Development of transport infrastructure in smart cities

I Makarova*, A Boyko, I Giniyatullin and A Ahmadeeva

Department of Transport Systems Service, Kazan Federal University, Russia, Kazan, Kremlevskaya street, 18
* E-mail: kamivm@mail.ru

Abstract. Smart Mobility is one of the main directions of development of the transport system in intelligent cities. In this case, along with management intellectualization, the issue of transition to “green”, safe and sustainable modes of transport, such as bicycles, should be resolved. Democracy and availability, cheapness and environmental friendliness, promotion of a healthy lifestyle are the reason for the growing popularity of this type of transport throughout the world. This document proposes one of the possible ways to develop bicycle transport in a smart city, which allows you to expand the number of users by reducing the physical requirements for cyclists. The proposed development is the concept of Smart Bike, which controls the condition of the cyclist and the environment and turns on the electric motor in critical situations. This reduces the cyclist's physical activity, as well as the consumption of the battery, which has a positive effect on the ecology of Smart Cities.

1. Introduction
The world is undergoing the largest wave of urban growth in history. More than half of the world’s population now lives in towns and cities, and by 2030 this number will swell to about 5 billion. Much of this urbanization will unfold in Africa and Asia, bringing huge social, economic and environmental transformations.

UN projections show the world’s rural population has already stopped growing, but the world can expect to add close to 1.5 billion urbanites in the next 15 years, and 3 billion by 2050. How the world meets the challenge of sustainable development will be intimately tied to this process.

In 1950 about 2/3 of the population worldwide lived in rural settlements and 1/3 in urban settlements. By 2050, we will observe roughly the reverse distribution, with more than 6 billion people living in the messy, burgeoning atmosphere of urbanized areas.

According to the Sustainable Urbanization Policy Brief, urban centres currently occupy less than 5% of the world’s landmass. Nevertheless, they account for around 70% of both global energy consumption and greenhouse gas emission. Innovation in urban infrastructure and technology is essential when addressing this issue. For instance, greenhouse gas emissions could be reduced by up to 1.5 billion CO2e annually by 2030, primarily through transformative change in transport systems in the world’s 724 largest cities.
Urban planning decisions and strategic design thinking in the context of rapid urbanization account for social equity, mobility patterns, global competitiveness and energy-efficiency.

Strain on traditional service delivery from increasing populations poses a significant challenge to the sustainable growth of cities. Managing physical resources, such as energy or water as well as managing healthcare, traffic and city logistics, among others, is a major challenge that cities need to address to ensure sustainable growth in the future.

Smart City is an urban environment, which combines a variety of technologies to reduce the negative impact on the environment in general and, thereby, to provide a more comfortable living conditions. The main goal of the Smart City idea is to create a sustainable model of urban development and to preserve the quality of life for urban citizens. One of the main challenges to be solved for the successful operation of the urban ecosystem is the problem of citizens' mobility. At the same time, the transport system should cause minimal negative impact on the environment.

2. General trends in the development of smart cities

Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. But, many challenges exist to maintaining cities in a way that continues to create jobs and prosperity while not straining land and resources. Urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing and declining infrastructure. The challenges cities face can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty.

In November 2008, IBM’s Chairman, CEO and President Sam Palmisano, during a speech at the Council on Foreign Relations, outlined a new agenda for building a "Smarter Planet". The speech emphasized how the world's systems and industries are becoming more instrumented, interconnected and intelligent, and that leaders and citizens can take advantage of this state of affairs to improve these systems and industries.

In January 2010 Sam Palmisano gave a follow-up speech to the Chatham House called the "Decade of Smart". He highlighted dozens of initiatives in which leaders created smarter systems to solve the planet's most pressing problems. The speech aimed to inspire others to follow the leads of these innovators by helping to create a smarter planet.

The first question is what is meant by a ‘smart city’. The answer is, there is no universally accepted definition of a smart city. It means different things to different people. The conceptualisation of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. To provide for the aspirations and needs of the citizens, urban planners ideally aim at developing the entire urban ecosystem, which is represented by the four pillars of comprehensive development-institutional, physical, social and economic infrastructure. This can be a long term goal and cities can work towards developing such comprehensive infrastructure incrementally, adding on layers of ‘smartness’.

Some typical features of comprehensive development in Smart Cities are described below.
1) Promoting mixed land use in area based developments in order to make land use more efficient;
2) Housing and inclusiveness - expand housing opportunities for all;
3) Creating walkable localities –reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;
4) Preserving and developing open spaces - parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;
5) Promoting a variety of transport options: Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;

6) Making governance citizen-friendly and cost effective - increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices. Forming e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

7) Applying Smart Solutions to infrastructure and services in area-based development in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

ITS covers a number of types of transport including rail, freight and car and the associated technologies are a plenty. Today we start building our future vision of an ITS to not only run efficient transport networks, but also have access to predictive analytics to make better decisions with more accuracy, faster. This can benefit future services planning based on population trends and land zone changes, as well as having access to behavioural analytics from ticketing systems to aid flow and manage demand, provide specialized services to segmented users’ groups and even realignment of services based on customer insights.

3. Smart city and smart mobility

A “Smart City” is an urban region that is highly advanced in terms of overall infrastructure, sustainable real estate, communications and market viability. It is a city where information technology is the principal infrastructure and the basis for providing essential services to residents.

Transport system is one of the major intellectual systems in the Smart City. To ensure its sustainability and safety, the work is being done in three ways: smart infrastructure, smart vehicles and smart users. Solutions concern the creation of an efficient and integrated mobility system that allows for organizing and monitoring seamless transport across different modes, increasing the use of environmentally friendly alternative fuels and creating new opportunities for collective mobility.

Addressing the mobility challenge calls for a paradigm shift in urban planning, encouraging compact cities as a way to increase accessibility and to reduce the need for transportation altogether. Because the purpose of mobility is to gain access to destinations, activities, services and goods, urban planning should therefore be resident-centred, so that functional endpoints – the reasons for travel – are as close as possible to each other, in effect reducing distances and transportation needs. Thus, city residents should be able to address their needs using as little travel as possible.

Bicycle infrastructure planning should include the creation of bike parking’s, bike sheds and bikeways as well as it should be taken into account the terrain and the structure of population, who want to use the bike to get around the city. Despite a fast growing literature on the bike lanes design the problem of terrain identification and topographic conditions modeling is still actual. The most common method of bicycle wayfinding is the shortest path method. As far as bicycle routing is not always possible to avoid hilly terrain, bike-lifts and electric drives creation can solve the problem of overcoming steep climbs.

Effective segregation of road traffic is central to most campaigners’ demands for greater safety, and SkyCycle is one of the most extreme methods of separating bicycles from cars on the agenda. By building a new network of cycle paths high above existing roads and railways, the scheme would create a series of cycle superhighways across London, with specific entry and exit points throughout the city. “Any long distance bicycle commute would be less likely to encounter large heavy goods vehicles if we are able to build a few of these elevated cycleways”, says Sam Martin, founder of Exterior Architecture, the firm behind the designs [2].

Brian Macdowall, of the Alliance for British Drivers, thinks the project could work in principle. The problem with inserting cycle lanes at the roadside usually means narrowing the road itself, which can
aggravate congestion. “If the cycle lanes could run along major routes without loss of road space to motorists, then it would help”. He is concerned that the cost would prevent the plans becoming a reality, however. Martin estimates the initial cost at £200m for the first 6.5km artery [3]. To solve transport problem in large cities Dominican architect Richard Morita Castillo offers to build dedicated lanes for cyclists. Innovation lies in placing these lanes over city highway. Such overpasses for cyclists Castillo calls ecobahns (like autobahn) or Cycling underground. A similar solutions are proposed for Moscow and Kazan. And for Russia it is not only about the division of space and reduction the number of conflict points, but it is also necessary protection for cyclists in difficult weather conditions.

4. Development of DSS for assessing the effectiveness and safety of infrastructure projects

The development of cycling in cities will lead to an increase in the number of cyclists and the size of their transport work. Therefore, safety requirements for bicycle paths will constantly increase. In this regard, it is important, based on interdisciplinary research, to establish and evaluate the values of safety indicators at different stages of automobile, cycling, and pedestrian traffic from beginning to end the route, i.e. when potentially there is a risk of accidents. The authors of the article believe that the safety of cycling in an urbanized area can be assessed by the magnitude of the hazard level σ, which reflects the likelihood of accidents involving cycling. When σ = 1, an accident is unavoidable; if σ = 0, the probability of an accident is zero. The degree of danger is affected by: the presence of intersections, the frequency and speed of movement of vehicles, the type of bike lane, as well as its width.

The safety level of cyclists depends on a variety of statistical and dynamic factors:

1) The presence of isolated bike paths in the city;
2) The need and ability to use the bike in conjunction with public transport;
3) Availability of bicycles (personal and rented);
4) Individual characteristics of bicycles (average speed of overcoming a route, travel time, average speed of movement, distance to the onset of fatigue and the need for repair, time for rest and repair);
5) Transport behavior (the presence of a bicycle helmet, compliance with traffic rules, conflict with other road users - car drivers, cyclists, pedestrians).

When drawing up routes of urban movements, it is necessary to choose the safest possible route, taking into account the peculiarities of the traffic participant. Categorizing a route can be performed by the presence of various factors complicating traffic conditions. Depending on the type of travel, the routes in the city can be road, pedestrian, bicycle and combined. The combined route, as a rule, includes the areas where the movement is carried out by public transport, and the movement between the starting (end) point and the stop of public transport is on foot or by bicycle. These sites are assessed using the multi-criteria route safety assessment methodology developed by us. The enlarged diagram of the assessment algorithm is shown in Fig.1.

![Figure 1. Assessment algorithm.](image_url)

At the first stage, factors that determine the category of the route by complexity for pedestrians and cyclists were identified. Since the significance of a factor for different categories of road users is determined by their characteristics, to determine the weight of factors, categories of pedestrians and
cyclists were identified by age and health status. The route can be estimated using a complex indicator, which is calculated using the weighted average formula: (1)

$$K = \sum_{i=1}^{n} \frac{K_i \cdot \alpha_i}{\alpha_i}$$  

(1)

Here $K_i$ is the value of the i-th parameter, $\alpha_i$ is the weight of the indicator. In order to summarize dissimilar indices in the formula their reduced values are calculated.

Factors that determine the safety of the route can be both objective (e.g., terrain, presence of unregulated intersections, etc.), and subjective due to the features and physical condition of the road user (age, health condition, etc.). Adequacy of the assessment will depend on the correctness of the selected factors and their combined inclusion. For example, the same route can be safer in the daylight than in the dark, in the summer than in the winter, etc.

Since a significant part of moving around the city is made up of mixed routes, the transfers number on the route should be estimated, because it is the interchange points safety on such routes that can be decisive. In articles of researchers studying ways to improve the safety of cyclists, existing bike routes are evaluated. We propose to predict the effectiveness of projects, choosing from several options that which will initially be most appropriate in each case considered. For these purposes, it is proposed to develop a control decision support system, the intellectual core of which will be imitative models. A conceptual model of a decision support system is shown in Figure 2.

Figure 2. Conceptual diagram of the DSS.

The correctness of the work of the DSS is largely determined by the quality of the source information and the adequacy of the method of its processing. This is ensured by the presence of:

1) a module for collecting, storing and administering data on the quantitative and qualitative properties of bicycle infrastructure objects, parameters of the transport system, as well as monitoring data on the parameters of cycling and pedestrian flows;

2) module for analysis of statistical and dynamic data;

3) a module for decision making with the purpose of analyzing and evaluating data and the subsequent development of recommendations (calculation of the track width based on passenger traffic and throughput of the existing bicycle infrastructure; justification of the need for other infrastructure facilities);

4) module for development of simulation models before / after changes in accordance with the received recommendations).

The developed module (figure 3) for choosing the optimal route will be included in the composition of this system. With it help, it will be possible to assess the security of both existing and projected infrastructures.
5. Conclusion

Transition to eco-friendly and non-motorized modes of transport is one of the key elements in ensuring sustainable urban mobility. It also contributes to improving the environment, reducing emissions of CO2, NOX, CH, PM. There will be a decrease in the load on the transport system of the smart city. In addition, the experience of developed countries shows that environmentally friendly and efficient mode of transport also contributes to the development of the economy. In addition, health and longevity also benefit from cycling. However, there are still many obstacles to the widespread use of bicycles as an alternative mode of movement. Some of these problems can be solved by integrating the bicycle with public transport. This is possible by creating bicycle paths and parking lots. Successful development of Smart City needs complex solutions. This will create a comfortable urban environment for citizens, as well as get a synergistic effect that will contribute to the sustainable development of Smart City.

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