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The assessment of traffic livability, including local effects at home, during trips and at the destination, based on the individual activity pattern and trip behaviour

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1 ABSTRACT

The environmental quality of the living environment is mainly linked to the direct and indirect impact of traffic in the neighborhood of the dwellings. In the Flemish mobility and urban planning, the term 'livability' is used focusing on the living conditions of people's home location: what is the satisfaction about their living environment? The more specific term 'traffic livability' is used to describe the impact of all types of traffic on the livability of a dwelling location. Some methodologies were developed for an objective measurement of the traffic impact on quality of life. In Flanders the most commonly used methodologies are the 'traffic livability index' 1 and the 'bearing capacity'2, which use a very narrow interpretation of the traffic livability, as they are highly based on the local road design (number of lanes, cycle path, …) and the local traffic characteristics (traffic flow, speed, traffic safety, …) of the street of the dwelling. The main critic is that these methods should measure over the complete living environment of a person, rather than just at the dwelling. For this reason, an alternative methodology was developed for an objective measurement of the impact of traffic on the local quality of the living environment. Compared to the current practice, this new methodology aims at the following objectives:

- The evaluation is not done for the average person, but includes individual needs and travel patterns, based on personal characteristics, representing the large diversity of the mobility needs.
- The methodology should reflect a daily activity pattern, including the traveled routes and destinations. The traffic livability of a specific household in a specific area will reflect the full extent of their needs at home, during the trips and at the destinations.
- Traffic livability is measured by means of a broad set of indicators, representing different types of traffic impacts (accessibility, traffic noise, traffic emissions, …). The separate indicators are combined into an evaluation of the traffic livability, including an extensive set of secondary effects.

This is mainly realized by a better simulation of the personal trip behavior, using the data from the Flemish Trip Behavor Survey. In order to evaluate the livability at a certain home location (a number of) households are sampled from this database, with the specific characteristics of the household (composition, car availability, children, …), the people in the household (age, employment, …) and their activities and trip pattern. With this information, the different indicators for traffic livability can be evaluated on the home location, as well as during the trip and at the destination.

2 PROBLEM STATEMENT

The environmental quality of the living environment is mainly linked to the direct and indirect impact of traffic in the neighborhood of the dwellings. In the Flemish mobility and urban planning, the term 'livability' is used focusing on the living conditions of people's home location: what is the satisfaction about their living environment? This is different from international litterature, where the term is normally used in a more general sense, taking into account the social, economical, environmental, circumstances in a certain city or area.

More specificly the term 'traffic livability' is used to describe the impact of all types of traffic on the livability of a location. In Flanders, with its typically strong interference between different road functions (transit vs. local traffic) and between urban and traffic functions (traffic vs. housing, shopping, …), traffic livability is an important issue in mobility and urban planning. As traffic livability is an important indicator for the evaluation of urban projects and traffic measures, for setting policy priorities, etc, it is important to have an instrument for an objective measurement of the traffic livability. Two major difficulties are that (1) a large series of different traffic impacts on the surrounding functions need to be measured and that (2) the relative appreciation of each impact is a rather subjective matter. Some methodologies were developed for an objective measurement of the traffic impact on quality of life. In Flanders the most commonly used methodologies are the 'traffic livability index' [1] and the 'bearing capacity' [2]. Typically these methods use indicators about the local road design (number of lanes, cyclepath, …), the local traffic characteristics (traffic flow, speed, traffic safety, …), the local traffic emissions (traffic noise, traffic emissions, ...) and the sensitivity of functions along the road (e.g. schools). The livability at a certain address is expressed as a composition of the characteristics of the local road section in front of the house. This is a very narrow interpretation of the traffic livability, with important restrictions:

First of all, this presumes that quality of life is very locally determined by the location and situation of the house. This is contradictory to elementary planning theories, as by Klaeboe[3, 4] or Appleyard [5], both stating that quality of life is determined by the complete living neighborhood, rather than just the house location. People judge their living quality during a vast set of activities, some taking place at home, some taking place at other locations (office, shop, sports center, …). In this view, 'livability' should also include annoyance at work, at school or at other locations, and even the effects during trips to these locations. For example traffic noise disturbance is often not caused by the traffic in the local street, but by traffic from a nearby major road.

A second limitation of the current methodologies is that they ignore the importance of traffic networks. Local shortcomings do not only harm the local residents, but harm all road users passing by, which means that the impact of a local shortcoming spreads out to a much wider extent. Evenso not the local traffic emissions are determining, but the cumulation of the emissions on all nearby streets. A dangerous pedestrian crossing doesn't only harm the residents of the street, but all pedestrians passing by.

3 PROPOSED METHODOLOGY

3.1 Selection of an indicator set for 'traffic livability'

The existing methods all split down the 'traffic livability' into the separate types of traffic impacts, and define a set of indicators for each of them. The newly proposed methodology will follow the same structure, with a similar set of indicators. The main improvement will be on a technical level, concerning the way the indicators are evaluated. The indicator set is based on a litterature review7 of the term "traffic livability", collecting an overview of the frequently used traffic impacts and indicators. This resulted in a breakdown of the term into four components: accessibility of basic functions, health impact (as traffic emissions, sleep disturbance, …), effects on environment (noise annoyance, visual impact, …) and effects on the social functioning of the neighbourhood (barrier effect, attractiveness, …). Each component is divided into some partial effects with their specific indicators.

Measuring traffic livability will be realized by measuring these indicators and aggregating them to a global score for each component and for the total traffic livability.

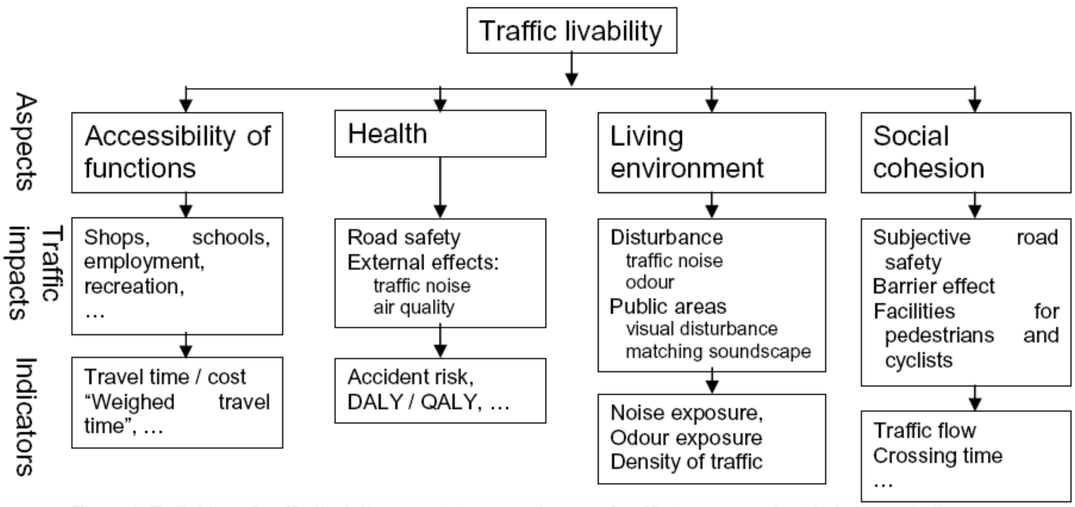


Figure 1: Definition of traffic livability, containing several types of traffic impacts, each with their own indicators

3.2 Methodology for the evaluation of the indicators

The main shortcoming of the existing methodologies for measuring the traffic livability is the (over-) simplified way of evaluating the indicators. The living quality of an address is considered to be determined by the traffic impacts at this very specific location: the local noise level, local air quality, etc, as if making a simple overlay of several layers. As ersatz indicators, these impacts are measured using the local characteristics of the nearest street (road width, bicycle facilities, …) and its traffic (e.g. traffic flow, traffic speed).

To reach a better representation of the neighbourhood perception, an alternative methodology was developed for an objective measurement of the impact of traffic on the local quality of the living environment. Compared to the current methods, this new methodology aims at the following objectives:

- Traffic livability is measured by means of a broad set of indicators, representing different types of traffic impacts (accessibility, traffic noise, traffic emissions, …) . The separate indicators are combined into an evaluation of the global traffic livability.
- The evaluation is not done for an average person, but takes into account individual needs and travel patterns, sampled from the Flemish large-scale trip survey. This means that personal characteristics (age, marital status , professional activities, …) and family characteristics (number and age of children, car availability, …) and the consequent diverse mobility needs, are incorporated in the evaluation.
- The methodology reflects the daily activity pattern and trip pattern. Beside the traffic impacts at home, also the effects during the trips and at the destinations are included in the evaluation. This means that the evaluation of traffic livability covers the complete living neighborhood, rather than limiting it to the dwelling itself or the street it is located in.

The Flemish Trip Behaviour Survey

A major input to reach these objectives is the Flemish Trip Behaviour Survey (Onderzoek VerplaatsingsGedrag, OVG), a large scale survey collecting trip data by means of trip diaries covering the whole of Flanders. The survey data consist of three data sets containing the family characteristics, the person characteristics and the personal trip data. The survey has been executed in 1994-1995 (OVG-1), in 2000-2001 (OVG-2) and in 2007-2008 (OVG-3).

- OVG-1 and OVG-2 used the ‘family’ as basic entity. The surveys covered 2.500 families each, surveying all family members, representing about 8.000 persons. The methodology in this paper was elaborated using the data from these surveys.
- In the most trip survey OVG-3 the methodology was slightly modified: the survey now used ‘persons’ as the basic entity: again 8.000 persons were surveyed, but covering 8.000 different families. The survey still includes the family characteristics, but the trip diaries are completed for only one selected family member.
- For OVG-4 and following surveys, the approach will be further modified. Instead of surveying 8. 000 every 5 year, there will be a yearly survey of 1.600 persons. Every 5 years, there will be a similar sample of 8.000 people. This change will not affect the proposed methodology for the measurement of traffic livability.

The different approaches in OVG-3 and further OVG-surveys will necessitate a slight adaptation of the proposed methodology, in order to use the survey data in a correct way. Evaluation of the indicators by sampling the trip behaviour The main issues for improving the existing methods, are to take into account the specific personal activity pattern and trip behaviour, instead of evaluating the perception of the ‘average person’, and to make an evaluation over all trips, all modes and all routes for this person. This is done by a Monte Carlo simulation, sampling random families and/or persons from the Trip Database of the Flemish Trip Behaviour Survey, and consequently sampling a logical destination from a set of pinpoint locations.

The traffic livability of a dwelling location is then evaluated in the following steps:

First of all, a random household[1] is sampled from the Trip Database of the Flemish Trip Behaviour Survey. In the database a large set of characteristics are available about the household (composition, car availability, …) and its members (age, income, …) and their daily trips (number, purpose, distance, …). These parameters can be taken into account during the later evaluation, to simulate specific desires and appreciations. In the current stage this sampling is done completely random, but in a later stage some specific parameters could be take into account to sample rather younger or elder families, larger or smaller families, rather mediated or not, etc. according to the neighbourhood characteristics.

For all the trips that are made by this household, the following step is to select a logical destination. This destination is again sampled from a database of possible destinations per trip purpose. For school trips one of the schools in the area will be selected, for shopping trips one of the shops. The destinations for the purpose 'recreation' could be sport grounds, leisure centers, restaurants, etc. The sampling of a destination is not completely randomized, as the trip distance from the survey is used as a parameter in the selection, in order to keep a close reproduction of the survey results (for example to keep a logic mode choice for the given distance, avoiding 10 kilometres walking of 500m car drives).

For the collected trips (with mode) and destination, the third step is to calculate a logical route from the dwelling to the destination. Several methods are possible, for example by means of an interactive communication with a supporting traffic model or GIS-tool (the traffic livability model questioning the route from location A to location B). At this moment, preference went to a method using 'centroids' representing the surrounding streets (as used in traffic modelling). Using the centroids, it is possible to prepare a set database of routes between 'centroids', so that the route between two locations is approximated by the route between the nearest centroids.

Knowing the destination location, the route and transportation mode of all the trips of each household member, it is possible to make the evaluation of this person's perception of the traffic effects at home, during the trips, and at the destinations.

By sampling a sufficient number of dwellings per street segment (or a sufficient number of households per dwelling), this method results in an aggregated perception of traffic livability, representing a realistic variety of activity patterns and transportation needs and covering the complete living space of the population, rather than just the dwelling location. The expectation is that this will better reflect people's perception, as stated in surveys or interviews.

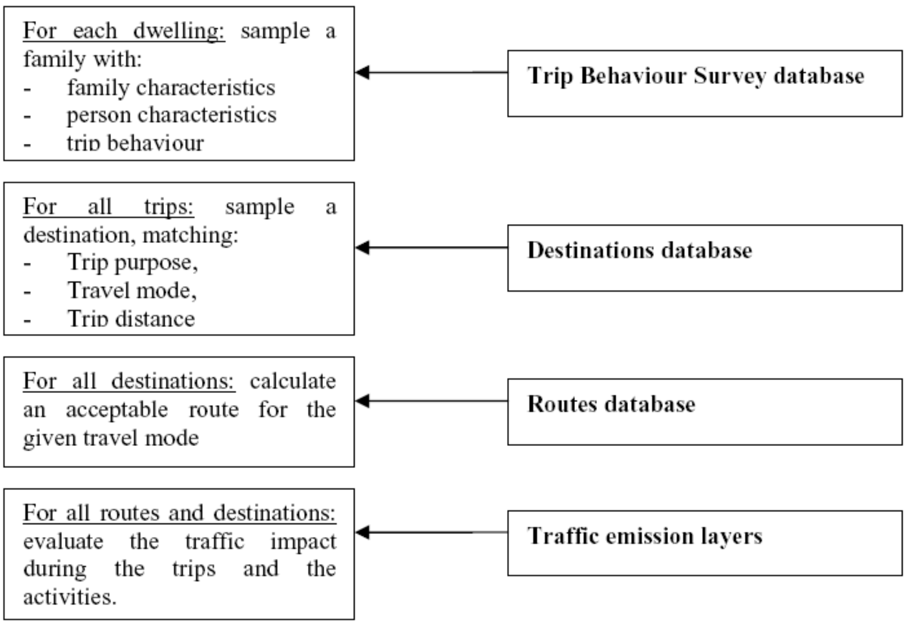


Figure 2: Structure of the evaluation of traffic livability by means of household sampling

Estimation for the generation of local traffic

[1] Starting from OVG-3 the survey is based on persons instead of households. This means that the methodology will be slightly adapted. Instead of sampling complete households including all the members, loose persons will be simulated.

Another result of this sampling, is that, after sampling all families living in the model area, the routes of all local car trips, bicycle trips and pedestrian trips can be totalized to an estimation for the local traffic generation by car, by bicycle and on foot. For car traffic, this local traffic can be a valueful addition to the existing macroscopic traffic models, which focus on the main roads, and therefore lack detail about the local traffic on minor streets. For bicycles and pedestrians, the method allows the estimation of the intensity and routes of the local bicycle and pedestrian flows, based on the local needs and destinations. This is important information for the evaluation of network quality, as will be illustrated in chapter 3.2.

3.3 Global model structure

The sampling of households and their activity and trip pattern is only a part –albeit the most innovative part– of a larger model structure, which is represented in the following scheme. As indicated, the model consists of four major parts:

- the input GIS layers and databases;
- the exposure simulation;
- the traffic model;
- the indicator aggregation.

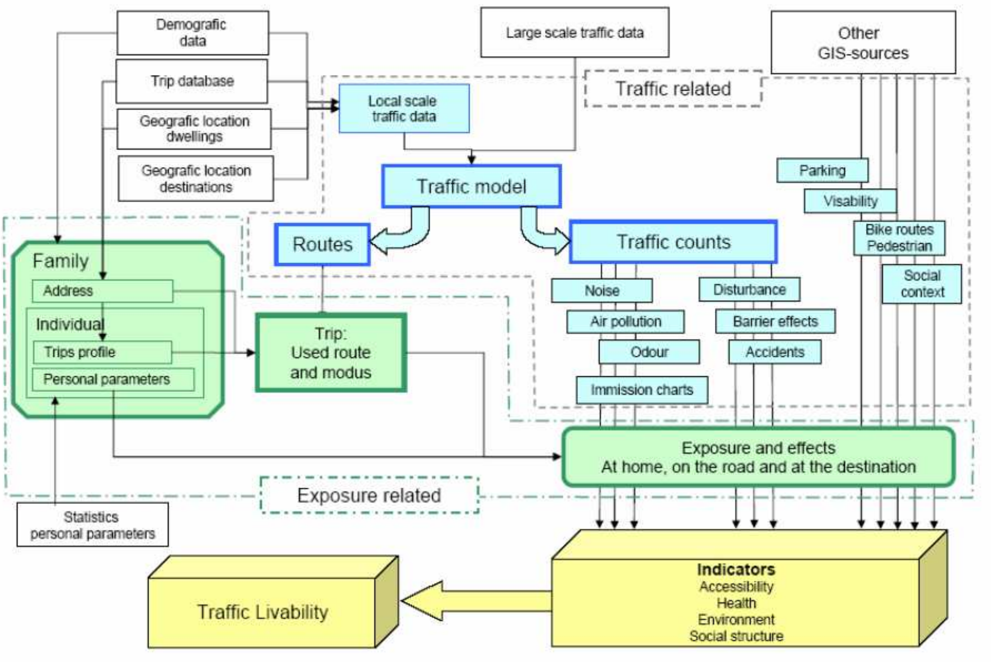


Figure 3: Global structure of the traffic livability model

The input components consist of GIS layers and databases. The GIS-layers contain attributes about the infrastructure, traffic, dwellings, points of interest, population density, etc. The databases contain demographic statistics and survey data about trip behaviour and time usage.

The core of the method is the exposure evaluation. For each household included in the simulation, a trip pattern is sampled from the trip database and linked to suitable routes obtained from the traffic model. These routes are used to sample exposure to noise, air pollution, and safety risks. With the data about the destination (location, purpose), the exposure at the destination can be included.

The traffic model is at first used to calculate the transportation mode and the route for these trips. Apart from this, the model is also used to generate the overall traffic flows and traffic characteristics (such as traffic speed and congestion), which are used to derive traffic noise immission and air pollution maps, evaluate safety risks, etc.

In the final component, the indicator aggregation, the results from the traffic model are used to evaluate the effects during the trips and activities from the exposure module. At first this evaluation is done for each separate indicator and for each individual person in the model. Afterwards, the results are aggregated geographically (grouping individuals to a street or neighborhood level) and/or thematically (grouping indicators to a thematic score and a global livability score).

Two alternative methods are possible to do this aggregation. A first possibility is to first aggregate the different components of traffic livability for every person in the sample individually. This approach has the huge advantage over existing techniques that it allows to accurately account for combined exposure. The alternative is to perform the aggregation first at a population level for every component of traffic livability separately, to obtain a population averaged effect. With this order of aggregating, the model keeps its explanatory value: when certain measures or scenarios result in an improvement or reduction of the livability, this change can be re-traced, in order to detect which aspects of traffic livability or which indicators cause these changes.

3.4 Technical implementation

The model is developed in Python, using GIS libraries. The sampling of households and destinations is functioning and the calculation of routes from the dwelling to the destinations. The evaluation of a number of indicators concerning accessibility and traffic noise is implemented, including the effects during trips. The aggregation of the indicators is in a premature state. The route calculation, is currently handled in the open source GIS system GRASS. One of the future steps will be the implementation of a (macroscopic) traffic model for this purpose, in order to take better into account capacity restraints and congestion. Further steps will be the implementation of the missing indicators, the technical implementation of the aggregation module, and the calibration and validation of the model results, including some sensitivity tests of the model results (sensitivity to the scores and weights of the individual indicators, the distinctiveness of scenarios, …).

4 THE GHENT CASE-STUDY

4.1 Intermediate steps in the evaluation

The traffic livability model is implemented for a case-study of the Flemish city of Ghent, including both the city center and the suburbs. By means of some of the intermediate results of the model, we first illustrate the working of the model. The fundamental model input is illustrated on the following map, showing on one hand (a selection of) dwelling locations ("origins") and on the other hand a set of destination points for several purposes (shopping, school, work, …) with a varying attraction (depending on the size and number of shops, the number of students, the number of employment, …).

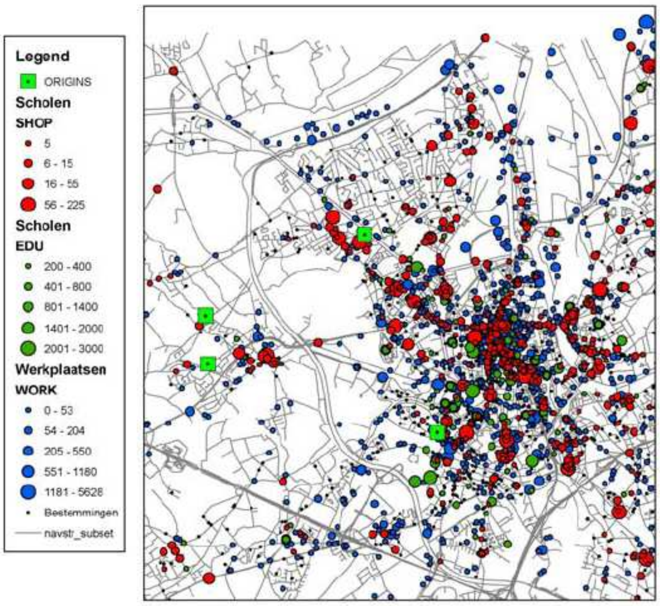


Figure 4: Illustration of the model input, consisting of a set of dwelling locations and destination points

In the first part of the model, a household is sampled for each of the dwellings to be evaluated. Using the reported trip behaviour, a set of logical trip destinations is sampled, and the routes and travel modes are calculated.

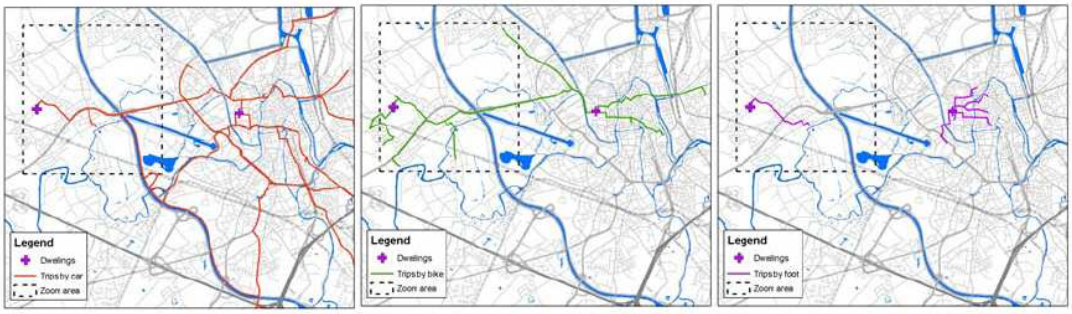


Figure 5: The calculated routes by the sampled households in two dwellings, including the trips by car (left), by bike (middle) an foot (right)

By means of overlays of these maps with 'emission layers' of the different indicators (traffic noise, traffic emissions, traffic safety, …), the indicators can be evaluated, considering the dwelling location, the destination location and the route and mode of the trip.

4.2 Preliminary model results

The preliminary model results for some typical situations will be used in order to highlight the added value of the proposed methodology, compared to the methods that are currently used in Flanders. Estimation of local traffic flows For each dwelling in the study area, a set of maps is calculated from the same type as in Figure 5. Aggregating the maps for all dwellings results in an estimation of the local traffic flows, as shown in Figure 6.

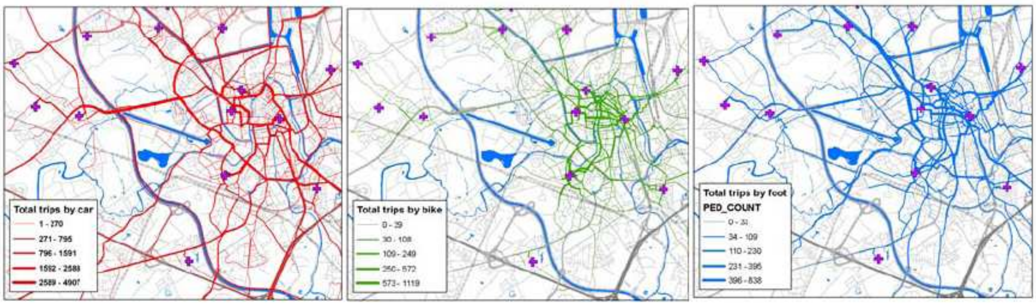


Figure 6: Estimation of the local traffic flows, generated by the sampled households, by car (left), by bike (middle) and on foot (right)

The local flows of car traffic will be an important parameter in determining the traffic emissions, traffic noise and traffic safety on the roads. This is especially useful for the traffic impacts and the exposure on minor roads, which are often poorly included in the existing (macroscopic) traffic models.

The local bicycle flows and pedestrian flows will be incorporated in the evaluation of the infrastructure for these road users. The absence of a cycle path will then score more negative if more cyclists use this road. On the other hand, the presence of a cycle path only has a positive effect if a sufficient amount of cyclists pass by. This is contrary to the classic methods which measure the quality of bicycle infrastructure near a dwelling simply by the presence of a cycle path on the nearest road (yes/no), regardless of the use of it. Furthermore, because the evaluation is based on routes instead of streets, a good infrastructure in the own street is not sufficient to get a good evaluation (as in the current methods). Only if the complete route from the dwelling to the destination is well-equipped, the bicycle infrastructure will score well. This means that a missing piece of cycle path has a negative impact not only for the people living nearby, but for all people using this link for their bicycle trips. Therefore it will affect the traffic safety and traffic livability for the whole neighbourhood.

Evaluation of the aspect 'accessibility'

The aspect of 'accessibility' is divided into the accessibility of several types of functions:

- accessibility of the dwelling;
- accessibility of working places;
- accessibility of schools;

- accessibility of shops;
- accessibility of locations for recreation.

The first item is measured in more general terms, such as the travel time of distance to the nearest train station, bus stop, city center, highway entry, etc. The other items are evaluated by means of the sampled trips for each of the purposes by the households in the area. Because the evaluation of accessibility is based on the actual routes, it is done on a network level. By feeding the model with realistic travel times (travel time data or results of a traffic model), traffic congestion can be incorporated in the evaluation. As the travel routes are separated by mode, the appreciation of accessibility can be made multimodal.

Evaluation of the aspect ‘traffic noise’

For the aspect ‘traffic noise’, the main improvement is the evaluation of the traffic annoyance during trips (e.g. for bicycle trips) and at the destination (e.g. at school). This is illustrated in Figure 7, where both dwellings A and B have a similar location, similar properties and a similar (local) noise level at the dwelling. In the trip behaviour, both dwellings will be strongly oriented towards the city center (e.g. for shopping, schools, services, employment, …?), situated in the North-East corner. This means that the noise annoyance on the routes from both dwellings will be very different, as routes from dwelling A are crossing the ring way with high levels of traffic noise, which is not the case for dwelling B. For this reason dwelling A will get a better score than dwelling B.

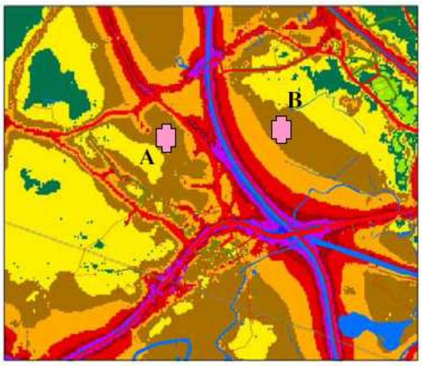


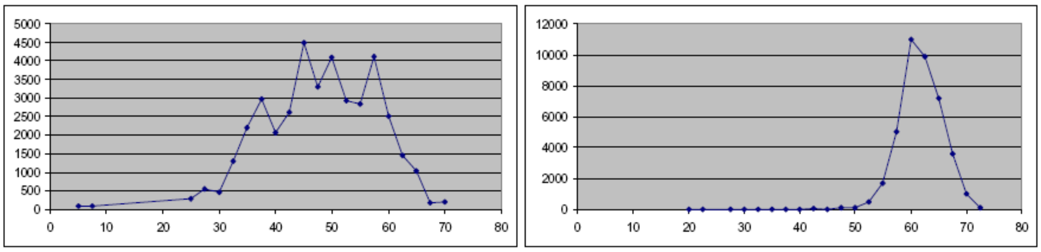
Figure 7: By including the traffic annoyance during trips in the evaluation, the complete living environment is considered.

The same effect will be noticeable for other aspects as the traffic emissions or traffic safety on the routes. This allows detecting several types of barrier effects within the traffic livability.

Another issue, as for most other traffic impacts, is to determine which indicator represents best people’s perception. Choices to make are for example which quantity to use for the noise level (Lden, Leq, …) and how to calculate the total noise exposure during a trip, as is illustrated in Figure 8 and Figure 9. In current practice only the exposure at the dwelling (a) is considered. An obvious alternative would be to totalize the total noise exposure over the whole length of the trip (b), but this may include effects that are too far away from the actual dwelling and are not perceived as a part of the living environment. Therefore it may be more representative to calculate the total noise exposure only over the first part of the route (c), within a certain range of the dwelling. A further correction may be to give more weight to the highest noise levels on the route, as these are perceived as most hindering. The noise annoyance during a trip is also likely to depend on the travel mode used (e.g. higher sensitivity during bicycle trips).

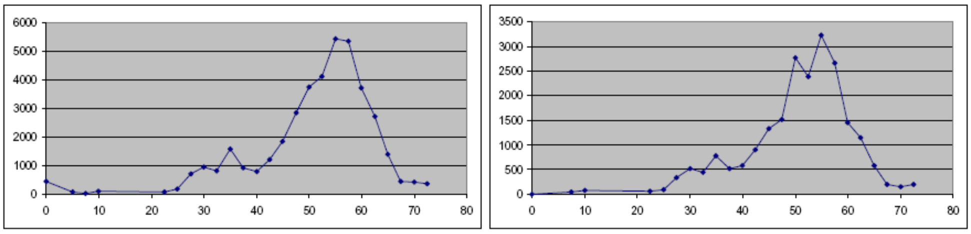
The graphs show that the noise level at the dwelling (a) has little correlation to the noise exposure on the routes. The noise exposure on the routes (b) is quite concentrated, as most (long distance) trips meet high level somewhere on the route, which dominate the total exposure. This shows another advantage of restricting the exposure to the first part of the route, closest to the dwelling: this measure is more distinctive between noisy and quiet areas. Graph (d) shows that on average, bicycle route follow more quiets routes than the other travel modes.

The choice of the indicator with the best representation of people’s perception will be a part of the model calibration. This will be based on the results of the Written Survey on the Living Environment (Schriftelijk Leefomgevingsonderzoek), a survey about perceived annoyance by noise, odour and light in Flanders.



(a) (b)

Figure 8: The distribution of the sampled exposure for some relevant indicators for the annoyance by traffic noise: the noise level at the dwelling (a), the total noise level over all trips (b).



(c) (d)

Figure 9: The distribution of the sampled exposure for some relevant indicators for the annoyance by traffic noise: the total noise level over the first section of all trips, closest to the dwelling, calculated for all trips (c) and for all bicycle trips (d).

5 CONCLUSIONS

In this paper, an innovating model is presented for objectively measuring the traffic livability. Whereas classic methods focus on the traffic impacts at the dwelling location, the proposed method incorporates the whole activity pattern, and the corresponding trip behaviour in the evaluation. This is reached by a Monte Carlo simulation of households, including their trip behaviour, using the database of the Flemish Trip Behaviour Survey. The trafic livability at a specific location is evaluated for a sampled household, simulating their trip and activitues as if they were living at this location. This way, the traffic annoyance is evaluated on the dwelling location, during trips and at the destination. This guarantees that not only annoyance by traffic on the nearest road is considered, but that also traffic noise, traffic emissions, etc from surrounding roads is incorporated. This also allows to evaluate some indicators on a network level, as complete routes are considered. For example, a absence of a cyclepath on a road section can be weighted with the number of cyclists passing by.

After a geographical (per road segment, quarter, ...) and thematical aggregation, this results in 'traffic livability maps', showing the traffic livability per location for specific traffic effects or the global traffic livability.

Further model applications include:

- explanatory analysis for specific indicators, about the average scores and distributions at different aggregation levels.
- predictive calculations for forecast scenarios including spatial development, traffic projects and/or environmental measures.
- analysis for specific target groups, by restricting the sampling of households to a specific subset.

This will allow specific results for the living quality of target groups like elder people, households with children, frequent bicycle users, … These results will offer a valid ground for policy decisions, as well on a strategic level (defining policy priorities in terms of problem areas or thematic focuses) as on an operational level (evaluation and comparison of specific measures).

6 ACKNOWLEDGEMENTS

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