondary ones, or, eventually to local roads. The average speed of this kind of network is usually lower than the speeds of the Primary Network and also here, some traffic components are excluded.

3. Secondary Network

It includes C and E roads that ensure movements towards the local connections. The average speeds result to be still lower than the previous networks but this time there are not any limitations to traffic components.

4. Local Network

F class roads belong to this network with access function; in this network one finds the lowest average speeds and, also here, there are not any limitations to traffic components.

To these four network levels, four interconnection classes are associated, with the same names: Primary, Principal, Secondary and Local. In order to achieve a suitable functioning of the global network, connections should be realized between roads of the same class of network (*homogeneous connection*) or between roads belonging to adjacent network classes (*non homogeneous connections*), as reported in Tab. 3.1.

Network Classes	**Roads**			
	Primary (A-B)	Principal (B-D)	Secondary (C-E)	Local (F)
Primary	PR-H	PR-NH		
Principal	PR-NH	PN-H	PN-NH	
Secondary		PN-NH	SC-H	SC-NH
Local			SC-NH	LC

PR-H = Primary Homogeneous connection
PR-NH = Primary Non Homogeneous connection
PN-H = Principal Homogeneous connection
PN-NH = Principal Non Homogeneous connection
SC-H = Secondary Homogeneous connection
SC-NH = Secondary Non Homogeneous connection
LC = Local connection

Tab. 3.1 - Connections allowed for the network classes

	A Non urban	A urban	B	C	D	E	F extra	F urban
A Non urban	OE							
A urban	OE	OE						
B	OE	OE	OE					
C	OI	OI	OI	PI/ TL*				
D	OE	OE	OE	OI	OE/ TL*			
E	OI	OI	-	PI/ TL	OI/ TL*	PI/ TL*		
F extra	-	-	-	PI	-	PI	PI	
F urban	-	-	-	PI	-	PI/ TL	PI	PI

OE = Overpasses with exchange lanes
OI = Overpasses with exchange lanes and planar intersection
TL = Traffic Light controlled intersection
PI = Planar intersection
* In some exceptions for particular local configurations

Tab. 3.2 - Connections allowed for intersections typologies

It is important to remark that Homogeneous Connections are always convenient to be realized, while connections between different classes, if allowed, have to be carefully examined, especially on the economic point of view.

In Tab 3.2, the allowed connections and the intersection categories are reported per each couple of roads, according to the [14] ranking.

At this point, the typology of intersection, inside each categories, is chosen according to the following elements:

- Safety
- Functionality
- Environmental Impact
- Building Costs and Maintenance

In particular, referring to safety issues, the position of the crossing is very important: it is necessary that it is clearly visible and perceived from users and pedestrians. In order to perform an optimal design, one should also consider the statistics of accidents and injuries corresponding to different typologies of intersections. These statistics, in fact, could be used as indexes of high or low safety.

Functionality is evaluated determining some performing indexes particularly significant, such as: waiting time intervals, average number of queued vehicles, total average delay, level of service, capacity and, in the roundabout configuration, simple or overall capacity.

Concerning the effects of traffic on the environment, it must be considered that noise and exhaust gases or fine dust (air pollution) emissions grow especially in correspondence of planar intersections. In fact, in these cases, because of the intrinsic features of circulation (interrupted flow), characterized from the preeminence of accelerating and decelerating phases, one could find significant values for noise levels emissions and exhaust gases and fine dust concentrations.

In local urban ambits, a particular care has to be devoted to weak users, such as pedestrians, bicycles and light motorcycles, and it should be preferred to use traffic lights, especially in the major intersections.

Finally, from these considerations, one can affirm that, at least in the most difficult cases, the choice of the typology of intersection cannot be performed only on the basis of regulation issues and/or expertise and knowledge of the designer, but it should be supported by an analytical calculation which compares direct and not direct benefits and costs, considering all the social components, not only the users.

IV. INTERSECTIONS NOISE IMPACT

In this section a brief review of studies on the acoustical impact of intersections is reported, with a particular emphasis on the noise reduction corresponding to some useful interventions [15].

In general, the presence of an intersections leads to a growth of the noise level in that point, proportional to the traffic flow, since there will always be many conflicting actions, such as turning, breaking, acceleration, etc.. In literature several studies tried to give an estimation, both on an experimental and on a theoretical basis, of the noise impact of different typologies of intersections.

For example, on the experimental point of view, an American study [16] affirms that roundabouts decrease noise level compared to traffic light controlled intersections. On the other hand, due to the high rate of accelerations at the exit of the roundabout, noise equivalent level could be increased from 1 to 2 dBA with respect to continuous traffic (without intersections).

Another paper [17] reports that, in the Japan case study, the installation of traffic lights brings to different noise impacts, depending on various traffic conditions. In average, the noise level close to signalized intersection is reported to be 2.4 dBA higher than a fluid continuous traffic flow.

On the other hand, in the past, many theoretical Traffic Noise Models (TNMs) have been developed [4]. Many of them do not consider the presence of intersections, except, in some cases, for a constant corrective element. A deeper description can be found in [18], where three different typologies of traffic noise prediction models are presented and applied to an intersection case study, with the simulation of a roundabout or of a traffic light controlled junction. The result is that in a under-saturated traffic flow regime, the roundabout induces to a 2.5 dBA noise reduction compared to signalized intersection, while in over-saturated regime, i.e. in presence of traffic congestion, the noise impact is quite balanced.

Despite of these considerations about noise increase due to traffic lights, very often one cannot replace signal-controlled intersections with roundabouts because of geometrical issues or high pedestrian flows (see previous sections). In these cases, the optimization of traffic fluidity close to traffic light controlled intersections, can result in a lowering of the noise equivalent level.

In fact, a study in Geneva [19] demonstrates that the active adaption of traffic lights cycles to the vehicles speed, so that a vehicle should not decelerate or accelerate in correspondence of the intersection, can lead to a decrease up to 2 dBA in the noise equivalent level.

V. PREDICTIVE SOFTWARE SIMULATIONS

This section is devoted to the simulation of noise impact of three different intersection configurations, by means of a noise predictive software, CadnaA, licensed by DataKustik, which can predict the noise equivalent level induced by different kind of sources.

This software is based both on “Angle Scanning” and on the inverse “ray-tracing” principle: area under analysis is divided in many small surfaces in which a receiver is placed at a variable height, so that to build a determined calculation grid. Each receiver releases many rays with a full angle coverage (omni directive) and these rays, eventually after many reflections, intercept the noise source. The path length of the single ray describes the attenuation of the sound wave coming from a certain noise emitter.

In some previous papers [20, 21] we exploited the simulation tools related to railway noise, embedded in this framework. In this case, instead, the simulation is performed according to the French traffic noise model (*Nouvelle Méthode de Prevision du Bruit* – NMPB), embedded in CadnaA, which is also suggested by European Community as a standard reference model [22]. According to this model, the long-term prediction level for each path $L_{Ai,LT}$ is evaluated as follow:

$$L_{Ai,LT} = 10 Log\left(p_i \, 10^{\left(0.1 L_{Ai,F}\right)} + (1 - p_i) 10^{\left(0.1 L_{Ai,H}\right)}\right) \quad (5)$$

where $L_{Ai,F}$ and $L_{Ai,H}$ are the global levels evaluated respectively for favorable (as defined in ISO 9613) and homogeneous conditions and p_i represents the probability of occurrence of favorable conditions. These two levels are calculated for each octave band and for each path from the source, according to the following formulas:

$$\begin{aligned} L_{Ai,F} &= L_{A,w} - A_{div} - A_{atm} - A_{grd,F} - A_{diff,F} \\ L_{Ai,H} &= L_{A,w} - A_{div} - A_{atm} - A_{grd,H} - A_{diff,H} \end{aligned} \quad (6)$$

For each path the algorithm subtracts three different attenuations from the power of the source $L_{A,w}$: the geometrical spreading A_{div} and the atmospheric absorption A_{atm}, that are the same in both formulas, and the boundary attenuations A_{bnd}, which depends on the propagation conditions and are determined by ground effect (A_{grd}) and diffraction (A_{diff}).

The case study here considered is a building placed in proximity of an intersection between a principal road, which is a non urban secondary road (class C), and two local connections.

The principal road is characterized by a design velocity interval ranging from 60 Km/h to 100 Km/h and by a single carriageway 7.50 m large, with double lanes, each of them 3.75 large, with 1,50 m of external path.

Finally, the simulation needs as input the following parameters:

1. The geometry of roads and intersection.
2. Traffic flow data, chosen as 400 vehicles/h for the principal road and 200 vehicles/h for the local roads, together with accelerating or decelerating features, if necessary.
3. Road pavement, chosen as smooth asphalt.
4. Speed limits, chosen as 60 and 100 Km/h for the principal road, respectively for heavy and light vehicles, and 50 Km/h for the local ones.
5. Road gradient, fixed at 0%.
6. Heavy vehicles percentage, fixed at the default value, i.e. 20% of the overall daily traffic flow.

After these parameters have been fixed and the configuration is implemented in CadnaA, the simulation is performed with three different intersection typologies: traffic light controlled intersection, roundabout and linear planar intersection with exchange lanes. The calculation is performed inside a suitable grid formed by 10 x 10 m cells. Moreover, the height of the receiver is fixed at 1.5 m from the ground.

In Fig. 2, the results of the simulation are shown. Observing the noise maps, it is quite easy to notice that the traffic light configuration results in a higher equivalent level, while the roundabout gives the better result, with a significant lowering in the noise evaluated on the building façade.

VI. CONCLUSIONS

In this paper an almost complete description of the road intersection problem has been presented, both on the transportation issue and on the acoustical point of view.

The simulation schemes of three different intersection configuration has been implemented into the CadnaA software. Let us remark that this software has been employed both on the predictive and on the graphical point of view. In fact, a clear and "easy to read" representation of the simulation results can provide a direct feedback of the expected noise coming from a particular configuration.

In our opinion, this is a really important issue, since, very often, designers cannot easily predict the noise impact of a project under development and cannot foresee which configuration better fits the need of that specific area. Thus the development of a tool able to easily give the noise environmental impact information of a particular intersection, by means of a predictive software, can become a useful step in the design process, in order to optimize the acoustical part of the project.

REFERENCES

[1] HARMONOISE Project, Final technical report, HAR7TR-041213-AEAT04.doc

[2] IMAGINE Project, State of the art, IMA10TR-040423-AEATNL32

[3] Quartieri J., Troisi A., Guarnaccia C., D'Agostino P., D'Ambrosio S., Iannone G., Development of an Environmental Quality Index Related to Polluting Agents, Proceedings of the 7th WSEAS Int. Conf. on "Environment, Ecosystems and Development" (EED'09), Puerto De La Cruz, Canary Islands, Spain, December 14-16, 2009, ISBN: 978-960-474-142-7 / ISSN:1790-5095, pp. 153-161.

[4] J. Quartieri, N. E. Mastorakis, G. Iannone, C. Guarnaccia, S. D'Ambrosio, A. Troisi, TLL Lenza, *A Review of Traffic Noise Predictive Models*, Proceedings of the 5th WSEAS Int. Conf. on "Applied and Theoretical Mechanics" (MECHANICS'09), Puerto De La Cruz, Canary Islands, Spain, December 14-16, 2009, ISBN: 978-960-474-140-3 / ISSN: 1790-2769, pp. 72-80.

[5] *Highway Capacity Manual*, National Research Council, Washington, DC, 2000.

[6] Myer Kurz (editor), *Handbook of Transportation Engineering*, McGraw-Hill (2004)

[7] D. Helbing, S. Lämmer, J.-P. Lebacque, *Self-organized control of irregular or perturbed network traffic*, in C. Deissenberg and R. F. Hartl (eds.) "Optimal Control and Dynamic Games" (Springer, Dortrecht, 2005), pp. 239-274

[8] J. Esser And M. Schreckenberg, *Microscopic Simulation Of Urban Traffic Based On Cellular Automata*, International Journal of Modern Physics C, Vol. 8, No. 5 (1997) 1025-1036

[9] J.J. Wu, H.J. Sun, Z.Y. Gao, *Dynamic urban traffic flow behavior on scale-free networks*, Physica A 387 (2008) 653–660

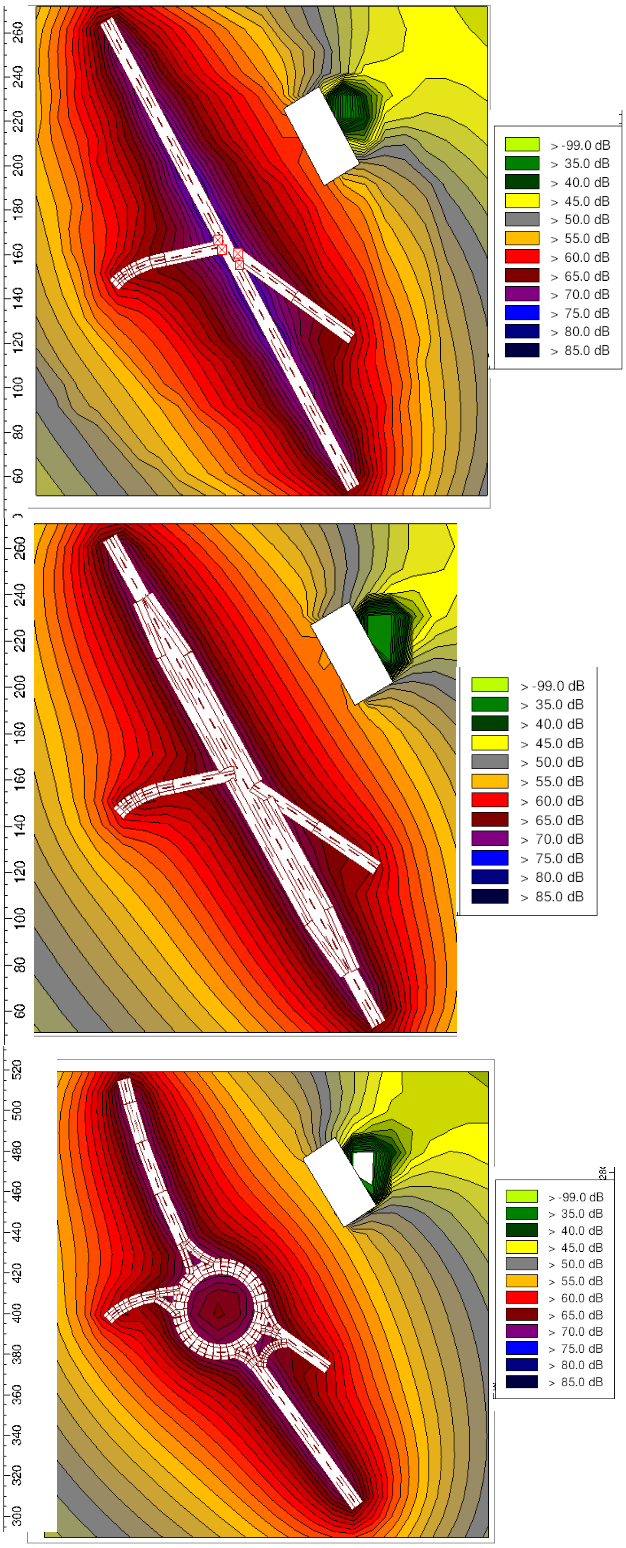

Fig.2: Simulation results. Top: Traffic light controlled intersection. Middle: Planar intersection with exchange lanes. Bottom: Roundabout.

[10] D. De Martino, L. Dall’Asta, G. Bianconi, M. Marsili, *Congestion phenomena on complex networks*, Physical Review E 79, 015101 R (2009)

[11] R. Elvik, *Effects on road safety of converting intersections to roundabouts—review of evidence from non-US studies*, Transp. Res. Rec. 1847 (2003) 1 – 10

[12] R.A. Retting, et al., *Crash and injury reduction following installation of roundabouts in the United States*, Am. J. Public Health 91 (4) (2001) 628– 631

[13] A. Flannery, *Geometric design and safety aspects of roundabouts*, Transp. Res. Rec. 1751 (2001) 76– 81

[14] D. L. 30 April 1992, n. 285, “*Nuovo codice della strada*”, Suppl. ordinario Gazz. Uff., 18 May 1992, n. 114 – Updated with D.L. 15 July 2009, n.94

[15] V. Desarnaulds, G. Monay, and A. Calvaro, *Noise reduction by urban traffic management*, International Congress on Acoustics-2004, Kyoto

[16] Nelson, P. M., *Transportation noise reference book*, Butterworths, London, 1987

[17] Tsukui, K. and Oshino, Y., *Basic Study of the Increase in Road Traffic Noise Caused by the Installation of Traffic Lights*, Japan Automobile Research Institute Journal, 23(10), 2001

[18] E. Chevallier, A. Can, M. Nadji, L. Leclercq, *Improving noise assessment at intersections by modeling traffic dynamics*, Transportation Research Part D 14 (2009) 100–110

[19] Plan des mesures d'assainissement du bruit routier selon OPB art. 19, République et canton de Geneva, 1998.

[20] Quartieri J., Troisi A., Guarnaccia C., Lenza TLL, D’Agostino P., D’Ambrosio S., Iannone G., *Application of a Predictive Acoustical Software for Modelling Low Speed Train Noise in an Urban Environment*, WSEAS Transactions on Systems, Issue 6 Vol.8, pp. 673-682 (2009), ISSN: 1109-2777

[21] Quartieri J., Troisi A., Guarnaccia C., Lenza TLL, D’Agostino P., D’Ambrosio S., Iannone G., *An Acoustical Study of High Speed Train Transits*, WSEAS Transactions on Systems, Issue 4, Vol.8, pp. 481-490 (2009), ISSN: 1109-2777

[22] Directive 2002/49/EC of the European Parliament and of Council of June 25 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities, L189/12-25,18.7.2002

[23] J. Quartieri, M. Guida, C. Guarnaccia, S. D’Ambrosio, D. Guadagnuolo, *Complex Network Applications to the Infrastructure Systems: the Italian Airport Network case*, WSEAS Int. Conf. on Urban Planning and Transportation (UPT’07), Heraklion, Greece, July 22-24, 2008. ISBN: 978-960-6766-87-9 / ISSN 1790-2769, pp 96-100

[24] J. Quartieri, M. Guida, C. Guarnaccia, S. D’Ambrosio, D. Guadagnuolo, *Topological Properties of the Italian Airport Network studied via Multiple Addendials and Graph Theory*, International Journal Of Mathematical Models And Methods In Applied Sciences, Issue 2, Vol.2, pp 312-316 (2008), ISSN 1998-0140

[25] J. Quartieri, L. Sirignano, C. Guarnaccia, *Equivalence between Linear and Curved Sources in Newtonian Fields: Acoustics Applications*, WSEAS Int. Conf. on Engineering Mechanics, Structures, Engineering Geology (EMESEG '08), Heraklion, Greece, July 22-24, 2008. ISBN: 978-960-6766-88-6 / ISSN 1790-2769, pp 393-395

[26] J. Quartieri, L. Sirignano, C. Guarnaccia, *Infinitesimal Equivalence between Linear and Curved Sources in Newtonian Fields: Application to Acoustics*, International Journal of Mechanics, Issue 4, Vol.1, pp. 89-91 (2007), ISSN: 1998-4448

[27] Quartieri J., Troisi A., Guarnaccia C., Lenza TLL, D’Agostino P., D’Ambrosio S., Iannone G., *An Italian High Speed Train Noise Analysis in an Open Country Environment*, Proceedings of the 10th Int. Conf. on “Acoustics & Music: Theory & Applications” (AMTA '09), Prague (Rep.Ceca), 23-25 March 2009. ISBN: 978-960-474-061-1 / ISSN: 1790-5095, pp 92-99

[28] Quartieri J., Troisi A., Guarnaccia C., Lenza TLL, D’Agostino P., D’Ambrosio S., Iannone G., *Analysis of Noise Emissions by Train in Proximity of a Railway Station*, Proceedings of the 10th Int. Conf. on “Acoustics & Music: Theory & Applications” (AMTA '09), Prague (Rep.Ceca), 23-25 March 2009. ISBN: 978-960-474-061-1 / ISSN: 1790-5095, pp 100-107

[29] J. Quartieri, C. Guarnaccia, et al., *Measurements of high speed Train Noise Detected at a Relevant Distance and a Simple Numerical Model*, Proceedings of the 13th Int. Conf. on “Applied Mechanics and Mechanical Engineering”, AMME13, Il Cairo, Egypt, 27-29 May 2008

[30]J. Quartieri, C. Guarnaccia, et al., *Measurement and Analysis of Train Noise Detected on a Building Façade*, Proceedings of the 13th Int. Conf. on “Applied Mechanics and Mechanical Engineering”, AMME13, Il Cairo, Egypt, May 2008

[31] Quartieri J., Guarnaccia C., D’Ambrosio S., Iannone G., *Room Acoustics Experimental Study: Characterization of the Sound Quality in a New Built Church*, Proceedings of the 10th Int. Conf. on “Acoustics & Music: Theory & Applications” (AMTA '09), Prague (Rep.Ceca), 23-25 March 2009. ISBN: 978-960-474-061-1 / ISSN: 1790-5095, pp 108-115

[32] J. Quartieri, S. D’Ambrosio, C. Guarnaccia, G. Iannone, *Experiments in Room Acoustics: Modelling of a Church Sound Field and Reverberation Time Measurements*, WSEAS Transactions on Signal Processing, Issue 3, Vol.5, pp. 126-135 (2009), ISSN: 1799-5022

[33] J. Quartieri, S. Steri, M. Guida, C. Guarnaccia, S. D’Ambrosio, *A Biomathematical Study of a Controlled Birth and Death Process Describing Malignancy*, Advanced Topics on “Mathematical Biology and Ecology”, 4th WSEAS Int. Conf. (MABE'08). Acapulco, Mexico, January 2008. ISBN: 978-960-6766-32-9 / ISSN: 1790-2769

[34] S. D’Ambrosio, C. Guarnaccia, M. Guida, J. Quartieri, S. Steri, *A biomathematical study of a controlled birth and death process describing malignancy*, International Journal of Biology and Biomedical Engineering, Issue 1, Vol.1, pp 17-24 (2007), ISSN: 1998-4510

[35] J. Quartieri, S. Steri, G. Volzone, C. Guarnaccia, *A Nonlinear Model for Controlling the Evolution of Malignant Cells*, Proceedings of the 9th WSEAS International Conference on “Mathematics & Computers in Biology & Chemistry” (MCBC '08), Bucharest (Romania), 24-26 June 2008. ISBN: 978-960-6766-75-6 / ISSN: 1790-5125, pp 164-169

[36] Quartieri J., Steri S., Volzone G., Guarnaccia C., *A Model on Controlled Evolution of Malignant Cells and on Drug Balance between Blood and Tumor*, International Journal of Biology and Biomedical Engineering, Issue 3, Vol.1, pp 62-67 (2007), ISSN: 1998-4510

[37] S. Steri, J. Quartieri, G. Volzone, C. Guarnaccia, *On Picard Iteration and Lie Series in Analytic Evolutionary Problems of Physics*, Proceedings of the 9th WSEAS International Conference on Mathematics & Computers in Biology & Chemistry (MCBC '08), Bucharest (Romania), June 24-26, 2008. ISBN: 978-960-6766-75-6 / ISSN: 1790-5125, pp 157-163

[38] Steri S., Quartieri J., Volzone G., Guarnaccia C., *Evolutionary Processes Solved with Lie Series and by Picard Iteration Approach*, International Journal of Mathematical Models and Methods in Applied Sciences, Issue 2, Vol. 2, pp 262-268 (2008), ISSN: 1998-0140