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Research paper

Flexible design of Park-and-Ride facility in the city center proximity

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Abstract: The problem of the proper functioning of Park-and-Ride facilities seems to be of key importance for ensuring appropriate transport in cities in which the intensity of road traffic is systematically increasing, together with the increase of environmental pollution (air pollution, noise etc.). The attractiveness of a car park of this kind seems obvious – instead of a burdensome journey in one's own car, one changes the vehicle to fast municipal public transport or another means of transport (a bike, a scooter), or reaches the destination on foot. This results in benefits – above all in terms of comfort (shortening the time of the journey), health advantages etc. As has been proven by experiments, facilities of this kind are an expensive investment, the location of which (e.g. stand-alone) does not always ensure full utilization. The concept presented in the article assumes the possibility of a gradual extension of the multistorey car park following the increase of the demand. The article attempted to demonstrate that one of the sources of increasing attractiveness is the appropriate location (guaranteeing easy commute to the car park), the possibilities to continue the journey in an attractive way, then increasing the attractiveness through the possibility to use various services (shopping, the gym, the swimming pool, cinema, restaurants) and thirdly: the plan of launching the car park and its utilization in the life cycle should ensure the possibility of flexible reacting to changes of the demand (the experiences of the ongoing pandemic indicate that there is no guarantee of ensuring systematic demand increase). An element which also seems significant is the limitation of costs in the initial stage of investments of this kind with the possibility of gradual extension following the change of user habits.

Keywords: flexibility, engineering design, Park-and-Ride, life cycle, *NPV*

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1. Introduction

The growing intensity of car traffic in cities is becoming an increasing problem which is not only social, but it is also related to health. For many years, possessing a car was a strong stereotypical symbol of social status and freedom. The possibility to live in a detached house generates the necessity to commute to work/school from peripheral areas (frequently the cost of land and of maintaining a house is much lower than that of living in the city center), resulting in intensified traffic in the morning and in the afternoon. One of the proposed solutions for limiting these problems may be based on using one's own car (or e.g. bike) to commute to a P&R facility and continuing the further journey using fast public transport. The idea of P&R facilities is quite known, however, its basic condition is the existence of fast and reliable public transport and the change of the habits of car drivers driving individually "door-to-door" to work/school and back every day. The traditional solution based on the systematic extension of the road network is out of the question due to limited resources, and it is inconsistent with the sustainable development policy adopted at a global level (UN Declaration) [1], European level (UE directive) [2] and the level of national [3,4] and local [5] policy.

As has been demonstrated by examples (Cracow in the 1990s), the construction of P&R facilities itself may not lead to solving the problem [6].

The aim of the article is demonstrating the advantage of a flexible approach in the designing of a P&R facility located at the downtown zone border, which – thanks to the option of gradual extension in the scope of a commercial center – guarantees the possibility to adapt to varying demand. The typical scenario of the increase of user interest may be threatened e.g. by changes of the scope of congestion (the deterioration of the conditions of commuting to the discussed car park by car) or limitations in the scope of using public transport in the conditions of an epidemiological threat. In a city in which the number of inhabitants is about 600 000, the traffic hindrances do not necessarily force to using a P&R facility – the demand is rather based on a change of habits of people who currently commute by cars – e.g. due to additional attractiveness associated with parking (e.g. shopping). The methodology/approach used in this paper is based on *NPV* estimation by simulation for different demand's scenarios taking into consideration flexible and non-flexible options. The scope of presented paper is limited to underline advantages of flexible approach for all scenarios in comparison with traditional (non-flexible) options, but not compare of different flexible options in details. The novelty of the presented approach consists in taking into account the possibility of providing high-quality services despite changes in the environment (changes in demand for park and ride services), which are difficult to predict in the time of pandemic, climate change and uncertainty in politics and economy.

After this introduction the work describes the assumptions of the transport policy associated with the construction of Park-and-Ride facilities and indicates the necessity to use a flexible approach in the designing of a car park due to difficulties in forecasting the demand (the elements which may have an impact are e.g. carsharing or autonomous cars, the dynamic development of which may completely change the situation). Disruptions of the functioning of the economy and changes of typical behavior patterns of travelling people as a result of the COVID-19 pandemic clearly indicate that the validity of typical tendencies (e.g. the systematic increase of the intensity of road traffic) is not at all guaranteed. Subsequently, the paper describes the

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basics of flexible design as an approach, the use of which is justified in conditions of uncertainty, when adjusting to the changing demand may result not only from the number of vehicles but, above all, from the change of habits of potential users. The paper mentions an example of a Park-and-Ride facility located inside a commercial center with using the option of a potential extension (the construction of another level) in case of an increase of the demand for car park services.

2. Park-and-Ride fundamentals

In accordance with the basic assumptions [6, 7], a Park-and-Ride facility is a place where one can park his/her car for an affordable fee and use public transport to reach the destination of his/her journey. It seems that it is also possible to use pro-health options (a municipal bike, an electric scooter or simply walking).

Building Park-and-Ride facilities alone does not have to mean the success of this initiative – Cracow is an example of that (in 1992 a system of 5 car parks of this kind was created – the last of them was shut down in 2003). In 2012, in turn, a system was launched with car parks located near tram loops and agglomeration railway stops [9].

According to Bullard and Christiansen [10], the first location of a P&R facility was Detroit (in the 1930s), however, the breakthrough took place in Europe in the 1970s when after the phase of the economic boom, which resulted in the dynamic increase of the number of passenger cars and the development of the infrastructure, it turned out that further infrastructure extension is not possible due to the narrow streets in city centers (e.g. Oxford) and the energetic crisis [11].

For the purpose of the efficient functioning of a system based on the change of the means of transport, it is necessary to achieve above all two goals [12]:

1. Increasing the attractiveness of the system of public transport (the relatively short transit time thanks to priority in road intersections and/or establishing bus-and-bike lanes, transport comfort, high frequency of shuttling, safety).
2. Reducing the attractiveness of driving one's own car (the reduction of the number of parking spaces in the city center, the introduction of high fees for parking in the city center, introducing fees for driving into the city center, limiting the possibility to drive into the city center – e.g. access only for electric vehicles or vehicles meeting the highest standards).

Moreover, the proposed concept assumes the increase of the attractiveness of the parking location through appropriate services (e.g. trade, sport, entertainment, car service etc.)

Due to the distance from the city center, as the basic journey destination, besides traditional long-distance P&R facilities (Remote and Suburban distance 80÷160 and 18÷80 km, respectively), the following types of P&R facilities may be distinguished [10]:

1. Local – car parks located relatively close to the city center (1.6 ÷ 16 km). They fill the gap between the city center and car parks located in the suburbs (suburban P&R). Changing a car to non-motorized transport options (a bike or going on foot) plays a significant role in this case.
2. Peripheral – car parks located before the city center boundary (up to 8 km from the city center). The main aim of these car parks is providing parking spaces for travelers before

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the downtown boundary. For commuters they are an attractive alternative for suburban car parks, especially when the time of commute via public transport is relatively long.

Similarly in case of the division of P&R facilities, besides Informal and Park-and-Pool, the ones that are significant from the point of view of the discussed concept are [13]:

1. Opportunistic – car parks used for the P&R function while the facility is used for fulfilling another function – e.g. a church, a theatre, a commercial center, which may decide on the utilization of the P&R facility.
2. Satellite – car parks located at the boundary of a center of activity (e.g. airports) in order to provide an affordable alternative for the car park at the center of activity.

In literature we can frequently find general guidelines referring to the planning, designing, location of P&R facilities [10–16] which include principles referring to the size of the car park, the distance between the P&R facility and the city center etc.. For example, Bolger et al. [14] suggest locating Park-and-Ride facilities at least 5 km from the city center, at the same time indicating general recommendations for planning Park-and-Ride facilities following Morrall [15] in a range of from 5 to 6 km. Spillar [16] suggests the minimum distance from the city center in a range of from 6.4 to 8.0 km and recommends 16 km. Defining the minimum distance of a P&R facility from the city center seems to be a provision which is quite impractical – the city can have an asymmetrical layout and completely different situations in the transport system at various directions of access to the city center from the suburbs.

Besides the principles mentioned above, it is worth to note attempts of applying various methods (fuzzy logic, AHP methods or logit models) for the purpose of defining the appropriate location of a P&R facility.

Lower at al. [17] suggested applying fuzzy logic in calculations based on two elements – the assessment of the attractiveness of the location (traffic intensity, the quality of the connecting road, the availability of a car park and the distance to the city center from the P&R facility) and the quality of the public transport.

Krasic and Lanovic [19] suggested applying the AHP multicriteria analysis method – the attention was focused on five criteria: the size of the area of gravity for a given location of the P&R facility, the multifunctional nature of the location (besides the typical commute to work/university it is also possible to consider other motivations: shopping, meals) which may guarantee the utilization of the car park also during weekends, the easiness of the implementation with taking into consideration the technical and economic factors, the quality of public transport and of the access to a given location of the P&R facility. It is valuable to notice two typical problems for the selection of the location of a P&R facility:

– an initially questioned location turned out to be opportune thanks to its multifunctional nature,
– locating a P&R facility in a zone of limited demand or of the implementation of only one function is difficult to consider appropriate.

Aros-Vera et al. [12] suggested a logit model which determines the probability of the selection of a given option from among a set of alternatives with taking into consideration the socio-economic characteristics of a user and the relative attractiveness of a given journey mode. The applied logit model defines the proportions of users who prefer a given P&R facility or travelling only by passenger car, assuming that all the persons travelling from one staring point (origin) to the point of destination demonstrate the same characteristics. These proportions are

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a function of the generalized cost which is based on time and on the cost of the journey as well as on the attractiveness and on the penalties in every journey mode. Pang and Khani [19], also applying the logit model, indicate the following preferences of users of P&R facilities:

a. Car parks with a higher frequency of public transport.
b. The time of the journey via public transport up to 10 minutes.
c. The lowest possible number of changes in the public transport.
d. Shorter time of reaching a location on foot.
e. Car parks near the underground.

These researchers also mention other methods of estimating the demand for P&R facilities (network models and passive models based on the analysis of GPS data) which may provide more accurate results referring to the selection of the P&R facility.

A significant problem is foreseeing the realistic demand and the rational size of the Park-and-Ride facility resulting from it. An element which deserves attention is the concept by Szaraty [20] assuming the possibility to estimate the number of potential users of a Park-and-Ride facility and its size. It is worth to underline the analysis of the attractiveness of the location of a Park-and-Ride facility which is included in that concept, based on the estimation of the generalized cost of the journey of a potential user. While assessing the possibilities of making a decision about using the Park-and-Ride option by potential users, it is worth to indicate the concept of Chen et al. [21] which assumes the possibility of increasing the share of this option by those travelling by rail thanks to a system of appropriate discounts.

As is mentioned by Rodrigue [22], even though transport systems and journey patterns change, the feature which remains constant is the tendency of the majority of people to travel in one direction for 30-40 minutes (Marchetti's constant). In an agglomeration which is not big enough to force a decision on the user, the element which remains is referring to the idea of leaving the car in the proximity of the "walking city" zone – Fig. 1.

Fig. 1. P&R located near the walking city – figure based on Newman and Kenworthy [36]

It seems logical to invert the traditional pyramid which indicates a car as the dominating means of urban transport – taking into consideration the possibility of active mobility (a walk, a bike, a scooter), using environmentally friendly means of transport and public transport – aiming at the development of the primary form of the city (walking city) [23]. The walking city is a type of city that is created to avoid internal transportation – one can use walking to

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navigate the city. It is near 15-minutes city idea where all essential functions can be fulfilled by residents in 15 minutes walking or biking from their dwellings [40].

In a city with the number of inhabitants of about 600 000 (XL according to the OECD classification [35]) forecasting the behavior of potential P+R users seems difficult to perform due to the lack of sufficiently developed fast municipal transport (underground, fast tram) and the lack of attractively located Park-and-Ride facilities.

3. Problem description

The problem in the presented case of an XL size city is the uncertainty during the determining of the demand for a Park-and-Ride facility, which is illustrated by the below causes of uncertainty and examples indicating errors in the forecasts referring to the transport infrastructure which result not only from the transport policy in a given area, but also from problems of a much greater reach which may change the situation in a way which is sudden, dynamic and difficult to foresee.

While analyzing the sources of uncertainty in prognostic models referring to undertakings in the scope of transport infrastructure besides typical uncertainty factors such as changes in the transport policy or uncertainty factors resulting from a simplification in the modelling process, Patrik et al. [25] came to the conclusion that there are also elements of a lack of statistical data allowing to forecast changes of socio-economic factors. And factors which seem impossible to foresee are ones associated with e.g. the course of cyclical changes of economic circumstances [26].

The typical factors generating uncertainty during the defining of the number of users include: local policy referring to fees for parking in the city center, the fuel prices resulting from the global market situation, the prices of public transport tickets in an agglomeration, creating new possibilities to utilize public transport (without the need to commute using a passenger car), a change of the habits of potential users due to the weather (short-term), a lack of necessity to commute (finding a job outside of the city, graduating from school, leaving for an internship, remote work), the gradual reduction of the number of people who study and work – demographic changes, new possibilities (carsharing, autonomous cars), which may completely change the typical developmental trends, shifting the congestion zone (e.g. as a result of modernization works) in a way which limits the accessibility to the P&R facility.

Moreover, it is necessary to take into consideration the factors which generate changes of a typical trend which may include (de Neufville and Scholtes [31]): economic crises (global, national), political changes (both, resulting from democratic procedures (elections) as well as from war activity – e.g. the increase of fuel prices), new technological solutions (high-speed elevated railway, autonomous cars), new conditions of functioning (changes of the policy referring to environmental protection – limited access to the city center, fees for driving through the city center)

An element which seems significant are the indicators mentioned by Dickins [32] and Krasica and Lanovica [18], who underline the low share of accurate forecasts of the demand for car park services in both, the USA as well as in Europe. On the basis of the quoted studies by Morrell, it was 36%.

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Cornejo et al. [27] indicate that an element which is a significant point of the procedure of estimating the demand for car park services is the adjustment to demand changes resulting from the weather, the day of the week, the season of the year etc. and the importance of an agreed business model between the agency managing the car park, the owners of real estates in the proximity of the car park as well as the transport operator.

Flyvbjerg [28] clearly points to serious problems resulting from inaccurate forecasts of the demand in transport, which is a risk factor in case of both, a too optimistic forecast (frequently referred to as 'White Elephant') which means problems resulting from the investment, the demand forecast of which was overestimated, as well as a too pessimistic forecast, when unexpectedly high demand requires a quick decision about an extension (for contrast: 'Black Ant'). As an example Flyvbjerg mentions the fourfold overestimation of the demand and the problems with the implementation of the Bangkok Skytrain project. The subsequent analysis of the situation of that project indicated systematic progress (Verougstraete and Enders [29]), however, the elements which contributed to the causes of the significant error of the forecast were also the high cost of the transit and the problems of a lack of synchronization with other investments, as well as difficulties in access to the station designed as a three-level facility (Zang [30]). The initially planned target demand in the case of the Bangkok Skytrain was only achieved after 15 years (in 2014) from the opening in 1999.

Summing up the numerous recommendations and basing on own observations, it is possible to list the basic factors which are the conditions for using a Park-and-Ride facility:

- The proper location of the car park (in a transport corridor),
- The benefits for the users of P&R – the car park ensures access to various services,
- Easy access to means of public transport of high quality,
- Difficulties in finding a parking space in the city center and high parking fees,
- The relatively short transit time to the P&R facility – location at the border of congestion,
- Integrating the P&R facility with the interchange station – the availability of various transport options, high frequency of shuttling and quality of transport services,

The foreseen variability of the demand for car park services speaks in favor of applying a flexible approach in the designing and utilization of the car park.

4. Flexible approach in engineering design

Applying flexibility in engineering design has traditions in many areas such as energetics (consecutive launching of energetic blocks) or technologies associated with the management of cosmic space (satellites equipped with options allowing for the subsequent utilization of innovative opportunities). A flexible approach in construction is not commonly applied, however, it is possible to find examples of its utilization:

- the construction of the 25 de Abril Bridge over the Tagus river in Lisbon (the construction of the first phase in the 1960s) and the extension (the construction of the second level for the needs of creating a regional railway line) – the 1990s [31],
- the construction of a multilevel car park with the possibility of extension (the Bluewater Commercial Center, about 25 miles from London),

– the construction of a fragment of a highway two-lane ring road of Poznan in the beginning of the 21st century with options for extension to three lanes in a subsequent term (implemented in 2019) and the ring road of Gorzow Wielkopolski from one lane to two lanes (after 15 years).

In the typical procedure of the application of flexibility in design, the point is limiting the investment in the beginning and, subsequently – following the increasing interest of customers – the extension based on the earlier prepared options. This is justified by the uncertainty and risk associated with forecasting changes of parameters of the model in a relatively long life cycle.

The idea of flexibility is treated as a right, but not an obligation to act (to activate the prepared options) when the situation has changed in order to eliminate the risk and take advantage of the opportunities [31]. A key condition for the application of flexibility is to operate in conditions of uncertainty – first of all, difficulties in predicting. This is of particular importance for the ability of the designed system to achieve the assumed effects despite changes in the environment (thanks to the installed flexible options). This means the necessity to systematically update the decision situation in accordance with the concept of agility understood as the ability to quickly reconfigure the system [41], which is based on the flexibility built into the system. The agile approach is a breakthrough in the field of management based primarily on the acceptance of changes (often related to the necessity to operate in a dynamically changing environment). The beginning of these changes is the idea of Project Management 2.0 [42] and the subsequent implementation of the agile approach under the PRINCE2 (2015) and PMBoK (2017) standards.

Calculations aiming at demonstrating the justification for the application of the considered flexibility option may be carried out using various methods [33, 34], e.g.: Net Present Value (*NPV*), Real Options Analysis (ROA) [43], Binominal Lattice (BL) and other ones. In the proposed approach, the *NPV* calculation was applied based on the below formula 4.1:

$$NPV = \left[\frac{CF_1}{(1+r_1)} + \frac{CF_2}{(1+r_2)^2} + \ldots + \frac{CF_n}{(1+r_n)^n}\right] - I_0 \tag{4.1}$$

where: NPV – net present value, CF – cash flow, r – discount rate, I_0 – initial outlays.

The proper analysis of the possibility to apply flexibility (Fig. 2) must, above all, be based on the collection of information about the analyzed facility (the type of the construction, the number of parking spaces at particular levels, the possibility for extension, data referring to revenue and costs etc.). The subsequent stage is the creation of a static model which enables the assessment of the model in the view without taking into consideration the dynamic changes of the demand. *NPV* calculation models are consecutively created for various options: without flexibility (according to the traditional approach – implementation in one stage) and with flexibility (including multistages). For example, in the scope of the option without flexibility it is possible to take into consideration the option of the construction of only one level and of a higher number of levels (e.g. two). In the case of the option with taking flexibility into consideration, it is possible to assume one level in the first stage and the gradual inclusion of subsequent levels (trough extension or the inclusion of existing levels) to the Park-and-Ride facility. Next, it is necessary to generate subsequent scenarios – the most probable one – REAL – and at least two supplementary scenarios – an optimistic one (OPTI) and a pessimistic one (PESS). The next step is the simulation experiment conducted for particular scenarios which is based on generating demand with some deviation from the adopted base curves of particular scenarios (e.g. 30÷50%). The results of these simulation experiments (performed e.g. in EXCEL sheets) may be juxtaposed in histograms, Discounted Cash Flow curves etc.

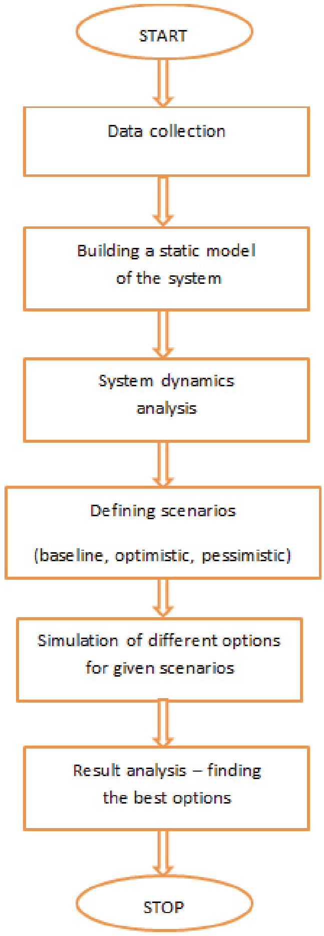

Fig. 2. Basic algorithm for flexibility implementation

In the traditional approach to *NPV* calculations (in accordance with the provided formula 4.1) there is no room for changes in the analyzed model. In the model which takes flexibility into consideration, a conditional statement (IF. . . THEN) has been introduced which allows for modifications of the system through the addition of a subsequent level with the assumption of exceeding the capacity of the utilized car park during the subsequent two years.

Naturally, a typical strategy in analyses is the adoption of the strategy of the gradual increase of the demand (e.g. for car park services), which results from typical conditions of development and traffic forecasts, however, it is necessary to take into consideration the fact that forecasts are incorrect [31]. A significant element of the analysis of the costs of the project life cycle is the preparation of scenarios of demand development and the analysis of the costs of utilization and maintenance in the period of 20 ÷ 30 years of use.

In the case study analyzed next, increasing the capacity of the car park can be done very simply – by switching one and the existing levels of the existing car park provided for the customers of the shopping center to the park and ride car park. In the case of greater needs, it is planned to build another level above the building supplies store. Due to the use of precast concrete elements, limited difficulties are assumed for the functioning of the existing shopping center (very short expansion time and location of the next level outside the existing facility).

Generally, it seems clear that the implementation of the expansion will create some difficulties, however, comparing them to the construction of a parking lot that is too large (which will turn out to be unprofitable) or too small (disappointed potential customers of the Park and Ride car park), logic indicates the advantage of a flexible approach. As evidenced by the already successful cases of the flexible approach (25 de Abril Bridge [31], Dental Clinique in Boston, and Poznan By-Pass A2), this must be designed taking into account the flexibility option that can be implemented after several decades. The traditional approach (one-stage construction) seems risky, especially in times of pandemic, climate change or political tensions.

5. Case study

The discussed example refers to a Park-and-Ride facility inside an exemplary commercial center in Poznan. The total number of parking spaces is 3300, out of which 376 on one level (level 3) may be devoted for a Park-and-Ride facility. The possibility to extend this car park by another level (376 parking spaces) has been foreseen.

In accordance with the principles discussed in point 2, the location of the discussed car park corresponds to a local car park – it is located relatively close to the city center – it allows for changing a passenger car to non-motorized transport options (a bike, an electric scooter or walking) and it constitutes an attractive alternative in reference to the car parks located far from the city center (when the transit via public transport is relatively long – a private car ensures faster transit). An element which encourages users is the possibility to do shopping after work or to use other services.

While considering the possibilities of using the discussed P&R facility, three scenarios were taken into consideration which define the demand in a perspective of 20 years, which is illustrated by the tables: Table 1 for the most probable scenario (REAL Scenario), Table 2 for the optimistic scenario (OPTI Scenario) and Table 1 for the pessimistic scenario (PESS Scenario).

Table 1. Projected scenario for demand – REAL Scenario

Year	1	2	3	4	5	6	7	8	9	10
Demand	228	291	348	400	448	491	530	566	598	628
Year	11	12	13	14	15	16	17	18	19	20
Demand	655	679	702	722	741	757	773	787	799	811

The predicted demand volume juxtaposed in Tables 2–3, was determined by analogy to similar situations using the formula 5.1:

$$d(t) = d_{\text{fin}} - a \exp(b \cdot t) \tag{5.1}$$

where: d_{fin} – the assumed target demand, a, b – coefficients selected experimentally.

Table 2. Projected scenario for demand – OPTI Scenario

Year	1	2	3	4	5	6	7	8	9	10
Demand	340	420	490	551	605	652	694	730	762	790
Year	11	12	13	14	15	16	17	18	19	20
Demand	815	836	855	872	886	899	910	920	928	936

Table 3. Projected scenario for demand – PESS Scenario

Year	1	2	3	4	5	6	7	8	9	10
Demand	139	208	269	323	371	413	451	484	513	539
Year	11	12	13	14	15	16	17	18	19	20
Demand	562	582	600	616	630	643	654	664	672	680

The presented scenarios form the basis of simulation calculations in Excel, with the assumption of deviations from the assumed scenario in the limits of 50%.

The results of simulation experiments (EXCEL package) in the form of histograms of *NPV* distribution for various scenarios have been presented in Figures: 3 (REAL Scenario), 4 (PESS Scenario) and 5 (OPTI Scenario).

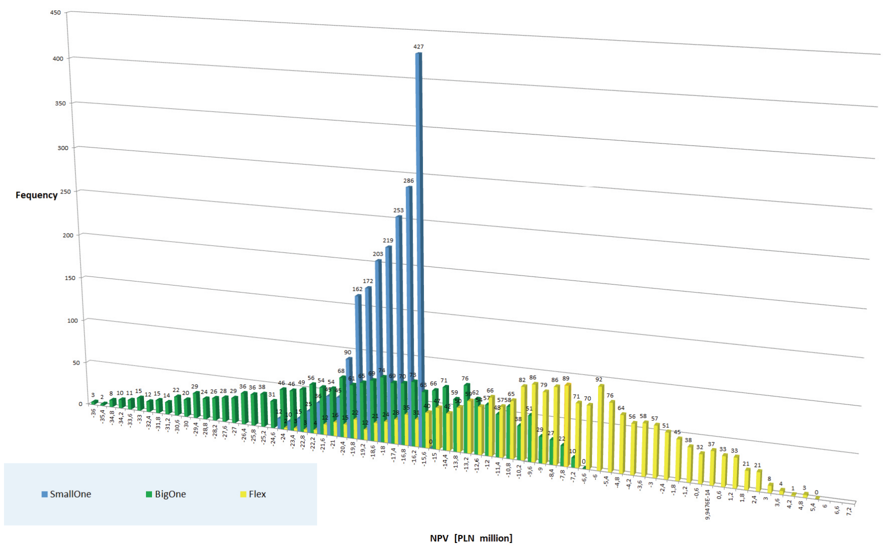

Fig. 3. Estimated *NPV* for most probable scenario – REAL

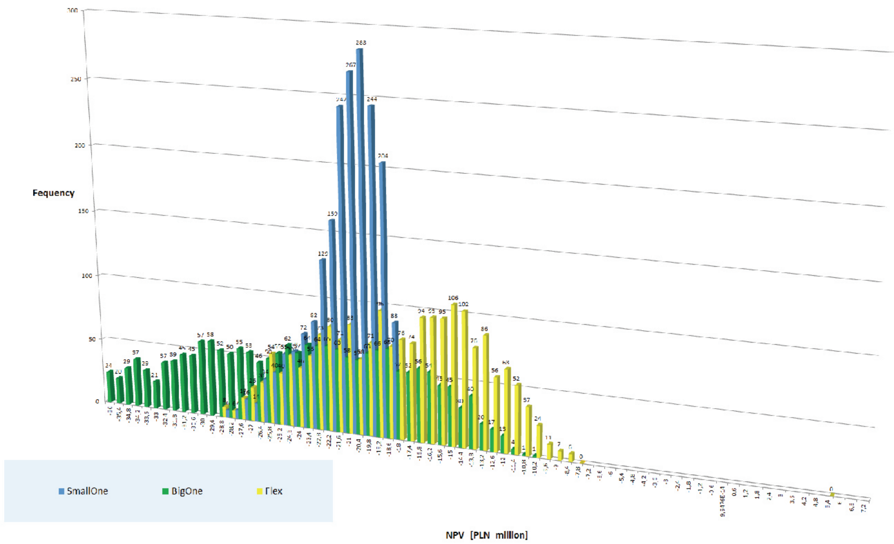

Fig. 4. Estimated *NPV* for pessimistic scenario – PESS

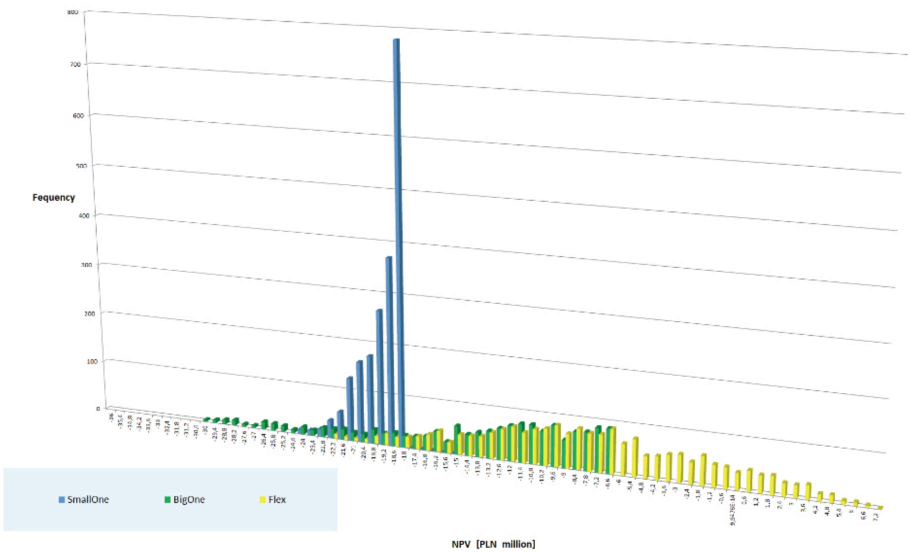

Fig. 5. Estimated *NPV* for optimistic scenario – OPTI

As may be concluded from the presented charts, in each of the analyzed cases the option based on the flexibility variant – marked as Flex (initially one level with the possibility to additionally construct another one in case the demand exceeds the capacity of the existing solution during the subsequent two years), demonstrates advantage over the remaining ones. For the REAL scenario and the Flex option, the *NPV* will change in the range of from –24 to +6 million PLN. The option without the possibility for the extension (only the first level without the possibility to include another one) – marked as SmallOne – demonstrates a relatively narrow range of *NPV* changes and it achieves values in the middle of the presented range (e.g. in the range of from –24 to –16 million PLN). The BigOne option, demonstrating the initial double number of parking spaces – 772 (both levels of the car park launched in the beginning without the possibility for changes) demonstrates a very wide range of *NPV* changes (from –36 to –6 million PLN).

The presented initial analysis – due to limitations of the possibility of presentation – indicates the advantage of the flexible approach in comparison to a one-stage investment policy – understood here as a typical solution (traditional).

The introduction of the flexible approach is justified in the conditions of uncertainty and risk [37], the presence of which gives value to the introduced flexibility strategies. Strategies of operation during the planning of undertakings may be based on robustness [38] (based on undertaking actions in order to limit the delay) and/or adaptability [39] aimed at the current adaptation to changes.

Naturally, the assumed systematic increase of the demand for the services of the Park-and-Ride facility does not have to be the only possible scenario. The changes we have been witnessing in the last year due to the COVID-19 pandemic make us aware that it is necessary to take into consideration the possibility of the occurrence of also more pessimistic scenarios (such as Black Swan). On the other hand, it is worth to note that the option with limited initial possibilities (SmallOne) constitutes a solution which is clearly concentrated on *NPV* of negative values, which does not qualify such an option for implementation – especially in case of the increasing interest in the discussed P&R facility.

6. Conclusions

The presented idea of applying a flexible approach during the planning of the launch of a Park-and-Ride facility in an XL size city according to the OECD classification, allows for drawing the following conclusions:

1. The benefits of using the Park-and-Ride facility seem evident in big agglomerations, where the burdensomeness of driving to the city center using one's own car is permanent, especially when the public transport is efficient and available without problems.
2. In case of XL size cities it is difficult to guarantee demand for Park-and-Ride services without ensuring attractiveness thanks to the offered additional possibilities, an example of which is a commercial center (shopping, services, entertainment etc.).
3. The generated uncertainty of using this kind of car parks in an XL size city may be limited by applying a flexible approach which provides the possibility to start functioning with relatively small initial demand and the gradual introduction of further parking spaces following the increasing demand.
4. In the discussed case, the possibility to flexibly react to increasing demand has got a significant advantage – the assumed change of habits („door to door" transit using one's own car) is based on convincing the potential user, and not on forcing a behavior through e.g. a several dozen kilometers long traffic jam. An element which may also be

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significant in the scope of habit change are health values (finishing the trip on foot or using a municipal bike).

5. The location of a P&R facility inside a commercial center seems justified by the benefits for both, the potential user (increasing the attractiveness of the P&R facility), but also for the owner of the commercial center – an opportunity to gain customers. An element which is of key importance is elaborating an appropriate business model between the agency managing the car park, the owners of the commercial center and the municipal transport manager.

As we can see, in case of XL size cities it is necessary to create additional attractions in order to obtain P&R facility customers. Of course, an element which is also important is the appropriate transport policy in the city – creating efficient public transport (which guarantees advantage over transit by one's own car) and limiting the attractiveness of driving to the city center using one's own car (high parking fees in the city center, a limited number of parking spaces, limiting the possibility of driving to the city center for cars with combustion engines).

It is also worth to underline that in case of a commercial center, the crisis referring to the limitation of interest in the constructed car park is not as poignant as in case of an investment dedicated only to car park services (the transformation into office space, exhibition space, etc.). The spread of new technologies (carsharing, electric scooters, remote work and education) may significantly limit the current problems generated by the transit to the city center using own cars. The idea of supporting the development of the pro-health walking city, in which in the reach of a short walk one will be able to find all the services necessary in life, and work/education will be carried out remotely, may significantly change today's reality of urban transport.

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Elastyczne podejście przy projekowaniu parkingu Park-and-Ride zlokalizowanego w pobliżu centrum miasta

Słowa kluczowe: elastyczność, projektowanie inżynierskie, parkuj i jedź, cykl życia, NPV

Streszczenie:

Problem poprawnego funkcjonowania parkingów Park and Ride wydaje się być kluczowy dla zapewnienia właściwego transportu w miastach, w których natężenie ruchu systematycznie rośnie i stosowanie do tego wzrostu rośnie zanieczyszczenie środowiska (zanieczyszczenie powietrza, hałas). Atrakcyjność tego typu parkingu wydaje się oczywista – zamiast uciążliwej podróży własnym samochodem, przesiadamy się na szybką komunikację miejską lub inny rodzaj transportu (rower, hulajnoga) albo docieramy na miejsce pieszo. Daje to nam korzyści – przede wszystkim w zakresie komfortu (skrócenie czasu podróży), zdrowotne itp. Jak udowodniły doświadczenia tego typu obiekty są drogą inwestycją, której lokalizacja (np. indywidualna) nie zawsze zapewnia pełne wykorzystanie. Przedstawiona w artykule koncepcja zakłada możliwość stopniowej rozbudowy parkingu wielopoziomowego w miarę wzrostu popytu. W artykule starano się wykazać, że jednym ze źródeł podniesienia atrakcyjności jest właściwa lokalizacja (gwarantująca łatwy dojazd na parking), możliwości atrakcyjnego kontynuowania podróży, następnie podniesienie atrakcyjności poprzez możliwości realizacji różnych usług (zakupy, siłownia czy pływalnia, kino, restauracje) i po trzecie: plan uruchomienia parkingu i jego eksploatacji w cyklu życia powinien zapewniać możliwość elastycznego reagowania na zmiany popytu (doświadczenia podczas przedłużającej się epidemii wskazują, że nie ma gwarancji zapewnienia systematycznego wzrostu popytu). Istotnym wydaje się także ograniczenie kosztów w początkowym etapie tego typu inwestycji z możliwością stopniowej rozbudowy w miarę zmiany nawyków użytkowników.

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