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Original Article

Strategic Transportation Planning: Soft Mobility Network Planning Technical Report

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ABSTRACT

This technical report presents a comprehensive approach to soft mobility network planning, focusing on assessing the potential for growth in bicycle infrastructure. Utilizing GIS-based analysis and multi-criteria decision-making, the study aims to identify and prioritize areas for new bike infrastructure development. The methodology involved defining influential factors, selecting variables from available datasets, assigning value levels, weighting parameters, and generating cycling infrastructure potential maps. Factors such as connectivity, safety, and attractiveness are considered, with each variable assessed and scored based on current conditions and ideal benchmarks. The results highlight high-potential areas for infrastructure improvement and propose desired lines to enhance the existing network. Limitations of the study, including data currency and grid dimensions, are acknowledged, suggesting avenues for future research and improvement. Overall, the study underscores the importance of integrated planning approaches and the utilization of spatial analysis tools in promoting cycling as a sustainable and accessible mode of transportation.

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INTRODUCTION

The physical infrastructure that is created to facilitate cycling as a method of transportation is referred to as cycle network infrastructure. This can include bike lanes, bike pathways, cycle tracks, shared streets, and bike parking facilities.

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Building a cycling network infrastructure is vital for various reasons. For starters, it promotes cycling as a safe and accessible means of transportation, which may inspire more people to pedal instead of driving. Second, it can help to minimize traffic congestion and improve air quality in metropolitan areas. Finally, riding can promote public health by giving chances for exercise and physical activity.

Cycling networks are either developed to meet the demand of an increasing number of cyclists, providing users with high-quality and safe infrastructure, or they are developed to create cycling demand and actively increase the number of cyclists, creating a cycling-friendly environment and developing cycling as a proper alternative for motorized urban transport as well as a feeder to public transportation systems (Arellana et al., 2020).

The soft mobility network planning aims to assess the potential for growth in bicycle infrastructure. The goal of the study is to use GIS-based analysis to plan for new bike infrastructure by using different data derived from GIS and external data. The analysis, carried out by Africa's international transport company (Zhao et al., 2021) Żochowska et al. (2021) makes the best use of available data to make a model and spatial analysis tool to test the plausibility and the potential that the infrastructure will derive using different variables.

The soft mobility network plan seeks to analyse the potential variables in the spatial dataset that influence bicycle friendliness. Several factors influence the development of cycle infrastructure, the aim of this analysis will be limited to the usage of technical data that will be processed in a spatial planning tool, namely QGIS, to identify and classify the area’s potential to attract a cycle network. The report seeks to quantify the nature and extent of the variable’s potential in identifying bicycle network desire lines. The result from the analysis is a tool to locate the desired line to cycle in a safe environment with consistent, direct connections.

The soft mobility network plan was developed using the multi-criteria analysis to compare results for multivariate analysis. Multi-criteria analysis (MCA) combines different identified criteria to evaluate and compare options effectively. Each criterion is assigned a weight and a score relatively. The weights and scores reflect the criterion’s importance in the decision-making process. The model helped to map areas with great potential. From the analysis, practical interventions were made to improve cyclist level of service and demand with well-planned infrastructure.

METHODOLOGY

This chapter describes the methodology used to identify bike network potential, how that methodology has been applied and the implications associated with different decisions on the outcome of the analysis. The mixed method approach, includes literature review analysis, spatial analysis, and the utilization of multi-criteria analysis. The approach followed the following steps:

- Study area definition,
- Definition of factors influencing bike infrastructure,
- Determination of variables from the available dataset,
- Development of value levels,
- Weighting each parameter, and
- Generating cycling infrastructure potential map with grid-based analysis in QGIS.

The Cycling infrastructure Potential was developed using existing data obtained from public institutions and the OpenStreetMap wiki. The data includes accident data, populations, existing bike networks, public transportation data, traffic data, land use, location of leisure activities, road slopes, and existing zone 30 areas.

Study Area

The study boundaries were predefined with Hasselt being the focus and its surrounding areas.

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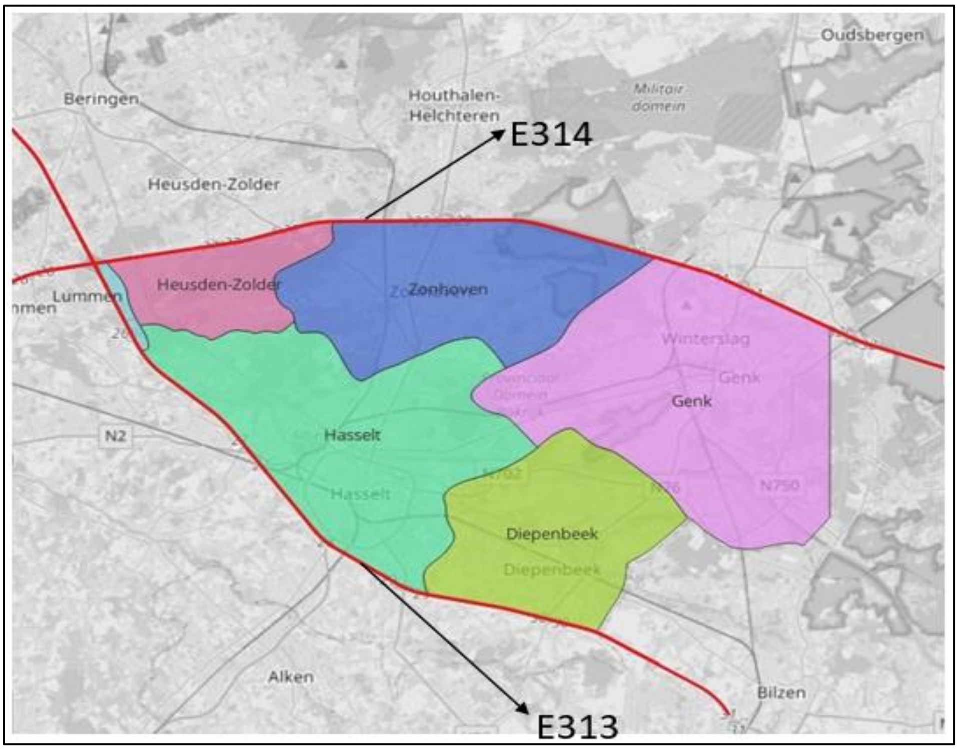
The study area was defined using existing attributes, in this report the study area was chosen using the intersection of European highways E313 and E314. The study has focused on the area defined by the polygon inside those existing boundaries. *Figure 1* illustrates the boundaries of the study area and the composition of the area.

Figure 1 Study area characteristics



Source: Researchers, 2024

The polygon defined is a combination of 5 municipalities which are Bilzen, Diepenbeek, Genk, Hasselt, Heusden-zolder and Lumen.

Influential Factors Selection

The cycle Infrastructure potential was derived from combining the pool of data described above using spatial analysis tools which is QGIS in this study. The soft mobility network follows a destination-oriented approach, which assumes that between certain Origins and Destinations present as well as potential demand for cycling exists, which needs to be covered by a cycle-friendly network.

From that, the origins and destinations of cyclists have been analysed and form the basis of the infrastructure potential. Cycle-friendly infrastructure is influenced by different variables which in this study were defined using the given dataset. The factors were chosen based on the principles of cycling infrastructure design developed by (Bertolini et al., 2006). The following three aspects were the basis of choosing the variables:

- Connectivity: people need to link consistently their origins and destinations.
- Safety: the network must guarantee cyclists road safety and help to prevent accidents and if it happens the chances of fatal and/or severe injuries are limited.
- Attractiveness: The network must be integrated and be in harmony with its environment for cyclists to be attracted to use it.

Soft mobility networks enable citizens to cycle in a safe, attractive environment with consistent, direct connections. With these aspects, different variables were chosen, the critical factor is that these aspects are interrelated, and one can impact

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the other. For example, for the network to be attractive must be safe and able to link different urban functions, and vice versa. *Figure 2* shows the variables that were chosen and their influence on bike infrastructure friendliness using the previous research (Bertolini et al., 2006).

Figure 2 Factors of bike friendliness

Connectivity
Land use
Cycleways
Population

Safety
Accidents level
Zone 30
Traffic speed and volumes

Attractiveness
Leisure locations
Road slopes

Requirements for a bicycle-friendly infrastructure may conflict, in this study, straightforward assumptions were made to make the right balance using past research studies on bicycle networks.

- Relating to the built-up environment all road slopes cannot be engineered to fit the flatness that cyclists find acceptable.
- All road network speeds will not be changed to fit bicyclists.

Given these constraints, careful selection of measurement variables becomes essential for the model to produce reliable results. Through the utilization of data from various datasets, each variable was defined and past research findings were analysed to understand their respective effects on the friendliness of bike infrastructure.

Table 1: Variables definition

Population	Variable	Symbol	Definition	Effect On Bike Friendliness
Strategic model Flanders	ADT	AVG_TR	Average daily traffic	The higher the average daily traffic the lower the friendliness for biking and vice versa
Road slopes	Slope percentage	Slp_perc	The rate of rise and fall along the length of the road	Elevation changes increase the energy expense of cyclists, therefore reducing the comfort of using and competitiveness of cycle highways.
Land use	landuse	L_Type	Allocation of land to different functions which defines the point of interest that formulates potential OD matrices	Different land use functions attract people to those places depending on activities (These are key origins and destinations)
Zone 30		Z_30	Designated area where the maximum speed does not exceed 30km/h	Priority for cyclists implying friendliness and safety as traffic is calm around these areas
Accidents data	Bikes	ACC_Bike	Accidents involving bikes at particular locations	Accidents involving bicycles determine areas that need intervention in terms of safety which involves improving infrastructure

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Population	Variable	Symbol	Definition	Effect On Bike Friendliness
Bike network	Cycleway		These are dedicated ways of cycling	Safety, convenience and comfort for bicycling depend heavily on dedicated infrastructure to this mode
Leisure	Leisure	Bike_LE	Social and recreational areas	Leisure cycling encourages people to cycle frequently
POPULATION	pop_2020	Pop	Number of people living in a predefined area	Population creates potential demand for infrastructure between origins and destinations.

Developing Current Variables Indicators and Values

To develop the current variables indicators and values, we followed a methodology similar to (Hartanto, 2017). First, we selected the factors known to influence bike infrastructure friendliness. These factors were then categorized into measurement variables, each represented by different value levels. In this categorisation, the highest level, denoted as 1, signifies ideal conditions, while the lowest level, represented by 0, represents that are far from ideal. These value levels provide a standardized way to assess and compare the current state of bike infrastructure across various criteria, helping to identify areas for improvement and prioritize interventions effectively.

Table 2: Current values levels

Data Set Name	Symbol	Current Values	Measurement Variables	Values Levels
Strategic model Flanders	AVG_TR	Traffic volumes & speed	Speed = 30km/hr and ADT<= 6000	0.6
			Speed between 31km/hr and 55km/hr and ADT <= 5500	0.4
			Speed >55km/hr and ADT>5500	0.2
Road slopes	Slp_perc	Slope percentage	0-2%	0.8
			2-6%	0.6
			6-10%	0.4
			10% and above	0.2
Zone 30	Z_30	Binary based on availability	Available	1
			Not Available	0
Accidents Data	Acc_Bike	Level of severity	Slight	0.4
			Severe	0.2
			Fatal	0
Bike network	C_Route	Binary based on availability	Available	1
			Not available	0
Leisure	Bike_LE	Binary based on availability	Available	1
			Not available	0
Population	pop	Population density	Normalized	1
				0
Land use	L_type	Land allocation	Residential	0.6
			Commercial & Industrial	0.5

Traffic volumes and speed were categorized following the Dutch manual for bicycle traffic (Ignatia, 2017) and Flemish design guidelines for bicycle facilities (Verwee & Daniels, 2022), (Cartolano et al., 2022). Road accidents were given a below 0.5 value as accidents are undesirable without considering the severity of the accidents.

Road slopes were categorized using the Dutch manual for bicycle traffic (Ignatia, 2017). Zone 30 areas improve the quality score when a cycle lane or track passes through the zone (Urbanczyk,

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2010). Land uses were categorized following (Hartanto, 2017), (Moreno et al., 2021).

Developing Acceptable Values for Variables

The acceptable values were developed with a reference scenario of the ideal conditions of each variable. The acceptable values are quantitative, and each variable's measurement level is assigned. Important notes with relevant references are provided in *Table 3*.

Table 3 Acceptable values and notes

Data Set Name	Symbol	Acceptable Values	Value	Notes
Strategic model Flanders	AVG_TR	Traffic volumes & speed	0.8	Traffic calming speeds which are less or equal to 30km/hr with trajected speed between 15-20km/hr (Cartolano et al., 2022; Verwee & Daniels, 2022)
Road slopes	Slp_perc	Slope percentage	0.8	Bicycle-friendly slopes from the Dutch Design Manual for bicycle traffic (Ignatia, 2017)
Zone 30	Z_30	Binary based on availability	-	These will act as complementarity areas to cycle infrastructure (Dirk Dufour, 2010), their values were kept as in the current situation.
Accidents Data	Acc_Bike	Level of severity	0.8	Target to reduce accidents by 50% towards zero in 2050 (Cartolano et al., 2022; Verwee & Daniels, 2022)
Bike network	C_Route	Binary based on availability	-	Existing cycle ways help to create robustness and cohesiveness; their future values were kept as actual.
Leisure	Bike_LE	Binary based on availability	-	These areas act as points of attraction for cyclists.
Population	pop	Population density	-	Population forecast in the short term remains the same (Tom Bellemans, Lecture on Land Use and Urban Design,2023)
Land use	L_type	Land allocation	0.8	15-minute cycle city vision with all daily provisions (Moreno et al., 2021).

An important note in this table is that certain variables are used for complementarity in this analysis therefore their acceptable values were neglected.

Weighting Parameters

The parameters were weighed on a percentage basis using the importance of each variable to impact infrastructure friendliness and its effect on purposes the bicyclists want to achieve. Bicyclist usually rides for utility or recreational purposes (Urbanczyk, 2010), Cyclists on those two different networks have different concerns while riding and the importance of requirements differ for each group. This study concentrates on the significant requirements for a cycle-friendly infrastructure for the utility network. The weights are positive similar to (Winters et al., 2011), where factors were chosen to indicate their utility in developing cycle network infrastructure.

From the user's perspective, we consider their concerns when travelling on the utility cycle network, and we weigh each requirement represented by different indicators in this analysis. Following the Europe policy guide for cycling infrastructure (Urbanczyk, 2010), the requirements rank is described in Table 4.

Table 4 Utility network requirements

Rank	Utility Network Requirement
1	Safety
2	Connectivity
3	Attractiveness

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From this ranking, we assigned weights to each of our variables as indicators in percentage.

Table 5 Variables weights

Data Set Name	Symbol	Weights	Justification [Sources]
Strategic model Flanders	AVG_TR	12%	TpBases, fietsberaad*, Design manual for bicycle traffic*
Road slopes	Slp_perc	10%	Design manual for bicycle traffic
Land use	L_Type	12%	PRESTO Cycling Policy Guide Infrastructure
Zone 30	Z_30	10%	Fietsberaad Zone 30 assessment framework
Accidents data	ACC_Bike	17%	Flanders Road Safety Strategic Plan
Bike network	C_Route	17%	Fietserbond Meetfiets
Leisure	Bike_LE	10%	TfL data on leisure & cycling
Population	Pop	12%	Design manual for bicycle traffic*

Development of Scores

The next step is to compute the scores using the current and acceptable values' attributes. The acceptable values represent the ideal conditions of a bike-friendly infrastructure, while the current values represent the current situation.

The current situation is represented by VC for each variable as defined, and VA represents the acceptable value. The difference between the ideal (VA) and the current situation (VC) represents potential infrastructure development or improvement. Equation (1) is the Potential value

$$POTENTIAL\ (VP) = VA(ACCEPTABLE\ VALUE) - VC(CURRENT\ VALUE) \quad (1)$$

The potential values coupled with the weights of each variable on the model indicate areas that boast opportunities for cycle infrastructure development. Each variable score is obtained by multiplying the weights and the potential values. Each variable attribute is given a score (Equation (2) is the score value):

$$Score = weights * potential\ value(VP) \quad (2)$$

Since our model has multiple variables, each is scored separately. The multicriteria analysis is applied to gain the total scores. Equation (3) Multicriteria analysis for all variables

$$f(VP1, VP2, ..., VP8) = WP1*VP1 + WP2*VP2 + WP3*VP3 + ... + WP8*VP8 \quad (3)$$

Where WP represents the weights and VP is the potential value for each variable.

GIS Procedures

This section describes how to manipulate geographic data to construct and combine data layers to produce the infrastructure potential map, with enough specificity for others to duplicate our research and produce a similar map when identifying potential corridors to improve cycling infrastructure. Briefly stated we used the variables’ value level described in Table 1. QGIS was used to make all manipulations. Each variable has its layer where the values are loaded using different QGIS tools. To sum the scores for all variables from different layers, the grid-based analysis was used as our layers consist of different vector spatial information, namely points, lines, and polygons. The study area is divided into 500 m x 500 m grid cells.

Generating Variables Layers to Create Potential Map (Potential for the Cycle Network)

Soft mobility Network Planning cannot be done on the basis of conventional road infrastructure development, due to the different network requirements and demands of cyclists which are different from motor vehicle users. Ideal

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connections in cycling, especially utility cycling are the ones that are within 10 to 15 km radius (Riehle, 2016). The analysis of the network followed a destination-oriented approach, where cyclists are drawn to different locations in order to fulfil specific functions.

Strategic model Flanders. Using this data set the measurement variables were assigned value levels as defined. Values for the current and ideal were added using the field calculator and then the potential difference was added. The score was then calculated by using Equation (2). The value was added to the grid using the join attributes by location (summary) by summarizing the score to the minimum for each cell. We give priority to routes with low speed as they have a high effect on friendliness on the cycle network (Urbanczyk, 2010).

Population. The population dataset was normalized depending on the urban density, with the highest density representing highly scored and the lowest representing the lowest density. The potential for this variable is based on the current dataset as the planning analysis has a short-term scenario. The score was added using Equation (2) and the score was added using the field calculator.

Figure 3 Population distribution map

Cycle network. Cycle network planning aims to complete the available network and create a cohesive network of cycle infrastructure. The dataset was also added and scored as described in *Table 1*. The field calculator was used to create a scoring field following Equation (2). The values were added to the grid by using the join attributes by location on a one-to-one join type on the first matching feature.

Land use. The land-use patterns were added to the model based on the values as described. Furthermore, equation 1 was used to get the variable potential which is then used to score using Equation (2). The value was added to the grid using the join attributes by location (summary), summarizing each cell's score to a minimum. We give priority to residential areas as they have high destination density (Winters et al., 2011).

Zone 30. The zone data set was added to the grid using the join attributes by location. The zone potential does not have an ideal value as we used them to make a direct cohesive network with traffic-calming roads.

Accidents data. Accident data set were processed to have accidents that involve bicyclists only, and measurement variables depend on the severity. The potential scores were added to the field and grid by joining attributes by location.

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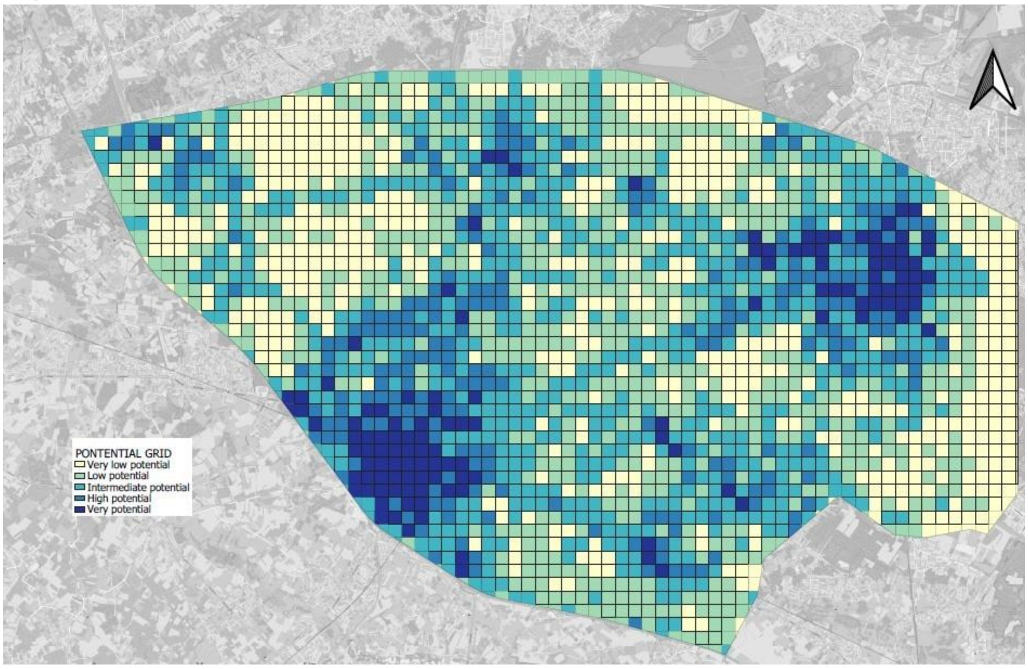
Figure 4 Accidents involving bikes

Leisure. The data set was added to the grid by joining attributes by location. The leisure score was also used as a complementarity for a bicycle-friendly infrastructure as other researchers have shown (Krenn et al., 2015).

Road Slopes. A bicycle-friendly infrastructure was characterized by its flatness according to the research by (Winters et al., 2011). equation 1 was used to get the variable potential which is then used to score using Equation (2). The value was added to the grid using the join attributes by location (summary), summarizing each cell's score to a minimum.

After joining all layers, the total score for each grid was added together in a new field. The total score is a sum of all variable scores for each grid cell and then turned into potential levels.

Figure 5 Result map



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RESULTS

Figure 4 shows the model output. The very high potential areas to improve the soft mobility network are in dark red while very low potential areas are light red as shown in *Figure 7*. Our focus was on existing physical conditions and used data for bicycle networks, road slopes, topography, land use, accident data, traffic data, leisure activities in the area, and zone 30. The high potential areas are characterized by a combination of factors as defined generally, high population density, availability of cycle networks, zone 30. The results from the total scores were categorized into levels as shown in *Figure 6*.

Figure 6 Score categorization

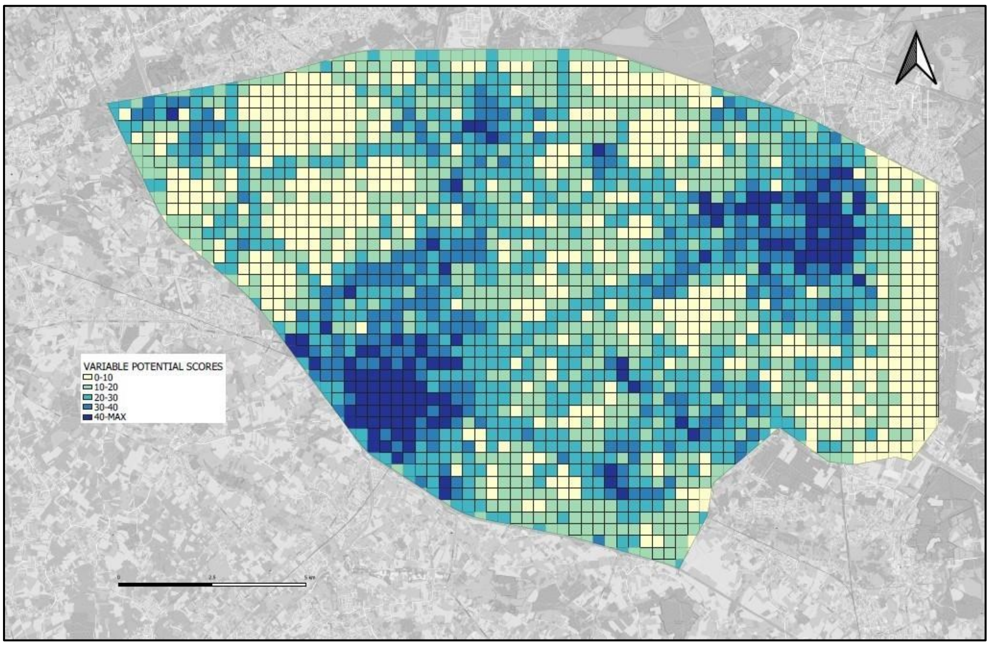
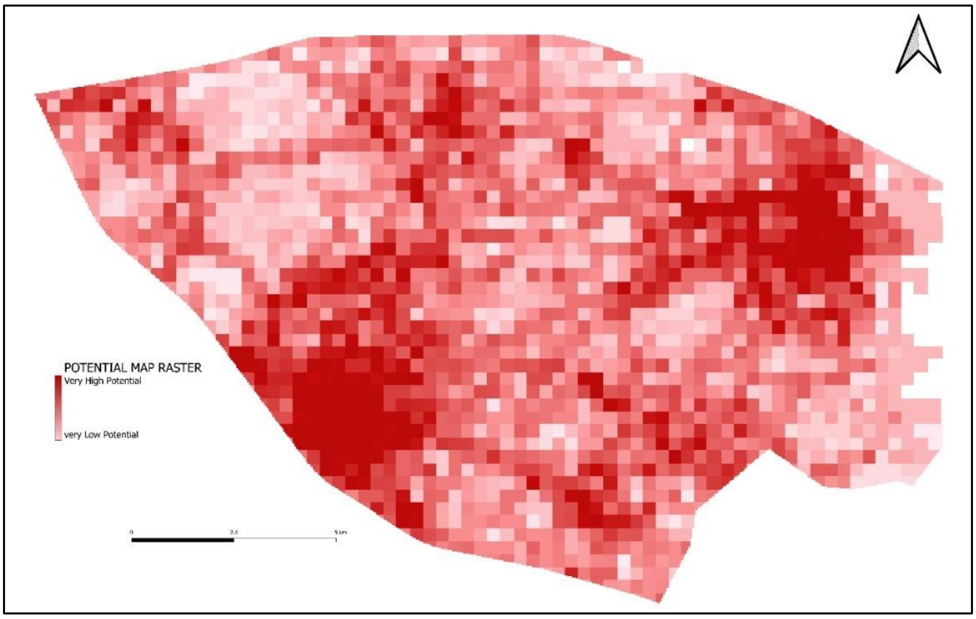


Figure 7 Potential map



Drawing of the Network

Using the potential map, the desired lines can be created to improve areas located in high-potential areas. Combining existing cycleways with map potentiality helps to locate areas that demand the improvement of cycle infrastructure to create a more cohesive infrastructure. The existing cycle

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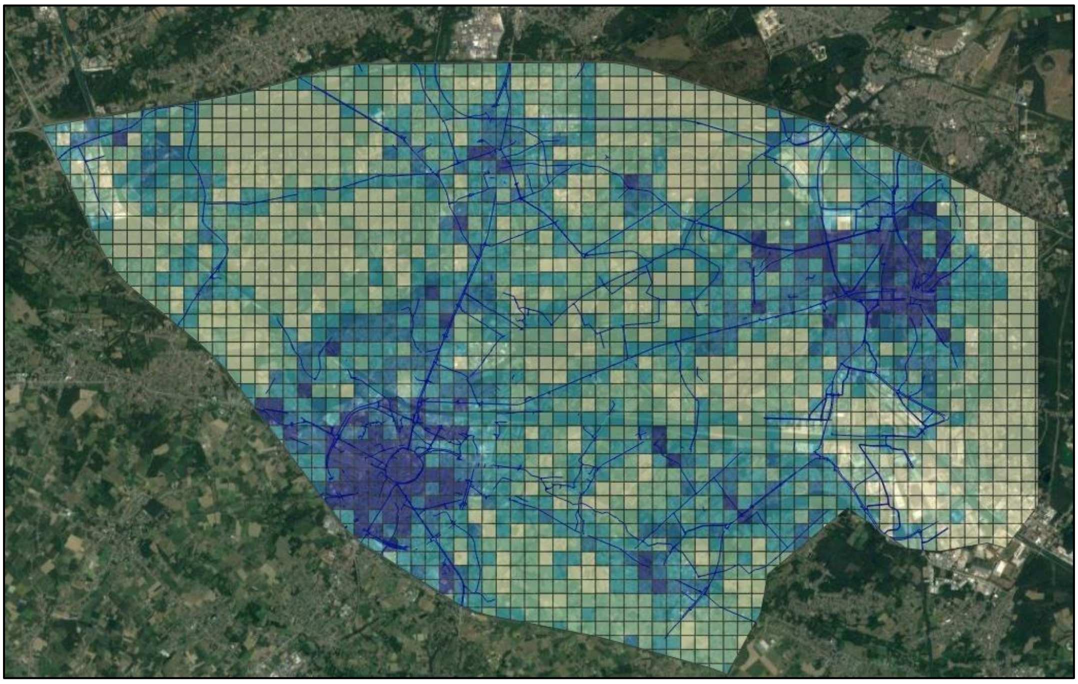
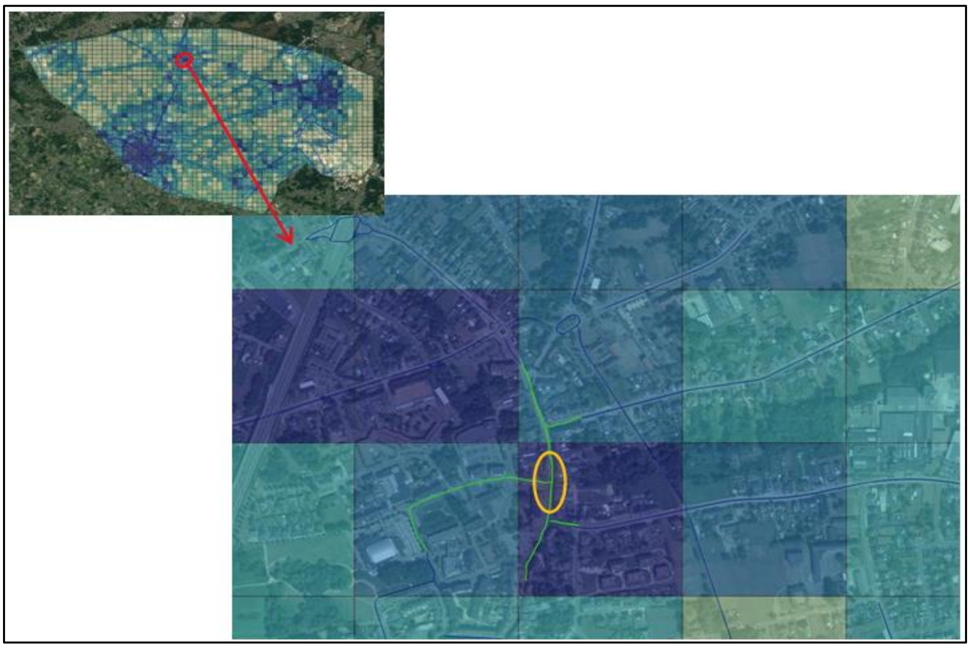
lanes are illustrated in blue lines, and areas of incomplete networks are evident in the study area as shown in *Figure 8.*

Figure 8 Potential map overlay with Existing network



To make the desired lines of our study area, we focused on a single high-potential grid in Zonhoven. The green lines indicate the desired lines of cycle infrastructure that complete the existing cycle lanes in blue.

Figure 9 Proposed project area of implementation



The area of improvement is bounded in a yellow circle characterizing the area of focus to improve the mobility network in this paper. The pictures in *Figure 10* show the area's current situation.

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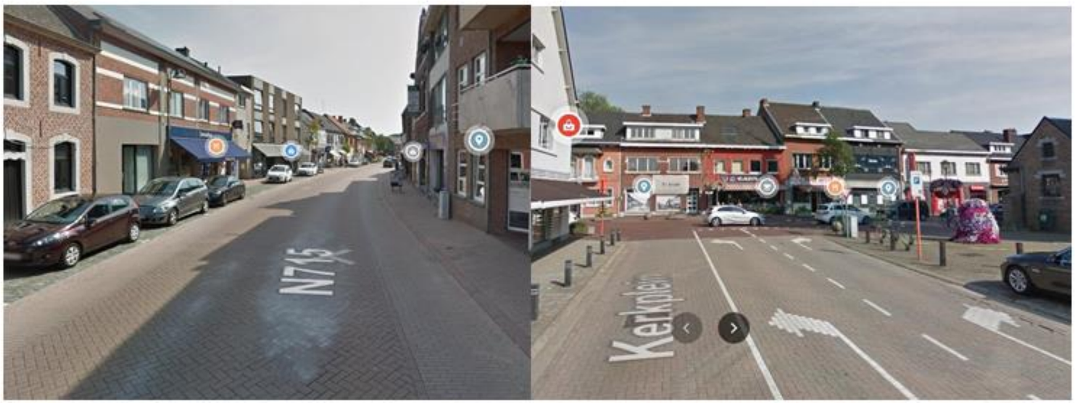
Figure 10: Current situation by Google Street View



Source: Google Maps

Using Google Street View information coupled with GIS data as provided by Flemish GIS data repository geopunt. be. The public space was identified and the boundaries of the road were.

Figure 11: Public Road reservation width

The route as shown on the right of *Figure 11* has 14.3 meters which are reserved for public roads. While at the intersection the dimensions are shown in *Figure 12*.

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Figure 12: Junction Width parameters

With this base information data, a current situation plan was drafted using Vector works. The proposed plan was drafted following Swiss standards for road design requirements with a focus on improving soft mobility network plans. *Figure 13* shows the current aerial view of the junction.

Figure 14 shows a proposed project plan to improve the junction and make it more friendly to cycling. Using Swiss standards, the junction and the adjacent road were transformed. The whole project plan is attached as an annexe.

Figure 13 Aerial view of the junction from Geopunt.be (before)

Source: Google Maps

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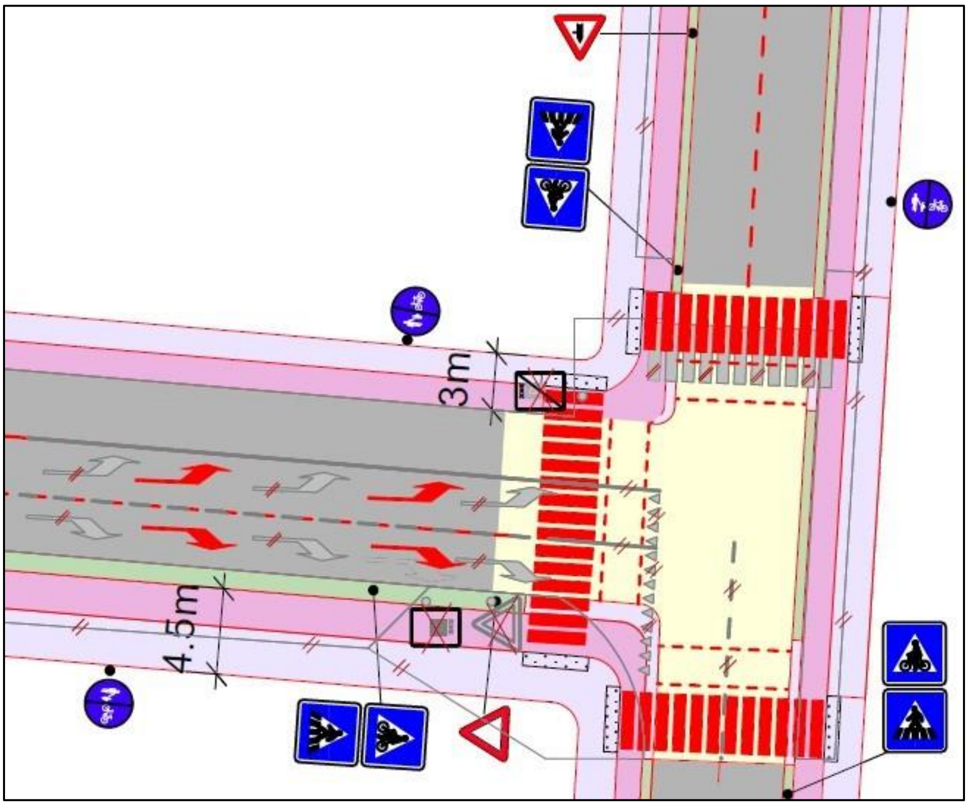
Figure 14 Project plan sample (after)



LIMITATIONS

The components of the bike-ability index have been empirically derived from objectively assessed environments along actually used routes. Only a small number of cycling-related environmental characteristics are required to create an informative bike-ability index, and the GIS data for these components are widely available, allowing bike-ability maps to be easily produced in other regions. One limitation of this study is the use of GIS-based data which are not updated sometimes. Another limitation is that the study has used an ideal scenario to create the potential of developing a bicycle network, however developing a new infrastructure can also lead to a trickle-down situation, with a new infrastructure creating new demands as well as new opportunities. The grid dimensions were also chosen arbitrarily with limited research to support it, but sensitivity analysis could be done using different dimension values. Finally, future implementation of GIS-based potential infrastructure analysis may incorporate data related to amenities which also complement bicycle infrastructure, for example, bicycle parking, and connection to public transport. Focus groups can also be used to gain perspectives on the weights of different components from the user's perspective.

CONCLUSION

The soft mobility network infrastructure development summarizes the use of different components which are related to cycling. GIS and external data were used to create maps of potential corridors to improve bike infrastructure by applying transportation standards. The grid-based analysis helps to combine data with different spatial information and joins different layers depending on the considered fields and summarises depending on the necessary output. The model can be improved by adding other bike-related facilities and travel demand surveys to have a more accurate presentation of the potential of an infrastructure.

REFERENCES

Arellana, J., Saltarín, M., Larrañaga, A. M., González, V. I., & Henao, C. A. (2020). Developing an urban bikeability index for different types of cyclists as a tool to prioritise

Article DOI: https://doi.org/10.37284/eaje.7.1.1930

bicycle infrastructure investments. *Transportation Research Part A: Policy and Practice*, *139*, 310– 334. https://doi.org/https ://doi.org/10.1016/j.tra.2020.07.010

Bertolini, L., Binkhorst, G. J., Burden, D., Eind, A., Huismans, G., Immers, B., Vuchic, V. R., & Walraad, A. (2006). Urban design and traffic–a selection from Bachs toolbox. *CROW, Ede*.

Cartolano, P. P., Vold, H., & Straten, E. (2022). *2021 Pan European Road Network Performance Report CEDR Working Group Performance of Road Network October 2022* (Issue October).

Hartanto, K. (2017). *Developing a bikeability index to enable the assessment of Transit-Oriented Development (TOD) nodes: case study in Arnhem-Nijmegen region, Netherlands.* http://essay.utwente.nl/83741/

Ignatia, J. (2017). Design manual for bicycle traffic. *Delft, Crow*.

Krenn, P. J., Oja, P., & Titze, S. (2015). Development of a bikeability index to assess the bicycle-friendliness of urban environments. *Open Journal of Civil Engineering*, *5*(4), 451–459.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities*, *4*(1), 93–111.

Riehle, E. R. (2016). How to plan and develop a pedestrian and cycling network-Basis for the Development of a NMT Strategy for Windhoek. *Retrieved July*, *15*, 2020.

Urbanczyk, R. (2010). *PRESTO Cycling Policy Guide. Promotion of cycling.*

Verwee, I., & Daniels, S. (2022). *CEDR Call 2016 Safety End of Programme Report* (Issue July).

Winters, M., Davidson, G., Kao, D., & Teschke, K. (2011). Motivators and deterrents of bicycling: comparing influences on decisions to ride. *Transportation*, *38*, 153–168.

Zhao, X., Zhang, J., Zhang, N., Wong, Y. D., Zhou, Y., & Meng, M. (2021). A GIS-CA model for planning bikeways upon the footpath network. *Sustainability (Switzerland)*, *13*(16). https://doi.org/10.3390 /su13168926

Żochowska, R., Jacyna, M., Kłos, M. J., & Soczówka, P. (2021). A GIS-based method of the assessment of spatial integration of bike-sharing stations. *Sustainability (Switzerland), 13*(7). https://doi.org/10.3390/su13073894