SPECIFIC DESIGN REQUIREMENTS OF MULTI - STOREY GARAGES

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Summary: This paper presents the most important requirements that are necessary for the proper analysis of the problem of parking in cities and proper design of multi-storey garages. By using different methods the parking problems in Kosovska Mitrovica have been analyzed, the division of the city in zones has been suggested, and recommendations for building multy-storey garages in certain zones have been made. All important requirements necessary for proper design of the garages have also been analyzed.

Keywords: multi-storey garages, design, specific requirements, parking places

1. INTRODUCTION

All the traffic participants in Kosovska Mitrovica share a common problem, and that is the lack of space. While drivers say that there is not enough room for their vehicles, pedestrians claim that their walking zones have been usurped by four-wheelers. Whatever the case may be, public surfaces of this city are most often used as parking areas even though they are not designed for that purpose. The areas in question include pavements, roads, pedestrian zones and green areas that are most definitely not intended for this purpose.

The main task of solving the parking space issues is to liberate all areas that are not designed for parking vehicles, which will enable the reorganization and pre-design of this space. Building public multy-storey garages stands out one of the most efficient solutions to the problem.

2. DETERMINING PARKING NECESSITIES

When determining the necessary number of parking spaces for a certain area or structures several methods are used. All these methods are characterized by orientations since their results yield an estimated number of parking lots. This study uses several methods which are briefly described in the following section.

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2.1 The City Factor Method

This method is based on a fact that certain number of citizens are in need of using vehicles for transportation to the city center, therefore parking space needs to be provided. It is estimated that every 5 to 8 vehicles need one parking space in the city center.

The City Factor Method uses population and motorization rate data, which are mostly determined by calculating numbers of registered vehicles. However, a lot of unregistered vehicles are widely used in the city and that needs to be taken into account. The data is therefore practically useless without a direct verification.

The following formula provides the orientation number of parking spaces:

$$P = c \cdot k \,,\tag{1}$$

where:

$$c = \frac{1}{d} = 0.12 \div 0.15 - City\ factor$$
$$d = 5 \div 8 - local\ quotient$$

$$k = \frac{E}{D} - total\ number\ of\ motor\ vehicles \tag{2}$$

$$E - number\ of\ citizens$$
$$D - number\ of\ citizens\ per\ one\ vehicle$$

Based on the research, the value of D, depending on the size of the population in E, varies and occurs widely. The next diagram shows the coodependence of these parameters. Notably, the increase in population increases the quotient D, while the quotient K basically 'drops'. Also, with the decrease of population the quotient D also decreases, while K 'grows'.
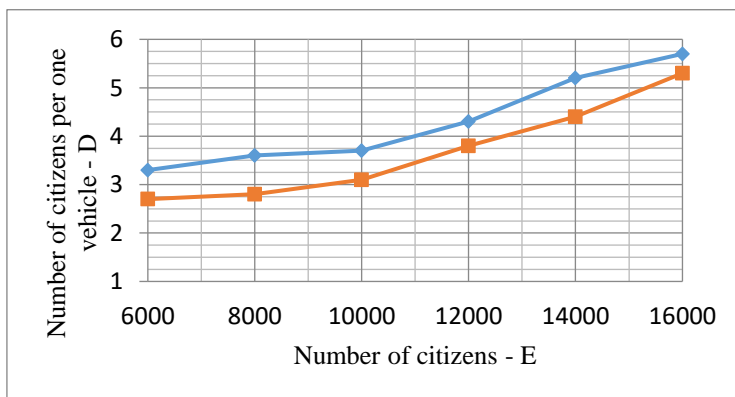

Figure 1. Codependence of parameters E and D

If the population number of 12, 000 people in the area is taken into account, the assumed values of the factors c = 0.12 and D = 4, the formulas (1) and (2) result in the potential number of parking spaces:

$$k = \frac{12000}{4} = 3000 \; vehicles$$

$$P = 0.12 \cdot 3000 = 360 \; PP$$

When the city's metropolian zone which numbers approximately 15, 000 people is analyzed, the same number of necessary parking spaces is obtained by assuming c = 0.12 and D = 5.

2.2 The City Centre Quotient Method

It is relatively simple to determine the number of necessary parking spaces using this method since certain parameters contained in the formula are relatively easy to obtain. As its name says, this method is used for determining the necessary number of parking spaces in the city center, which when input parameters are adequately used yields satisfactory data. The average number of necessary parking spaces is obtained by this formula:

$$P = R \cdot c + P_s ,$$ (3)

where:

R – The number of expected vehicles that may occur as parking space occupiers
P_s – The number of parking spaces that city center inhabitants need provided
c - The city center quotient – signifies the percentage of vehicles coming to the city center (c < 1, and is decreased when the number of vehicles is increased)

The formula (3) is easy to segregate, but it is better to use said form in this case. It is estimated that the city center inhabitants need approximately 400 parking spaces more ($P_s = 400$). By using the results of the previous method and assuming that of potential 360 users (R=360), 50% (c = 0,5) of them will require parking in the center, the formula (3) results in the number of required parking spaces:

$$P = 360 \cdot 0.5 + 400 = 580 \; PM$$

2.3 The Normative Method

This method generates normative values for each significant structure. It is believed that there is a specific relation between the size of the structure, the number of employees, or some other third parameter that characterizes the structure and the required number of parking lots in its surrounding area. This method should be used with caution because it is not possible to define the unique normative which will describe the parking space requirements of different areas in a satisfactory manner, and all specifics of the macro location need to be taken into account.
This method is suitable for the part of the city which has been under construction the most lately (Vlade Ćetkovića, Sutjeska, Drvarska and Čika Jovina street).
The results are arranged in the table:

Table 1 Normative for determining parking space by structure

Category and structure type		One parking space per:		
Category	**Type**	**Measuring unit**	**Obejct/Person**	**m²**
Habitaion	Residential Complex	m²	0,1-0,5	65-75
	Multi-storey Building Outside the Complex	m²	0,5	65-85
	P+1 family	Appartment	1	
Administration, Business Area	Administrative Building	Employed	5-7	40-60
	Banks, Post Offices	Employed	5-7	30-45
Education, Recreation	Primary Schools, Daycare Centres and Nurseries	Students	7-12	
	High Schools	Students	10-15	
	Sports Facilities	Spectators	8-12	
Shops	Shopping Malls	Employed	25-60	100-150
	Supermarkets			50-80
Accommodation Facilities	Restaurants, Clubs, Cafes	Seats	8-12	
	Hotels A and B	Rooms	3-5	
	No Category	Beds	5-8	

Table 2 Category and type of the structure and the necessary number of parking spaces

Category and type of Structure	The Necessary Number of Parking Spaces
Appartments and Houses	400
Banks, Post Offices	5
Schools, Pre-schools, Nurseries	15
Restaurants, Clubs	20
Shopping Malls, Supermarkets	10
The Rest	10
Existing Number of Parking Spaces	130
Total	**460-130=330 ПМ**

2.4 The Parking Generation Method

This method originates from USA and was developed by the Institute of Transportation Engineers Washington experts. It is used quite often and is quite simple. It is based on collecting data on existing objects and their statistical analysis

After analysis, the mathematical formula has been obtained (4) and it displays the codependence of the number of accommodation units and the number of parking spaces.
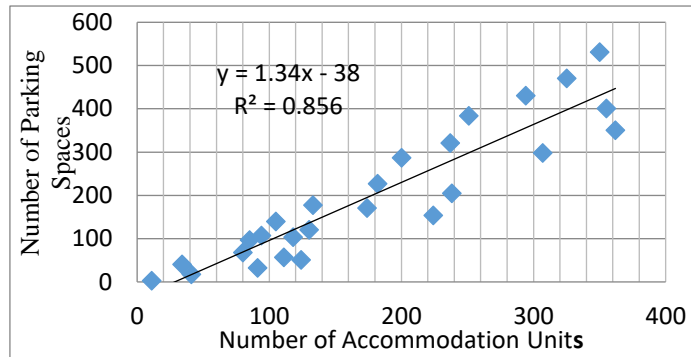

Figure 2 Analysis using Parking Generation Method

Depending on different city areas and structures being observed, the formula uses different forms. By using the given formula testing of the results obtained through normative method will be carried out. In the above-mentioned part of the city there are approximately 350 residential units.

$$P = 1.34 \cdot x - 38$$
$$P = 1.34 \cdot 350 - 38 \approx 430 \ PP$$

(4)

When the number of necessary spaces for the non-residential part is added to this number, while the existing parking spaces are taken out, the difference compared to the previous method reaches around 9%. Determination quotient results in $R^2 = 0.856$, while the linear correlation quotient results in $R=0.92$, and is therefore safe to conclude that a high level of correlation has been achieved, which attests to this method's reliability.

2.5 Result Analysis

Based on the previous analyses, separating the city into three city zones has been suggested. The central zone I is the inner center of the city and most activities take place in this area, while zones II and III belong to the outer city center. The construction of two multi-storey car parks is suggested, with capacity for around 600 PP in zone I and one car park with the capacity of 300 PP in zones II and III.

All methods described in the second chapter only provide the orientation number of the necessary parking spaces, so the results should be observed in the same light. After the analysis has been conducted, the obtained data should be checked in the field. If field data is gathered correctly, a whole set of very useful data can be obtained.

The following diagram shows the parking space demands for all city zones during the week. The diagram shows the gradual increase of demand during the beginning of the week, while the second half of the week shows a decrease in parking space demand except for Zone II, where weekend activities cause the demand to rise. The demand reaches its minimum at the very end of the week.

Figure 3 City zones suggested for constructing multi-storey car parks

Comparing the data collected during the field portion of the research to the data gathered using the analytic methods shown in the second chapter, it is readily apparent that a satisfactory level of accuracy has been achieved. Deviations equal 10 to 15% at their maximum, while the middle value of all the deviations stands at about 5%.
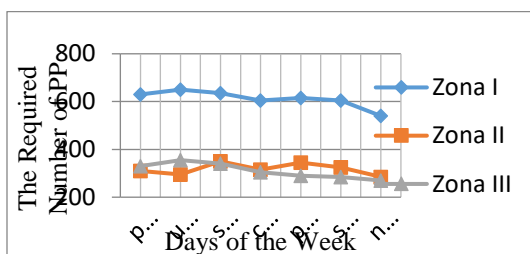

Figure 4 Parking space demands during the week

The demand for parking space was also monitored during various times of the year. A decrease in daily demand of about 30 to 40% was marked during the summer months, while the weekends during the same period marked a decrease in demand of up to 50%. On the other hand, during some of the more popular events in the city, the demand for parking space increased by up to 70%, though this increase was temporary in nature.

3. DESIGNING MULTI-STOREY GARAGES

Constructing a multi-storey garage has a lot in common with construting any multi-storey building, but there is a set of specifications that need to be taken into account during the earliest stages of planning. Fulfilling user demands depends largely on the quality of the project itself. In practice, designers don't always take these demands into account, which can lead to insurmountable problems later on.

3.1 The Dimensions of a Parking Space

The dimensions of a parking space depend on the dimensions and the turning radius of the vehicles. Major differences in the dimensions of various vehicles are the reason why the

parking space must be constructed so that it can accept a fictitious example of a vehicle which represents at least 85% of vehicles projected to use the same parking space. Add to this the dimensions of the protective space at the front and at the sides and the dimensions of the parking space equal 5.0x2.5m.

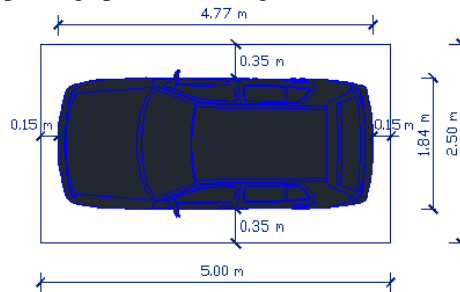The dimensions of the parking space, according to the JUS standard, equal 4.8x2.3m.

Figure 6 Standard vehicle dimensons, protection space and parking space dimensions

Table 3   Comparative analysis of parking space dimensions

Suggestions	Length	Width	Area
JUS	4.8	2.3	11.04
European	5.0	2.5	12.5
Increase	4%	9%	13%

The parking spots along the edges (next to a wall or a column) should be enlarged by 0.2-0.3m.

The width of the driveway connecting to the parking space at the angle of 90º (best in multi-storey garages) must equal 6.0m for one-way traffic, and 7.0m for two-way traffic. The JUS standard suggests a width of 5.4m, which is about 11% smaller.

Up to 25 parking spaces should be reserved for persons with reduced movement, each of them 3.5 m wide.

3.2 Ramps

Ramps are parts of the garage which are used to scale the height differences between storeys while enabling vertical communication. They can be one-way or two-way and, depending on their position, internal or external. The incline of the internal ramps should not go above 15% (20% for very short ramps), while the incline on the external ramps should be 10% at a maximum. If the incline is greater than 8% the ramp should have a transitional zone with a slighter incline, in order to avoid vehicle damage.
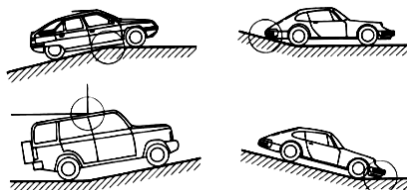
Figure 7 Potential damage due to the lack of transitional zones

3.3 Pedestrian Traffic in Parking Buildings

There are no special zones for pedestrians. Instead, they use the usual traffic space. Special attention must be paid to the location of stairwells and elevators. Keeping with the existing safety regulations, the distance between stairwells should not be greater than 50m for open garages, while enclosed and underground garages should keep the distance between stairwells under 20m. Stairwells are, of course, constructed strictly out of fire-proof materials. If only stairwells are used for pedestrian vertical communication, the minimum width of the stairs should be 1.2m. The width of the stairs depends on the number of levels of the garage itself and on the number of people who would potentially be evacuated out of the garage in case of fire. The suggested widths are provided in the following tablet.

Table 4 The number of persons that a stairwell can receive

The number of storeys	The number of people a stairwell can receive		
	1.2m	1.5m	1.8m
1	240	300	360
2	285	360	435
3	330	420	510
4	375	480	585

If ramps are used for vertical communication between pedestrians, the width of pedestrian pathway must not measure less than 0.6m and they should be separated and secured by railing. With structures higher than three storeys it is advisable to include elevators (at least two).

3.4 Parking Garage Location

The location choice of the garage itself is the most important parameter which directly influences the capacity, and therefore the cost effectiveness of the garage. A lot of demands need to be meet while determining the location, for instance:

- The garage should be in less than five minute walking distance (400-500m) from the center of all activities
- Fulfilling the users' needs within the high activity zones
- Ensuring safe access (from the side most frequented by the largest number of vehicles)
- If possible, the garage should be located within the less frequented road which is in direct vicinity of the main one
- Adequate orientation of the entrance and the exit
- Public transport station

Based on the above mentioned details, it is safe to conclude that determining garage location represents a complex issue whose solving requires a detailed and serious approach. This is why, in practice, various expert studies are used besides numerous mathematical and statistical methods and multiple criteria determining methods. This study analyses the locations within all suggested city zones, but the results will not be displayed here to avoid favoritism if building of these garages should occur in the foreseeable future at some of the potential locations.

It should be mentioned that the location in Kolašinska Street in the near vicinity of the Three Apartment Buildings block is not suitable for this purpose, even though the building of a garage has been planned for this site.

3.5 Parking Garage Loads

This section displays those structure loads that are typical of multy-storey garages.

- The weight of the installations – additional permanent load measures the intensity of 1.0-1.5 kN/m^2 in case of open garages, the closed ones and underground garages recommend 2.0-2.5 kN/m^2
- Traffic – variable load, for traffic and parking surfaces 2.5 kN/m^2, while the recommended value of ramps amounts to 5.0 kN/m^2
- Vehicle collision with a wall or a pillar – accidental load, with the intensity of 25-40 kN, and it usually happens at 0.75m height, which can be increased to 1.0m for safety precautions.
- The forces created by acceleration and breaking, horizontal load, are most often neglected due to lower speeds since more relevant horizontal action are
  - seismic, or rarely, due to the wind.
- Temperature influence – it is advisable to adopt adequate object dimensions which will in turn eliminate these effects

The comparison between real and assumed traffic load on a parking space is also being made:

- parking space surface 5.0x2.5 = 12.5 m^2
- fictitious (assumed) weight of a vehicle 12.5x2.5 = 31.25 kN
- real net weight of the vehicle 13-20 kN
- weights of the passenger and possible luggage should also be added to the weight of the vehicle 3- 4 kN
- real gross weight of the vehicle 16-24 kN
→ the difference between real and assumed loads varies within a wide range of 30-95% (with an average deviation of around 50%)

Based on the previously mentioned facts, it can be concluded that certain dynamic influences are included in the load, and though small, they nevertheless exist. It is the only logical conclusion since the huge difference between real and assumed loads cannot be assigned to safety measures or estimated load value.

4. CONCLUSION

After the detailed analysis has been conducted, it can be said that planning and building of parking garages represents a complex technological and financial endeavor, which includes the use of considerable resources.

Multy-storey garages represent one of the most efficient solutions to the parking issues in cities since they can accommodate a large number of vehicles on a relatively small surface. Functionality and cost-effectiveness of a garage can reach a satisfactory level only if they are properly designed. In practice, a lot of requests are being neglected by the designers or outdated guidelines are being used, which creates a lot of problems during garage utilization which are later impossible to solve.

Even though a garage construction is similar to other buildings, it still possesses certain characteristics which need to be taken into account, and that is why additional safety precautions are required during the planning process.

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SPECIFIČNI ZAHTEVI PRI PROJEKTOVANJU SPRATNIH GARAŽA

Rezime: U radu su prikazani najvažniji zahtevi koji su neophodni za pravilno analiziranje problema parkiranja u gradovima, kao i za pravilno projektovanje spratnih garaža.Uz korišćenje različitih metoda analiziran je problem parkiranja u Kosovskoj Mitrovici, izvršena je podela grada na gradske zone i date su preporuke za izgradnju spratnih garaža u određenim zonama. Takođe, analizirani su svi bitni zahtevi neophodni za pravilno projektovanje spratnih garaža.

Ključne reči: spratne garaže, projektovanje, specifični zahtevi, parking mesta