# Using system dynamics and GIS to overcome decrease in number of regular children cyclists

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***Abstract*** – Today situation in active children transport is much different than a few years ago. Nearly half of the children are transported to schools and sport facilities by parent's car. This situation is caused mainly by parents fear of rush traffic on the streets. This article deals with identification of factors that can make the situation better. The main emphasis is placed on ensuring safety on route. System dynamic model was prepared to study the impact of different policies on safety route. Authors of this article believe that only improvement in cycling infrastructure is insufficient if the infrastructure is not mapped and this information is not published. Therefore, we propose the creation of such geoinformation portal that will contain information about the type of bikeway, so that parents can plan a route merely on safe roads.

***Keywords –*** children cyclist, cycling, bikeway, model, WebGIS, geographic information system, Internet

## I. Introduction

Public policy makers increasingly promote cycling as an alternative for commuting or recreation purposes. The key to this is to provide appropriate bicycle facilities such as wide lanes and bicycle paths. Investment in cycling facilities improves the level of cycling in the country and is an important part of the government initiatives to increase the number of cyclists. Linking cycling infrastructure, particularly in the form of urban networks of protected bikeways and bike trails and regional networks also allows smooth movement of cyclists and bikers. [1]

All over the world are becoming more frequent traffic jams, pollution and a dramatic increase in obesity, particularly in the U.S. The rationale for promoting cycling is that it would shift some trips from the car, thus reducing roadway congestion, parking problems, air pollution, noise and energy use. Cycling is therefore increasingly recognized as a clean, enjoyable and sustainable mode of transport in urban areas, and a means to encourage physical activity as a component of public health [2].

Cycling as a mode of transportation is not a minority trend, but the full form which supplements other modes of transport. [3][4]Despite this fact, more and more people use car as the main mean of tra nsport, even at very small distances. For example in the European Union 30% of all car journeys are less than 3 km long. Efficiency of different means of transport can be explained on this example: in the city can be transported on lane 3.5 meters wide (normal lanes) for 1 hour, 22 000 people by tram, 19 000 people on foot and 14 000 people on a bike, but only 9,000 people by bus and 2,000 people by car. [5]

Major proportion of cycling is in cities with flat terrain, good weather conditions and good transport system of the city, where bikeways are created. Bikeway network should be regularly updated with new section and buildings. The city should be performed integration of cycling into the transport system of the city to bicycle could become a full and competitive vehicle for everyday use. [6]

Definition of bikeway is not unified but it cover segregated cycle facilities consisting of marked lanes, tracks, shoulders and paths designated for use by cyclists and from which motorised traffic is generally excluded.

Fig. 1: Example of bikeway marking [7]

Bicycle paths (bikeways and bike trails) form irregular network of inconsequential territory. Partial organization is only at the level of individual regions that are trying to coordinate the building of bikeways and local bike trails. The main problem is also in the competencies. Cycling as the mean of transport is covered by ministry of transportation but recreational cycling is supported by ministry for regional development. As a result, it may happen that bike trails are built out of bikeways, along local roads.

Bike trail is a route for cyclists marked by landmarks or tourist traffic signs. Bike trails should effectively link points where cycling can be assumed. Bike trails may be places on bikeways, or roads.

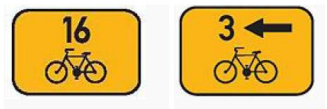


Fig. 2: Example of bike trail marking [7]

To best use limited funds it is necessary to determine city districts that need to be preferably improved and what kind of cycling facility have to be build. Solving the problems of cycling in urban areas is mainly in the compromise use of roads shared with motor traffic and pedestrians. When city council decides to support mainly commuting cyclists they

should bear in mind that commuting cyclists prefer fast and safe way. Recreational cyclists are willing to accept detour in 10% of path length if this way will be calm and scenic. [1]

## II. Types of Cyclists

When dividing cyclists into types, usually the division is based on two categories: recreational and commuter. This division is justified by the division of competencies in the field of cycle transport. Cycling as the mean of transport is covered by ministry of transportation but recreational cycling is supported by ministry for regional development. In the following text is added category of children's cyclist, which has its own characteristics and therefore cannot be simply assigned to one or the other category.

### *A. Commuting cyclist*

The term "commuting" covers driving to work, to school, shopping and so on. Mainly it represents the way of transport - fast, cheap and clean. The requirements for route selection are secure communications without the high elevation and the possibility of safe storage of the wheel. When users move around the city usually take into account the parameters of the bikeway marking, safety, slope, surface, length or type of communication [8] [9]. Commuting cyclists are goal oriented; their goal is to move from A to B with minimum effort. As some studies suggest, they are not so dependent on the weather. Commuting to work and school in the Czech republic has the largest proportion in region Pardubice (7,4%), region Olomouc (6,5%) and in region Hradec Králové (6,1%). City of Prague is in last place (only 0,6%). [10][11]

### *B. Recreational cyclist*

Cycling is not only useful, being the way of transport, but it is also fun. Cycling is a great way to explore: fast enough to cover the ground and provide a continual change of scene but slow enough to take it all in. Recreational cyclists are also goal oriented but their goal is not to pass the trail with minimum time but to find clean scenic way without crossing with busy road routes, required is quality marking of trails and necessity is some service in the surrounding (restaurant, accommodation, bike storage...).

In this group there is often the requirement for cruise route with different route for departure and return [8] [9].

### *C. Children cyclist*

Children cyclists are much more vulnerable than adult. It is because of less motion stability, their perception is not on the high level, they also do not predict situations as adults do and children are more prone to distraction. Safety concerns are a key reason why many parents don't let their children cycle to school. Actual injury risk is only part of the picture. Parents are feeling personal guilt if their child is injured cycling to school.

All these attributes caused today's situation when majority of children do not commute by bike to school or afternoon classes. European commission [5] declares that as many as 20 % of journeys in the rush hour period, in town; involve transporting children to school in cars.

Despite the problems with children cycling, it has to be said that cycling is a good way to encourage young people to take exercise on a daily basis and it is the way how to promote cycling for the future. Children who were used to cycling in the childhood are more likely to be commuting and recreational cyclist in the adulthood.

## III. How to Enhance Children Cycling

### *A. Infrastructure establishment*

Cycling infrastructure involve mainly cycling paths (bikeways and trails) that gives cyclists the feeling of safety on the road. To January 1st 2012 was in the Czech Republic prepared total of 1903 km of cycling paths. The largest network of trails is in the capital city of Prague and in the region Central Bohemia. The large number of paths is also in Moravian-Silesian region, region Zlín and region Olomouc. [12]

Equally significant are also other cycling facilities that give feeling of safety storage of parked bike. Unfortunately bicycles are often stolen, mainly in the rush places so safety storage is necessary condition for cycling enhancement. Extended network of bicycle rental or possibility to take bike to the bus or train represent additional infrastructure.

From the children cycling point of view it is necessary to emphasize two infrastructure features: safety on the road and safe bike storage. Bikeways can be carried by roads or outside. Bikeways on the road can be marked as "with-flow" or "contra-flow" lane. These lanes can be used exclusively by cyclists or can be shared with buses, taxi or tram. Adult cyclists have normally no problem using all those on-road bikeways nevertheless children (because of the features mentioned previously) can be vulnerable. For this reason, it is appropriate to use mostly outside-road trails and where it is not possible, choose a less busy road. Safety bike storage should be provided by schools, sport centers, and other facilities providing recreational activities for children.

Essential model, presented on Figure 3, shows the impact of change in safety on the number of commuting children cyclists in particular town. The model contains one stock, two flows and 17 variables. This simplified model does not include other factors that may affect the amount of children as can be the attractiveness of cycling, continuity and directness of routes, and comfort.

The main principle of operation of the model is that an increase in traffic intensity leads to the formulation of the requirement for building bikeways in order to maintain the safety on the same level. This presumption is built on the fact, that cycling is much safer and more popular in those countries where bikeways, bike lanes, special intersection modifications, and priority traffic signals are the key to their bicycling policies.

As shown in the article "Making Walking and Cycling Safer: Lessons from Europe," [13] the modal split share of cycling is more than ten times higher in the Netherlands (28%), Denmark (20%), and Germany (12%) than in the USA, where fewer than one percent of urban trips are made by bike. Moreover, the fatality rate per 100 million bike trips is less than a tenth as high in the Netherlands (1.6) and in Germany (2.4) as in the USA (26.3).

If the actual bikeway coverage does not reach the desired level, then it decreases the safety of travel. This has an impact on the conversion ratio (ie how many children able to commute really start regularly ride a bike) and also on decrease ratio (children who lose feeling of safety can stop commuting).

Construction of bikeways does not start earlier than the city government registers problem. This means that as the traffic intensity growth, the number of children fall until it reaches some threshold value, and then the problem is detected. In contrast to reality, this model is significantly simplified. It takes into account only number of children but it does not include other factors such as the ability to obtain grants from the European Union, the impact of central policies, etc.

Construction rate of building bikeways may be different for various cities and may be changed in the model. By default it is set to 1% of city coverage per year, which corresponds to the time and financial cost of such the project.

Described model core represents balancing loop with the delay (delay is cover by recognition of the loss of children). One part of this loop has not been described yet which is safety storage of bike. Safety of route without safety storage is insufficient tool to promote cycling. No one wants his/her bicycle to be stolen. If a child has no place to store the bike in addition to the fact that his school or sports facility are located in a busy place, then the probability of commuting is low.

Input into the model is the number of 6 – 15 years children able to commute. In the group of six years old it is a minimal number, but in any other age group, this amount increases. For simplicity, expected amount of children in this model is equal to the population size of one age group. Conversion rate is determined not only by the normal rate of conversion, which is different in different cultures, but also due to safety. Decrease ratio is given by a number of children who exceed the age limit and by the effect of lifestyle changes.

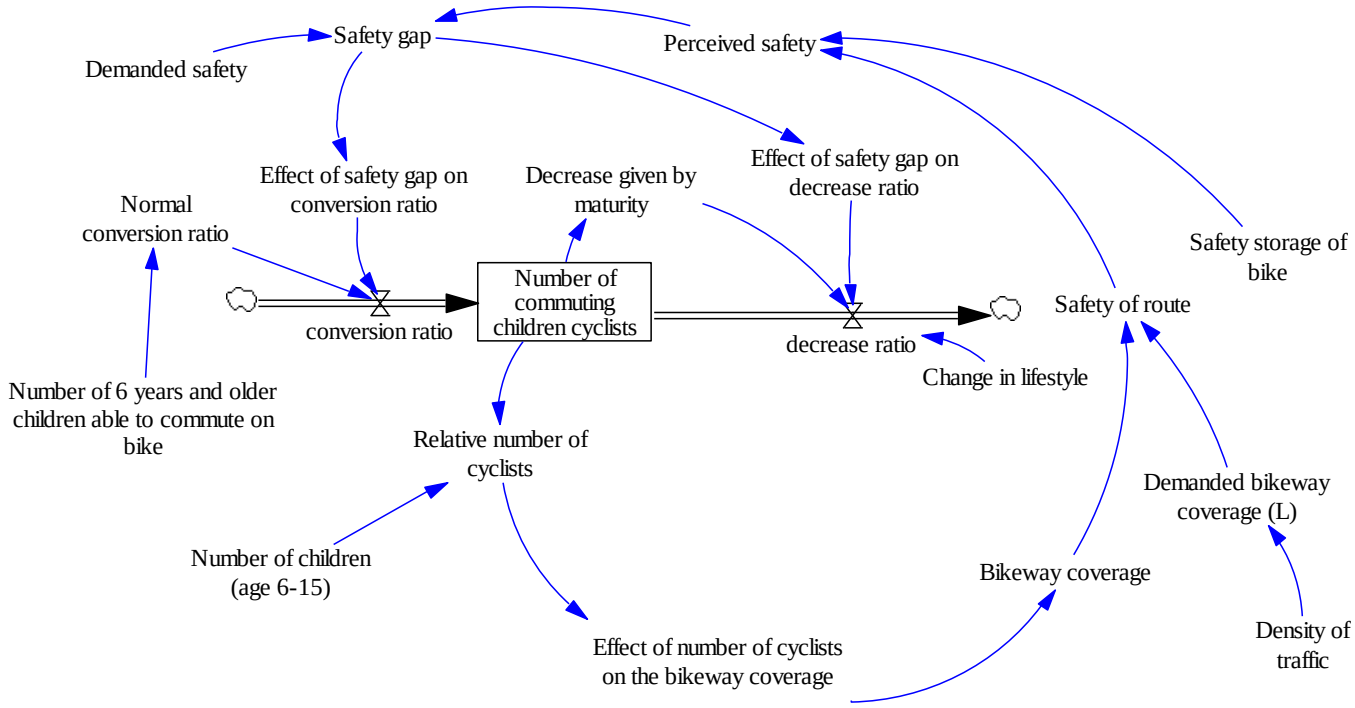


Fig. 3: Essential model of safety impact on the number of commuting children cyclists

The model that was described is generally usable after setting of variables. In the following text we will introduce three scenarios applicable to the city of Pardubice. For all scenarios are given the same conditions according to these variables:

- Change in lifestyle = 1
- Safety storage of bike=1
- Density of traffic= 1+RAMP( 0.1 , 1995 , 2005 )

Setting of these values means usage of original balance loop (safety of route) without any other impact. Function of density of traffic is based on statistics that show doubling of traffic between years 1995 and 2005. Last data from 2010 show stabilization or light decrease of traffic probably due to

world crisis (measurement of intensity of traffic is provided once in five years).

Designed scenarios show how the model can work under different conditions.

*Scenario 1*

Intensity of traffic is increasing, however city council does not react and no bikeway is constructed. Figure 4 display the impact of zero bikeway policy on safety of route variable. Maybe the term policy is not appropriate because it happens mostly unintended; however it is useful therefore it distinguish inactivity from different types of activities. From the figure it is obvious that safety of route is falling down to zero that affects number of commuting children as shown at figure 5. Decrease of the stock shows that in 50 years there will be almost no commuting children cyclist. Moreover since 2005 there is no inflow into the stock, only outflow.

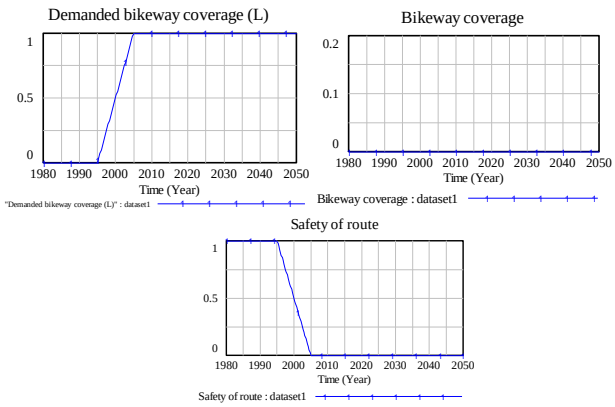


Fig. 4: Impact of zero bikeway coverage on safety of route

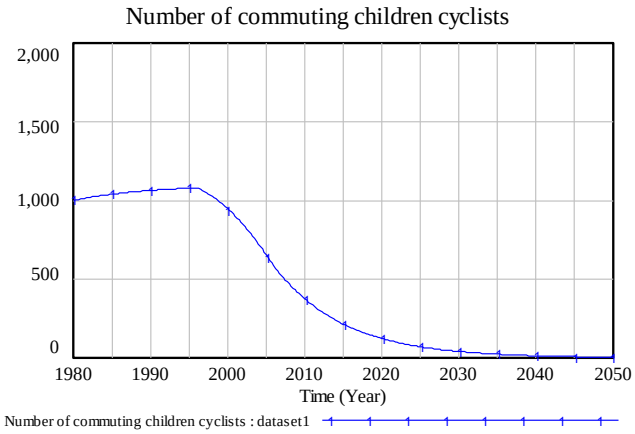


Fig. 5 Decrease in number of commuting children during zero bikeway policy

*Scenario 2*

Second policy represents more realistic approach. Decrease in number of commuting children cyclists is not noticed till the threshold is achieved. The reasons for this delay in behavior might be different. The basis is the fact that a person needs a certain amount of time to accept new facts. At this time either no changes are noticed or they are perceived as temporary with believe that it is not a long-term trend.

In order to prepare this simulation we needed to change the Effect of number of cyclists on the bikeway coverage so that if relative number of commuting children cyclists is above the threshold (half of the initial value – 10%) it stays 0 and after the crossing the threshold building of bikeways starts with the speed 1% of coverage per year.

- "Effect of number of cyclists on the bikeway coverage"=IF THEN ELSE(Relative number of cyclists<=0.05, 0.01 , 0 )

From the results on figures 6 and 7we can see how is the change in bikeway coverage, safety of route and number of commuting children cyclists. Even more then 50 years is insufficient for the stock to cross the threshold. From the above example it is apparent that the bikeways must be realized at higher speed.

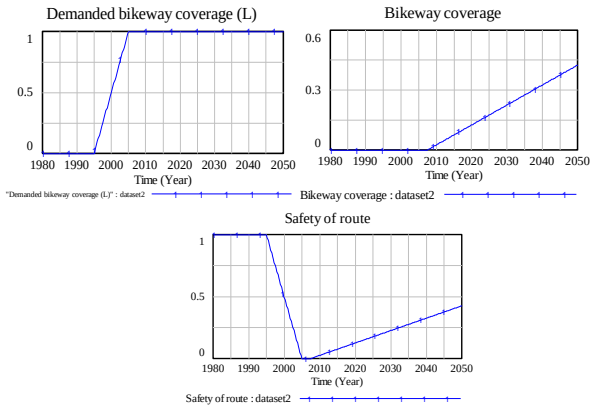


Fig. 6 Impact of delayed policy (decrease below half)

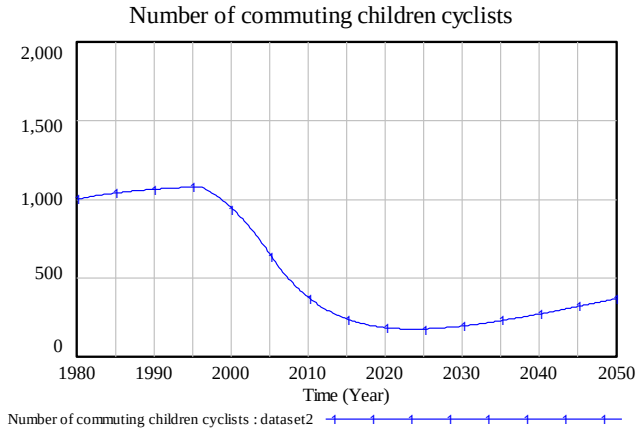


Fig. 7Change in number of commuting children due to delayed policy

*Scenario 3*

Third scenario is based on the second one with the modification that takes into account safety of different types of bikeways. There are many different types of bikeways, however from the safety point of view we can distinguish three types:

- Only cyclists path - is the safest type of bikeway therefore it obtain weight 1

• Cyclists with pedestrian path - is safe, however there is possibility of collision with pedestrian so the weight is lower 0.8

• Bikeway on the road - should be built only in the case when other types cannot be realized. Probability of collision with motor vehicle is higher; the greater is the speed difference. Weight for this type is 0.4

Share of different types of bikeways is dependent on external factors, so we are not able to incorporate them into the model. The most important factor is the budget. Particular types of bikeways differ not only in terms of safety, but also in the costs. Only cyclists path is five to ten times more expensive then usage of existing sidewalk or road. Nevertheless there is second external factor influencing choice of bikeway type – layout of road. If there is enough space, it is possible to choose only cyclists bikeway, if there is sidewalk with sufficient width, cyclists can share the sidewalk. Narrow roads without sidewalk require bikeways on the road.

In this particular scenario we set the ratio of types in such a way that respects the budget and the layout:

Only cyclists 10%, Cyclists with pedestrians 50%, Road bikeways 40%.

In order to use weighting of bikeway coverage we had to introduce new variables. Three of them are constants with defined share as defined above; weighted bikeway coverage is defined as follows:

• Weighted bikeway coverage=Bikeway coverage* (Bikeway on the road*0.4+Cyclists with pedestrians path*0.8+Only cyclists path*1)

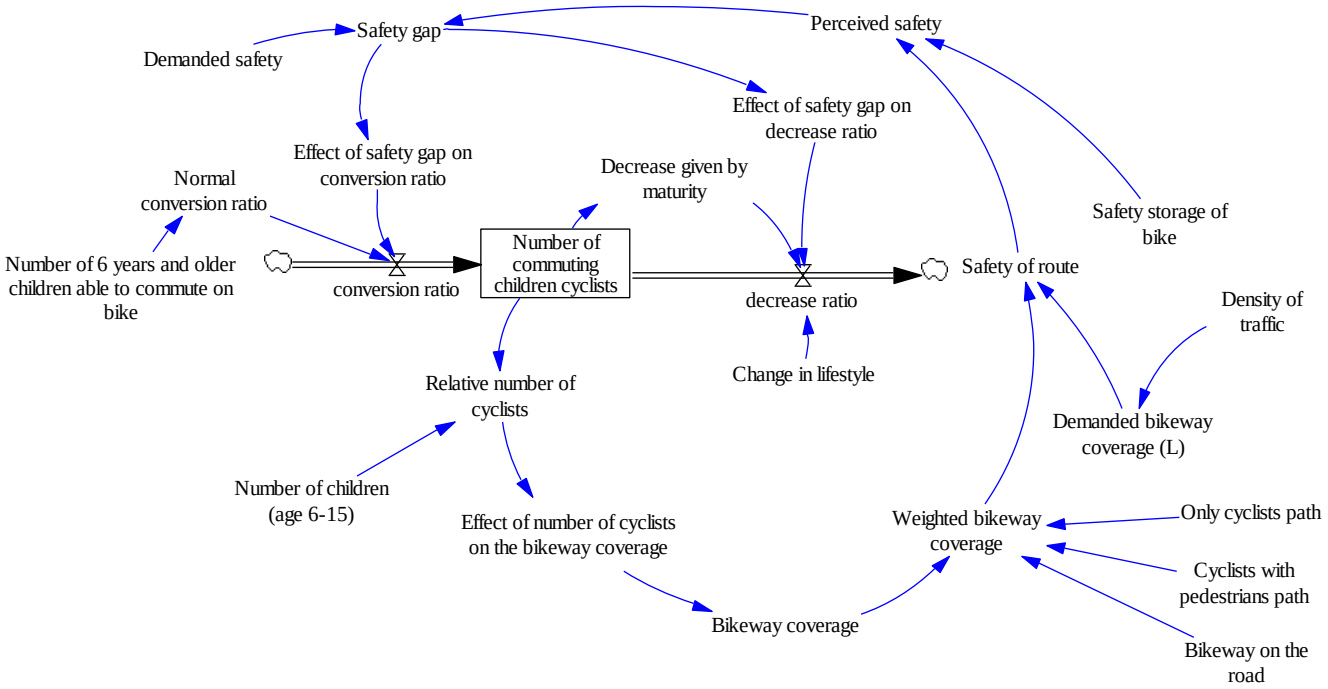


Fig. 8 Model with weighted bikeway coverage

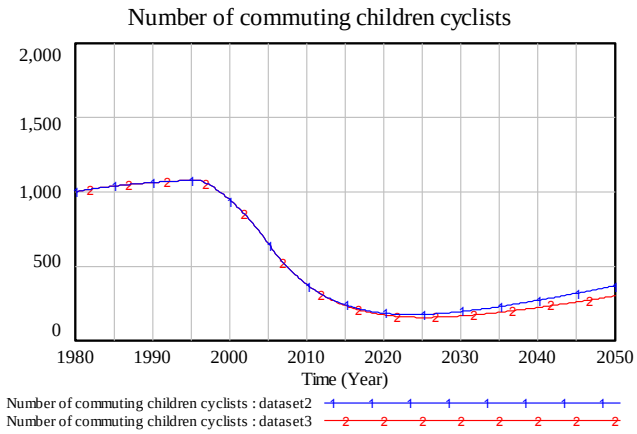


Fig. 9 Impact of weighted bikeway coverage – dataset3

Results of scenario 3 show that the impact of weighted bikeway coverage (dataset3) is not very significant. Results can vary in different setting of share; nevertheless the importance of any bikeway is undeniable.

### *B. Actions for promotion*

Promotion actions for adults are based on two main actions in the Czech Republic „European week of mobility" and „Cycling to work" action. Children education of bikeability (the ability to ride bicycle safely on the road) is now on the poor level in the Czech Republic as can be seen from the following information [14]: In the Czech Republic is currently the traffic education in nursery schools and at the first level of primary schools (elementary teaching), with a focus on the issues of safe walking and orientation on the road (Framework Educational Programme for basic education). Older children

can learn how to ride well and safely mainly because of the dedication of teachers at their free time or thanks to the courses on special playground with bike transport focus. According to the increasingly unfavourable statistics of traffic accidents, this situation does not meet the needs of our society and education of bikeability has to be enhanced.

In the contrast to Czech Republic can be given comparison with Danish promotion of bikeability. The main objective of the project is to motivate people to ride a bike instead of car (especially in urban areas). Although Denmark is equipped with good cycling infrastructure in recent years, the proportion of cycling traffic decreased (between 1990 and 2009 by 14%). Support for cycling is though necessary in order to improve air pollution, public health or to effectively reduce the traffic congestion the city. [15]

### *C. Development of webGIS portals*

Popularity of cycling has led to development of large amount of bikeways and bike trails. This situation brought requirement for availability of information on cycle routes accessible on the Internet.

It is necessary to say that already exist many information systems, with data focused on cycling, available to the general public. These systems usually use geoinformation technologies because maps and data generated using geographic information systems can be easily used and published on the Internet. [15]

Web portals serve as support for cyclists planning routes. Information published on those portals usually do not concern only cycle routes, but put them into context of other facilities with relation to cycling. These facilities include [1]:

- information centres,
- accommodation,
- possibilities of refreshment,
- transport with bike (bike bus),
- bicycle rental,
- bike service,
- hospital...

Additional information published on WebGIS portals can be [17]:

- monuments,
- tourist marking,
- background orthophotomap,
- cadastral map...

#### *1) Examples from abroad*

As the best example of WebGIS solution for cyclists can be mentioned bicycle suitability map for Broward County. In the mid 90´s Metropolitan Planning Organization developed the first bicycle suitability map based on Bicycle Safety Index Rating (BSIR) developed by Davis [18]. Today is used slightly adapted Road Condition Index (RCI) that takes into account 20 factors that affect bicycling. Information about bikeways can be displayed in the map or used as a criterion for adequate route selection. Optimization criteria can be selected from fastest, simplest, shortest, scenic and safest route. [19]

The German software-development company alta4 Geoinformatik AG developed a bike routing tool for the german tourism agency of Schleswig-Holstein. Portal gives the possibility to choose fastest, shortest or scenic (thematic) route. New features like the export of GPS data in several formats like GPX,KML or OVL are now available. [20]

#### *2) Examples from Czech Republic*

*Pardubice region cycling portal* - portal provides data at a scale of 1:1000. Bicycle paths are divided into local, regional, transregional and European. The map shows the information cetres. The portal functions include zoom, scrolling image, locking recess, selection lines or measuring distances and areas. Searching for safe passage on the portal is not possible. [21]

*South Moravian region cycling portal* - the most interesting function of the portal is route selection function display of points of interest. The interest points that can be displayed are cinemas, museums, cycling services, monuments and more. After positioning the mouse on the icon, description of the item is displayed. On the portal exist the prearranged routes. Each road has a verbal description and route parameters (e.g. intensity, length, elevation and other). Searching for safe passage on the portal is not possible. [17]

*Portal cyklo-vectormap* - the portal includes routes in Czech Republic. After login you can create your own rote and these routes saved only for personal use or view to others users. Create a route is also possible to send e-mail (you can send only public routes) or import file in format GPX. Searching for safe passage on the portal is not possible.[22]

*Cyklo server* - this portal has zoom function, map shift, routes selection and distance measurement, labeling of points with description, display of elevation profile and export/import data in format GPX. This portal combine several map layers (e.g. underlying Google map, tourist map, layer with tourist attractions or layer with possible trips). After logging it is possible to save trip information. Searching for safe passage on the portal is not possible. [23]

*Tourist map portal Vysočina* – possibilities of portal cover zoom function, map shift, setting the start, end and middle points of route. Elevation profile can be calculated, routes and areas can be measured. Buffer function is used for selection of points near selected route. In addition to cycling routes can be viewed also a route for car or walkers. Server allows to export data to format GPX and KML. The route can be sent by e-mail. Other features include a design view for trips: bike tours, bike tours for children, cinemas, theaters, rest and more. Searching for safe passage on the portal is not possible. [24]

*Cycling South Moravia and Bike portal in region Karlovy Vary* – On the portal there are many types on cycling trips in South Moravia (just as a static text). Portal also includes interactive cycling map, the map is a possible shift, zoom, set the start line, the end of the route and point of transit. The route can be filtered based on **the surface** (surface to determine the different types of cycles) or difficulty (for athletes, children and other) and omit the routes that are

**dangerous**. When planning a trip to view points of interest (cycle, cenemas, monuments, caves and other). You can also view some points of interest in 3D perspective. Both of these portals are user friendly. [17] [25]

The data for portal South Moravia are used for GIS Regional Office, ČUZK ZABAGED, CEDA StreetNet, DPA Tourist map of South Moravia, ARCDATA Prague ArcČR 500 and VARS Brno) [17]. The data for bike portal Karlovy Vary are used for GIS Regional Office, ČUZK underlying data (ZABAGED) and VARS Brno. [25]

*Bike portal in region Ústí nad Labem* - the portal is a possible shift in the map, zoom, add waypoints, measure areas and sections in the map. [26]

*Cycling routes Ústí nad Labem* - map can be zoomed in and shifted. It is not possible search routes, biking trails are only marked on the map. The map shows significant objects. Bicycle paths are highlighted in each section on a surface (the surface for road bikes, hardly passable, uneven surface and others) and the safety sectors (safe route, busy car traffic, steep ascent (descent) and others). [27]

*The uniform GIS database of cycling* infrastructure - this portal is under construction in the Czech Republic. The aim is to promote a unified form of cycling data in order to unite them into one information system.

Parameters to create are in the following groups [10]:

- identification
- basic infrastructure (registration of communication (dedicated lane, bikeway, roads marked by a traffic sign and others) and the type of surface (asphalt, gravel, unpaved surface and others)
- safety (parameters of the heavy traffic, narrow stretch, unsatisfactory surface of the state, railroad crossing, intersection, steep ascent (descent) and others)
- tourist attractive

Overall, the portals provide sufficient information to cyclists in order to be better prepared before riding. This statement applies fully for adult recreational cyclists who easily manage safe ride on the road. Nevertheless, cycling portals have some constraints that limit their usage mainly on this type of cyclist (recreational, adult), these include the following.

1. Cycling portals display mainly marked bike trails that lead through places of interest (routes of commuting cyclists usually lead through non interesting places, without marking).
2. Information gathered on those portals does not cover data about bikeways on the trail, which makes portals insufficient for transportation with young children.

## IV. Proposal for utilization of WebGIS to support children's cycling

Cycling with young children, or the children themselves, requires safe routes and good planning. When planning a safe routes, parents can rely on personal experience (they can go personally through the route), or bet on geoinformation technologies to help them find a safe route. Examples from abroad show that it is possible to prepare WebGIS portal containing information about route safety (on-road or outside-road bike lanes, dangerous places...). At present, however, such a portal in the Czech Republic does not exist. Only at the universities some projects are arising that map city networks of cycle paths, including hazardous locations. As an example can be mentioned theses [28] [29]. This situation motivated the proposal of WebGIS portal specialized on cycling.

Before the proposal was prepared, we passed informal interviews with parents of young children (4-8 years old) from Pardubice city in order to find what information they are missing about bikeways in Pardubice. The inquiry arose the demand to display a complete map of Pardubice (in the form of internet portal), which indicates the suitability of ways for cycling of young children.

Pardubice city is very suitable for cycling because of flat terrain. Percentage of people commuting is highest in the Czech Republic 16%. Still, lots of parents are afraid of cycling with small children and unnecessary use cars for delivery to school and leisure classes. We are convinced that clear comprehensible children bike suitability map on the Internet can help to solve this problem.

Data model will be based on street section file. This file contains identification of street sections between intersections and type of road (highways, main roads, minor roads). Basic data model would use necessary enlargement of street sections file. Attribute of bikeway has to be assigned to each section in this notation (x for non-existent, r for on-road bikeway, o for outside-road bikeway). The reason for presenting only two types of bikeways is an effort to maintain clarity of the output map. The second reason was that parents put emphasis on the distinction between on-road and outside-road bikeways, while the interaction with pedestrians was not identified as a problem.

Information about trails should be kept in separate file linked with street sections with many-to-many relationship.

Third file should contain information about dangerous places on bikeways and roads where cyclists can be injured. This file would contain ID of street section as a link.

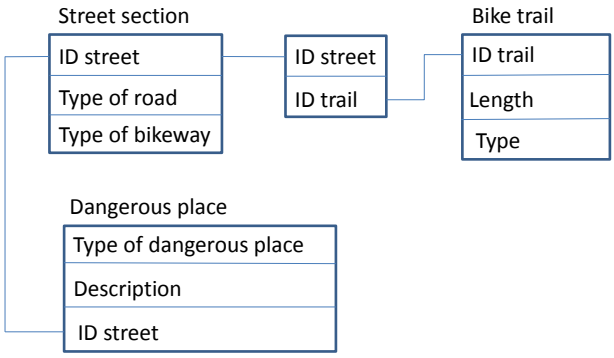


Fig. 10 Proposed data model webGIS portal

One would expect that bikeways are built off the main roads and therefore the attribute “type of road” for bikeways would not be necessary. Nonetheless the map displayed below shows that sometimes there is interference between main road and bike way, which can be potentially dangerous place for

children cyclists. Therefore, the "type of road" attribute must be saved also for bikeways, in order to display those that are outside-the road, or on a minor road.

Proposed model can be easily applicable in any town under condition that the data about bikeways will be gathered and saved in digital form. Many municipalities todays, does not have digital evidence of bikeways, on the other hand, university students at their bachelor theses proved to be able to gather such data. Nevertheless, to use students for data collection, coordination should be ensured at the national level. Otherwise happens, as it is sometimes today, that one theme handle more students.

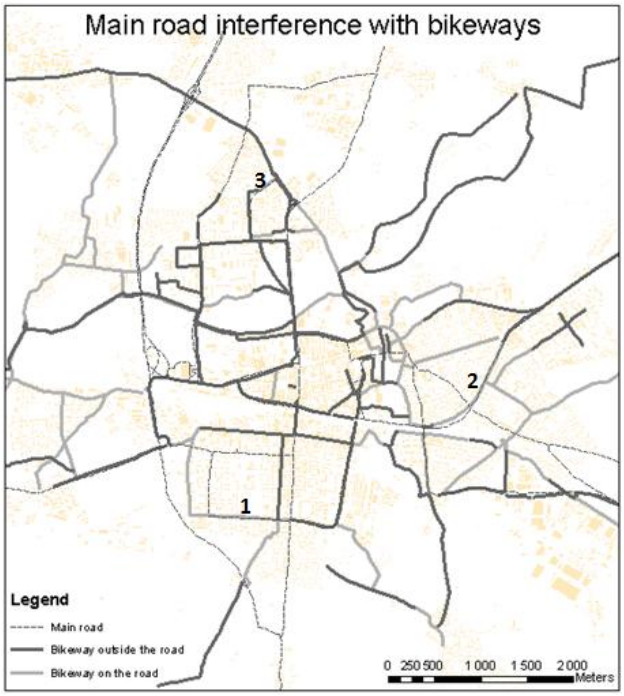


Fig. 11 Interference between main road and bikeways (three potentially dangerous places were found)

## V. Conclusion

The aim of this article was to contribute to the highly important topic that is commuting of children. Commuting by car is convenient, but it brings many problems. The main three can include creating of traffic congestion, worsening air exhaust and obesity in children. In contrast, commuting by bike is less expensive alternative that is healthier and in many cases even faster. Using system dynamic we prepared general model of the impact of traffic density and bikeway infrastructure on the number of commuting children cyclists. Presented model is prepared in Vensim PLE and it is easy to change variable setting or add other parameters in order to use the model in specific situation.

Furthermore we showed that there are large reserves in the use of WebGIS portals as a tool for supporting children's cycling. Simultaneously, this article shows a simple way how to make available information about safe routs for parents and their children. At the end, there is also a suggestion how to deal with data collection and digitization.

## Acknowledgement

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