# Design Criteria for a Cycleway Network Using GIS, Topographic Levelling and Spatial Analysis

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http://doi.org/10.29227/IM-2024-01-27

Submission date: *2.2.2023* | Review date: *19.2.2023*

## Abstract

*The current need for the creation of cycleways in traditional cities often presents problems. Converting existing roads into cycleways frequently creates serious traffic issues without leading to the expected increase in bicycle use. In order to overcome some of these problems, this paper presents a composite methodology using GIS, topographic levelling and spatial analysis. Upon application of this methodology in a case study in the city of Patras, Greece, problems with the city's existing, recently-constructed cycleway are identified. After applying topographical, qualitative and population criteria, an alternative network of cycleways is proposed. This proposed new network does not create traffic congestion, as the basic criterion for selecting roads is their low traffic load. At the same time, topographic leveling is employed to select routes with a very low gradient (<2%), which is a determining factor in making the network attractive to users. Using spatial analysis, the network is spread in order to serve all areas of the city, making it available to the vast majority of residents. Finally, the findings of a social research poll (through the use of a questionnaire) indicate that the creation of such a network could increase bicycle use by a factor of up to18, which would make bicycles the main mode of transport for 22% of residents.*

*Keywords: design criteria, cycleway network, GIS, topographic levelling, spatial analysis*

**Introduction**

By the term "cycleway" [1] we mean a traffic lane that allows only the passage of bicycles. It is located either on the right-hand side of the road, right next to the motor vehicle traffic lane, or integrated with the sidewalk. In the second case, it can be in the middle of the pavement, or on one side of it that is considered safe, as it has no contact with the road, ensuring the physical integrity of the rider. The construction of suitable infrastructure for a cycleway is essential in modern cities [2-3] in order to promote safe and frequent use of the bicycle, thereby reducing the need to travel in motorized vehicles. In 2018, 2.6% of urban journeys were made exclusively by bicycle [4-5]. In some countries, such as the Netherlands, in the same year 30% of the population moved exclusively by bicycle, significantly reducing levels of gaseous pollutants [6].

The researchers calculated the amount of greenhouse gas emissions and the direct consequences of increasing the number of bicycles. Thus, their proposal for an expanded installation of infrastructure exclusively for bicycle use arose. According to the International Institute for Energy and Sustainable Development, in 2018 9.5 Gtn of carbon dioxide was produced from the use of motor vehicles. The construction of cycle paths could reduce these annual emissions by 0.18 Gtn [8-9]. Adopting the use of bicycles has many advantages. First, the traffic system in cities is decongested and the emissions of carbon dioxide and other gaseous pollutants derived from fuels, for example sulphur, which causes acid rain, are significantly reduced. Moreover, the problem of noise pollution is limited, especially in large urban centers. Cycling is also adopted by some as a means of physical and mental exercise [10-12].

In the last few decades, the increasing demand for sustainable and healthy urban transportation has led to a growing interest in the development of cycleway networks in cities [13-15]. Well-designed cycleway networks promote sustainable urban transportation, enhancing public health, reducing traffic congestion, and mitigating environmental impacts [1].

There are many positive examples. There are several cities around the world that have implemented well-designed cycle track networks, some of which include:

A) Amsterdam, Netherlands: Amsterdam is renowned for its cycle-friendly infrastructure and is considered one of the best cities for cycling in the world. The city has over 400 km of dedicated cycle tracks, providing a safe and convenient way for cyclists to get around [16]. B) Copenhagen, Denmark: Copenhagen has a comprehensive cycle track network that covers much of the city and is considered one of the best in the world. The city's cycle tracks are well-maintained, well-signed, and provide a safe and convenient way for cyclists to get around [17]. C) Utrecht, Netherlands: Utrecht is another Dutch city with a well-designed cycle track network. The city has invested heavily in its cycling infrastructure, including the construction of several high-quality cycle tracks that provide a safe and convenient way for cyclists to get around [16]. D) Berlin, Germany: Berlin has a growing cycle track network that provides a safe and convenient way for cyclists to get around. The city has implemented several initiatives to encourage cycling, including the construction of high-quality cycle tracks and the provision of bike-friendly infrastructure. E) Portland, Oregon, USA: Portland has a well-designed cycle track network that provides a safe and convenient way for cyclists to get around. The city has invested in a range of cycling infrastructure, including high-quality cycle tracks and bike parking facilities, to encourage more people to cycle. These cities serve as examples of how well-designed cycle track networks can encourage more people to cycle and provide a safe and convenient way for cyclists to get around [18].

However, despite these positive examples, the introduction of cycleways in traditional cities often creates serious problems related to worsening traffic, poor planning and traditional land use. Thus, the introduction of cycleways often creates more problems than it seeks to solve without increasing bicycle use [19].

The vast majority of traditional cities that have cycleways fail. In this paper, some basic principles of redesigning and integrating a bicycle path in a traditional city are proposed, using Patras (Greece) [20-21] as an example. These principles are based on a model that combines G.I.S. techniques [22-23], spatial analysis and social research and focuses on small interventions that can be implemented immediately, have very low financial costs and which have the consent of the local community.

**Case Study: Patras, Greece**

Patras is the third largest city in Greece, the capital of the prefecture of Achaia and is an important urban centre in the Peloponnese, with significant commercial and industrial development. It has a population of 250,000 and is divided into an old and a new city.

Regarding its geographical location, it is located in the northwest of the Peloponnese and looks onto the Gulf of Patras. Its port is one of the largest in the country at a key point and is a channel of communication with Italy and Western Europe.

Patras, being the largest urban center of the time, could not help but be designed in such a way as to ensure the optimal movement of citizens. Initially, the Town Plan was assigned to the experienced Corfu engineer, Stamatis Voulgaris. However, the political and socio-economic reasons of the time did not allow the implementation of this plan and thus Patras was gradually built up based on city plans of other engineers.

Initially, in Patras, there was the area of the center and gradually extensions were made around it. The first cycle of expansions, in fact, was completed in 1929. Then, in the modifications that were made from time to time, the green areas provided for in the Plan were parcelled out including those areas with archaeological findings. In the extensions that followed 1929, the concept of common space did not exist anywhere. From 1858 to 1929 the plan was extended 12 times – in 1877, 1882, 1883, 1885, 1886, 1900, 1903, 1923, 1924, 1926, 1927, and 1929. All these extensions constitute the old plan, which maintained its extent until 1971, when a new cycle of extensions began. While initially the Voulgari plan envisaged a geometrically organized city, the modifications it received from time to time altered the form of the plan, resulting in a significant reduction in green spaces such as parks and squares.

Patras is a city ideal for cycling. Many residents in the area have already adopted the bicycle as an exclusive means of transportation within the city. However, what is missing is the existence of an organized bicycle path that will ensure the safe and fast movement of citizens to their destinations. From 2021, the necessary studies have begun to be carried out in order to build a cycleway, which mainly crosses the coastal part of the city. In fact, a part of it has already been built. This bike path starts from the Plaz area on Iroon Polytechniou street, continues straight to Othonos Amalias and then to Akti Dymaion street. There are also individual streets which are either pedestrianized, or meet the criteria for pedestrianization and which could function as individual streets exclusively for the passage of pedestrians as well as bicycles. These streets are Papaflessa, Trion Navarchon, Kanari, Pantanassis, Gerokostopoulou, Agios Nikolaos, Riga Feraio, as well as a section of road around Ypsilon Alonia square and the ancient Roman Conservatory.

Fig 1. The study of the cycle path of Patras and the pedestrian network.

Despite its considerable extent, the cycleway in Patras is an example of incorrect planning as it neither connects key areas of the city nor serves the majority of residents. At the same time, the design along the coastal road has created additional traffic problems while users' access to the cycle paths cannot be effected safely. In some locations, moving from one area to another is difficult, since the user will have to pass between areas of great height differences and gradients.

The result of all the above is that city cyclists do not use the cycleway. In this work, through a series of criteria, we propose a new method and the creation of a new network of cycle paths.

**Methodology**

The two main aims of designing a cycleway are a) to ensure the cycleway network connects key origins and destinations, such as residential areas, schools, workplaces, commercial centers, and public transport hubs. B) to aim for a continuous and seamless network that minimizes interruptions, providing a smooth flow for cyclists without unnecessary detours or gaps.

In an attempt to properly redesign a bicycle network, we propose the following step-by-step methodology:

A) identification of the main points of the city from which the most popular entrances and exits to the cycleway system are expected. Such points might be the commercial center of the city, the universities, the large school complexes, work and entertainment areas, etc.

B) selection of main and alternative routes through low-traffic roads that meet the minimum requirements to include bike lanes.

C) selection of the optimal main route through topographic leveling [24-25] (minimum slope per length)

D) application of a spatial cycle analysis methodology in G.I.S to identify the areas not covered by the main route.

E) repetition of steps B and C for each region and extension of the main path with branches.

F) evaluation of the overall design through a social survey questionnaire aimed at future users and an attempt to predict the future increase in bicycle use.

**Results and Discussion**

Based on the above principles, a 12.5 km route was designed which penetrates the main axis of the city. As terminal stations, we chose the University of Patras and the University of the Peloponnese (TEI), with a total of 30,000 students attending. Also, the cycleway crosses the main axis of the city so that it can be accessed from all neighborhoods on the one hand, and on the other hand it can serve most possible journeys. Particular weight was given to the feeling of safety of the users. For this reason, roads with very low traffic volume and already extant pedestrian / cycle paths were chosen. Special attention was also paid to the safety of crossings as well as the connection of the cycle path to mass transit such as the suburban railway.

Another key concern of our proposal was to investigate the altitude differences in order for the route we chose not to exceed a 2% gradient at any point. In the gradient diagram (Figure 2) the cycleway runs from the TEI on the left to the University on the right. As can be seen, the gradient at no point exceeds 1.2%.

Taking the above into account, we present the basic route of our proposal. Our basic route starts from the University of Patras and the Hospital. Then there are four main sections. The first, in the Bozaitica area, follows Australia Street, a very low-car street and very smooth for bikes. On the way there are several squares and parks. The second part of the route follows Pheidias Street (with its extensions), a very low-traffic road that is mainly used for parking. Here our route passes by two stops of the suburban railway, while it is connected with popular squares, parks and public services. In the third section, the route crosses the main commercial center of the city and extends mainly to the pedestrian street of Riga Feraiou Street. In this section the user can connect to the commercial area of the city and all the important services. The fourth section is mainly located in the area of Terzi, an area of very low circulation and quite poor. The aim is for the cyclist to pass through here on a quiet journey without risks, but also to develop the area itself. The cycleway ends at the University of the Peloponnese (TEI).

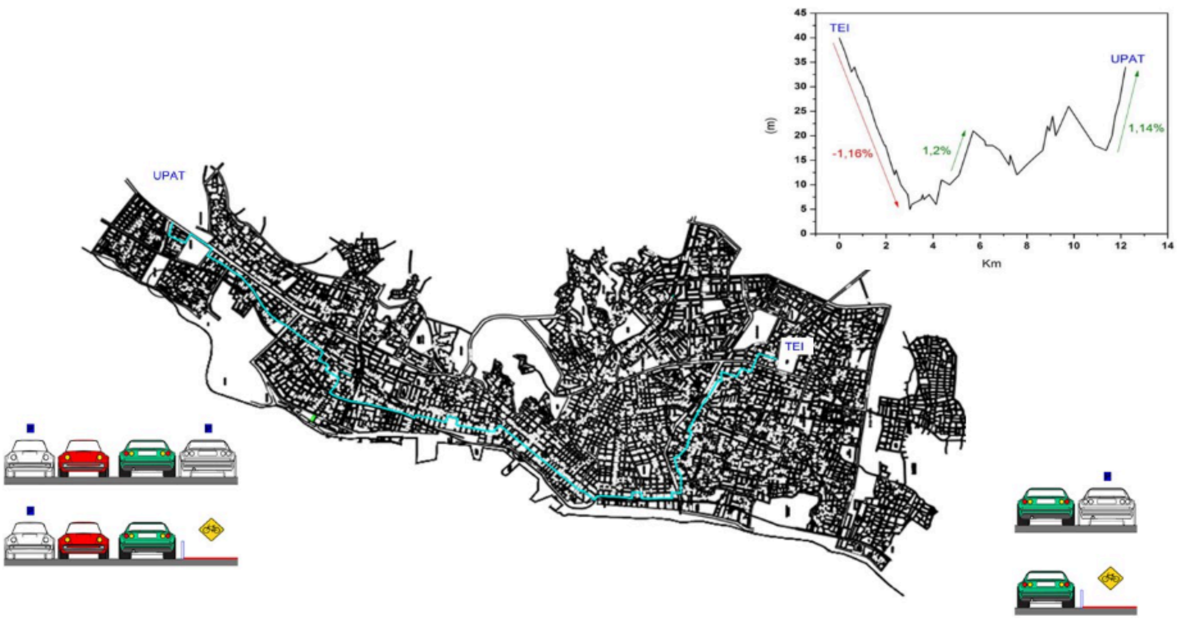


Fig 2. Main cycling route and longitudinal gradients

However, by using only the main route, there are parts of the city that are not covered. Thus, using GIS and spatial analysis, 4 areas in need of expansion were identified using circles with a radius of 740 metres. (Fig 3).

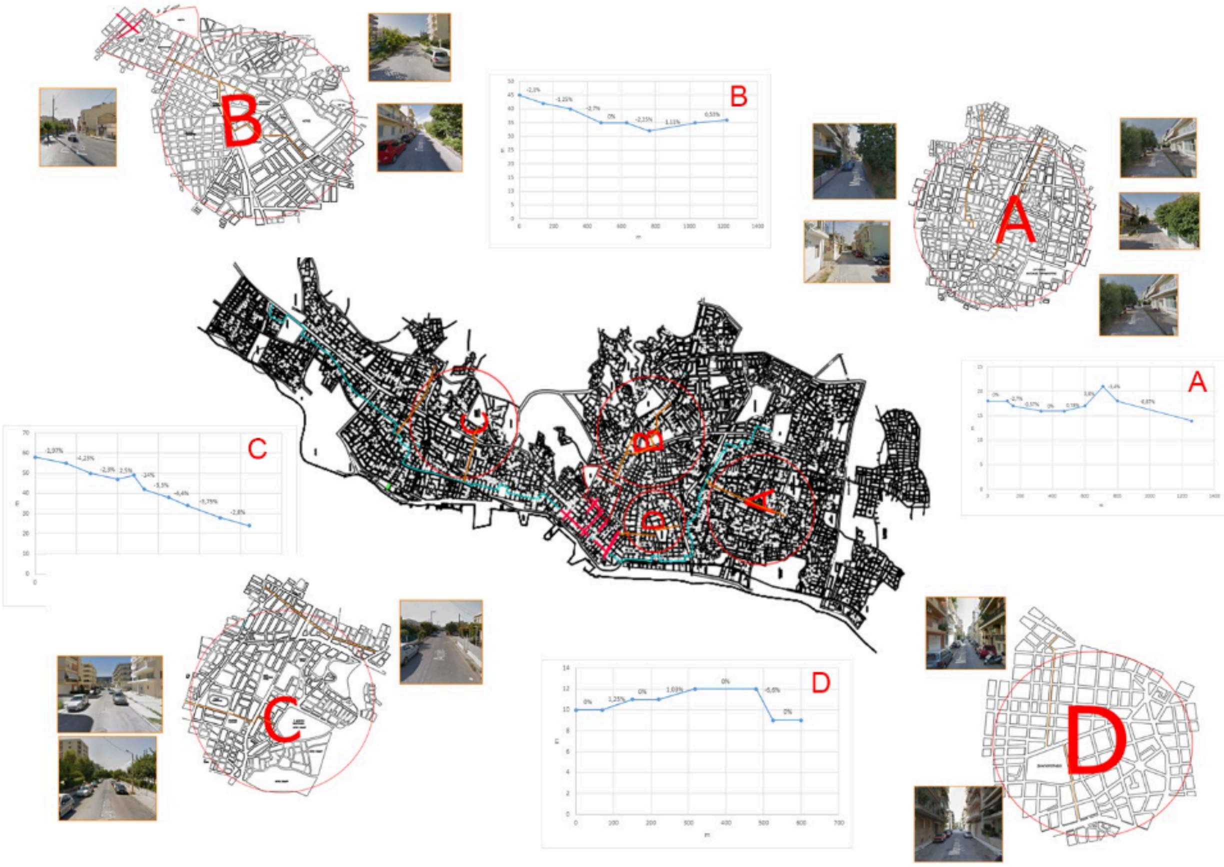


Fig. 3. The 4 extension areas of the bike path and the longitudinal gradients.

Outside these areas, the same methodology was repeated and cycling extensions were drawn up. These expansions as well as their gradients are shown in the figure above (Fig 3.). As we can see in these extensions, the gradients in some places exceed 2%. However, this excess is not prohibitive for use as these are small auxiliary routes that are mainly used to give the user access to the main route.

A structured questionnaire, taking into account age, gender and place of residence and statistically weighting them, was given to 1072 residents of the city. The questions, concerning the present research, focused on the current use of the existing cycle path but also on the possible use of the proposed cycle path. As for the proposed path, questions were based on the main route only as the extensions had not yet been proposed.

The results of the research were impressive as, while the current cycle path is used by only 1.2% of the city's residents, the proposed path increases this percentage to 22%. If this were to become a reality, the actual number of cyclists would increase 18 times, with multiple positive effects on citizens' health as well as on the functioning of the city.

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