METHODOLOGY FOR OPTIMISING OF THE ROUTE NETWORK IN THE CITY

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Abstract: Sofia is the largest city in Bulgaria and continues to grow. From 2011 to 2021, its population increased by 9.8%. Fifteen years ago it had a monocentric structure, or to put it another way, most jobs, commercial space, cultural and social institutions were in the city center. As the population increased, the situation changed and the city acquired a polycentric structure with separate centers in all areas of the city. The transformation into a polycentric area also leads to the need for adaption of the route network to the needs of the growing population. The main task of urban passenger transport is delivery of rapid transport between two or more regional centers. In order to function at its best, any transport network needs to meet the conditions for a short journey and the overall transport service needs to be of the highest quality. In the 18th and 19th centuries, models for monocentric cities were developed to explain their economic organization. Cities subsequently evolved from monocentric to polycentric with multiple regional centers. The forces of agglomeration and dispersion determined the emergence of the polycentric city. Climate change, demography and the challenges of globalization also influence the development of cities. The main objective of the study is to develop a methodology to optimize Sofia's future transportation network needed for the growing number of people living in the city. Currently, Sofia's network is designed as a loose structure. In the optimization methodology, certain steps are followed in a specific order to obtain the desired result. The programs used for this type of optimization consist of four consecutive steps and the constraints are the required number. Although in the reorganization of the routing network, their minimization should also be aimed at. Problem formulation is important for the development of the optimization model. The result with the least constraints will always be chosen. In order to adopt a particular course of action, data must be selected and processed to obtain optimal results, which must also be analyzed. The standard four-stage models work with an origin-destination matrix (O-D matrix). It will show us the number of trips people want to make. The peak hour data is mainly used to test the model. The data used in the optimization program must be in a format suitable for the program. In models of this type, blocks of travel flows are used to determine only those routes that meet certain criteria. And from an economic point of view it is important to achieve a balance between the ticket price and the shortest vehicle travel time, and this is a linear combination. The result of optimizing the route network in any major city should be the best service for the growing number of public transport journeys.
Keywords: urban transport, transport network, methods, methodology, optimization

1. INTRODUCTION

The main object of the study is public transport in Sofia city. As the capital city of Bulgaria in the years after the Liberation has undergone transformations related to the continuous population growth. At the beginning of the 19th century and until the middle of the 20th century Sofia was a monocentric city with a dominant urban centre. In the later period, however, as the number of citizens, it became a city with multiple centres and, as a result, the need to improve the transport network arose. As a result, not only the number of people but also the number of jobs increased in regional centres. The change of the structure of cites requires stronger links between the different regional centres and, as a result, it is necessary to structure the transport system so that public transport plays a central role and to be more attractive for use, rather than the population being transported primarily by their private cars. There is a strong need to develop regional centres as an alternative to the city centre to reduce congestion.
The aim of this study is to develop a methodology to optimise the future transport network of Sofia.

2. THEORETICAL BASIS

The structure and the distribution of a city's population is directly related to the planning of the transport network. Sofia is not the only city to move from monocentric to polycentric. There are cities that have had a polycentric structure from the beginning and have adapted their transport network to this fact. Others, due to population growth and the emergence of new areas in the city, have been forced to restructure their network and adapt it to new needs of the population. And those that are monocentric and leave theirs as such. These cities can thus be classified:
- Cities with a polycentric structure, with some outer centres, with an adapted transport network;
- Cities with a polycentric structure, with some external centres, without an adapted transport network;
- Cities that do not have many external centres and have a more monocentric structure with a polycentric one in the public transport nodes;

- cities that do not have many external centres, have a more monocentric structure and do not have a polycentric structure in public transport nodes.

The purpose of the transport network is to provide high-speed transport between the different regional centres of the city. The principles of designing and improving the same boil down to the following: all regional centres should be connected by the shortest distances; the length of the transport network should be minimised while maximising the quality of transport service in the city; regional centres should be connected by routes to the city centre and between different areas; the density of the network in the central part should be higher than that in peripheral areas.

2.1. Monocentric city – models

The monocentric model was developed with an approximation by von Thunen (1863). It describes the relationship between farmland value and accessibility. It was later developed further by Alonso (1964), Muth (1967) and Mills (1972). This monocentric model has been a very useful tool because of its simplicity, accuracy, and the possibility of empirical contrast. One of its greatest achievements was the explanation of the process of decentralization of housing that occurred in most urban systems in the early twentieth century. It can also explain the economic organization of cities. The aim of the first models was to analyse the location of housing. The assumption of these models made on all jobs were located in the central part of the city and families competed for housing with better access to the center. This competition led to a reduction in costs, mainly for transportation trips.

2.2. Policentric city – models

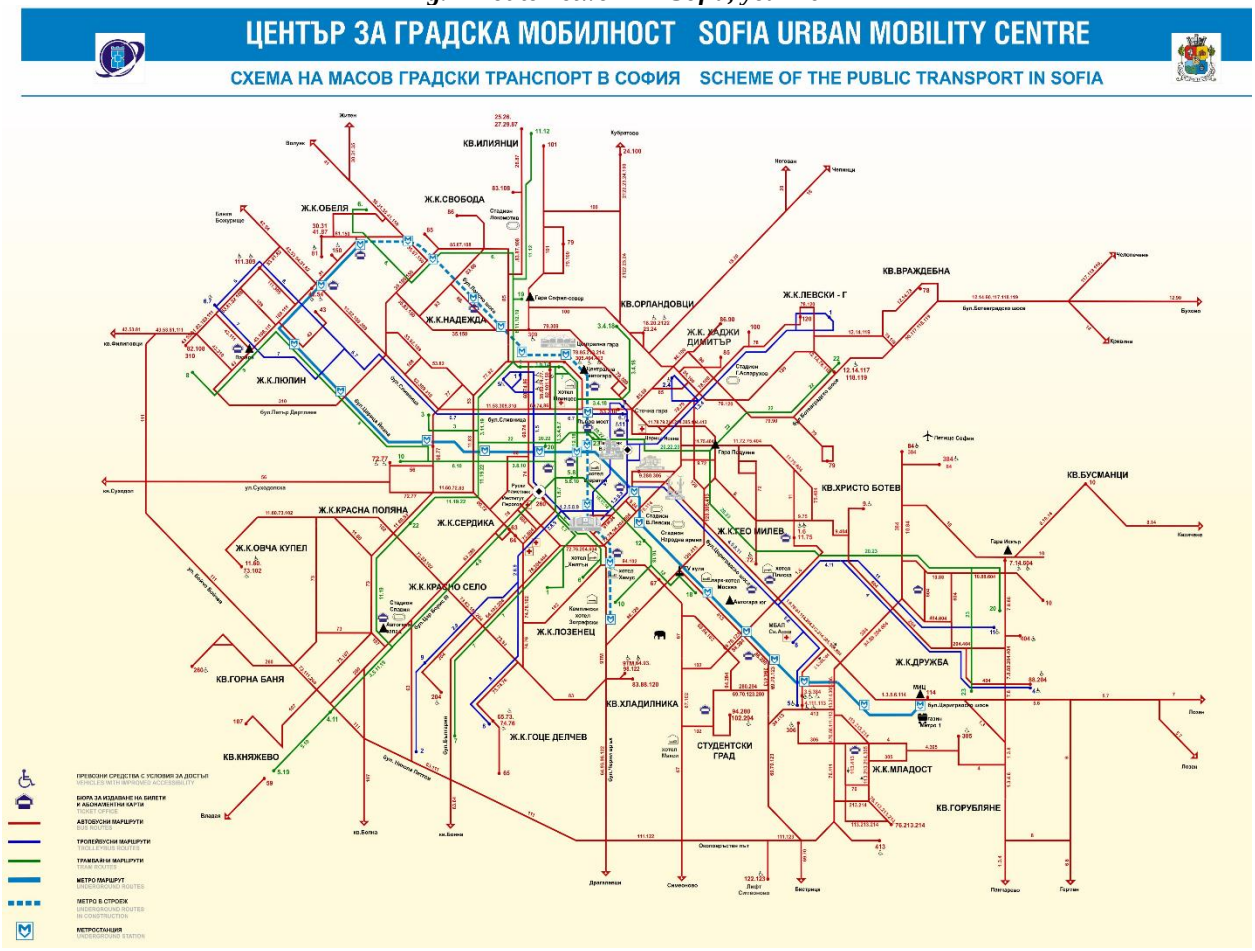
The development of cities leads from monocentrism to polycentrism, i.e. regional centres are formed. The basic models are developed by Fujita, Krugman and Veables (2001). They have outlined the theoretical framework of the development of polycentric structure, and this leads to intensification and agglomeration of economic linkages between firms. So, urban polycentrism is a spontaneous process of organization of economic activity in a limited territory with a growing population, of invested capital in large amounts and generally distribution is underway. Finally, monocentric models provide no explanation for the configuration and organization of large cities. They cannot explain the existence of regional centers that pay higher costs than other areas much closer to the central city. The forces of agglomeration and dispersion, as well as changes in climate, demography and globalization, are emerging and influencing the development of society and leading to the structuring of a polycentric city. Bertaud (2003) argues that the last years of the twentieth century have seen a dispersion of employment. The percentage of jobs in central cities has been declining over time, and new businesses are locating outside central parts of cities.

Thus, regional centers became more popular for jobs, over a large period of time, than concentrating jobs in a single urban center. In a polycentric city, the passenger transport is organised to serve the individual industrial centres optimally. If the city is functionally polycentric, then public transport will function easily and make travel between different work centres convenient.

3. STRUCTURE OF THE ROUTE NETWORK IN SOFIA

The first real network with more than one mode of transport in Sofia appeared in 1948, when the city was served by trams, trolleybuses and buses. In 1998, the first section of the metro began operating. The main task of the underground railway is to make direct connections between the main points in the city and the suburban areas, or more precisely the "mountain recreation and industrial areas". As it written above, it is clear that Sofia's transport network is mainly served by four main modes of transport. The trams and metro have a higher capacity and are suitable for areas with a high demand for transport services, unlike buses. The route network of the capital city in the early and mid-20th century was of the radial type. Nowadays, as the city develops and its population increases, it is loosely designed but serves all regional centres and has the shortest expressways with the central part of the city (fig. 1).

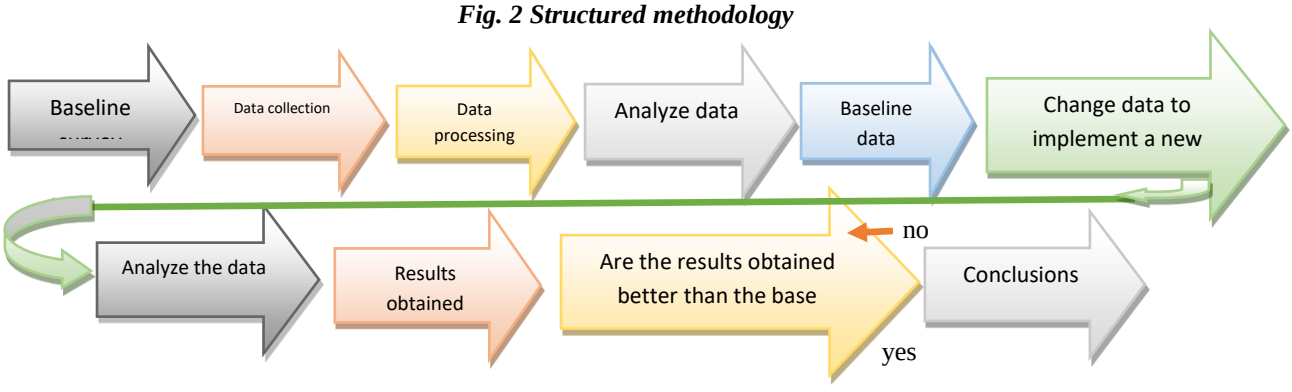
Fig. 1 Route network in Sofia, year 2022



4. OPTIMIZATION METHODOLOGY OF ROUTE NETWORK

In the following figure the optimization methodology is structured (fig. 2).

Fig. 2 Structured methodology



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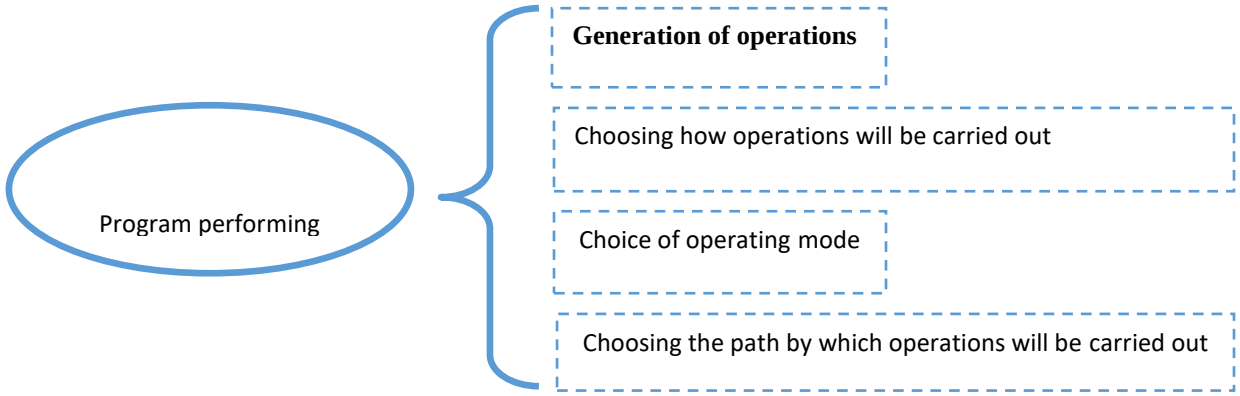
When using optimizing programs (MATLAB, VISUM and etc.), each of them can work with the required number of constraints and basically function four-step (fig. 3). The data entered must be in the form corresponding to the program used. They should then be checked to see if they meet the requirements of the actual route network.

Fig. 3 Four-step optimization model



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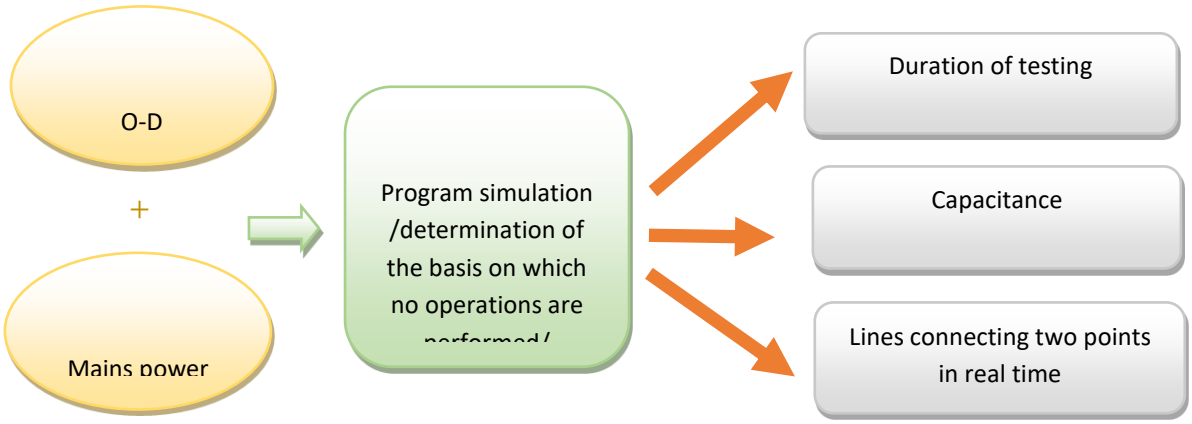
Sofia's transport network outside the city centre is not as concentrated as in the city centre itself. Vehicles travelling on lines in outlying areas do not pass through the city centre. In order to build an optimization model with a well-defined and correctly formulated problem, in many cases a block of passenger flows using public transport is used to highlight those routes that meet certain criteria. In this way, for example, certain network objects - stops, links or zones - can be used. The selected result will be the one with the least restrictions. More complex models contain trip generation and distribution and mode choice. The output of the problem will be input information for the different steps in the model.The choice of result is whit the least restrictions.
When applying the specified scenario, it must be analyzed, the data processed to obtain the results, which will be evaluated after analysis. There are three possible tasks: on the basis of transport system, on the basis of passenger traffic and on the basis of schedule. Some models use the length of the lines instead of the departure time on the same. Such a procedure is suitable for short and longer-term plans where the timetable for the analysed period will be amended (Andersson, 2014). A possible scenario is one of "the inaction", i.e. no changes are made to the network and the timetable or the supply and demand for transport service will be allocated to a future period. In standard four-step optimization models, it choses selected route from the transport network.
Finally, the principle of operation of the optimization program is illustrated (fig. 4). Models of this type work with an "Origin – Destination" matrix (O-D matrix) .

Fig. 4 Optimization program for data input and output



The Origin – Destination matrix shows the number of trips that people want to make between areas.
The data that is most appropriate to use are those in rush hour, because this period has the greatest saturation of trips. From other site, can show whether a problem with the capacity of the transport network as well whit exist the rolling stock.
A balance must also be perceived between the price and the planned time for making a trip.
An important element is the isochrones. With them measure we can consider the travel time from one part of the route network to the rest of it. They can also be used to establish accessibility to sites in the network – stops, zones. It is important to note the distance between the stops when planning them should be fixed. There are several options when planning lines:

- one with many stops along the entire length;
- line with fewer stops;
- or one with many stops in different regions, but no stops in between.

Each area has indicators and they are:

- ✓ required travel time;
- ✓ the time for the optimization program to use to decide which link to select from the job;
- ✓ a large number of passengers are more likely to be carried over a short distance.

A key element of any point-to-point line travel is the time passengers have to wait to transfer from one vehicle to another.

5. FURTHER STUDIES

Any tool that works with a dynamic matrix can offer a better methodology and, as a consequence, a more accurate result.
With a significant increase in the number of passengers, it is a good idea to plan a high-speed line between regional centers. The advantages are: greater speed, shorter travel time; short frequency of vehicle movement, small number of passengers; reducing traffic problems; use of intelligent transport systems; greater travel comfort; fewer delays, greater reliability; reducing congestion.

6. CONCLUSIONS

This research was conducted to investigate the optimal way to improve the performance of urban public transport. With the growth of Sofia every year by 1%, let's make the route network more functional in serving the individual areas and the connections between them. When a good scheme is developed, it supports the good polycentric and densely populated structure of the city. It is necessary individual neighborhoods represent unifying elements of urban subsystems. The district centers of Sofia have nearby structures, but they should be developed in a different way to attract people from other areas, to allow the avoidance of transport movements to the central part, which will lead to a reduction of the traffic jams currently existing. When comparing monocentrism with polycentrism, it is found that there are more advantages in the route network of Sofia exists today and can be improved in the future. The travel time is reduced and more people are attracted to use urban public transport instead of their private cars. Also, the number of people using the transport service will continue to increase in the future due to the reduced travel time. The improved route network provides greater accessibility for people living between two regional centers, because there are more stops. The use of high-speed vehicles is also required to improve connections between individual regional centers and minimize travel time by public transport.

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