CETRA2022 11-13 May 2022, Pula, Croatia
7th International Conferenceon Road and Rail Infrastructure

COMPARATIVE COST AND BENEFIT ANALYSIS OF PARKING SYSTEMS REGARDING THE TYPE OF PARKING OFFER

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Abstract

In developed countries, sustainable forms of transport are increasingly evolving and encouraged. Despite this, and due to the growing trend of urbanization and urban development, there are higher demands for mobility in a smaller spatial coverage. That is why a large number of personal vehicles in urban centres are still present. As a result, there is an increase in external costs in transport such as traffic congestion, climate change and air pollution caused by gas and noise emission. To change such negative trends in the transport system in favour of sustainability, it is necessary to optimally manage the transport system, especially the supply and demand for mobility. Today, optimal management of the parking system in urban areas is one of the most important measures in the process of achieving sustainable transport organization for the purpose of reducing the negative impacts of mobility on humans and the environment. Accordingly, when assessing the quality of the parking system, it is no longer enough to analyse classic financial indicators such as the average time spent in the parking lot, the coefficient of vehicle change per parking space, the number of generated parking hours etc., but it is also necessary to analyse the social loss caused by missed opportunities for more adequate use of urban space in order to increase the quality of human life. Therefore, the purpose of this paper is to evaluate the economic costs and benefits of the parking system considering the type of parking offer. In addition to the classic indicators, the external costs that the parking system has on society through inadequate use of public urban space will be considered. After evaluating all costs and benefits there will be a comparative study showing the results of cost-benefit analysis of individual parking system regarding the type of parking offer, for the purpose of improving the process of optimizing the urban parking system. In this way, another important variable is introduced into the management and planning processes of the parking system, which refers to the optimal use of public space in urban areas.

Keywords: CBA, urban areas, traffic congestion, parking system

1 Introduction

Due to the development of cities and urban areas, there is an increase in the motorisation rate, more precisely the number of motor vehicles in city centres, which leads to various negative phenomena. One of the main causes of the increase in the number of personal vehicles in cities is inadequate planning and management of parking capacities. Effective management of the parking system can contribute to reducing traffic congestion and emissions, and can also encourage the use of sustainable forms of transport [1-3].
One personal vehicle spends 90 % time inactive, so parking is a big problem in terms of rational use of urban space and it is necessary to choose the optimal parking solution that

will meet the demand for parking spaces by users and at the same time will not affect the increase in the number of vehicles in city centres.
The parking system is interactively linked to the area purpose, the economy, and the environment, so often the goals of the overall transport policy are achieved through its management. Parking provides an essential link between vehicle transport demand and urban land use, so it is necessary to establish an optimal parking system to achieve the overall goals of the policy of an urban environment [4-6].
In accordance with the above, and when designing a new parking system or reconstructing the existing one, it is necessary to plan and encourage the economic development of the urban environment. Very often, financial profitability falls into the background compared to economic profitability when building a parking system in urban centres. City policy and development measures are highly dependent on the quality of life and satisfaction of the population. Therefore, economic profits can be much more profitable than financial ones.
This paper contains an analysis of the costs and benefits of a parking system considering the type of parking offer. Equally so, with the analysis of the types of parking offers based on all relevant elements, the most economically profitable solution of the parking offers has been determined, which will at the same time satisfy the demand and have a minimal harmful impact on society.

2 Analysis of parking systems in urban areas

In this paper, street and off-street parking systems, underground and above ground garages are analysed in detail. This division refers to the position and manner of construction of the parking system that is currently most used in world cities. That is why these parking systems were analysed to determine the cost-effectiveness of each system, and to determine the financial and economic viability of the system.
For the purposes of calculating the cost-effectiveness of an individual solution, it is important to consider the investment costs. The total investment costs include the costs of land acquisition, construction costs and the costs of maintaining the parking lots on an annual basis [5].
The land price is not constantly determined and depends on the current state of the market. Likewise, the land price depends on its location in relation to the city centre and the environment in which it is located, for example, the price of a square meter on the outskirts of Zagreb is around 350 HRK, in the city centre is about 1.040 HRK, while in the in the central business zone is about 1.500 HRK. In Croatia, 1 EUR = 7.5 HRK.
When building underground garages, it is necessary to provide a floor space for access to the garage. When building an underground garage, a large number of parking spaces are usually built. If the floor space used to access the garage is displayed per parking space it will be a very small area. That is why the price of land per place for an underground garage is shown as zero. Construction costs include all elements and resources that were spent in the construction phase of the parking lot (parking space planning, all necessary permits and construction costs). The construction of garages, compared to street parking spaces, requires a lot more resources, which increases the cost of investment [5].
The costs of parking area maintenance include all repairs that need to be made in case of defects in the parking areas, maintenance and cleaning of parking lots, everything related to parking lighting, parking insurance, administration, and control of accessibility of parking spaces. It's important to note that the annual maintenance cost is the cost generated each year throughout the life of the system [5]. Table 1 shows the costs for the construction and maintenance of a single parking space depending on the parking system. Values for the price of land will be given on the example of the current state of the land value in the central part of the City of Zagreb.

Table 1 Display of costs for the construction of one parking space

Type of parking	**Price of land per place** [HRK]	**Construction costs** [HRK]	**Annual maintenance costs** [HRK]	**Total costs** [HRK]
Street	26.000	10.000	800	36.800
Off-Street	26.000	10.000	800	36.800
Above ground garage	8.600	108.000	5.400	122.000
Underground garage	0	150.000	7.500	157.500
Note: 1 EUR = 7.5 HRK				

As can be seen in the table 1, street and off-street parking spaces are the most affordable due to lower construction and maintenance costs. Parking areas that are built in several levels, greatly reduce the price of land per parking space due to the greater number of spaces in the same or smaller area than the street or off-street parking lots.

3 Financial benefits of parking systems

The financial benefits of the parking systems relate to the direct costs of using the parking space. Effective parking pricing can lead to many benefits, such as better modal traffic distribution, reduced congestion in urban areas, and increased revenue. The price of parking is best determined as part of an integrated parking management program. The main goals in determining the tariff policy of parking lots are to increase revenues from the parking fees and efficient management of the traffic system [5].
The main input variables related to financial benefit, used in the calculation of financial profitability are the cost of parking and occupancy of the parking system. In accordance with the above, the set price of an hour of parking is 6 HRK, while the provided information used on the occupancy of the parking system is variable and 10 % to 100 % of occupancy data is being used.

4 Economic benefits of the parking system

The analysed economic characteristics of parking systems relate to the purpose of the area in urban environments. With the expansion of the parking offer, there is a need to use urban areas that can be converted into other purposes such as the construction of housing, business premises and green areas, while street parking along the road infrastructure can be used for: construction of a larger number of traffic or bus lanes, construction of bicycle paths, construction of pedestrian zones and widening of sidewalks.
When designing a new parking system or reconstructing an old one, it is necessary to consider the following measures that have a direct impact on the economic development of the city: reducing in-circle rides, emptying up space and increasing sustainable forms of travel. These actions directly affect the economic development of the environment, and they can increase the economic profitability of a parking system.
To compare financial and economic characteristics, they first must be determined and valorised. In accordance with the above, Table 2 shows the values for individual economic measures in favour of cycling and walking in relation to the use of a personal vehicle. All values refer to one passenger-kilometre. The elements shown in the table were used to calculate economic profitability.

Table 2 Values of economic measures for cycling and walking [7]

Economic measures	HRK/km	Economic measures	HRK/km
Climate	0, 67	Tourism	2, 43
Environment	0, 04	Smart City	1, 1
Ground	0, 14	Shopping	6, 13
Energy	0, 15	Utilization of space	1, 1
Direct health profit	10, 26	Social issues	2, 76
Safety	0, 22	Mobility	0, 36
Health economic profit	0, 25	Infrastructure	1, 26
The bicycle industry	0, 33	Culture of non-motorized transport	0, 55
Sales of parts and equipment	0, 54		

5 Comparative analysis of financial and economic characteristics

The comparative analysis shows the financial profit in relation to the economic one. The methodology for calculating the profitability of a particular parking system shows the ratio of invested and received. In the case of financial profitability, the initial cost represents the cost of investment and the annual cost of maintenance. The investment costs include elements and resources that were spent in the construction phase of the parking lot. If the construction project is more demanding, the cost of investment is more expensive, so due to unexpected problems, this cost can increase significantly. The observed period for street and off-street parking systems is 25 years, and the observed period for above ground and underground garages is 30 years. The observed period also includes the time required for the construction of the system, so it takes 3 months to build a street parking place, and 6 months for off-street parking, while the above ground and underground garage takes two years. Parking area maintenance costs include all actions required to ensure the smooth operation of the parking area such as parking cleaning, all related to parking lighting, parking insurance, administration, and accessibility control of parking spaces.

Cost-benefit analysis (CBA) was used to calculate financial and economic profitability and shown through the financial internal rate of return and the benefit-cost ratio and the year of return. According to EU recommendations, a financial discount rate of 4 % and an economic discount rate of 5 % were used. All prices shown in the paper represent net prices without VAT. An internal rate of return (IRR) is calculated which represents the return earned on a given project. It is the discount rate at which the difference between the net present value of cash inflows and outflows is zero. The internal rate of return assumes that cash inflows are reinvested at the internal rate. This method includes experimental calculations to verify the errors committed. When the ratio of invested and obtained (B/C) is one, the investment is justified and followed by profit.

Table 3 shows the financial profitability of each solution to increase the number of parking spaces depending on the financial occupancy of the system for the price of an hour of parking of 6 HRK. Financial occupancy is the percentage of occupancy of the parking system in relation to the maximum occupancy (financial capacity) during 365 days a year, 24 hours a day. As can be seen from the table, the most financially profitable system is the street parking system, while the least profitable is the underground garage system.

In the case of street and off-street parking systems, it is cost-effective at an early stage of the observed period, even with minimal occupancy. Such a result is justified by the low cost of investment and low maintenance costs. The results of the street and off-street parking system are very similar due to the equal cost of investment and maintenance per parking space.

The only difference is, already mentioned, the construction time, which is estimated at three months for the street parking system and half a year for the off-street parking system.

Table 3 Financial profitability of the parking system

	OCCUPANCY								
	10 %	**20 %**	**30 %**	**40 %**	**50 %**	**60 %**	**80 %**	**100 %**	
Street	61 %	199 %	799 %	-	-	-	-	-	FRR
	4, 2	8, 5	12, 7	17, 0	21, 2	25, 5	34, 0	42, 4	B/C
	3	2	2	1	1	1	1	1	Year of return
Off-Street	56 %	147 %	314 %	744 %	4285 %	-	-	-	FRR
	4, 2	8, 4	12, 6	16, 8	21, 0	25, 2	33, 6	42, 0	B/C
	4	2	2	2	2	1	1	1	Year of return
Above ground garage	-8 %	4 %	11 %	16 %	21 %	25 %	34 %	42 %	FRR
	0, 5	1, 1	1, 6	2, 1	2, 6	3, 2	4, 2	5, 3	B/C
		29	13	9	7	6	5	4	Year of return
Underground garage	-	-1 %	6 %	10 %	14 %	17 %	24 %	30 %	FRR
	0, 4	0, 8	1, 1	1, 5	1, 9	2, 3	3, 0	3, 8	B/C
			24	14	11	9	7	6	Year of return

The investment costs of the above ground and underground garage systems are significantly higher than the street and off-street parking systems due to the complexity of construction work. Therefore, the later financial profitability of the project occurs.

The methodology for calculating the economic profit of a particular parking system shows the ratio of invested and received. The same input data for investment costs and annual maintenance costs are used in the calculation. The discount rate in economic analysis is 5 % per year.

The economic benefit of a particular parking system relates to the utilization of urban area, so the profit refers to the bicycle path and walkway whose length is reduced to the surface of one parking space for easier comparison with financial benefit. The length of the bicycle path that can be made instead of one parking space is 5 meters in one direction, or 10 meters of two-way bicycle path. The same values apply to the walkway. The data shown in Table 4 is obtained by assuming that one hundred cyclists and one hundred pedestrians pass the observed bicycle path and walkway daily.

As can be seen in Table 4, off-street parking is the most economically profitable, which is to be expected due to the low investment and maintenance costs, and at the same time not occupying areas for the development of non-motorized traffic.

Graph 1 shows the economic profit of an individual parking system at the end of the observed period. The most economically profitable parking system is the off-street system, followed by an above ground garage, then an underground garage, while the street parking system is the economically worst option at the end of the observed period.

Table 4 Financial profitability of the parking system

Street	33 %	ERR
	2, 3	B/C
	5	Year of return
Off-Street	127 %	ERR
	5, 6	B/C
	2	Year of return
Above ground garage	10 %	ERR
	1, 4	B/C
	15	Year of return
Underground garage	8 %	ERR
	1, 3	B/C
	19	Year of return

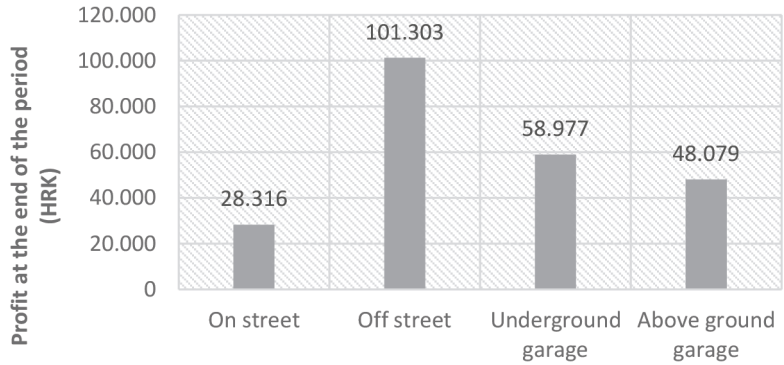

Figure 1 Economic profitability of the parking space at the end of the observed period

6 Conclusion

With the increased motorisation rate there is a higher demand for parking spaces in city centres. Despite the trend of discouraging vehicles from entering the city centre, there are a number of people who still need to come by car. In such cases, it is necessary to provide a sufficient number of parking capacities on off-street areas to make the best use of the street area.

When designing a parking lot, it is necessary to consider as many elements as possible and based on that choose the most acceptable variant. Some of the main elements is the financial and economic characteristics of the solution for increasing the number of parking spaces, which are analysed in detail in this paper, with their comparative analysis.

The research results in this paper show the difference between the financial and economic profitability of a parking system. The paper analyses street and off-street parking systems, underground garages, and above ground garages. The financial profitability of a system depends on the occupancy of the parking lots and the cost of parking per hour. The street parking system is the most cost-effective system, followed by the off-street parking system. The underground garage is the most financially unprofitable and largely depends on the occupancy of the system.

The results of economic profitability differ from the financial one, so the off-street parking system is the most economically profitable. Off-street parking system is often an impossible solution in city centres due to lack of free space. In some countries, off-street systems are successfully used as Park & Ride systems by being installed at public transport terminals outside the city or on the outskirts of the city. This reduces the number of vehicles in city centres. The next economically profitable system is an above ground garage followed by an underground garage. The most economically unacceptable solution is the street parking system due to the great impact on the traffic system and the irrational use of areas in the city centre that can be used for economically better solutions.
The street parking system will pay off economically before the above ground and underground garages, but at the end of the observed period the garage systems generate higher revenues than the street parking system. The year of return for the street parking system is after 5 years, for off-street 2 years, in the case of an above ground garage after 15 years, and in the case of an underground garage after 19 years.
Financial characteristics show the ratio of invested and received financial resources. Based on them, accurate data on the financial justification of a system are known. Economic characteristics, unlike financial ones, are elements that are crucial for the proper development of cities. Every city should take care of the rational use of space, which ultimately leads to a better life. Because of this, in the city areas, it is necessary to rely on the economic profitability of the solution to increase the number of parking spaces, even though in some cases it is the most financially expensive option.

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