Benefits of the Completion of Sofia’s Subway System as Part of Sustainable Urban Mobility

S D Tzvetkova

University of National and World Economy, Sofia, Bulgaria
E-mail: svetlatzvetkova@abv.bg

Abstract. Over the past several years all European capitals have been dealing with traffic-related problems, the harmful influence of passenger transport on the environment, and the necessity to adopt measures for achieving sustainable urban mobility. The dynamic development of the city of Sofia in recent years has led to an increased number of personal vehicles, air pollution, and the necessity for servicing large passenger flows effectively and relieving traffic in the city’s center. The global practice is to solve urban mobility transport problems in larger cities with a population of over one million by developing a subway system which should become the primary mode of urban passenger transport, securing quick access to work places, guaranteeing high-quality, safe and secure travel, while simultaneously minimizing pollution, greenhouse effects and energy consumption. The purpose of the present article is to substantiate the necessity for finishing the construction of the capital’s subway system, to indicate the social benefits of the functioning of the first and second subway lines in the context of sustainable urban mobility, and to prognosticate the future social benefits of constructing and commissioning the third subway diameter through analysis of the dynamic of the city’s public transport and the available statistical data.

1. Introduction

Stable urban mobility should be based on the construction of socially effective, fast and high-quality transport which fully satisfies citizens’ transport needs and at the same time observes environmental protection regulations in major cities [1]. Sofia, the capital city of the Republic of Bulgaria, is one of Europe’s oldest cities, with a history that spans thousands of years. In the latter half of the previous century, when its population reaches 500 000 people, construction of more buildings commences in the city’s peripheral parts. Over the past several decades, large housing estates, some of which have a population of over 100 000 people and are significantly far removed from the center, have been built. As a result of that and the significant migration of the population over the past 15-20 years, the capital’s population, including temporary residents, is over 1.6 million people [2]. Due to the exhausted transmissivity of the street network and the increased traffic intensity, traffic jams along main transport lines have become an everyday occurrence in the city. This leads to extremely low speed of movement during rush hour, which is barely 10 km/h with public transport. The growth in the city’s population has resulted in the everyday formation of large passenger flows from the periphery to the center and vice versa, with some of those flows reaching 15 000-30 000 passengers per hour along one line. The necessity for effective public transport along the lines of the largest passenger flows, as well as the city’s transport and environmental problems, have necessitated the construction of a subway system along those lines, which should have three diameters with branches in the periphery, with a total length of 75 km and 69 subway stations. Sofia’s subway system (Line 1 and Line 2) is undoubtedly the most environmentally friendly mode of transport in the capital, reducing...
travel time and providing passengers with high-quality and comfortable transportation, which is of the utmost importance for the city’s conditions. High velocity is achieved because the subway is completely isolated from street traffic due to it being equipped with tunnels under ground and above ground, as well as the rail lines being off-limits to pedestrians. The subway surpasses all other means of urban passenger transport with its high freight capacity which can reach up to 50 000 passengers per hour in one direction and is equipped with tools that guarantee safety and security when traveling at 80 km/h. Due to the high freight capacity, the subway provides effective servicing for busy lines instead of having a significant number of parallel ground transport lines (especially bus transport) function along them, which would have a highly negative effect on the environment and the air in the capital due to the obsolete rolling stock [3]. This vast, long-standing and expensive project also has undeniable social benefits – environmental, social and especially ones concerning the improved transportation of hundreds of thousands of people, traveling residents and guests of the capital. The final stage in the realization of Sofia’s subway system foresees the transportation of approximately 1 million passengers per day [4].

2. General information for the development of Sofia’s subway system
The construction of the subway starts from the first subway diameter (the busiest one), which is the point where the largest passenger flows in the city, with prognostic maximum values of 38 000 passengers during rush hour, are formed [5]. In 2009 construction of the line is completed, with a total length of 18 km and 14 subway stations. Post-2009, after entering the “Transport 2007-2013” Operative Program and receiving funding from the European Fund for Regional Development (EFRD) and the EU’s Cohesion Fund (CF) with local co-funding, the large-scale “Project for Expanding Sofia’s Subway System” is underway. The project involves the construction of Line 2 and the significant expansion of Line 1, which are differentiated in three stages. The three-stage construction is completed in 2016. In 2017, based on the strategy for the development of Sofia’s transport network outlined in the General Spatial Plan, the city’s needs, along with the fact that the main sections of Line 1 and Line 2 are in commission, engage the next stage in the development of Sofia’s subway system – the construction of Line 3, with a length of 21 km and 21 subway stations. Line 3 is a new type of line, with next-generation automatics, safety systems and traffic regulation. Taking into account the large scope of the project, the various foreseen methods of construction, the specifics of individual sections, and the limited financial resources, the construction of Line 3 is divided into 4 stages, with the first two stages currently underway [4].

3. Analyzing the dynamic of public transport in the city of Sofia. Analyzing the demand for public transport
Public transportation in the capital is carried out through bus, trolley, tram and subway transport. Figure 1 presents data for the percentage of people who use public transport, personal vehicles, bicycles, and people who prefer to walk.

![Figure 1. Distribution of citizen travels in 2018](Image)

**Source:** The National Statistics Institute
The figure’s percentage shows that the majority of Sofia’s citizens prefer to use public transport – 44%, or their personal vehicles – 38%; only 20% of the citizens prefer to walk, and only 2% prefer to use bicycles. Sadly, the figure makes it clear that in 2018, a large percentage of citizens still prefer to use individual automobile transportation, which is one of the main air pollutants in the capital (about 70% of the harmful emissions result from the functioning of automobile transport). In order to gain a concrete idea of the demand for public transport in the capital, the structure and number of conducted freights with individual types of public transport over the past several years need to be compared [6].

In 2011 the capital’s public transport has recorded approximately 400 000 000 travels. Figure 2 offers a graphic presentation of the percentage of freights carried out through various types of public transport.

![Figure 2. Freights carried out with various types of transport in 2011](source: The National Statistics Institute)

The figure shows that in 2011, or two years after putting Line 1 of the capital’s subway into commission, the majority of citizens – 54% – still use bus transport. The remaining 35% use ground electrical transport, and only a mere 11% use the subway [6].

In 2018 the capital’s public transport has recorded approximately over 550 000 000 travels, showing a significant change in freight structure.

![Figure 3. Freights carried out with various types of public transport in 2018](source: The National Statistics Institute)

The figure makes it clear that the percentage of passengers transported by subway in 2018 (two years after putting the expansion of Line 1 and Line 2 into commission) has increased significantly, showing a growth
of 45%, i.e. 34% more compared to 2011. Bus transport has recorded 34%, tram transport – 12%, and trolley transport – 9% [6]. Based on the data from the figures, a good trend in the development of public transport can be ascertained, considering the ecological advantages and social benefit which result from the subway’s functioning. Figures 2 and 3 present an undeniable progress for the subway as the mode of transportation that Sofia’s citizens use the most.

4. Analyzing the supply of public transport

**Subway** - as Figure 3 shows, in 2018 the subway has transported the largest number of people, compared to other types of electrical transport. Due to its high velocity and large freight capacity of 50 000 passengers per hour in one direction, it is the most preferred mode of transportation. The subway is only effective along the lines with the strongest passenger flows in the capital.

**Bus transport** is the second most preferred mode of public transport. In 2018 it has transported 34% of Sofia’s residents, with its percentage dropping by 20%, compared to 2011. Currently, “Capital Motor Transport” JSC has 466 buses at its disposal, 211 of which are 18 meters in length; the other 255 are 12 meters long. The bus fleet’s usage coefficient is 79%, but the average age of the car park is 12 years. The capital’s bus fleet consists of 340 buses with low floors, or 58% of the association’s rolling stock [6]. At present, it is the largest air pollutant in the capital, which is due to many factors, especially the type of fuel it uses. In order to reduce its harmful effect on the environment, specific measures need to be taken, starting with the gradual replacement of the rolling stock with more modern and environmentally friendly vehicles, thus substituting the conventional fuels it currently uses with alternate types [7]. This will improve the quality of the bus transport and the ecological indicators of the capital’s air significantly. The realization of these goals is within the context of stable urban mobility and European legislation – the parameters and criteria stipulated in Directive 2009/33/E0 of the European Parliament and Council on April 23 2009, pushing for clean and energy efficient vehicles.

**Tram transport** - in recent years the percentage of citizens who use tram transport has dropped significantly – in 2018 it is only 12%. This is due to the poor condition of the rail-track, the decommissioning of a large portion of the vehicles and the overall drop in the quality of transport services. Over the past 10 years the number of trams in the capital has dropped doubly – at present they are 270, compared to 540 in 2006. It should be noted that their average age is 23 years [6].

**Trolley transport** is secondary and an alternative to bus transport. Annual travels by trolleys drop every year – by 2018 they are merely 9% of the total number of freights carried out by public transport. The available rolling stock of the trolley transport has also experienced significant drops in recent years – in 2016 only 128 trolleys have traversed the streets of Sofia. The average age of the rolling stock is eight years.

5. Social benefits of the functioning of line 1 and line 2

Following the completion of Line 1 and Line 2, Sofia’s subway transports 380 000 passengers per day, with its speed reaching 80 km/h. Its share of the total number of passengers who have used public transport for 2018 is 45%, indicating a 34% growth compared to 2011. It takes between 10 and 18 minutes for citizens to travel by subway from the city’s periphery to the city’s center [8]. The significant drop in ground traffic and accidents should also be noted. Fewer emissions of harmful gases into the atmosphere and a drop in the level of noise pollution have also been ascertained. There has also been a rise in the demand for apartments along the subway line and the appeal of the surrounding areas as a whole.
The more significant social benefits of putting Line 1 and Line 2 into commission in Sofia in percentage (%) include:
- reduced travel time – over 150 000 hours per day;
- reduced traffic in the capital – 15%;
- reduced number of traffic accidents – 15%;
- reduced emissions of harmful gases from car engines – 15%;
- reduced level of noise pollution in the city – 20%;
- decommissioning a significant number of vehicles from duplicate ground public transport lines – 140 units;

6. Prognosis for eventual social benefits after the completion of the capital’s subway system
Once Lines 1, 2 and 3 are put into commission, Sofia’s subway will be able to service a total of approximately 500 000 passengers per day. That way, there will be 21 000 less cars traversing the streets of Sofia per day. The whole city will experience a 20% relief in traffic, which could exceed 25% in subway station areas, thus reducing the amount of harmful emissions from cars by another 11 000 tons approximately. About 200 000 man hours per day will be saved compared to urban transport, and about
60 000-65 000 man hours compared to the use of personal vehicles by citizens, or an average of about 18 minutes every day [8].

Figure 5. Line 1, Line 2, Line 3
Source: “Subway” JSC

The main forecasted benefits (expressed in percentages) of putting all three lines of Sofia’s subway system are expected to include: reducing traffic in the city’s center by about 20-25%; reducing the number of traffic accidents in the capital by about 15-18%; reducing noise pollution caused by the functioning of cars and public ground transport by about 20-25%; reducing harmful emissions from automobile transport by about 15-20% [6].
A short overview of numbers and facts shows that the main benefits of putting all three lines of Sofia’s subway into commission include: cleaner air, less traffic, security for citizens and reduced travel time.

7. Inferences

The construction of Sofia’s subway system is the largest and most complex transport objective and the most ecological project in the capital. The subway proves that in the areas it passes through people are willing to get out of their cars and use the convenience and speed of the underground railway[9]. The data unequivocally shows drastic drops in the amount of harmful emissions in the air, the number of personal vehicles and traffic overall both in the city’s center and its periphery, around the subway line zones. The subway is also a project that makes significant changes to people’s living conditions and the quality of the urban environment. Once the construction of the underground railway’s facilities is completed, new modern boulevards will be built over them, the status of their adjacent territories will change, and the areas will have a modern emplacement and a new appearance. With the completion of Sofia’s subway system, citizens’ dependency on their cars will drop even further; the subsequent social benefits from that will include better accessibility to urban zones and services, better environmental parameters and an overall improvement in the population’s health status. There will also be significant improvement in the quality of life for people with impeded mobility, as well as people who live in areas which have had no connection to the urban transport network in the past. The effective functioning of the capital’s subway system is one of the main pillars that guarantee stable urban mobility in the capital, as well as better image and successful development for the city[10].

8. Conclusion

The achievement of the objectives and goals set in the strategy for stable urban mobility in the city of Sofia involves the construction of the capital’s entire subway network. This will guarantee the functioning of an environmentally friendly, high-quality urban passenger transport which provides opportunities for attracting more people and fully satisfying their urban travel needs. In recent years there has been a noticeable progress in the construction of Sofia’s subway network and undeniable social benefits from the construction of the first and second subway diameter. A short overview of numbers and facts shows unconditional proof of that. The capital’s subway system is in complete compliance with the European vision for developing intelligent, environmentally friendly and integrated transport. European examples and
the EU’s Common Transport Policy put special emphasis on the development of fast, convenient and environmentally friendly urban transport. Urban mobility is the basis of the debate for effective use of resources and it plays a key role in finding a balanced approach between the social, economic and ecological pillars of stable transport systems in an urban environment.

9. References
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