112 YEARS OF PUBLIC TRANSPORT IN BELGRADE

When city fathers commissioned the first horse-tram on, now so remote, October 14, 1892, they did not have the slightest idea that they were the pioneers of the biggest public transport system in Balkans. Also, they were not aware that they started the development of one of the most spread transport modalities in the world – city rail system – which has been around for already 122 years.

Belgrade of that time, with approximately 60,000 inhabitants, had slowly started to acquire European image and it was one of the first cities to grasp the importance of the public transport development. Public transport has been developed along traditionally most attractive Belgrade's streets and farther, to more remote picnic points like "Topčider". Electric traction for trams started in 1904. The system has been gradually developed and in 1912, only 20 years after the introduction of the tram, 7.5 million passengers were transported.

The first traction

Beginnings of public transport in Belgrade

Omnibus in Belgrade

Of course, accelerated development of Belgrade, especially after the end of the World War I, required the development of other systems as well, so bus traffic started its intensive expansion in the third decade of XX. Century. "Omnibuses of Belgrade City" resembling present day sightseeing tourist buses marked the period between the two World Wars. By mid thirties, approximately 65 km of tram network has been completed in Belgrade, while by the end of the third decade of XX. Century the bus network was exceeding 40 km. When the war started, the Belgrade had the tram network in the length exceeding 80 km.

DEVELOPMENT OF METRO IDEA

Belgrade is becoming a metropolis

After the end of the World War II, when only two tram lines remained functional, the sudden expansion of the public transport commenced. Already in 1947 trolley busses were introduced and numerous new bus lines were opened. With the annual average of a hundred million of transported passengers, by the end of forties, the number of passengers had grown to over 850 million annually by the end of the previous century.

In the last Century, by the beginning of fifties, when Belgrade started acquiring the characteristics of real metropolis, the need for serious reorganization of the complete transport system appeared. Tram, trolleybus and bus continued to develop almost independently and inconsistently, however almost in first visionary plans in fifties, the thinking about metro as the principal transport system in Belgrade started. Those were the first steps in metro projects which were especially intensified after Master urban plan was completed in 1972. The Department for metro was established at the Institute for the building of the City and it prepared the design for Belgrade's metro on the basis of appropriate traffic parameters and forecasts which were rather optimistic. However, despite the quality of the prepared studies and designs, various approaches of experts and politicians to the needs and possibilities of highly capacitated rail system in Belgrade were the reason that the decision about construction has not been taken till now.

During the past thirty or so years, designs of classic tram, modernized tram, classic metro, pre-metro, light rail transport, were exchanging each other. They all had appropriate expert support, however they were the reflection of certain political situation. All solutions had good and bad sides and the failure to reach the construction phase was their common feature.

Scheme of future rail systems in Belgrade

WHY LIGHT METRO?

Belgrade was in much more favorable social-economic and geopolitical position by the end of eighties. The prevailing optimism was giving hope that the development will take completely different pace. Hence, ambitious forecasts and plans regarding the development of metropolitan Belgrade stating that only classical metro was appropriate for Belgrade. However, such development did not happen due to known circumstances and Belgrade "sobered" and entered the Third Millennium aware of its own possibilities and its maximal reach. In this sense, the preparation of strategic plans for the City of Belgrade was approached, with only one essential assumption – real economic possibilities.

Simultaneously with the change of working and thinking approach of Belgrade's planners, recent investigations and measurements in Belgrade are showing somewhat different picture than the forecasts made in previous decades. Results are showing that the most loaded sections of the public transport are still the following: bridge in Brankova Street and Vojvode Mišića Boulevard. The highest loads appearing are in the volume between 8,000 and 9,000 passengers per hour. The most optimistic forecasts do not foresee the increase exceeding 50% in the next 20 years. In this sense, the value over 13,000 to 14,000 passengers per hour is not expected at the most loaded sections – i.e. loads insufficient for classic metro.

Those were the input parameters used in the Master plan of Belgrade for 2021. This plan has finally defined rail system that should satisfy the needs of the City in next several decades. The fact that the growth of Belgrade is much slower than it was planned before, the awareness of the economic possibilities of the City, as well as the knowledge of the contemporary technologic solutions enabling gradual upgrading of existing systems, have directed the experts to completely new solutions.

It is light rail system, or as it is called, Light rail transit, Metropolitana legera, Metro leger, Stadtbahn, Light Metro. All these are names for contemporary rail system which incorporates all the good characteristics of classic metro and classic tram.

Due to sudden growth of extent of individual motorization and intensive development of car traffic, during the sixties in previous century, in Europe started gradual termination of old trams. Considering the outdated technology, limited capacity and diminished accessibility, reduced speed in mixed traffic, tram has lost the battle not only with cars, but with modern buses as well.

Attractive appearance and modularity of light metro composition

However, during last decades of 20th century renaissance of city rail system emerged. As opposed to development of the most classic, so called, “heavy metro”, forming of complete “family” of light rail systems – light metros emerged. Due to the most modern technology of construction, contemporary control and guiding systems, types of vehicle, light metro has been laid in many cities as the basic element of transport system. In some big cities light metro is appearing as basic city system (Dublin - 2 million inhabitants, Porto - 1.2 million, Dallas - 1.9 million, Hannover – 1.1 million, Lisle – 1.1 million, Manchester – 2.6 million, Kuala Lumpur 2.1, Melbourne - 3.2 million, con-urban Colognje and Bonn – 2.0), while in others it is efficiently combined with existing or transformed tram systems (Stuttgart, Karlsruhe, Saarbrücken). In any case, these systems are always supplemented by bus network that almost in all cities represents the most widespread system.

Light metro in Barcelona, Spain

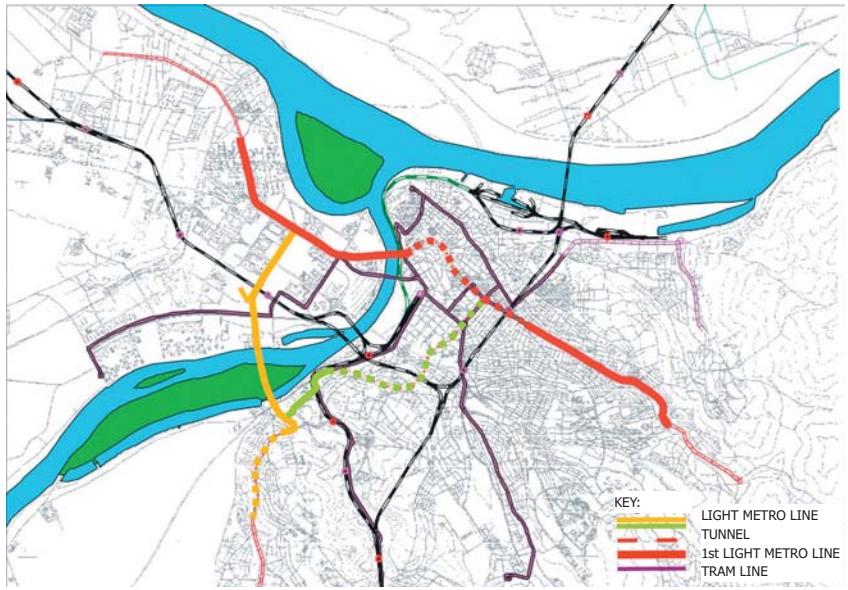
Basic characteristics of light metro in the world are as follows:

- 70 – 80% completely independent alignment (underground or surface)
- possibility for gradual adaptation of existing tram by using “the third rail” which opens the possibility for better and faster branching out of the system,
- capacity of approximately 20,000 passengers per hour per direction,
- exploitation speed up to 30 km/hour,
- contemporary vehicles with unit capacity up to 300 passengers, with low floor, accessible for handicapped persons,
- possibility for later upgrading to classic metro if the needs appear,
- lower unit prices for the construction for the realization in phases..

“Right-of-way” in Lyon, France

Master plan of Belgrade has foreseen that by 2021, the following 3 lines of light metro should be formed:

1. Ustanička Street – center of the City – Tvornička Street
2. "Prokop" – "Pravni fakultet"
3. "Banovo brdo" – "Ada Ciganlija" – "Novi Beograd"



Scheme of light metro system according to Master plan of Belgrade for 2021

"BELAM" PROJECT

Project BELAM offers general solution for the alignment of the first line of light metro, as well as the Pre-feasibility study which will help the City to make its investment decision. As the basis for design and preparation of the Pre-feasibility study the following separate studies concerning corridor of the first line of light metro have been used:

1. Preliminary environmental impact analysis
2. Urban-morphological study
3. Geotechnical study
4. Study on social-economic environment impact.

In addition, the following separate papers (books) have been prepared:

- Aspect of transport demand
- Impact on traffic
- System of superstructure
- Costs (budgets)
- Signalization, communications and electric power supply systems.

On the basis of the request made by Expert Council and based on detailed analyses, the Project has been expanded by examination of the possibility to introduce new underground station "Akademija" – so that two alternatives have been prepared for the complete project: basic variant – according to Master plan of Belgrade and variant "Akademija"

TECHNICAL CHARACTERISTICS OF BELAM

Earlier projects of city rail systems prepared in Belgrade proposed incompatible and non-transferable system in space and time, while project BELAM foresees the possibility of later upgrading of light metro into classic metro. Precisely that is one of the basic advantages of contemporary light rail systems. Also, this project enables the transformation of existing tram system into future light metro. That is why the elements of alignment, tunnel, structures and underground stations have been designed in a way which enables the acceptance of classic metro possibility if such need appears in the period after present time horizon visualization (year 2021).

The following design elements were used in project BELAM:

SURFACE TRACK ALIGNMENT (Basic design criteria)		
	Unit	Parameter
ABSOLUTE MAXIMUM GRADIENT STRAIGHT ALIGNMENT < 200 m	%	8
DEVIATION RADIUS	m	25
MAXIMUM PERMITTED SPEED IN DOWNHILL DIRECTION AT ABSOLUTE MAXIMUM GRADIENT	km/h	50
MAXIMUM GRADIENT	%	6
MINIMUM VERTICAL RADIUS WITH SPEED OF 50 km/h	m	500
MINIMUM VERTICAL RADIUS WITH SPEED OVER 50 km/h	m	1000
RECOMMENDED MINIMUM RADIUS	m	50
TRACK GAUGE	mm	1435

TRACK ALIGNMENT IN TUNNEL (Basic design criteria)		
	Unit	Parameter
ABSOLUTE MAXIMUM GRADIENT STRAIGHT ALIGNMENT <200 m	%	6
MINIMUM DIAGONAL RADIUS	m	60
MAXIMUM GRADIENT	%	7
MINIMUM RADIUS	m	60
RECOMMENDED RADIUS	m	200
RECOMMENDED TBM RADIUS (Ø8m)	m	275

ROLLING STOCK CHARACTERISTICS	
LENGTH OF VEHICLE	35 m
WIDTH OF VEHICLE	2.650 mm.
MAXIMUM VEHICLE HEIGHT (WITHOUT PANTOGRAPH)	3.300 mm
VEHICLE HEIGHT (WITH FOLDED, DOUBLE PANTOGRAPH)	3.600 mm
MINIMUM NUMBER OF DOORS AT EACH SIDE	4 double + 2 single
MAXIMUM FLOOR HEIGHT ABOVE TOR	600 mm
% SEATING	23
% STANDING	77
TOTAL NUMBER OF PASSENGERS (6 pass/m^2)	300

ALIGNMENT

The corridor of the first line of light metro has been defined as priority corridor in the General plan of Belgrade for year 2021 and it spreads from Zemun on the North to the intersection of Kralja Aleksandra Boulevard and Ustanička Street on the East. There are approximately 270,000 inhabitants and approximately 150,000 jobs In the direct impact area of the corridor.

The alignment is laid on surface, in right of way, in the middle of Kralja Aleksandra Boulevard and it goes to the intersection with Sredačka Street where it enters the tunnel. The tunnel goes under the Boulevard, to Nikole Pašića Square, then under Republika Square and in gentle arc it turns to Pop Lukina Street. Station "Varoš kapija" has been formed there, and from this point the alignment continues by the new bridge over the Sava River. On the left bank of the Sava River the alignment leads through the tunnel to the underground station "Hyatt" where it intersects with existing tram alignment. BELAM then continues to the West, along Milentija Popovića Street, it comes out of the tunnel at AVNOJ Boulevard and then continues by central right of way to the intersection with Omladinskih brigade Street. The alignment of light metro then turns to North, toward Municipality "Novi Beograd" and in the close vicinity of Municipality it dives into the tunnel and passes under existing roundabout intersection. Then the alignment goes along Mihajla Pupina Boulevard to terminal at Tvornička Street.

PARAMETERS FOR EXPLOITATION OF LINES 1A and 1B		
	LINE 1A: USTANIČKA STREET – TVORNIČKA STREET	LINE 1B: VUKOV MONUMENT – "NOVI MERKATOR", WITH TECHNICAL BRANCH TOWARDS BLOCK 41:
LENGTH (m)	12.200	7.240
AVERAGE DISTANCE BETWEEN STATIONS (m)	642	610
AVERAGE TIME OF STOPS (sec)	15 - 25 s	15 - 25 s
TERMINAL TIME (sec)	45	45
NUMBER OF STATIONS	20	13
COMMERCIAL SPEED (km/h)	26,37	24,4
TIME OF TRIP	27min 45s	16 min 30 s

ROLLING STOCK REQUIREMENTS				
	USTANIČKA STREET –VUKOV MONUMENT	VUKOV MONUMENT – "NOVI MERKATOR"	"NOVI MERKATOR" – BLOCK 41	"NOVI MERKATOR" – TVORNIČKA STREET
VEHICLES IN PEAK HOUR	32	40	8	32
VEHICLES OUTSIDE PEAK H.	6	8	2	6
VEHICLES IN RESERVE	6			
ROLLING STOCK	46			

OPERATING CHARACTERSITICS OF BELAM

For BELAM light metro such operation has been proposed that forms the structure in the shape of letter "Y". The common section starts at the beginning of Ustanička Street and goes to station 10+200; at this station the system branches – one branch passes Umetnosti Boulevard and goes to stations Block 39, Block 41 and the zone of depot, while another branch ends at Tvornička Street.

Considering the operation in "Y" structure, development in phases, as well as in the function of expected demand, the system is optimized by exploitation of two lines which havecommon link leading from the station Vukov Monument to the station "Novi Merkator". Such operation will enable the following:

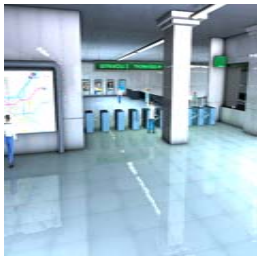
- Such frequency of passages which will in an appropriate way cover the demand, it will not cause congestions neither at platforms, nor in vehicles,

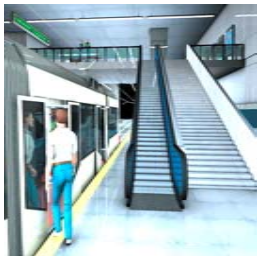
Beogradski
laki metro
linija Ustanička - Tvornička
Belgrade Light Metro
Ustanička - Tvornička line
BeLaM
Direkcija za građevinsko zemljište i izgradnju Beograda
Ustanička
Kluz
Olimp
Cvetkova pijaca
Lion
Đeram
Vukov spomenik
Pravni fakultet
Pošta
Trg Nikole Pašića
Trg Republike
Akademija
Varoš kapija
Šest kaplara
Proleterske solidarnosti
Arena
Bulevar umetnosti
Opština Novi Beograd
T. C. Novi Beograd
Tvornička
Zvezdara
Karaburma
Palilula
Vračar
Crveni krst
Konjarnik
Šumice
Medaković
Voždovac
Dedinje
Autokomanda
Topčidersko brdo
Senjak
Slavija
Kliničkí centar
Terazije
Dorćol
Kalemegdan
Beogradska tvrđava
Sava
Dunav
Veliko ratno ostrvo
Novi Beograd
Zemun
Gardoš
Gradski park
Pančevački most
Luka "Dunav"
Brankov most
Most "Gazela"
Beogradski sajam
Hotel "Intercontinental"
Sava Centar
Beogradska Arena
Palata Saveta ministara (Palata Federacije - SIV)
Hotel "Jugoslavija"
Studentski grad
Auto - put
Tošin Bunar
Treći bulevar
Bulevar Mihajla Pupina
Bulevar Nikole Tesle
Bulevar kralja Aleksandra
Hram Svetog Save
Narodna biblioteka Srbije
Železnička stanica "Beograd Glavna"
Železnička stanica "Beograd Centar - Prokop"
Železnička stanica "Novi Beograd"
INECO
JUGINUS
Jugoslovenski institut za urbanizam i stanovanje

- Punctuality, regularity and reliability, since it is the very basis of the commercial success of the system, and

LIGHT METRO SURFACE STOP (Basic Design Criteria)		
	Unit	Parameter
MAXIMUM PLATFORM LENGTH	m	80
RECOMMENDED SIDE PLATFORMS WIDTH	m	3,5
RECOMMENDED CENTRAL PLATFORM WIDTH	m	5
PLATFORM LEVEL FROM TOR	mm	250-350
MINIMUM HORIZONTAL RADIUS	m	1000
MAXIMUM GRADIENT	%	2

LIGHT METRO UNDERGROUND STATION (Basic Design Criteria)		
	Unit	Parameter
MINIMUM PLATFORM LENGTH	m	100
MINIMUM SIDE PLATFORM WIDTH	m	3,5
MINIMUM CENTRAL PLATFORM WIDTH	m	7
PLATFORM LEVEL FROM TOR	mm	300
MINIMUM HORIZONTAL RADIUS	m	1000
MAXIMUM GRADIENT	%	2
RECOMMENDED ENERGY GRADIENT	%	4





Interior of future underground stations

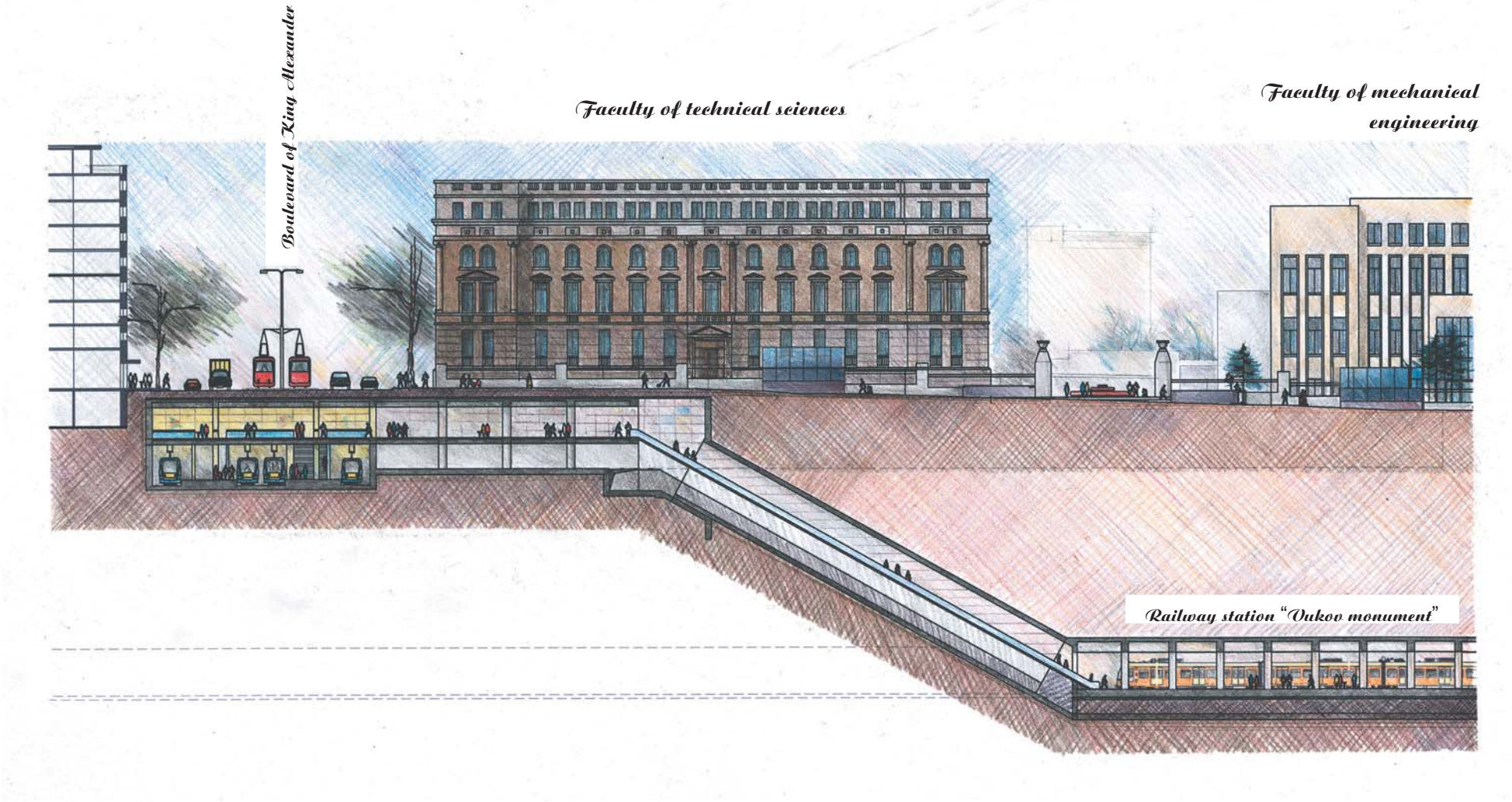
Future external appearance of station "Varoš kapija"

- Speed and comfort.

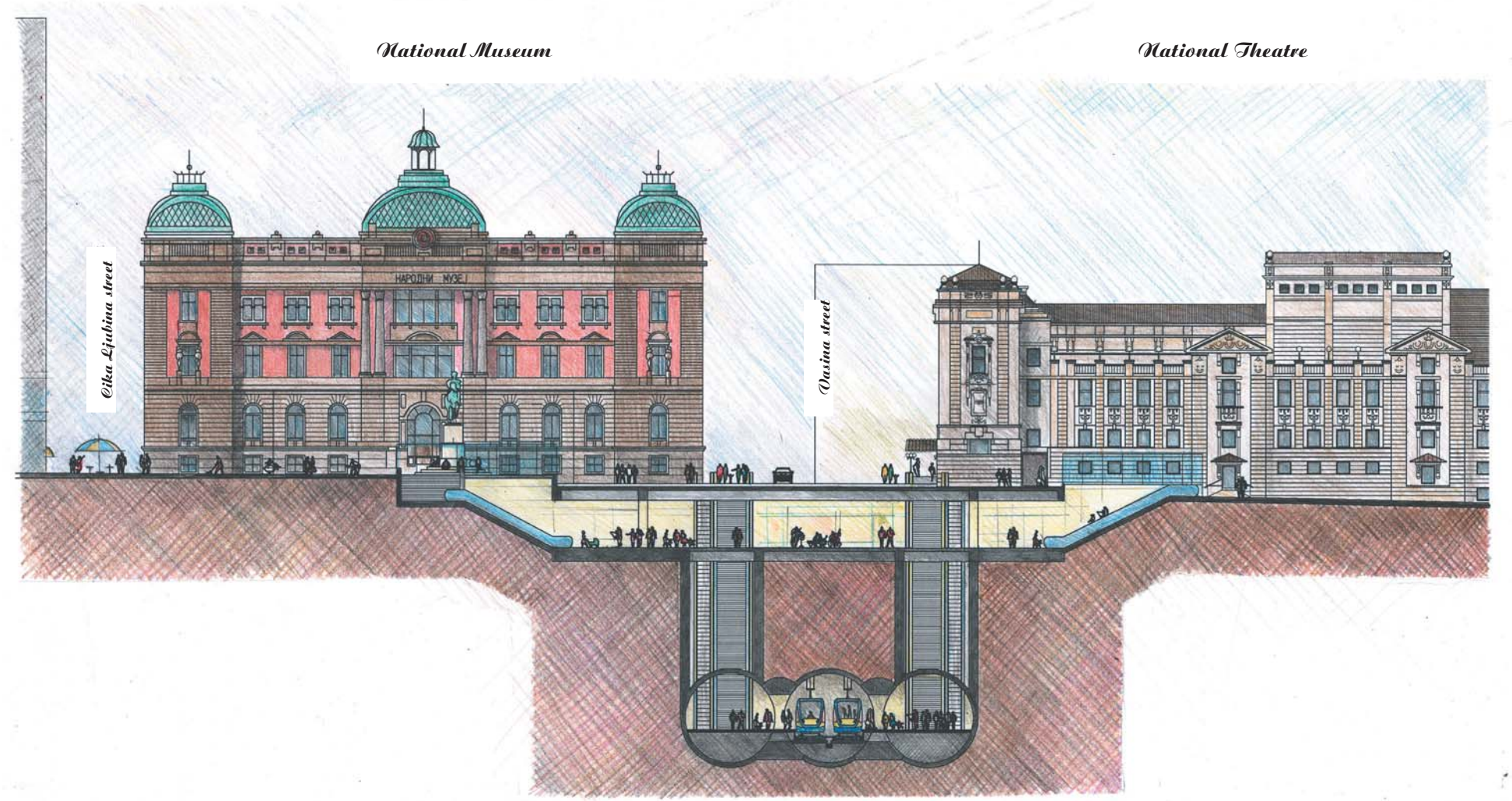
Distribution of two lines corresponds to criteria of adjustment to irregularities of demand and it also enables common functioning with trams at sections between Vukov Monument and Ustanička Street.

Future interior of "Varoš kapija"station

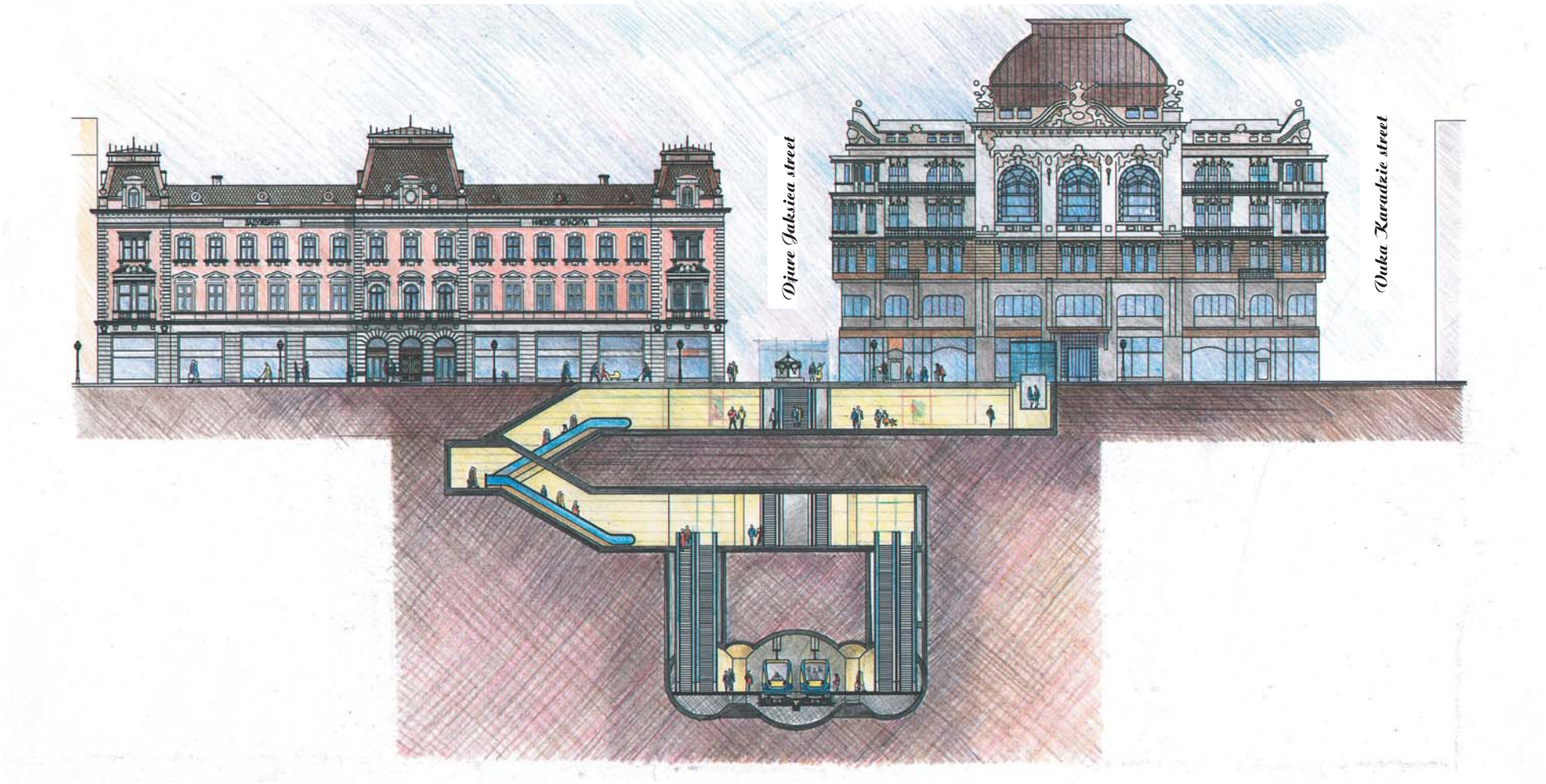
STATION "VUKOV MONUMENT"



STATION "REPUBLIKA SQUARE"



STATION "AKADEMIJA"



FEASIBILITY

Master plan of Belgrade for year 2021 represents the layout plan for the preparation of the Pre-feasibility study for construction of the first line of light metro with general design. During the preparation of the Study, on the basis of multi-criteria evaluation, the variant passing along AVNOJ Boulevard has been selected. In this variant the author has introduced new underground station "Pošta". On the basis of the proposal of Expert Council and in order to reduce the load at station at Republika Square, and also in order to achieve better accessibility to the city center (Knez Mihailova Street), another underground station has been introduced at the position between stations "Republika Square" and "Varoš kapija" – station "Akademija".

Two alternatives of the alignment elaborated within General design of light metro in Belgrade have been analyzed in Pre-feasibility study.

Basic variant: Total length of the alignment is 12,365 m. The surface part is 4,450 m and there are 800 m on the bridge, while the rest is underground/tunnel section in the length of 4,100 m. In the alignment there are 19 stations and waiting bays in total, including 2 terminals, 10 waiting bays, while the rest are underground stations.

Variant with station "Akademija" differs from the basic variant in the part of the underground section of the alignment between station "Pravni fakultet" and station "Varoš kapija", as well as in the part at municipality "Novi Beograd" where the alignment has been laid underground in order to avoid at-level intersecting with motor vehicle traffic in the roundabout intersection. The alignment is longer for 103 m than the basic variant and new underground station "Akademija" has been introduced.

In respect of construction, a scenario has been assumed according to which the construction would be executed in phases during the period of 5 years. On the basis of assumed investments dynamics and calculation of effects, the two following phases could be distinguished:

Phase 0 - comprises the section from hotel "Hyatt" to depot. Practically, this is the part of phase 1 representing trial section of future system that should show advantages of new type of transport. For constructors and for company exploiting public transport, it should serve for testing and smoothing of construction, exploitation and maintenance.
Phase 1 – consists of construction of the alignment from Vukov Monument to depot.
Phase 2 – consists of construction of the alignment from AVNOJ Boulevard to Tvornička Street.
Phase 3 – consists of construction of the alignment from Vukov Monument to Ustanička Street.

In order to integrate light metro more fully into other systems of public transport, reorganization of lines of other systems has been

done within both considered alternatives. Reorganization of lines of public transport relates, either to change of alignment, or to change of operational elements of the line.

Preparation methodology of Pre-feasibility study defined the following cost elements:

- investment costs
- functioning and maintenance costs of the system
- other costs (safety, informing, etc.)

Regarding the expected (direct) economic benefits the following aspects have been analyzed:

- tickets sale revenues
- other commercial revenues (commercials and space renting)
- saving in travel time
- reduction of vehicle operation costs on the level of the system
- increased comfort, reliability and suitability of the system

BASIC VARIANT demand		
PASSENGERS:	2011	2021
PEAK HOUR (pass/hour)	29.704	32.400
ANNUAL NUMBER OF PASS.	59.962.475	65.404.800

Expected number of passenger is the basic parameter that has been taken into account:

VARIANT "AKADEMIJA" demand		
PASSENGERS:	2011	2021
PEAK HOUR (pass/hour)	32.762	35.518
ANNUAL NUMBER OF PASS.	66.135.557	71.699.003

The most significant effect expected after the introduction of the first line of BELAM is saving in travel time. The values are shown for year 2012, i.e. for the first year of the expected exploitation of the system:

QUANTIFICATION OF THE TIME SAVING		
YEAR: 2012	BASIC VARIANT	VARIANT WITH STATION "AKADEMIJA"
TIME SAVING	27.421.061 hours	28.831.548 hours
MONETARY VALUE OF TIME SAVING	31.889.570 €	33.529.908 €

Expected indirect effects have been analyzed as well:

- Reduction of traffic congestions.
- Reduction of costs incurred by accidents.
- Improved efficiency of public systems.
- Improvement of overall energy efficiency.
- Improvement of environmental quality.
- Giving back streets to people.
- Humanization of inter-human relations
- Effects of induced construction (especially important for revenues of the City)

Basic investments

Considering that the construction of the first line of BELAM is to be executed in phases, the assumed investment dynamics for the project is 6 years. The same treatment has been applied for rolling stock which is conditioned by completion and commissioning of individual sections. Total investment for rolling stock, consisting of 46 vehicles, in both alternatives, amounts to 126,500,00.- euros, so together with the investment for infrastructure and equipment, the value of investment according to variants is as follows:

Basic variant: **349.205.000 €**
Variant "Akademija": **386.886.000 €**

Evaluation of effects

Estimation of economic justification of the investment in realization of the new project of the first line of light metro has been performed by application of cost – benefit relation method analysis. In the analysis of costs and benefits for the period of 30 years, general revenues and costs that may be calculated within project have been compared. In order to identify them, scenarios elaborated in general design have been compared to variant without changes in the system, i.e. the comparison with scenario without investment at the level of Belgrade's transport system ("do nothing') has been performed.
Although they cannot be directly quantified, which means that they cannot be included in the analysis of costs and benefits, estimations of indirect benefits and damages have been calculated (and partially quantified).

- Nominal values of internal rate of returns and net present value have been subjected to sensitivity analysis taking into account possible uncertainty in realization of the investment, as well as the uncertainty in realization of direct economic benefits based on possible deviations of demand from forecasted variables (number of passengers).
- Net present value (NPV) obtained for the Basic variant is 108.9 million €, while for the Variant with station "Akademija" it is 106.8 million €, for year 2005 at discount rate of 6,5%.
- Value of internal rate of returns (IRR) for the Basic variant is 9.4%, while for the Variant with station "Akademija" the obtained value of IRR is 9%, which is, in both cases, higher than the value of IRR of 7% that has been determined as target value. According to the experience from 400 important infrastructure projects, recommendation for the minimal value of IRR, for long-term period, is limited to 6%. Practical average value of IRR in traffic projects is 6.5%.
- The sensitivity analysis determines deviations of results obtained for IRR and NPV, taking into account possible deviations from forecasted (demand) / calculated (cost of investment) values. Considering the nature of the project, uncertainty of 20% of main variable has been taken as appropriate for this kind of analysis. In this case, satisfactory values of internal rate of returns (8.7% for Basic variant and 8.4% for Variant "Akademija") have been obtained as well.

Values of internal rate of returns (IRR) and net present value (NPV) obtained in this study are practically identical in both variants. Mentioned values exceed values as required by international financial institutions.

Thus, it is recommended to Investor to continue activities related to preparations for construction according to the variant "Akademija".

Special paper has been devoted to financing modalities and management of the future system, with the goal to define alternative financing models based on possibilities of the City.

Three alternatives of financing have been studied, and each alternative has its own management model:

Planned alternatives are as follows:

- Financing from public sources;
- Public-private partnership;
- Mixed system.

Each of these modalities has been tested separately and on the basis of experience, advantages and disadvantages of each modality have been determined.

CONCLUSION

After years of "wandering" in trying to select optimal solution for the problem of public transport, Belgrade has got Pre-feasibility study and General design for the first line of light metro. This gives hope that "Gordian knot" known as Belgrade's metro, will be finally solved. We are of the opinion that materials presented to City Assembly make good documentation basis for bringing decisions on design of future phases, as well as decisions concerning the construction. In case good management, including domestic and foreign experts, is provided and with good coordination of City administration and timely securing of required funds inflows, it could be expected that BELAM becomes functional in year 2012.