Analysis of planning diagrams of underground railroads in large cities of the World

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Abstract — In project were chosen the most suitable development model of Kharkov subway network (Ukraine). In order to archive this goal in the first place were established topological morphology on the level of configuration complexity and quantitative evaluation of quality of subway networks spatial composition. Secondly, were assumed four rational, provisional long-term subway development models in accordance with current and perspective subway network of Kharkov and urban development forecast. Result of analyzing subway lines maps of major cities in 20 countries of the world confirmed that it is possible to classify by type of schemes: linear, circular, X-shaped, rectangular, radiated, radiated and circular, radiated and chorded, combined. Results of this classification are present radiation type and economic indicators were helpful to devise 4 models of general plans of subway lines development. In the result by comparing models by feasibility indicators were chosen "combined model" as a long-term development model of Kharkov subway. Data derived in the present study and practical study of innovation at the time of pre-project analysis& planning of proposed model will attract interest in the following major cases: Firstly, elaborated types of schemes will be useful for all cities of the world at any stage of development to determined future schemes of subway lines development. Secondly, research development long-term provisional plan of Kharkov subway and usefulness as a result of the analysis for other cities. Project implementation remains as question due to Kharkiv City Subway have a debt of record-breaking of eighty million U.S. dollars.

Index Terms— Kharkiv City Subway Network development simulation, general plan of subway lines development, subway maps topology, subway networks rating, subway network analysis, pedestrian accessibility, feasibility indicators, subway lines evolution factors.

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1. INTRODUCTION

At the present time in year 2012 about Kharkiv it is hard to say that all districts of the city are covered by the underground, in fact all inhabitants of districts of the city have no possibility to use the underground. Also in Kharkov, along with inefficient use of land, there are many transportation problems. Low traffic capacity coming from highways full of traffic jams and narrow roads of the city center, lack of parking spots in the city center, burden and discontent of residents suburbs, due to deficiency of public transport units, increase in capital investment and operating costs, environmental issues. It is possible to solve these transportation problems by expanding the network of all subway lines.

In this way, despite a lot of traffic problems in the city of Kharkiv, in general plan until 2026[1] that adopted by city official concrete solution has not been shown. Scientific innovation consists of conducted investigation based on the predicted subway lines expansion plan in accordance with the economic indicators, were simulated 4 logic development possibilities, proposed cost- effective, convenient, sustainable in operational aspect long-term development model of general plan of subway lines development for further lines expansion. Also was established identical classification of planning schemes for all world cities, according evolution of largest cities of the world that always developed in combined form.

2. RESEARCH PURPOSE

The ultimate goal of this research is to devise a model long-term development of Kharkiv City Subway. Were determined following tasks in order to achieve it. First, were analyzed the subway network maps of major cities around the world, were classified by type, were evaluated rank on the basis of economic indicators. Second, were assumed four rational, provisional long-term subway development models in accordance with current and perspective subway network of Kharkov and urban development forecast. Thence, in accordance with provisional models that were moved from virtual theory to real city conditions were established 4 models of general plans of subway lines development and by comparing models by feasibility indicators were chosen the most suitable development model.

3. RESEARCH METHODS

This paper is divided into three chapters. In **Chapter 1** was begun by defining the factors that influence the formation and development in the direction of the subway lines configuration [2]. Were selected next seven external factors by incomplete induction. There are geographic, urban planning, demographic, social, traffic configuration, environmental and economic factors. Also following five internal factors were selected. Location relative to the ground level, inclination of the tunnels, laying depth, engineering and geological environment, hydrogeological environment [3].

In accordance with these external and internal factors, was put hypothesis that researched subway networks in all countries of the world have the identical attributes, also concrete definitions of different attributes are possible to determine as the difference between the evolutions of those underground networks. Using deductive method by the

subway lines forms in 20 countries of the world [2], [4], [5], [6], [7] categorized the following types of schemes: linear, circular, X-shaped, rectangular, radiated, radiated and circular, radiated and chorded, combined as shown in Fig. 1 and was analyzed those advantages and disadvantages.

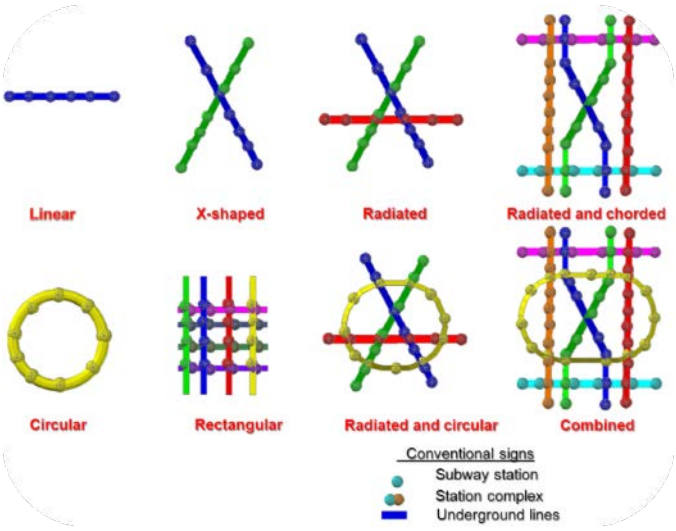

Fig. 1. Classification of subway planning schemes

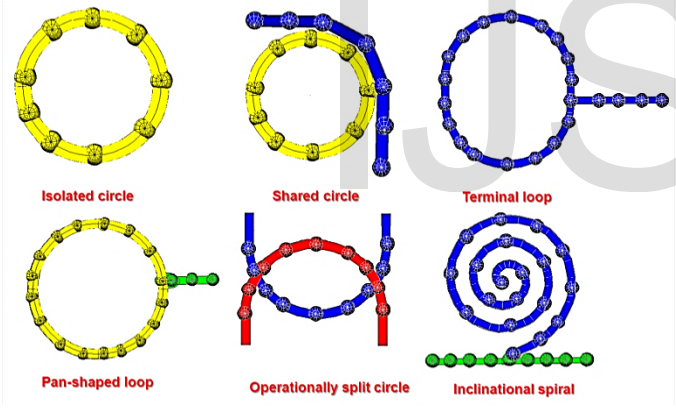

Fig. 2. Additional elements of planning schemes of subways (auxiliary rings and loops)

Were determined the auxiliary elements [8] that are used in subway lines in 20 countries of the world as shown in Fig. 2 by induction and reaffirmed their rationality. Also was convinced that subway networks converging on combined form (radiated, circular and chorded) [9], [10], [11]. Were evaluated and compared economic indicators of 20 subway networks [4], [6], [7] of largest cities of the world and was created a graphs and charts for those systems using indicators as shown in Fig. 3. As a result of this analysis, it helps to determine the world rank of Kharkov Metro system.

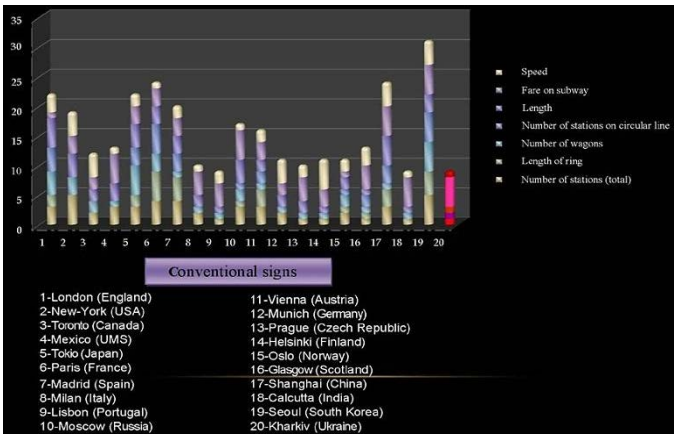

Fig. 3. Summary rating of 20 major subways networks (2011year)

In **Chapter 2** according useful results from present chapter was begun to analyze subway network in Kharkov [12]. Investigated present urban plan with overlaid in scale subway scheme of Kharkiv [13]. From this was found percent of city area that outside of pedestrian accessibility of subway stations, pros and cons, feasibility indicators. Then were analyzed adopted by city officials general plan and perspective public transport network plan, map of projected total transit demand volumes on subway lines due to Kharkiv general plan until 2026 [1] and determined feasibility indicators that was not included in general plan. In comparison with indicators of other modes of transport[1], was proved that the adopted general plan for public transport lines is not cost effective, not suited for residents and do not solve any one of transportation problems. Using results of above analysis according current and perspective subway network plan of Kharkiv and its indicators and urban development forecast from general plan [1] were simulated the development possibilities [8], [9], [10] of Kharkiv Metro system until 2036 were found to be valid the next 4 models of subway lines development by configuration: radiated, radiated and circular, radiated and chorded, combined as shown in Fig. 4-7.

In **Chapter 3** according to those external and internal factors that previously determined, from virtual theory to real conditions (attributes, economic indicators) to apply location of newly stations construction, terminals and station complexes and was decided to establish underground lines connecting them. In this way from many draft copies [14] were established 4 models of general plans of subway lines development as shown in Fig. 8-11. Were analyzed the pros and cons of several models and economic feasibility indicators [1], [11], as shown in Table 1. Summarizes the results of these analyzes, was judged that combined model as shown in Fig. 11 is the most suitable model for long-term development of the Kharkiv Metro system.

4. RESEARCH RESULTS

1) Result of analyzing subway lines maps of major cities in

20 countries of the world [2], [4], [5], [6], [7] confirmed that it is possible to classify by type of schemes: linear, circular, X-shaped, rectangular, radiated, radiated and circular, radiated and chorded, combined as shown in Fig 1. Results of this classification are present radiation type and economic indicators [1], [11] were helpful to devise a long-term development of a rational model of Kharkiv City Subway. 2) Analyzed the subway lines maps of major cities, were categorized by type, in result was evaluated rank on the basis of economic indicators [4], [6], [7] and concluded that Seoul Subway is the # 1, Kharkiv subway is last place (20th out of 20) as shown in Fig. 2. Based on classification by type of schemes, in accordance with evolution process [9], [10], [11], was determined that all subways in the world converging in combined form. 4) In order to enhance competition in the world of Kharkiv subway was confirmed that to be essential of an organization that operates the subway and modernization of the underground trains. 5) 88% of city area in 2012 year outside of pedestrian accessibility of subway stations[13], was determined that should be incorporated into the comprehensive plan an urban development model (for the optimum economic indicators)"combined model" as shown in Fig. 11 as a long-term development model of Kharkiv subway.

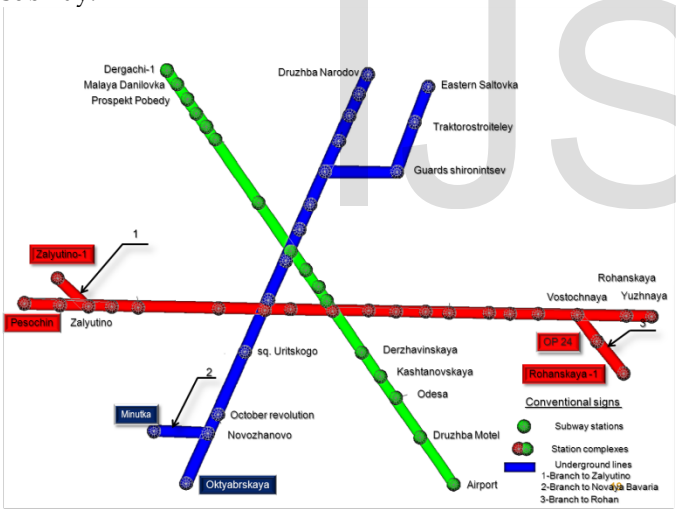

Fig. 4. Radiated model

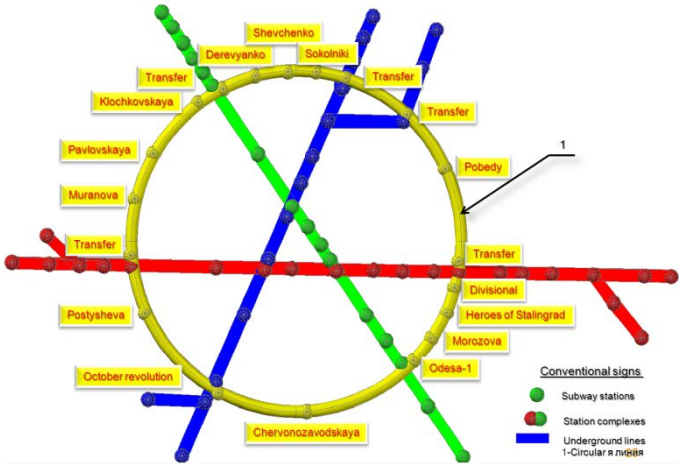

Fig. 5. Radiated and circular model

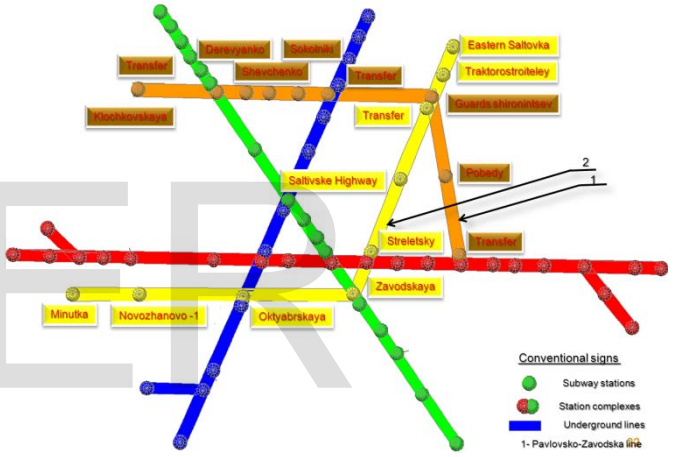

Fig. 6. Radiated and chorded model

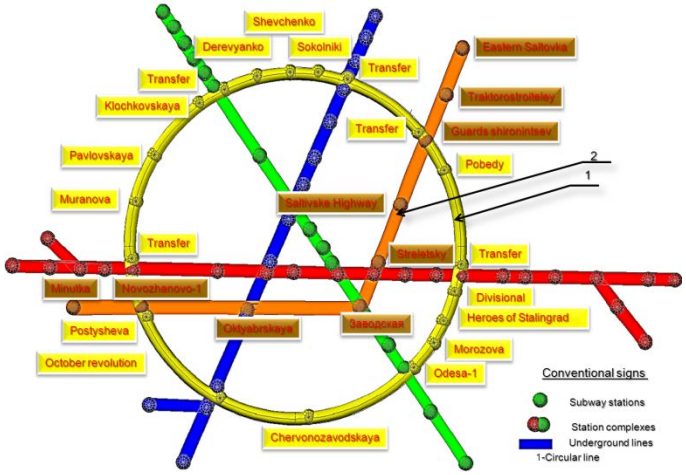

Fig. 7. Combined model

TABLE 1

ECONOMIC FEASIBILITY INDICATORS

MODEL	INDICATORS																													
	NUMBER OF STATIONS	RATING	TOTAL LENGTH, KM	RATING	BY NUMBER OF STATION COMPLEXES	RATING	BY COST OF CONSTRUCTION, MILLIARD DOLLARS.	RATING	BY AREA OF PEDESRIAN ACCESSIBILITY, KM^2	RATING	BY NUMBER OF WAGON DEPOT	RATING	BY DENSITY OF NETWORK, KM/KM^2	RATING	BY COEFFICIENT NONLINEARITY OF TRANSPORT NETWORK	RATING	BY NUMBER OF CONNECTIONS WITH MAJOR ARTERIAL HIGHWAYS	RATING	BY NUMBER OF POPULATIN UNDER PEDESTRIAN ACCESSIBILITY, THOUSAND PEOPLE	RATING	BY DENSITY OF PASSENGER TRAFFIC, PASSENGER-KILOMETERS IN YEAR/ TOTAL LENGTH OF LINES	RATING	AVERAGE RATING	OVERALL RATING
RADIATED	24	4	44,52	4	3	1	186,33	4	56,06	1	1	3	0,79	1	1,9	1	3	1	697	1	7,4	1	2,2	4
RADIATED AND CIRCULAR	36	2	76,81	2	7	2	321,49	2	84,81	3	2	2	0,91	3	1,28	3	5	3	990	2	5,13	2	2,3	3
RADIATED AND CHORDED	30	3	68,44	3	7	2	286,51	3	75,91	2	3	1	0,9	2	1,22	2	4	2	1107	3	4,8	3	2,4	2
COMBINED	37	1	86,06	1	11	3	360,24	1	89,53	4	3	1	0,96	4	1,17	4	6	4	1197,7	4	4,7	4	2,8	1

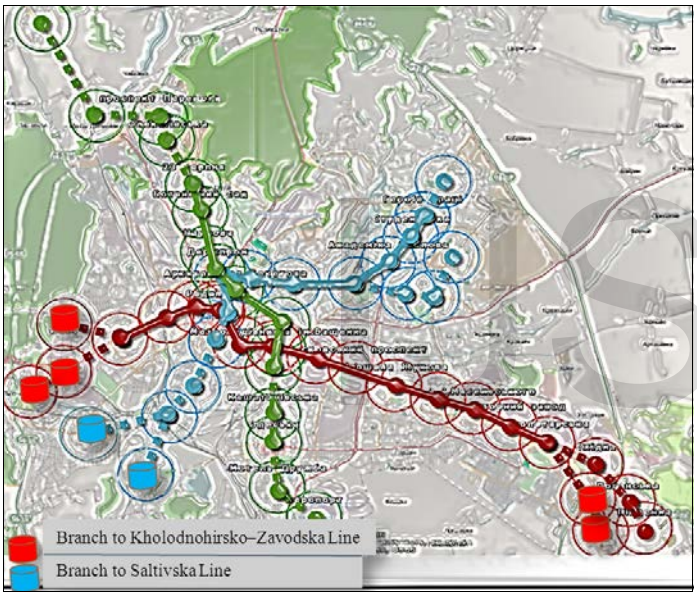

Fig. 8. Radiated model of general plan

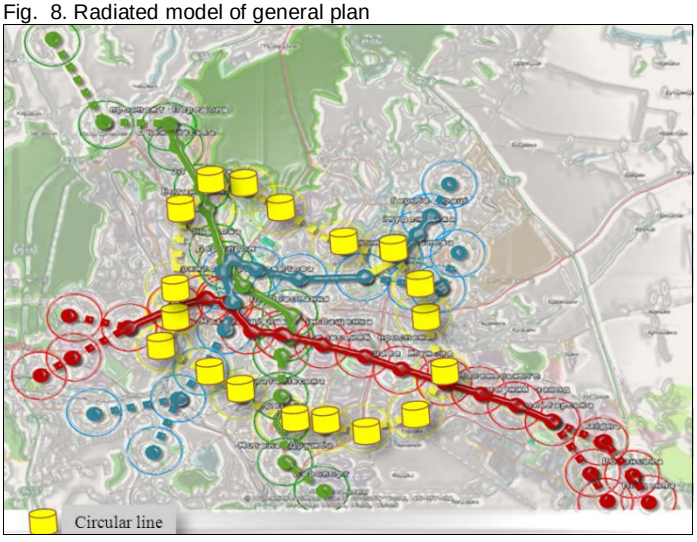

Fig. 9. Radiated and circular model of general plan

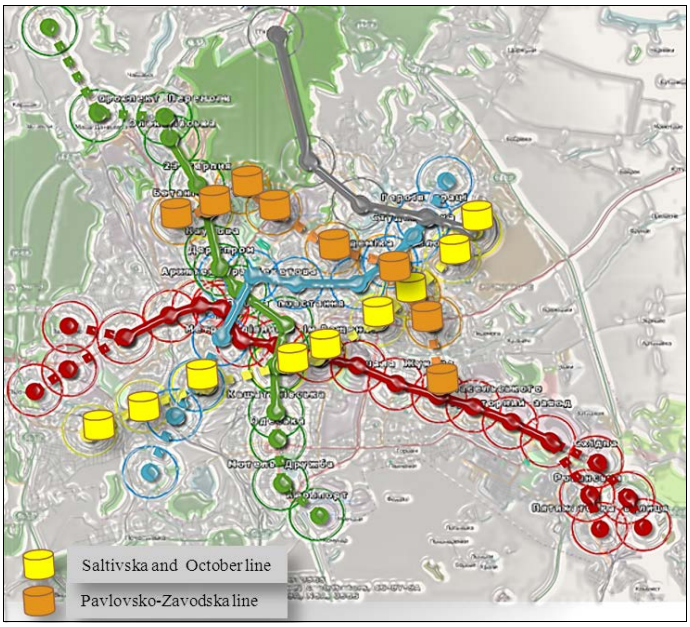

Fig. 10. Radiated and chorded model of general plan

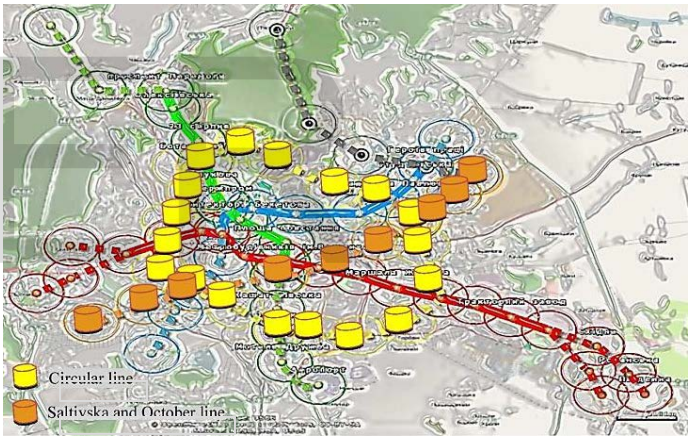

Fig. 11. Combined model of general plan

5. CONCLUSION

Data derived in the present study and practical study of innovation at the time of pre-project analysis& planning of proposed model will attract interest in the following cases: Firstly, elaborated types of schemes will be useful for all cities of the world at any stage of development to determined future schemes of subway lines development. Secondly, research development long-term provisional plan of Kharkiv subway and usefulness as a result of the analysis for other cities. Thirdly, models of general plans of subway lines development will be a basis for design of concrete subway line project and detailed location of stations, modern terminals and transport hubs on the line (on plan and longitudinal profile).

Can be raised following three points as an important

research issues in the future: First point that urban planning and transport conditions of each individual city dictate modifications in the combined model of general plan of subway lines development that leads to a change the total construction cost of a combined model. Second point that necessity of passage of circle line through districts of the city with low population density (for completion of construction of the closed circle line of the underground) that conducts to the compelled increase of cost of construction of the "radiated and circular" model and proposed above "combined" model. Third point that need to implementation and operation by one starting complex of the circle line in combined model and inability to calculate the exact cost of stations, tunnels, and as a result the entire cost of construction at the pre-project analysis stage.

At the present time Kharkiv City Subway had a debt of record-breaking of eighty million U.S. dollars [12] and loss every year for this purpose. Therefore, in order for it to realize the present study and in order to improve the convenience, connected terminal station to the railway and at present is unable to squeeze money to build the subway to the suburbs. Solution of this problem as way of direct investment of foreign capital at the moment would be the only decision. But irrespective of result remains question, whether or not the benefit to the citizens. As long as this financing issue is not resolved, there are still some graces to continue this study of long-term development of provisional plan of the subway mega polis, where 1.5 million people are living like in Kharkiv city.

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