How GIS can help to promote safe cycling

Martin Loidl[1]

Abstract

Geographical information systems (GIS) offer an integrated platform for relating, modeling and analyzing multiple perspectives on the road space. They can thus be employed in all stages of better understanding bicycle safety from an explicitly spatial perspective and provide the basis for informed decisions in the context of cycling promotion.

In the following it is briefly sketched why safety issues need to be addressed in all cycling promotion initiatives. It is further shown how GIS can be employed in accident analysis and integrated safety risk models and how these single steps can be consolidated in a single workflow. The benefit of employing GIS in this context is demonstrated in a case study where a GIS modeling approach forms the basis of a routing application which recommends safe routes for bicyclists. Based on experiences from the case study and findings from literature a brief outlook describes the road ahead.

1. The bicycle as sustainable mode of transport

Numerous negative impacts of motorized traffic – from air pollution [1] to economic externalities [2] and social inequities [3] – have led to a growing demand for sustainable modes of transport; especially in densely populated, urban environments. This development has increasingly brought the bicycle, as sustainable and cost-efficient mode, into the focus of researchers, planers and decision makers [4]. Masterplans for bicycle traffic and numerous bicycle promotion initiatives from local to transnational levels are indicators for this (re-) discovery of the bicycle [5].

1.1. Bicycle traffic and safety concerns

Due to extensive bicycle promotion initiatives, many cities in Europe have successfully built or extended their bicycle infrastructure. This has significantly contributed to a constantly rising number of bicyclists on the roads [6]. But still, there are some influential factors which keep people from using the bicycle for their everyday mobility needs, above all safety concerns [7]. Although sound exposure data are rare [8], there are indications from literature and official statistics, that cycling is healthy, but dangerous related to the travelled distance [9, 10]. These findings are in line with a recent report by the European Commission on road safety. There, the EC points to the fact, that contrary to the overall trend, the number of killed bicyclists has been increasing during the last couple of years [11]. Thus, it can be stated, that safety is a key issue in the context of promoting the bicycle as sustainable mode of transport [12].

1.2. Improving bicycle safety

In order to improve safety for bicyclists, at least three issues ("safety pillars", adapted from [13]), which are interrelated, need to be addressed:

- First of all, the infrastructure and regulative interventions need to be designed in a way that potential risks for bicyclists are minimized [14]. This can be done, for example, by separated bike lanes, controlled intersections or actions to reduce motor vehicle traffic and speed [15].
- Secondly, the bicyclist's physical condition, experience, compliance with road traffic rules and the technical condition of the vehicle must be taken into account. Although "individual" factors

[1] University of Salzburg, 5020 Salzburg, Austria, martin.loidl@sbg.ac.at, Department of Geoinformatics

do not fully explain all incidents, it is noteworthy, that 5-30% of fatal injuries to bicyclists are caused by single-bicycle crashes [16]. However, targeting the mentioned individual risk factors requires an integrated approach comprising actions from traffic control to awareness initiatives.

- As a third aspect, bicycle safety can be improved by specific information offers about optimal (safe) routes [17]. Such routing recommendations aim to minimize the bicyclist's exposure to risk factors, such as primary roads with a high traffic load or roads without any bicycle infrastructure.

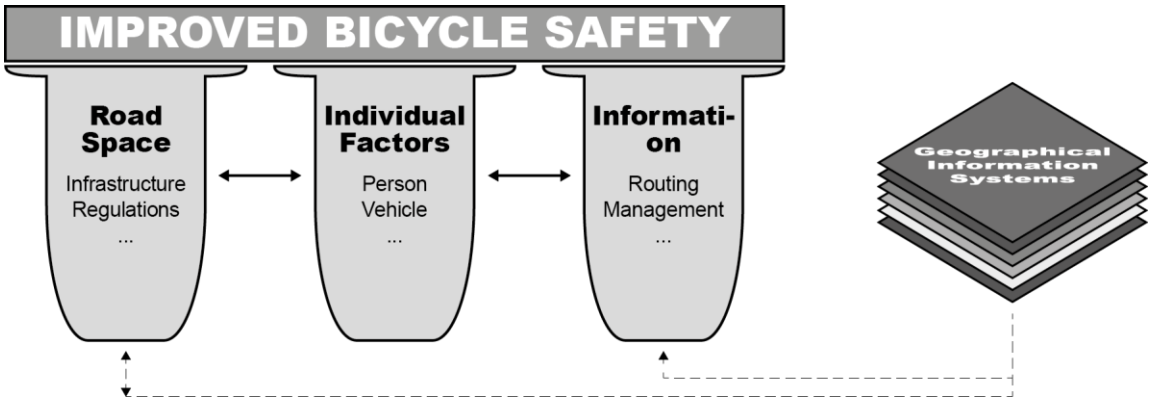

Figure 1: Three approaches for the improvement of bicycle safety, adapted from [13].

Individual factors which potentially contribute to an improved bicycle safety cannot be explicitly targeted by geographical information systems. But GI systems allow for a systematic, digital representation of the road space, including the physical and legal characteristics. These data can subsequently be managed, modeled and analyzed and in turn serve as basis for innovative information applications.

2. What GIS can offer

Bicycle safety is – if only external risk factors (inherent characteristics of the road space) are considered – a complex spatial phenomenon with multiple influential factors, such as the built infrastructure, the traffic volume or weather conditions. In order to better understand this multi-facetted phenomenon, an integrated perspective is required. Geographical information systems allow for such a perspective as external risk factors are spatial by their very nature or can be spatially related (geo-located). Thus they can be captured, related, analyzed and mapped.

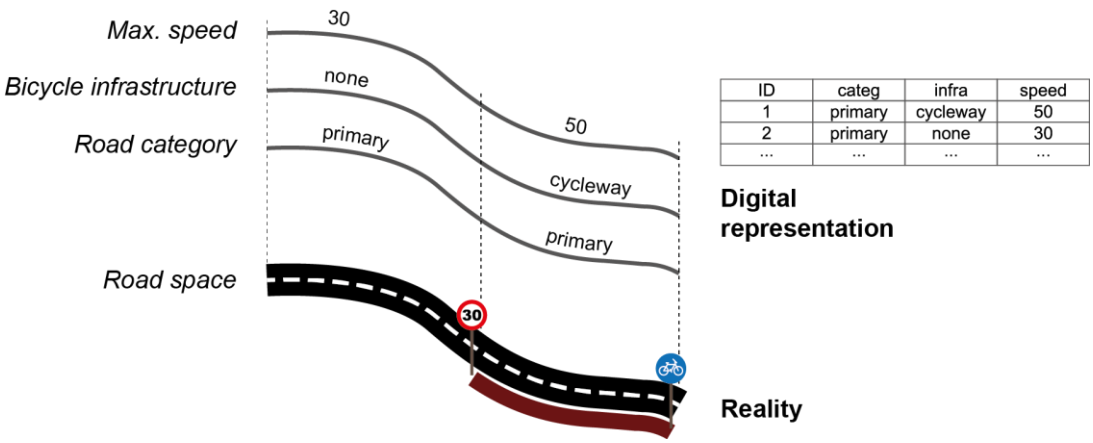

Figure 2: GIS as integrated platform for multiple perspectives on the road space.

Whereas established domains dealing with mobility and transportation, such as traffic engineering, telematics or planning, have a specific, rather "technical" view, geographical information systems

can beyond that serve as integration platform where multiple perspectives – "technical" as well as qualitative – on the road space can be merged. GIS thus facilitate an integrated approach for modeling and analyzing bicycle safety.

In the next section a generic workflow is introduced which facilitates an integrated analysis of bicycle safety with GIS. The applicability of this approach is than demonstrated in a case study.

2.1. GIS employment in a multi-stage workflow

Providing a sound data basis in the context of the promotion of safe cycling is of great importance for informed decisions. The consideration of explicit spatial characteristics is especially valuable in the analysis of bicycle accidents and in the assessment of the road network's quality in terms of bicycle safety.

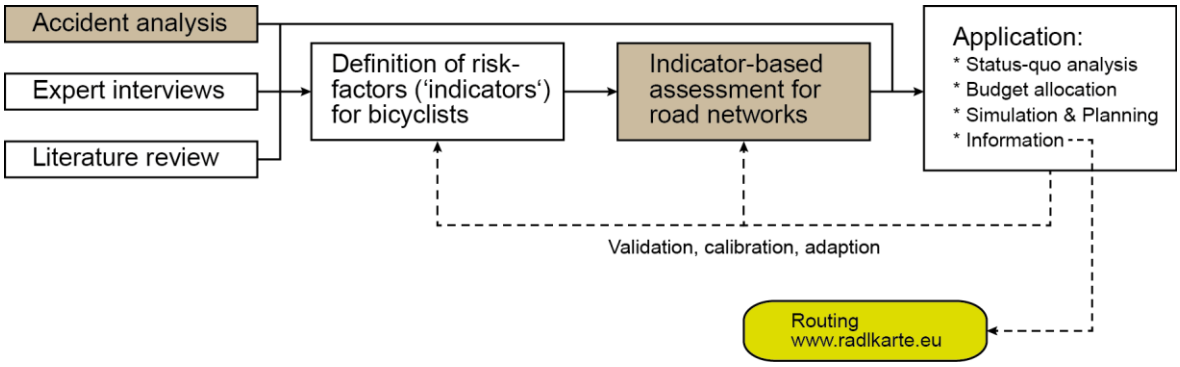

Figure 3: Multi-stage workflow to provide sound data and analysis results for informed decisions in the context of bicycle safety. The employment of GIS especially allows for additional insights in accident analysis and assessment approaches (light brown, see [18]). The result of an integrated spatial approach can then form the basis for applications, such as routing (green; case study see below).

Analyzing bicycle accidents with GIS helps to better understand where, when and under which physical conditions accidents did or are more likely to occur (ref. figure 4). For example the significance of accident hotspots can be tested in comparison to a random distribution or the risk exposure can be calculated (given the necessary data are available) for a network. Once the spatial determinants are identified from accident analysis this information can be merged with expert knowledge and results from related studies (e.g. non-spatial studies in epidemiology). These inputs allow for the identification of risk factors for bicyclists, which in turn can be used for a global assessment of road networks (see [18] for model details).

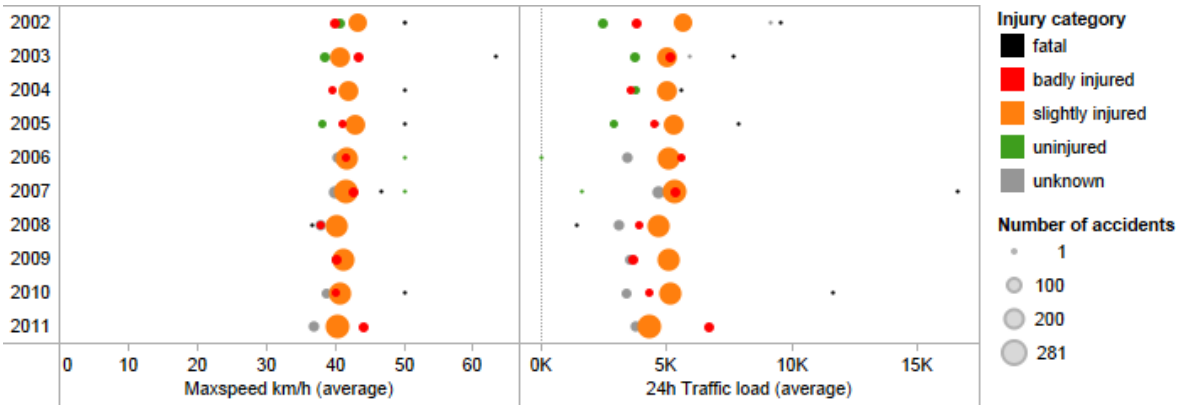

Figure 4: Accident analysis of 3,096 bicycle accidents in Salzburg (Austria): fatal accidents tend to occur on roads with high maximum speed and traffic volume (figure from [18]).

The assessment model itself can be employed for simulations as the input indicators and their weights can be easily manipulated. The results of the assessment routine form the basis for status-quo analyses (e.g. weak-point analysis), but can also be used for planning purposes. In a current project the assessed, digital road network was used as input for a web-based routing application. Thus it could be successfully demonstrated how a spatially driven modeling and analysis approach can be employed in several stages of better understanding bicycle safety and based on this, helps to promote safe cycling.

2.2. Case study

Salzburg – capital of the homonymous federal state, with approximately 150,000 inhabitants – has been following a sweeping strategy for bicycle promotion for more than two decades. A fixed sum is invested into infrastructure projects every year, resulting in a tight network of bicycle facilities with radial and tangential high-capacity connections (ref. fig.5). Through these substantial efforts, together with different accompanying actions, the city administration was able to reach a modal share of at least 16% for the bicycle [19].

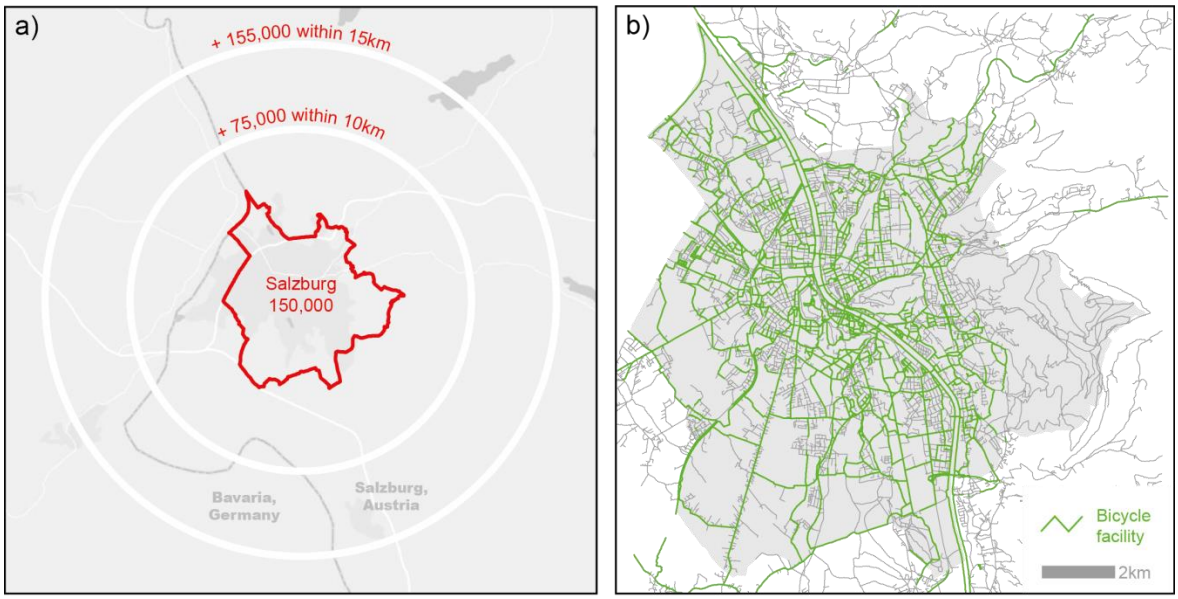

Figure 5: Central location of Salzburg in the Austrian-German border region (a). Tight network of cycleways and -lanes covering the whole city (b).

In order to further increase the number of bicyclists, the city administration, together with the federal state's department of transportation, have expanded their promotion strategy and started to invest into user-specific information.

The flagship of this information offer is a bicycle routing platform which is based on the results of the aforementioned (ref. figure 3) indicator-based assessment model [20]. This model results in an index value which expresses the suitability (or relative safety) for bicyclists on the level of segments. The amount of the index value corresponds with the potential safety risk (the higher the value, the higher the potential safety threat). This relation allows the index value to be used as impedance in a routing engine. With such routing engines the optimal path, in terms of minimized cumulative impedance values, between given points can be found. Feeding the engine not only with the travel time and distance of each segment, but additionally with the safety index value, enables the user to calculate the safest – additional to the shortest or fastest – route (ref. fig.6).

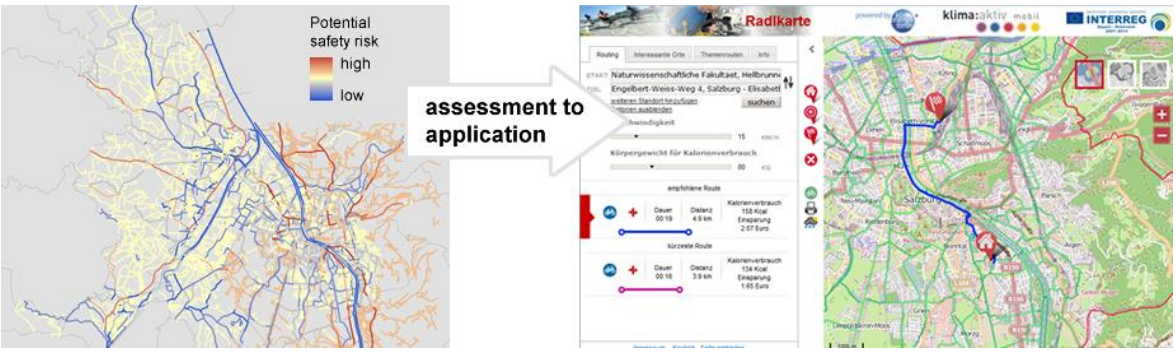

Figure 6: The indicator-based assessment model, run in a GIS, results in an index value which can be used as impedance in a routing application. Thus safe routes, reflecting the multi-facetted, user-specific perspective on the road space, can be calculated.

The routing application is freely available on the web (www.radlkarte.eu). It is intended to be an additional building block of a comprehensive bicycle promotion strategy, which considers both, the infrastructure and the user-specific information offer. Such offer about safe routes aims to support everyday bicyclists in their route choice and raises awareness for the bicycle as sustainable (and safe) mode of transport.

2.3. Conclusion and outlook

Referring to the threefold safety concept, sketched in figure 1, this case study shows how an integrated spatial perspective, operationalized in a GIS, can be employed in addressing two of the mentioned aspects. A thorough analysis of bicycle accidents as an explicitly spatial phenomenon and the consideration of various parameters contributing to the overall safety threat, allow for a reliable assessment of the road network's quality in terms of bicycle safety. This assessment approach can either be employed in more efficient infrastructure ("What's the effect of building a cycleway at a particular road?") and regulative actions ("To what degree would the road become more bicycle-friendly, if the maximum speed is lowered?") or as basis for innovative information applications such as the routing platform mentioned above.

As [21] and [5] state, bicycle promotion needs to be more than simply providing adequate infrastructure. A pro-active administration which offers relevant information and fosters a bicycle culture is indispensable for the establishment of the bicycle as sustainable mode of transport. In this context an integrated spatial approach facilitates status-quo analysis, informed decisions in planning and management contexts and user-tailored information applications.

In order to further enhance bicycle-specific, spatial information, the three following topics should be addressed in further researches: personalization, socialization and contextualization. Personalization means that individual preferences and perspectives on / perception of the road space can be integrated in the assessment model and consequently contribute to personalized information products. How individual peculiarities can be transformed to code-readable model inputs and how those inputs should be weighted is subject to research. Socialization in this context comprises all (technical and organizational) efforts that contribute to a more social environment where experiences, feedback messages and updates are shared among several instances (bicyclists, authorities, event organizers, public transportation operators etc.). Examples for research topics would be, just to name three: inter-bicycle communication, participatory planning processes or a vivid administration 2.0 environment. What all these efforts have in common is the explicit spatial context. Here the power of GIS comes into play: it offers the ideal platform or framework for building relations between various instances and data and thus allows for the generation and

retrieval of relevant information. In this sense, GI systems significantly contribute to the "intelligence" for the promotion the bicycle as sustainable transportation mode.

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