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NOISE EMISSION CORRECTIONS AT INTERSECTIONS BASED ON MICROSCOPIC TRAFFIC SIMULATION

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ABSTRACT

One of the goals of the European IMAGINE project, is to formulate strategies to improve traffic modelling for application in noise mapping. It is well known that the specific deceleration and acceleration dynamics of traffic at junctions can influence local noise emission. However, macroscopic traffic models do not always model intersections, and if they do, only the influence of intersections on travel time is incorporated. In these cases, it would be useful to know what increase or decrease in noise production can be expected at or near intersections. A correction factor for road crossings has been suggested in several national noise emission standards. The question is open whether such a correction factor should be included in future harmonized methods. In this paper, a case study is presented, consisting of a large set of microscopic traffic simulations and associated noise emission calculations, which provides some insight into the specific dynamics of the noise emission near different types of intersections. A spatial approach is used, in which inbound and outbound lanes are divided into deceleration, queuing and acceleration zones. Results from regression analysis on the numerical simulations indicate that meaningful relations between noise corrections and traffic flow parameters such as traffic intensity and composition can be deduced.

1 INTRODUCTION

Most engineering models for the prediction of road traffic noise assume that roads can be divided into sections where the vehicle flow can be considered smooth and homogeneous. Traditionally, traffic flow calculations are based on macroscopic traffic flows, and thus the sound emission level caused by the traffic on each segment is modelled as a function of the average vehicle speed and the traffic flow rate. However, the assumption of a homogeneous traffic flow does not hold in the vicinity of intersections. Next to this, average vehicle speeds calculated by macroscopic traffic simulation models become unreliable near intersections. Finally, noise emission of stop-and-go traffic depends highly on vehicle acceleration, a parameter which can often not be reported by traditional traffic flow models.

Because of these complications, the influence of intersections, and more in general of interrupted traffic flows, is evaluated mostly in a pragmatic way. Some models do not include the impact of intersections at all (e.g. the French NMPB-96 method or the UK CRTN method). Other models include a propagation correction term for intersections with traffic lights (e.g. the Dutch RMW2002 model and the German RLS90 model). In spite of the fact that intersection corrections are only marginally taken into account in most prediction models in use today, there has been a reasonable amount of research on the topic of noise (reduction) from traffic management in the last three decades; a review can be found in [1].

Possibly driven by new advances in the field of traffic modelling and by the introduction of microsimulation models in traffic flow prediction, the study of noise at intersections gained renewed interest in the second half of the 1990s. Most scientific models, constructed to evaluate traffic noise in urban areas, consist of a coupling of a fluid dynamics macroscopic traffic model (e.g. [2]) or a microsimulation model (e.g. [3], [4], [5]), with a vehicle noise emission model and an advanced propagation model, and make it possible to assess (statistical) traffic noise levels at intersections in complex urban built-up environments.

Traffic noise prediction models that are accurate in the vicinity of interrupted traffic flows, will have to model vehicle speeds and accelerations. Microsimulation models include these dynamic effects. When traffic noise prediction is based on a traffic model that does not simulate the dynamics of intersections, a correction factor could be applied to incorporate the effects on noise emissions. In this paper, a possible method to derive such corrections will be described, based on the microsimulation of a large number of simple intersection scenarios. This work was carried out in the framework of the European IMAGINE project [6].

2 METHODOLOGY

The microsimulation models, implemented in Paramics [7], all consisted of an intersection of a major road and a minor road with traffic demands of resp. D_M and D_m. Both arms have only one lane in each direction, and the speed is limited to 70 km/h. Four different intersection types were considered: an intersection with a *priority-to-the-right* rule, an intersection where the major road has *priority*, an intersection with *traffic lights* and a *roundabout*. Six different scenarios were created by varying the traffic demands D_x on both arms. Furthermore, three variations in traffic composition (fraction of heavy vehicles F = 5%, 10% and 20%) and two variations in the percentage of traffic that turns left or right (turning rate R = 20% and 40%) were considered, resulting in 4×6×3×2 = 144 unique scenarios.

The simulation time considered was 1 hour with a simulation timestep of 0.5s. However, the actual simulations included an additional 10-minute period for traffic build up, and a 20-minute period after the actual simulation for travel time calculations. Due to the statistical nature of microsimulation, results differ between runs of the simulation; e.g. the actual simulated traffic flows (noted as Q_M and Q_m) will each time be somewhere around the traffic demands put forward. For each unique scenario, results were therefore averaged over 5 simulation runs with different seed values, to enable statistically sound conclusions.

Travel times were averaged for all trips departing within the 1 hour simulation period and for each lane separately. This way it is ensured that the travel times are comparable to those generated by static assignment models, in which it is assumed that all traffic completes its journey through the network within the simulation period. To determine free flow travel times, a fifth intersection type was added as a reference: a simple intersection without priority rules, for which simulations were done separately for traffic originating from each arm of the network. There is no interaction between vehicles arriving from different directions onto the intersection, and vehicles reach their destination in the minimum time. This way, the average extra travel time T needed for a vehicle to travel a lane, compared to the corresponding free flow situation where there are no delays, will be compatible with intersection delay, which is often a parameter in non-microsimulation models.

The noise emission of each vehicle in the simulation within a distance of 300m from the center of the intersection, is calculated for each simulation time step using a Paramics plugin [5]; the Harmonoise road traffic noise emission model was used [8]. The noise emission of all vehicles is then aggregated in lane segments (length 1m) to obtain the sound power level emitted by each lane segment, averaged over 1 hour of simulation. Noise maps of $L_{Aeq,1h}$ in a square of 200m×200m without buildings were calculated using the ISO 9613 propagation model [9] (hard surface).

3 RESULTS

Table 1 summarizes the average extra travel time T, for both the major and minor arms of the intersection. One can see that travel times increase with increasing traffic demand. For the major arm, the priority junction will obviously be the best choice in all cases; for the minor arm this would be the roundabout, which also seems to be the overall best intersection layout. Traffic composition F and turning rate R did not have a significant influence on travel times and were averaged out in Table 1.

Some intersection scenarios resulted in congestion: no stable traffic situation was achieved on the major and/or minor inbound lanes during simulation, with ever growing jams. In this case the calculated travel times will be unreliable. However, these types of intersections will in practice probably never be used for these traffic volumes. In some scenarios, the formation of a queue has an impact on noise emission (this will be made more explicit in the next section). Small queues can be formed in other situations, but their impact on noise emission will be negligible. E.g. for the intersection with traffic lights, at lower traffic demands still a fraction of the traffic can traverse the intersection without slowing down; the noise emission of these vehicles will then be dominant in the queuing area. Limits are not clear, but as a rule of thumb derived from Table 1, one can say that important queues are formed when $\log T > 1.4$, and that the network is congested when $\log T > 2$.

Table 1. Average extra travel time T [seconds]. Light gray values indicate the appearance of queues with an impact on average noise emission; dark gray values indicate congestion.

Traffic Demand D_M-D_m	Priority-to-the-right		Priority		Traffic lights		Roundabout	
	Major arm	Minor arm	Major arm	Minor arm	Major arm	Minor arm	Major arm	Minor arm
100-100	3.9	3.8	0.4	3.2	8.1	8.1	1.6	1.4
250-100	6.8	5.9	0.4	4.4	8.9	8.8	1.8	1.3
250-250	24.9	22.7	0.7	7.9	10.5	9.8	2.4	2.2
500-250	408.1	72.8	1.2	37.6	11.4	18.9	4.0	2.9
750-250	650.6	93.1	3.1	311.3	25.7	50.7	8.0	4.7
500-500	559.8	484.6	1.5	439.5	36.0	38.5	6.6	5.6

Table 2. Total noise level [dB(A)] emitted by traffic on the intersection, relative to the most quiet scenario.

Traffic Demand D_M-D_m	Priority-to-the-right			Priority			Traffic lights			Roundabout		
	$F =$ 5%	10%	20%	$F =$ 5%	10%	20%	$F =$ 5%	10%	20%	$F =$ 5%	10%	20%
100-100	0.0	1.8	3.8	0.1	2.0	3.9	0.1	1.9	3.9	0.0	1.8	3.8
250-100	2.6	4.3	6.2	2.8	4.5	6.5	2.6	4.4	6.3	2.6	4.3	6.2
250-250	4.3	5.9	7.9	4.4	6.0	8.0	4.4	5.9	7.9	4.3	5.9	7.9
500-250	6.1	7.9	10.0	6.1	7.8	9.8	5.9	7.5	9.6	5.8	7.5	9.5
750-250	6.3	8.0	10.1	7.5	9.3	11.4	7.0	8.7	10.8	6.9	8.6	10.6
500-500	7.2	9.0	11.1	7.3	9.1	11.1	7.0	8.7	10.8	7.0	8.7	10.6

To have an impression of the total noise generated on the intersection, the intersection can be considered as one large emission segment of 300m×300m, which makes it possible to compare different scenarios using a single value. Resulting noise emission levels are given in Table 2. There is no significant difference between intersection types, in contrast to what was found for the average travel time. However, there are large spatial differences, as will be shown in the next paragraph. Traffic composition F and demand D_x have a clear influence on total noise emission level, as can be expected.

Noise map examples of the signalized intersection, together with the differences in noise immission level with the other 3 intersections, are given in Fig. 1. The intersection type has a large influence on vehicle speed and acceleration, and as a consequence on local noise immission. For the roundabout, the large differences can be attributed to the different physical road layout and to the higher average speeds of approaching traffic on signalized intersections. For the priority junction, noise emission is larger along the major road because vehicles do not have to slow down, but smaller near the stoplines; for the priority-to-the-right junction, the opposite is true. These conclusions remain quantitatively valid for all non-congested scenarios.

4 EMISSION CORRECTIONS

Noise emission profiles along the lanes of all intersection scenarios were calculated. It was found that at larger distances from the center of the intersection, the sound emission level is independent of the location, as can be expected for cruising vehicles. Noise corrections will be based on this limit emission, because it is assumed that this is the usual emission output of

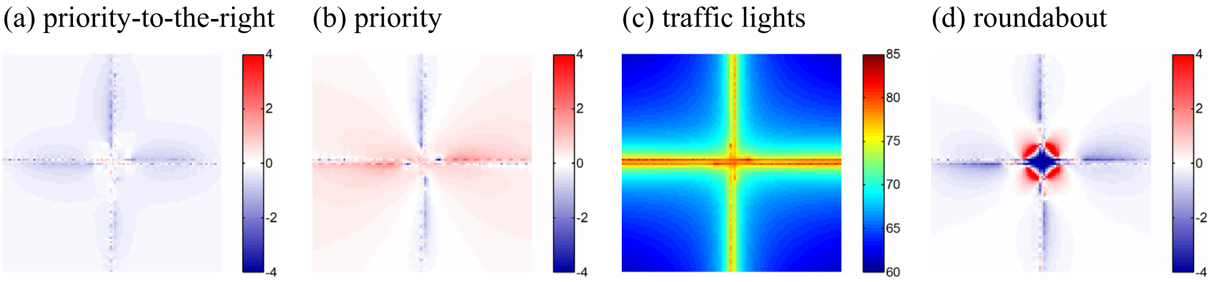
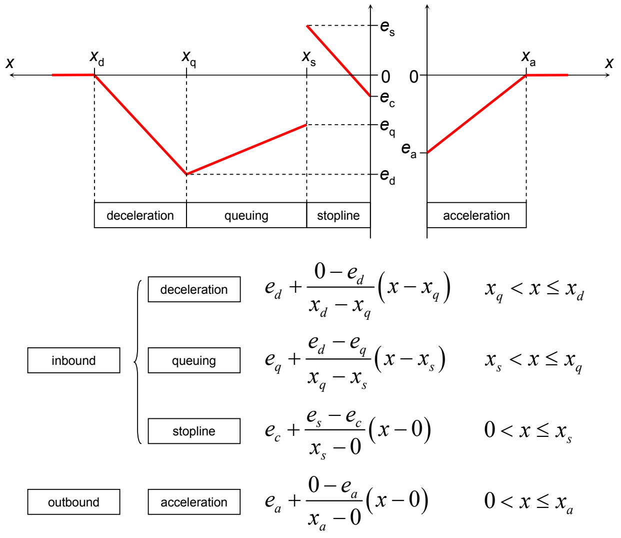

(a) priority-to-the-right (b) priority (c) traffic lights (d) roundabout

Fig. 1. Noise maps [dB(A)] for the different types of intersections (D_M=250 veh·h^{-1}, D_m=100 veh·h^{-1}, F=20%, R=20%). For maps (a), (b) and (d), the difference with map (c) is made.



$$e_d + \frac{0 - e_d}{x_d - x_q}\left(x - x_q\right) \qquad x_q < x \le x_d$$

$$e_q + \frac{e_d - e_q}{x_q - x_s}\left(x - x_s\right) \qquad x_s < x \le x_q$$

$$e_c + \frac{e_s - e_c}{x_s - 0}\left(x - 0\right) \qquad 0 < x \le x_s$$

$$e_a + \frac{0 - e_a}{x_a - 0}\left(x - 0\right) \qquad 0 < x \le x_a$$

Fig. 2. Proposed correction model for to the priority-to-the-right, priority and signalized junctions.

macroscopic model based noise prediction. Based on the visual inspection of the emission profiles, and inspired by previous work in the field of particle emissions ([10], [11]) by vehicles near intersections, a spatial approach was used, in which inbound and outbound lanes are divided into deceleration, queuing, stopline and acceleration zones. The model shown in Fig. 2 is proposed, which fits well to most of the emission profiles of the different intersection types. It is determined by the distances x_d (deceleration average vehicle), x_q (start of queue), x_s = 12.5m (at stopline) and x_a (outbound limit speed reached). The emission values e_i represent the rises or drops in emission compared to the limit emission value (inbound or outbound).

This curve was fitted to the emission profiles of all intersection scenarios considered. Meaningful relationships between the traffic flow parameters (Q_x, F, R and T) and the correction model parameters were then derived by the use of standard linear regression analysis. Parameters that did not pass a t-test ($\alpha = 0.05$) were excluded from the analysis. As an example, Table 3 summarizes the correction factors for the priority-to-the-right intersection. It has to be noted that the given formulas are only valid within the simulated limits; extrapolations outside these intervals should be handled with caution. One can see that the length of the deceleration area is highly correlated with the lane delay T. When a queue is present, the queue length is also correlated with the amount of heavy traffic F (heavy vehicles are longer). The length of the acceleration area is mainly influenced by the traffic flow Q and the amount of heavy traffic F (heavy vehicles accelerate more slowly causing a larger x_a).

Table 3. Correction factors for the priority-to-the-right intersection, for both major and minor arms.

	Deceleration		Queuing*		Stopline			Acceleration	
	x_d	e_d	x_q	e_q	e_c		e_s	x_a	e_a**
					log$T$<1.4	log$T$>1.4			
r^2	0.89	0.87	0.55	0.75	0.60	0.62	0.90	0.81	
constant		-16.2	-82.6	-8.2	12.0	-4.4	-3.1	-35.0	-1.8
log$Q$ [veh·h^{-1}]		3.6			-7.7			33.5	
log$T$ [s]	167.8	3.7	107.7	5.5	2.7	1.4	4.3		
F [%]			1.3	0.04			0.06	2.0	
R [%]						-0.02			

*If log$T$ < 1.4, then $x_q = x_s$ and $e_q = 0$; **No correlating parameters were found, so the average is given.

5 CONCLUSIONS

A case study consisting of the microsimulation of a large set of intersection scenarios was presented. The intersection type was found to have a large influence on travel times, but only a small influence on global noise emission. However, there are large spatial differences in noise emission. A correction for traffic noise prediction models that do not take into account the dynamics of intersections was proposed, based on a spatial approach. It is shown that meaningful relations can be derived between the proposed noise emission corrections and traffic fow parameters. However, for a practical application of these corrections, more research will be needed.

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