Road environment descriptors - a database for integrating urban environment protection aspects in route guidance systems

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1 Introduction

The european town is characterized by small streets, sensitive land use along streets with a certain density of inhabitants and quality of street design. Thus strategies of urban and transport planning have to lead in protecting this sensitive areas against undesired traffic impacts. Examples of criteria to estimate such impacts are traffic noise or pollutants.

An analysis of onboard navigation systems has shown, that their route recommendations usually directs drivers in subordinated roads with important impacts for residents. Moreover, it is remarkable that those recommendations are often suboptimal for car drivers. Currently simple route guidance systems consist of a router software and maintain a road network database of nodes and links representing the intersections and roads. Links are attributed by functional road classes, form of way, traffic restrictions, network class (to define closed subnetworks) and maneuver infos (to specify turn possibilities). More advanced (dynamic) systems add attributes like congestion hints or even actual traffic volumes which the system has to be considered during the routing process. A data-center driven system has the ability to maintain a much more larger database containing link attributes like volume histories or day-to-day volume patterns to anticipate typical congestion situations such that fine-tuned time dependent guidance recommendations are possible.

A router in such systems carries out his routing decisions with the sum of cost of passing through the links and nodes from current position to the desired destination. This cost is in most systems travel time delay in roads and turning delay in intersections. If urban environment protection aspects have to be integrated in route guidance systems (we call this urban sensitivity routing), the central question is which kind of cost a system has additionally taken into account to derive its guidance recommendation that is reasonable for the environment [KAUF00]. About whatever the cost is derived from, the guidance system needs information of the environment in the adjacency of the roads.

And here comes in our road environment descriptor (RED). REDs are a result of a research project [HMM01] for large-scale traffic assessment tasks used in the federal transport masterplan of the german Ministry of Transport, Building and Housing. In Germany this masterplan is the main planning instrument for classifying all intended infrastructure projects in the transport sector. The main component is a benefit-cost-analysis step which results in a ranking list where all projects are ordered by their specific benefit-cost quotient. All infrastructure projects above a cut-off-limit have to be realized by the government in the following 5-year period. The assessment of traffic impact on urban areas and the people living in that regions has a very high political importance in the actual masterplan.

In the research project we have analyzed the usual methods of traffic impact assessment and filtered out the most used indicators to estimate

- traffic noise,
- pollutant elements,
- separation effects and
- linger quality.

Essential indicators are urban land use, distance between development across the carriageway, density of development (open coverage or closed coverage), height of buildings or exposed persons.

The federal transport masterplan covers the area of the whole german country. But the indicators we have to provide are dealing with small scale aspects of urban land use and transport planning. As expected we were forced to find out that there is no complete and uniform database in Germany to retrieve this indicators.

2 Requirements of Road Environment Descriptors

So we had to develope a method to estimate those indicators with an appropriate reliability for the masterplan purposes. We had reused an old idea of the (in german called) „Stadtmodellbau-steine" and expanded it to the above mentioned road environment descriptors.

REDs enrich classical digital road network models with environment information in the adjacency of the modelled roads in urban regions. They have to describe all land use and structural shapes an urban space can have with a reduced set of really important indicators sufficient for the urban sensitivity routing. The indicator values ought to organized by usual classification schemes like the built-use-zone classification of germans Land Use Ordinance. Moreover, the values have to respect legal constructs. If mean traffic volume in an urban road exceeds (due to changed traffic diversion as an effect of proliferated route guidance systems) a defined legal threshold value, than the assessment procedure has to use other (higher) volume-valuation weigths. Thus the classification has to respect allowed threshold values specified for different land uses in one of the Implementing Orders on the Federal Pollution Protection Act. Fig. 2.1 illustrates the indicators with every indicator a RED provide.

Indicator*	**Indicator Values**	
	Categories	**Category Names**
urban roadside land use	6	Residential Zone | Mixed Zone | Commercial Zone | Unsensitive Special Zone | Sensitive Special Zone | Green Space
section share of the total link length	100	% values
mean number of floors	4	Interval 1 | Interval 2 | Interval 3 | Interval 4**
coverage type	2	Open | Closed
mean offset between buildings and roadside	2	Displaced | Not Displaced****
mean depth of 1. development	Integer	Meter values
mean width of carriageway	3	Interval 1 | Interval 2 | Interval 3***
cycle track	2	Yes | No****
exposed residents estimated	Integer	Number-of-persons values
exposed employees estimated	Integer	Number-of-persons values
exposed lingerers estimated (on pavement)	Integer	Number-of-persons values

* The 9 shaded indicators (between double lines) are derived by a set of rules (→see text)
** Actual interval limits depends on the number of (estimated) inhabitants in the municipal district the link section is situated in
*** Actual interval limits depends on the functional road class and form of way of the road (data from the digital road network model)
**** The implicit width of these road cross-section elements depends on the functional road class and form of way of the road

Fig. 2.1: Road environment descriptor for a link in a digital road network model
(a link can have more than 1 of such descriptors →see text)

As the environment usually changes along an urban road the corresponding network link is usually attributed by more than 1 RED. So the number of REDs subdivides that link in the same number of link sections. But this sections are only relevant for cost calculations resulting in a cost sum for the whole link. Thus it is not necessary to insert new in-between nodes in the road network model. It is appropriate to specify a share of the total link length as Fig. 2.1 shows.

3 Deriving Road Environment Descriptors

Although REDs are only defined for urban roads, to ascertain it in a nation-wide survey is a very expensive task. Moreover, as urban environment changes from time to time that data obsoletes after a few years. Instead of this, we adopt deriving REDs by a set of rules for every link. A rule from this set exploit some databases that are maintained by administrative authorities equiped with a lot of personal and instrumental resources.

RED-deriving gains mainly from the Authoritative Topographic and Cartographic Information System (ATKIS). Within the framework of ATKIS are provided a digital landscape model (in vector form), a digital terrain model (grid points) and digital orthophotos (pixel data). In this way ATKIS constitutes a geotopographic data base for computer-assisted digital processing and analog output forms, but is also a base of spatial reference for linkage to and combination with technical geothematic data. It is maintained by the surveying agencies of the federal states in a uniform way.

The digital landscape model (DLM) is an abstraction of the earth 's surface in the scales 1:25,000 (DLM25), 1:250,000 (DLM250) and 1:1,000,000 (DLM1000). The content of the DLMs and the rules for creating DLM objects are fixed in object catalogues.

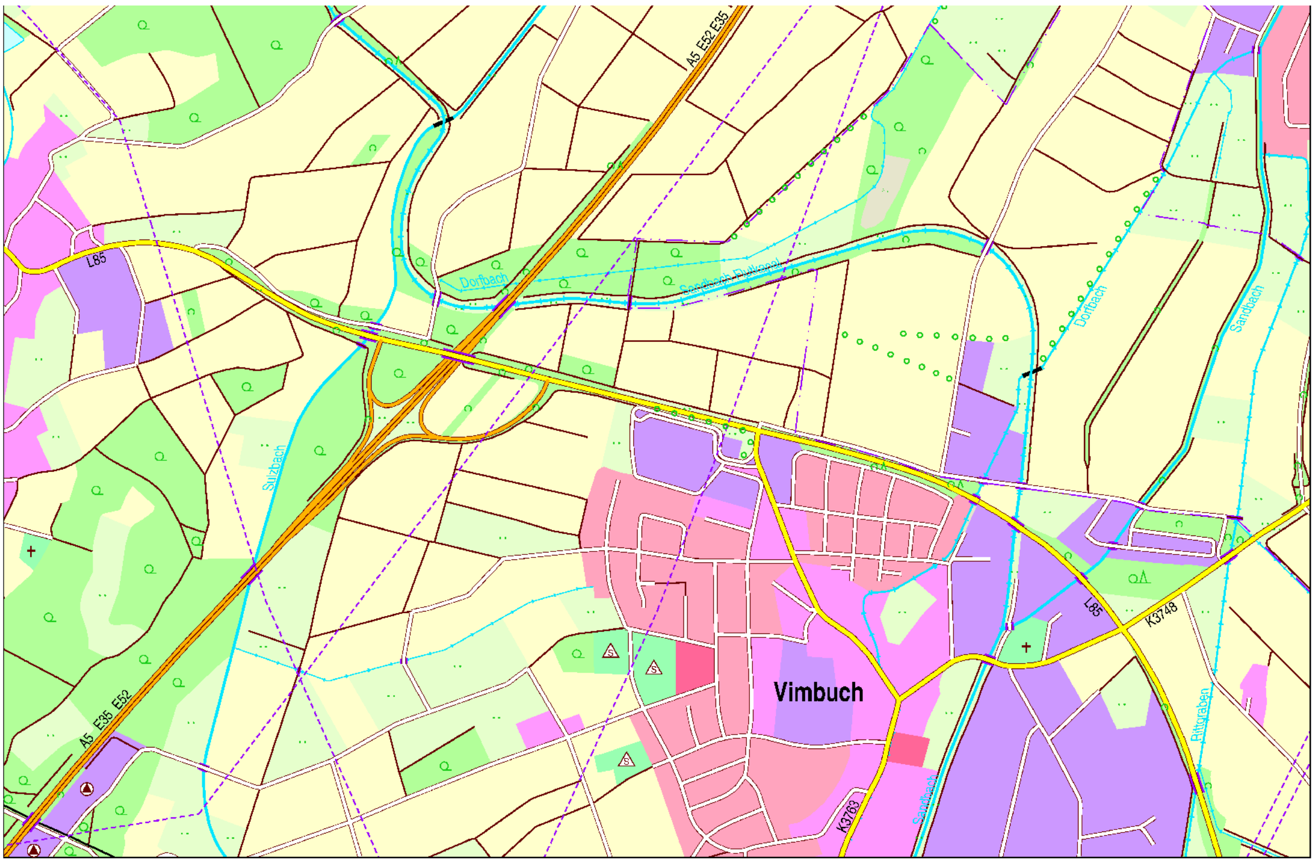

Fig. 3.1: DLM25 view of a village in the federal state Baden-Württemberg

The DLM25 is the data base that is used to derive the REDs. Especially land use objects and border objects of component localities (separated settlements of a municipality, districts) have been exploited. Fig. 3.1 shows a view of the district Vimbuch in the municipality Bühl togehter with the DLMs own road network model (which we did not used further). The colered areas in the figure (shaded gaps between road network) correspond to the land use.

Along with the polygonal data in DLM25, the road network model itself is a database carrying a lot of information that allows to narrow the selectiveness of the rules. As an example shows Fig. 3.3 exploitable entries in the Tele Atlas Road-Data of their *StreetNet* product.

Fig. 3.2 lists the Geodata exploited by rules to derive the 9 indicators in in Fig. 2.1. The rules are designed on the background knowledge from

- principles of urban planning,
- planing guidelines and directives as well as
- the past and current translation practice used to implement such guidelines and directives.

This assures a sufficient reliability of the REDs generated in the rule productions.

Given the polyline representation of the link the REDs for that link are derived in several steps (mainly GIS-based operations):

1 Identify the municipal district object.

2 Identify the set of adjacent land use objects.

3 Determine shares of total link length for every land use object identified in step 2 (see Fig. 3.4) by buffer operations available in GIS.

4 Estimate the remaining 9 indicators in Fig. 2.1 (see shaded areas) by the rule set for every land use object identified in step 2 using all information from the polygonal database objects in Fig. 3.2 and the link attributes like that in Fig. 3.3.

5 Attach all produced REDs to the link in the road network model

<table>
<tr><th>Database objects</th><th>Object components*</th></tr>
<tr><td rowspan="3">Municipalities</td><td>municipal border polygon (available from Federal Agency for Cartography and Geodesy</td></tr>
<tr><td>number of inhabitants (available from Federal Statistical Office)</td></tr>
<tr><td>settlement type of municipality containing information about central place function, urbanization intensity, density characteristics, rural space (available from Federal Office for Building and Regional Planning)</td></tr>
<tr><td rowspan="2">Municipal districts

(contained in ATKIS-DLM25 see text)</td><td>district border polygon</td></tr>
<tr><td>estimated number of in habitants (derived by a dividing all municipal inhabitants to the different districts in respect to the land-use distribution)</td></tr>
<tr><td rowspan="3">Land Use in municipal districts

(contained in ATKIS-DLM25 see text)</td><td>Land use border polygon</td></tr>
<tr><td>Urban land use {residential zone | mixed zone | business zone | special zone | green space | water space}</td></tr>
<tr><td>city regions {central region | middle region | outer region} (estimated by a circels with radius depending on inhabitants of municipals district)</td></tr>
<tr><td rowspan="3">10'×6'-Grid cells

(≈11×11km^2, size of germans topographical 1:25000 map series in paper form)</td><td>cell border polygon (automatically generated by GIS)</td></tr>
<tr><td>relief energy (elevation variance) influencing the urban density and packing styles of development (derived from GTOPO30, available from USGS EROS Data Center)</td></tr>
<tr><td>predominat village shapes containing information about density of development in old town districts (derived data from [ELLEN90])</td></tr>
<tr><td colspan="2">* Shaded areas describe database objects added in the above mentioned research project</td></tr>
</table>

Fig. 3.2: Polygonal databases used to derive REDs (all databases covers the whole german country)

Road attribute	Values	Description
Functional road class (Classification of a road edge on the basis of its functional importance in the road net-work)	Motorway	Motorways which create an international connection.
	Major road of high importance	Roads which create an international connection but cannot be considered as motorways.
	Other major road	Roads used to go from one region of a country to another.
	Secondary road	Important roads used to move within one region.
	Connecting road	Roads used to go from one settlement to another or within a large settlement to go from one part to another.
	Local road of major importance	Roads used for important local through traffic (in urban areas, industrial or residential zones).
	Local road	All local roads, not corresponding to the conditions of classes *„Local road of major importance“*
	Destination roads	Roads that are only used if the destination or address is situated in that road (destination roads).
Form of way (Classification of a road edge on the basis of its physical or traffic character-istics)	Freeway	Road which is not connected by roads on the same level.
	Multicarriage road	Road with separate lanes.
	Single carriage road	All single carriage ways: without central reservation.
	Roundabout	Road with a circular form and one-way traffic.
	Major slip-road (ramp)	These are the edges that form accesses, exits or connections between roads that cross on different levels.
	Parallel road	Road that starts and ends at a freeway, and runs parallel with it. It is always a one-way street.
	Service road	A service road can only be used by the proper authorities such as emergency service, fire brigade, polices, etc..
	Entrance/Exit	This category of roads gives access/exit to parking facilities or public rest places.
	Small slip-road (ramp)	These are roads that form accesses, exits or connections between roads that cross on the same level.
	Pedestrian zone	Roads that are especially constructed for pedestrians (e.g. shopping streets).
	Preferential lane	A preferred lane is reserved for a certain category of vehicles such as buses, taxis, etc..
	Frontage road	Road running parallel to and connecting to a road with a relatively high connectivity function, which is especially designed to enable access from the connecting roads with a low connectivity function in its vicinity.

Fig. 3.3: Road attributes that can narrow the rule selectiveness (from Tele Atlas‘ *StreetNet* product description)

Once all REDs are derived for the whole road network model it is ready to allow urban sensitivity routing. The produced REDs describe in a reliable manner the situation in the adjacency of any urban road in the network. In the above mentioned research project we had developed about 130 rules. Although that was sufficient for the masterplan needs it may be necessary for urban sensitivity routing to design a larger rule set containing rules with an even more selectiveness than now.

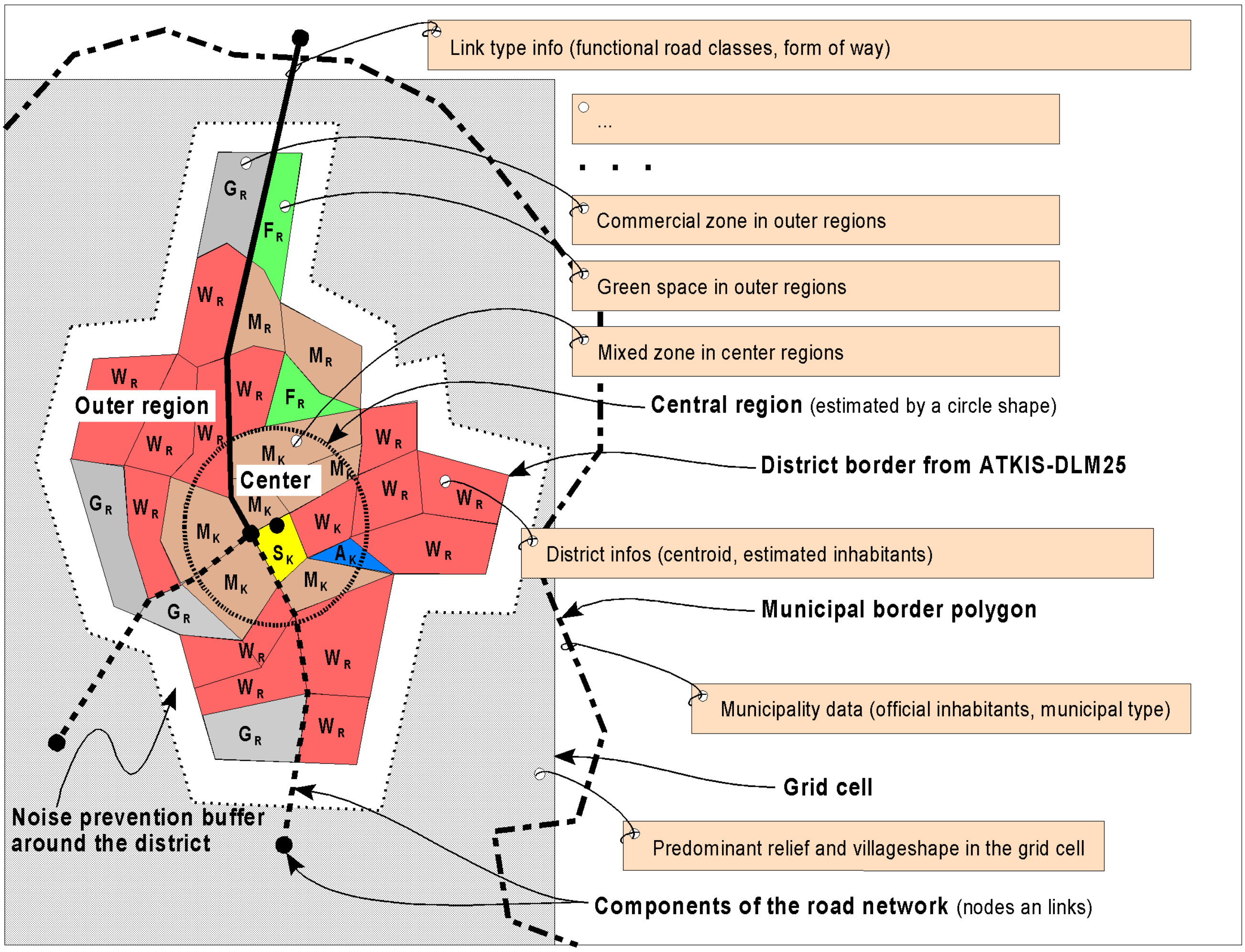

Fig. 3.4: Geoobjects to be dealed with during the RED deriving process

4 Conclusion

As route guidance systems proliferates in whatever form, sooner or later it will have been macro effects on traffic diversion. A route guidance systems knowledge of the whole network and eventually of the current or later link load conditions involves the risk to diverse traffic to lower loaded roads - roads in that adjacency are living, working or lingering (such as window-shopping or park-bench-using) people.

Currently no supplier of digital road networks has information of the road adjacent environment that fits the needs of urban sensitivity routing. Preventions made by defining hierarchical network classes in that routing takes place (the usual method in current road network models) does not fit the requirements of environment protection. Although higher level roads (primary roads, collector roads, etc.) are dedicated to carry higher traffic loads (by urban masterplans that an urban transport administration has to respect) the immediate adjacency of this roads are developed and usually crowded. This is especially true in agglomerated spaces (dense cities). And those people have a claim of protection against increased emissions resulting from increased traffic load.

We think if the environment is not an issue in route guidance system implementation than sooner or later leads this to political and finally to legal reactions. Urban sensitive routing driven by environmental knowledge of the roads adjacency like the REDs presented here are able to defuse this upcoming problem cause it will respect protection claims.

References

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