COMPARISON OF DIFFERENT OPTIONS FOR THE INTEGRATION OF INFRASTRUCTURE PROJECTS IN AN URBAN ENVIRONMENT DURING THE CONSTRUCTION OF THE III-RD METRO DIAMETER OF THE METRO IN THE CITY OF SOFIA

Boris Vasilev

Metropoliten JSC, 21 Knyaz Boris I St, 1000 Sofia
e-mail: radamant@abv.bg

Abstract. Often infrastructure projects in an urban environment come into conflict with each other due to the limited urban space and the large number of different development programs and the large number of funding sources. The accumulation of such type of problems can be solved through the integration of infrastructure projects. This article aims to compare the different types of integration (simultaneous, parallel and sequential) in terms of project scope, construction technology and duration. Through the use of methods of qualitative analysis and quantitative analysis, two separate projects from the construction of the III metro diameter of the metro in Sofia, built on one site, with the different types of integration of management and construction will be analyzed. The research results unequivocally show the superiority of the integrated management and implementation of the infrastructure projects over the non-integrated one.

Keywords: infrastructure projects in an urban environment; Sofia metro; integration of infrastructure projects; quantitative analysis; qualitative analysis.

1. INTRODUCTION

During the last twenty years the concept of "sustainability" has become increasingly important in the development of urban infrastructure. After Bulgaria's accession to the EU, many opportunities for financing infrastructure construction appeared, thanks to access to European financial instruments. All this has led to a big jump in realized projects in infrastructure construction in an urban environment. The implementation of a huge number of infrastructure projects of different sizes with different sources of financing, managed by different Employers, has started. Despite the drawn up long-term programs

DOI: 10.7546/EngSci.LX.23.03.07

for the development of the urban environment in different cities, often implemented infrastructure projects come into conflict with each other in terms of their scope, implementation technology and time. The accumulation of this type of problems has led in recent years to financial losses caused by frequent repairs, extension of deadlines for the completion of projects, overall incompleteness of the urban environment, and from there to social dissatisfaction and a loss of trust in the authorities.

Internationally, these problems are solved through integration in the management and implementation of infrastructure projects. In this way, the goal is to achieve maximum spatial and functional completion of the urban environment in the territory affected by the implementation of infrastructure construction. Three specific principles of functional integration can be distinguished:

- Parallel integration: performing activities that can be performed simultaneously. In land use planning, this implies the possibility of simultaneous occurrence of different land use functions in overall development.
- Serial (Sequential) integration: doing activities in a logical order to get the most out of it. In spatial planning, this means revising the order or position of process elements within the planning process in order to optimize those processes.
- Simultaneous integration: sharing resource flows and integrated budgeting to keep planning, implementation and management costs down by increasing investment efficiency.

The first two principles can create additional value for the participants involved in the planning processes: the results of the planning process can have a higher value for the participants involved because of the improved coordination of the specific functions included. The third principle is mainly aimed at saving costs for the participants involved.

In this article, a comparison of the different types of integration in terms of the scope of the project, the technology of the construction and the duration of the implementation is done. Two actually existing infrastructure projects from the construction of the 3rd metro diameter of the Sofia metro, implemented on one site, were selected as the object of the study. The research is part of the author's PhD thesis on the topic: "Effective management of large infrastructure projects in an urban environment" [1], in the Department of Organization and Economics of Construction" of UACG – Sofia.

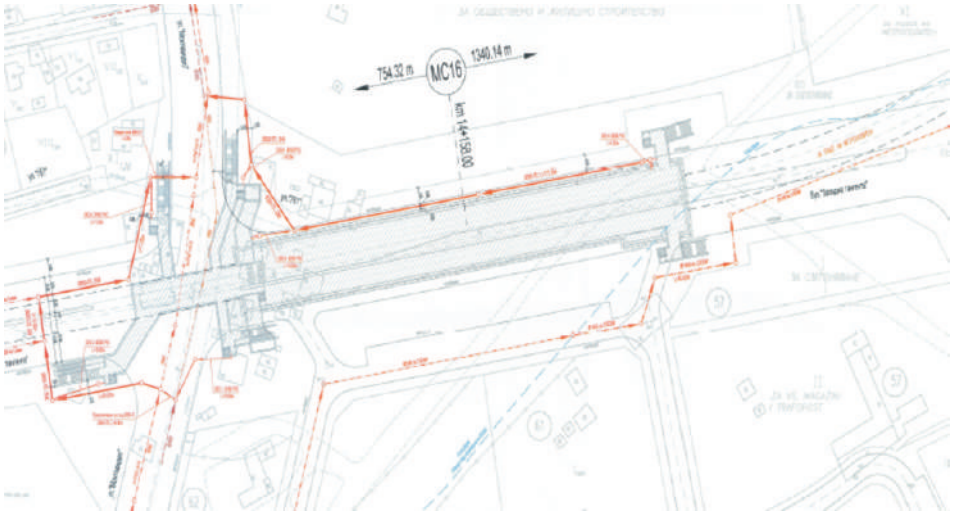

Fig. 1. Metro station III–16

2. OBJECT OF THE STUDY

The two projects realized on one site can be divided into leading and accompanying. The full name of the leading Project is: "Sofia Metro Extension Project, Third Metro Line – Botevgradsko Shose Blvd. – Vladimir Vazov Blvd. – Center – Ovcha Kupel RD", Stage II – from km. $11 + 941.33$ to km. $15 + 749.00$ with four metro stations; Lot 1 – from km. $11 + 941.33$ to km. $14 + 277.56$ with two metro stations; Metro station III – 16".

The title of the accompanying Project that will be used in the research is: "Construction of a temporary parking lot at Metro Station (MS) 16 from Montevideo Blvd. to 716 St. (761)".

Moesia/NBU metro station is located between Montevideo boulevard, 761 street and the yard of the 88-th high school Dimitar Popnikolov in the Ovcha Kupel I residential district. Before the start of construction, these were vacant municipal areas, through which an open ravine flowing diagonally in the direction of President Lincoln Blvd. The metro station is located along the route of the future Zapadna Tangenta expressway, which is planned to connect Montevideo Blvd. in Ovcha Kupel I with P. Dertliev Blvd. in Lyulin district. Already in the design phase of the work designs, the designers' task is to once again comply with the future easement of the metro station's future entrance on Zapadna Tangenta Blvd. and once again complied with the beginning extension of Montevideo Blvd. which was implemented in advance to the metro construction.

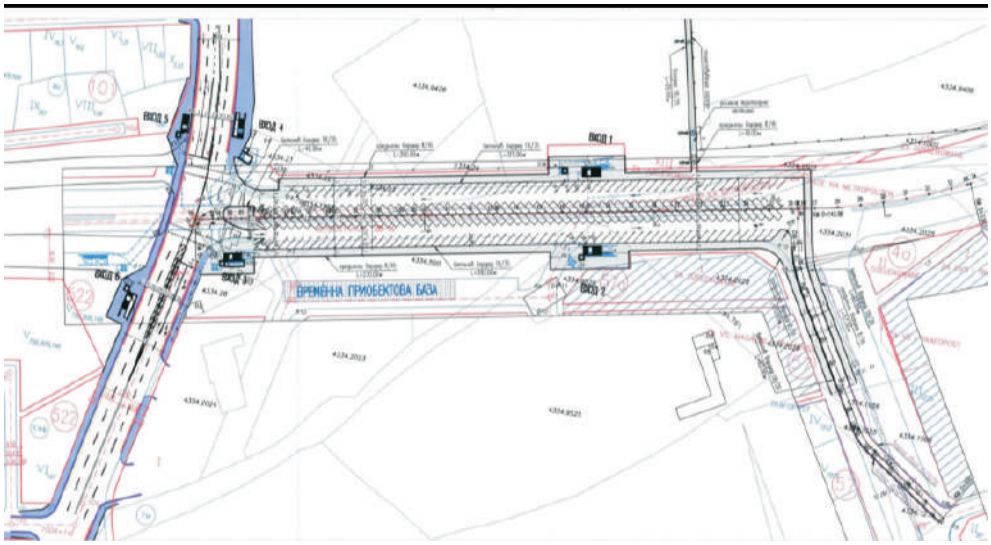

Fig. 2. Temporary parking lot at MC III-16 between Montevideo Blvd and 761 St

The layout of the surrounding space above the completed MS III – 16 is designed as a park, with suitable low shrub landscaping, trees parallel to the east and west sides, suitable garden furniture (benches). The design decision calls for one main park alley along the north-south direction, which will lead citizens from Montevideo Blvd. to the entrance of the 88-th high school. This alley connects all four entrances to the metro station located north of Montevideo Blvd. The possibility of pedestrian connectivity of the district comprised of new construction cooperatives around 761 street with Montevideo Blvd. The existing ravine is not planned to be reconstructed.

In the last year of construction of MC III – 16 Sofia Municipality changed its investment intentions regarding the areas above the already built metro station. In order to reserve the future route of Zapadna Tangenta Blvd., between Montevideo Blvd. and 761 St., a project was initiated for the construction of a temporary parking lot that would fit completely into the future gauge of Zapadna Tangenta Blvd.

In this way, the Contracting Authority tries to solve the following problems and created the following favorable opportunities:

- The intersection of Montevideo Blvd. and Zapadna Tangenta Blvd. has been built and regulated to a permanent gauge, but will act temporarily as an entrance/exit to the parking lot.
- The new boulevard is built in its entire dimension (including the sidewalks)

and includes solutions for all project parts (Electricity, Drainage, Street Lighting).
- The problem with the open ravine is solved, as it goes underground in fiberglass pipes with diameter $\varphi =$ 1400 mm with input and output facilities, thus complying with the future plan of the Sofia Municipality for a complete passage of the ravine underground.
- A vehicular and pedestrian connection is opened in the newly defined residential district around 761 Street and Montevideo Blvd.
- The subdivision of the section east of the ravine has been finally established.

3. RESEARCH METHODOLOGY

In carrying out the research, methods of qualitative analysis (SWOT analysis and "Omgevingswijzer" – method of the synergistic wheel) and quantitative analysis (comparative cost analysis) were used to compare the types of integration. The qualitative and quantitative analysis of the management of two infrastructure objects, implemented on the same site in the territory of the city of Sofia, is carried out in four integration options:
- No integration.
- Through Parallel Integration – the two objects are implemented in parallel by different contractors with different sources of funding. Management is carried out by the Project's Integrated Team. The two projects are integrated in time, scope and technology.
- Through Sequential Integration – the two objects are implemented sequentially. An Integrated Project Team exists only during initiation and design. Funding is from different sources, contractors are different. During construction, they are managed by separate Management Teams. Integration is achieved in terms of scope and technology (in terms of preventing duplicate and parasitic Construction Installation Works).
- Through Simultaneous Integration – the two objects are implemented at the same time by different contractors or by one contractor depending on the tender procedures. Funding is entrusted to the management of a single Beneficiary, although it comes from different sources An Integrated Project Team manages them from the initiation and design phase to commissioning. Integration is accomplished across time, scope, and technology.

Analyzes of the four integration options are performed in terms of scope, technology and project management time, using the following methods:

SWOT-ANALYSIS – a method of strategic analysis, which is expressed in an analysis of strengths and weaknesses and of opportunities and threats.

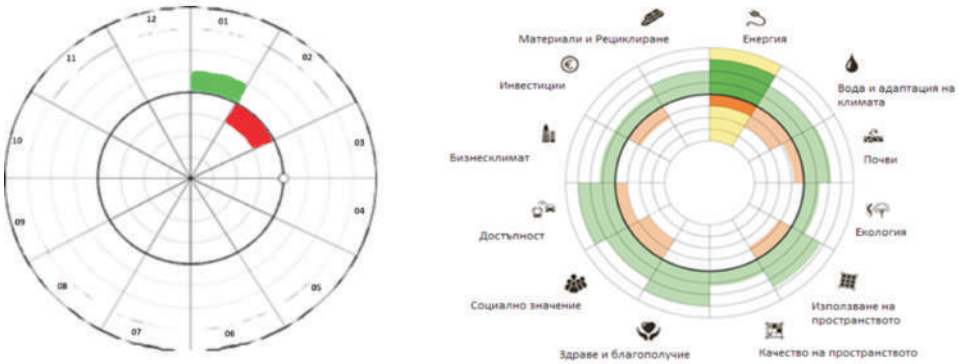

Fig. 3. "Omgevingswijzer" – "Synergy Wheel" (from 12 o'clock onwards: 01 Enegry, 02 Water and climate adaptation, 03 Soils, 04 Ecology, 05 Use of space, 06 Quality of space, 07 Health and well-being, 08 Social importance, 09 Accessability, 10 Business climate, 11 Investment, 12 Materials and recycling)

The goal is to achieve strategic success by using and developing strengths to take advantage of environmental opportunities and reduce weaknesses and limit external threats. In the present study, a SWOT analysis of the research objects is performed for each of the four integration options.

THE SYNERGY WHEEL METHOD – "Omgevingswijzer" – The Synergy Wheel Method [2] is composed of twelve topics, each of which contains a number of questions and allows for three answers to each of them regarding their impact on social, environmental and economic sustainability, respectively positive, neutral or negative. Each topic contains between three and five characteristic questions, with a positive response marked in green outside the "zero line", a negative response in red, and a neutral response having no effect on the graph.

COMPARATIVE COST ANALYSIS – to build on the results of SWOT Analysis, Cost Benefit Analysis is often used. This Analysis is set as a standard for all financial analyzes of projects applying for funding from the EU cohesion funds. For the needs of the present study, the costs during construction spent using the different integration scenarios of the two examined projects are compared.

4. ANALYSIS OF RESEARCH RESULTS

Results of SWOT-ANALYSIS: The analysis of the strengths and weaknesses, opportunities and threats of the considered options allow the following conclusions to be drawn:

- The option with the strongest points is the option with Simultaneous Integration. With it, integration is achieved by schedule, scope and technology. The two projects are being built in the fastest way, so that the public gets a ready-to-use public space in the shortest possible time. The structure of the territory is as complete as possible from the point of view of infrastructure and transport connectivity. Its management is carried out by an integrated Team, and the financing is taken care of by one Contracting Authority.
- The weaknesses of the option of Simultaneous Integration are related to the large volume of finances, as well as the need for in-depth planning and design, but in general the Integrated Project Team through modern and sustainable management techniques can cope with the difficulties.
- Regarding the possibilities – in the case of Simultaneous and Parallel integration, these are found in the social aspect. Through the implementation of sustainable construction, a sustainable urban environment appears, increasing the prestige of the neighborhood and attracting investment, thus raising the standard of living.
- Threats of asynchrony in actions between contractors can be eliminated by sustainable management of the Integrated Project Team.
- Because of the many similarities and few differences, the Simultaneous and Parallel Integration options can be considered as two subtypes of one integration.
- Sequential Integration is recommended in cases where the Financing Bodies of the project need time to procure the financing or to solve other problems requiring time.
- In the cases of choosing Sequential Integration, it is necessary to define a clear time horizon for implementation and to comply with it.
- A case of no integration is not recommended, as the most expensive to implement, with the most weaknesses and threats, providing unsustainable results.

Results of the "Omgevingswijzer"–Synergy wheel method: The graphical results of the analysis led to the following conclusions:

- Undoubtedly the best method of integration of the investigated infrastructure projects is the Simultaneous Integration method. An Integrated Team led by one Contracting Authority manages the implementation and financing of the projects. Construction works are integrated in terms of scope,

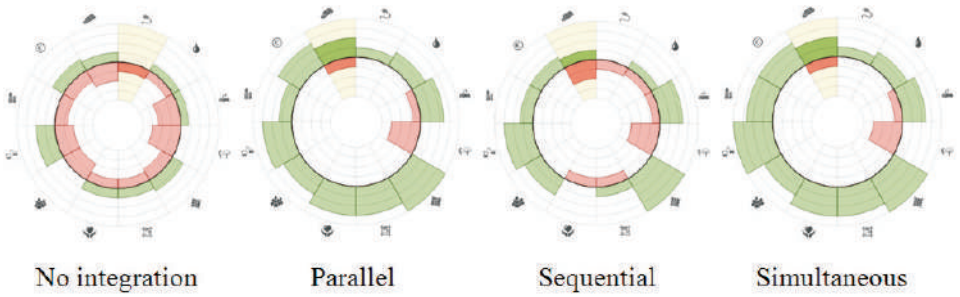

Fig. 4. Synergic wheel – comparison of the data obtained in the study at the various integration options[1]

technology and schedule, they are implemented in the fastest terms. The public is satisfied that it can relatively quickly start using the finished product. The results are sustainable construction and an integrated urban environment. The prestige of the neighborhood increases, private investments are attracted even before the end of construction.

- The differences between Simultaneous and Parallel Integration are minimal. Simultaneous integration wins in terms of ensuring quality, reliable sustainable construction, achieved through modern and innovative management solutions. Parallel integration can be considered as a subtype of Simultaneous and/or vice versa.
- Sequential integration is suitable for use only in cases where integrated financing cannot be provided within the framework of the implementation of the first (major) infrastructure project. In general, this type of integration is inferior in almost every research topic to Simultaneous and Parallel Integration.
- Regardless of the type of integration, infrastructure construction negatively affects ecology, habitats, flora and fauna. Since we are looking at infrastructure projects in an urban environment, it should be emphasized that they aim to increase transport connectivity and improve the urban environment of the city's society, not the preservation of species. The quality of the soils also deteriorates due to the thick layers of man-made embankments used in this type of construction.
- The worst indicators in the study are observed in the option with no integration. This option of infrastructure construction should be avoided, as

[1]Research conducted at https://www.omgevingswijzer.org. The result graphs were generated on 21.11.2022.

the most expensive and unsustainable results.

Results of the comparative analysis of the costs: In this study, some typical costs during the construction for the implementation of the same or similar construction works of the two sites – the construction of the metro station and the construction of the temporary parking lot – were examined and compared. These typical costs will be for the following:

- Excavation (demolition) of existing embankments (Parking lot).
- Research and soil treatment (MS).
- Restoration of the terrain after construction (MS).
- Road works (without asphalt works) – embankments, concrete, etc. until reaching the level for asphalting (Parking lot).
- Costs for establishing a temporary site, fences, etc. (MC and Parking lot).

By comparing the characteristic costs and the costs of temporary construction taken from the relevant CCC annexes to the construction contracts, the four different integration scenarios will analyze the funds spent and their appropriateness.

The total typical costs incurred during the construction of the metro station and the parking lot are as follows:

Metro station:

- For the study of the soils and their treatment in the area of the future parking lot – BGN 66,515.02.
- For restoration of the terrain after construction in the area of the parking lot – BGN 245,543.80.
- For roads, paths, pavements (this includes the project for the park in the area of the parking lot) – BGN 224,112.31.
- For temporary construction in the section – BGN 141,488.53.

Temporary parking lot:

- For excavations and demolition of existing construction – BGN 127,023.79.
- For embankments and road base before asphalt – BGN 287,951.87.
- For concrete and geogrids before asphalt – BGN 50,787.70.
- For temporary construction – BGN 23,511.18.

The comparison of characteristic costs and temporary construction costs under the four different integration scenarios produced the following results:

- No Integration, the total costs within the research are: BGN 1,166,934.20.
- When using Parallel Integration, the total costs are: BGN 558,498.71.
- When using Sequential Integration, the total costs are: BGN 604,876.12.
- When using Simultaneous Integration, the total costs are: BGN 499,177.17.

The results of this quantitative analysis led to the following conclusions:

- In the construction of the two sites without integration, more than twice as much funds are spent to achieve a sustainable result. In this case, it is necessary to pay an additional 87% of the refinement costs in order to demolish the refinements and bring the terrain into a form suitable for the realization of the investment intention of the second project.
- The use of Simultaneous and Parallel Integration saves at least 50% of the costs of temporary construction of the accompanying project.
- When using Sequential Integration, construction becomes more expensive by about 8–18% compared to Simultaneous and Parallel Integration, but a relatively long time horizon is provided for procurement of construction funds.
- When using any type of integration, the risk of duplication of Construction Installation Works from the type "building-destroy-rebuild" is reduced by 90%.

5. CONCLUSIONS FROM THE CONDUCTED RESEARCH

As a result of the research carried out in this article, the following more important conclusions can be summarized:

1. The results of the SWOT analysis show that the use of integration of infrastructure projects leads to fast and sustainable construction with a starting element of functionally completed urban space and infrastructure, but this becomes possible at the expense of investing large amounts of financial resources in a short time interval.
2. The results of the analysis using the Synergy Wheel Method confirm and build on the results of the SWOT analysis, emphasizing the socio-economic benefits of using integration in the implementation of infrastructure projects in an urban environment. Such benefits are the increase in the overall rating of the affected territory, the growth of investments and the quality of services, as well as the general increase in the quality of life and the public's trust in the authorities. However, it is proven that infrastructure construction, despite the socio-economic benefits it brings, does not have a positive impact on the environmental aspect of the environment.
3. The results of the comparative analysis of costs confirm that the lack of integration in the implementation of infrastructure construction increases costs. The costs of demolition and redevelopment of the territory in the absence of integration are over 87% higher than in cases of integrated construction, and the costs of temporary construction are 50% higher.

In general, the research results unequivocally show the superiority of the integrated management and implementation of the infrastructure projects over the non-integrated one. From the three types of integration considered – Simultaneous, Parallel and Sequential, it was found that the most sustainable results are obtained through Simultaneous Integration of infrastructure projects in an urban environment.

REFERENCES

[1] B. Vasilev, Effective management of large infrastructure projects in urban environment, Dissertation, University of Architecture, Civil works and Geodesy, Sofia, 2023.

[2] Omgevingswijzer, online: https://www.omgevingswijzer.org/

Received July 10, 2023