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Simulation analysis of the western 3rd ring road project in Krakow and its forecast impact upon the urban transport network performance

Abstract: The paper presents results from simulation analysis of the western 3rd ring road project in the city of Krakow (i.e. Trasa Lagiewnicka, Trasa Pychowicka and Trasa Zwierzyniecka), performed in the macroscopic model of transport system in the Krakow metropolitan area. Simulation works reveal shifts in traffic flows and changes in urban transport network performance which would likely take place after the stage-wise construction of consecutive 3rd ring road western sections. Results indicate that the analysed road schemes would indeed have a relevant impact upon travel conditions, though in initial stages these would be rather limited and confined to the southern part of the city. Therefore, completion of the whole western section of the 3rd ring road is crucial to its overall effectiveness and would only then bring substantial benefits on a city-wide scale. Simulation works seem to confirm that the future 3rd ring road would become an essential and highly-utilised link in the urban road network and would provide a much more efficient connection between the northern and southern parts of the Krakow city. However, apart from the projected benefits, it is also important to underline potential negative implications – and consequently, further changes in city transport system should envisage reduction of the road network capacity within the inner-city area. This would then provide the best possible chance of fostering the improvements achieved with the 3rd ring road scheme: i.e., positive changes in accessibility and travelling conditions across the whole city and long-term, sustainable traffic congestion relief in the inner-city Krakow area.

Keywords: Krakow 3rd ring road; Simulation analysis; Transportation model

Introduction

In recent years, increased investment activities aimed at expanding the road network and improving the quality of travel made by road transport can be observed in many Polish cities. In the discussion on the development of transport in cities, however, it is crucial to determine what investment projects are justified and which ones fit into the strategy of shaping the transport system in a sustainable manner. On the one hand, it is desirable to implement roads that will significantly improve the transport accessibility and capacity of the road system and road traffic from sensitive areas - on the other, avoid projects whose benefits (e.g. shortening

travel times) will be negligible and which may result in an undesirable increase in congestion and traffic nuisance.

Consistent with these postulates, it seems to be among others radial-peripheral model of development of the city road system, in which the main burden of road traffic is implemented by the system of radial (outlet) roads and peripheral roads on the city's periphery, while as the city's central area approaches the capacity of the road system for public transport is limited and so-called active forms of traveling (on foot, by bike, etc.). In this respect, it is important to use analytical tools that allow for forecasting the effects of considered road projects and constitute an important instrument in deciding on the directions of development of the city road network - e.g. simulation models for urban transport systems.

This article presents the results of analyzes carried out with the use of macrosimulation tools, the aim of which was to determine the potential effects of the implementation of the next stages of the so-called III ring road of Krakow. The subject of the analyzes are the western sections of the 3rd ring road, i.e. the Łagiewnicka Route, the Pychowicka Route, and the Zwierzyniecka Route - ie road projects that will have a significant impact on the functioning of the transport system throughout the city. Based on the work carried out, it will be possible to assess the potential effects resulting from the construction of the next sections of Krakow's 3rd ring road - including the possibility of obtaining the desired benefits in terms of improving the quality of travel in the city and reducing traffic in the area of the III ring road - as well as indicating directions for further development activities transport system of the city.

The 3rd Krakow ring road in the strategy of shaping the city road system

The development strategy of the Kraków transport system is consistently shaped on the basis of the target model of the road system, created by 4 ring roads supplemented with radial (outlet) roads [5]. Each of these ring roads will eventually fulfill a specific function depending on the location in the city, and according to the above-described paradigm - the importance for road traffic will decrease as it moves towards the central area of the city:

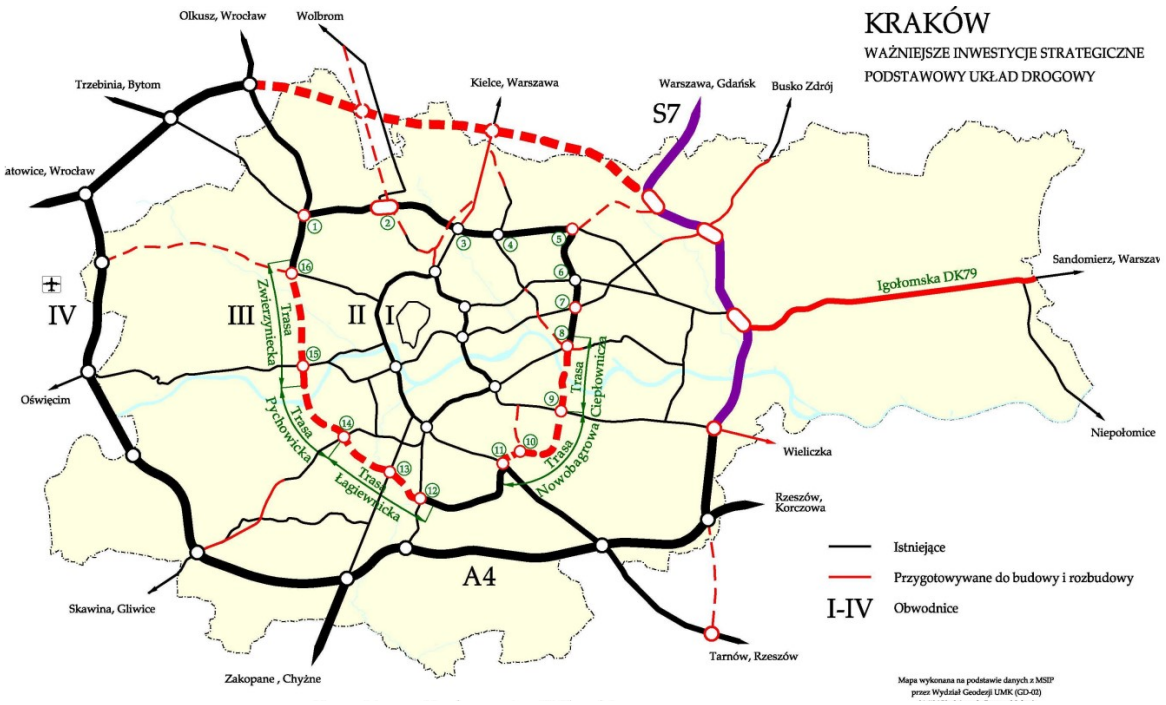
- I ring road - the innermost ring road, it is a sequence of local streets surrounding the strict area of the Old Town (ring road of Planty), with clearly limited access for individual traffic and privileged public transport and cycling,
- • II ring road- a sequence of collective and main streets constituting the boundary of the downtown area of Krakow (including the sequence of Aleja Trzech Wieszczów); the significance of the 2nd ring road is to diminish as the next sections of the 3rd ring road begin to be built and to be limited mainly to local traffic, and the preference for collective transport service should be increased,
- • III ring road - a series of streets of the main class of accelerated traffic, which ultimately is to constitute the basic communication axis in inter-district journeys in Krakow, as well as the connection between the external and internal transport system (including the route of the Zwierzyniecka, Pychowicka and Łagiewnicka routes),
- • IV ring road- the outer ring road of Kraków, the outermost one, created by a ring of expressways (A4 motorways and express roads S7 and S52) surrounding Kraków; this road is to have an important function primarily for the service of external and transit traffic and traffic of vehicles with limited access to the city center (e.g. truck transport).

According to the above assumptions, the 3rd Kraków ring road will constitute the basic communication framework for car traffic in the city. As construction and expansion of its subsequent sections, the 3rd ring road will take over the burden of road traffic between the largest districts of the city, enabling the implementation of many urban travels, bypassing the downtown area. In this way, it will be possible to relieve the road system inside the 3rd ring

road from inter-city and external journeys - including many journeys whose source and purpose are not related to the city center of Krakow, which in the absence of alternative connections must now lead through this area. This particularly applies to journeys made in the western part of Krakow, where the 2nd ring road (Aleje Trzech Wieszczów) is, in fact, the only road link between significant traffic generators in the north (Krowodrza, Łobzów, Bronowice) and in the south (Ruczaj, Dębniki, Kurdwanów). The next road crossing in the north-south axis, i.e. the 4th ring road (A4 motorway) is located only on the city border, which means no alternative route for a distance of about 9 kilometers. As a result, the corridor of Aleja Trzech Wieszczów is currently a road with a very high load of local and long-distance traffic, and its capacity is notoriously exhausted during periods of peak traffic. What's more, as a result of its location (dense inner-city buildings), it also results in significant nuisances related to the emission of noise and pollution.

The road investment, which is expected to improve the traffic conditions in the whole city, is postulated for years the implementation of the western part of the third ring road of Krakow - consisting of three sections [1] – Figure 1:

- Łagiewnicka Route - southern section about 3.7 km long, with the following route: Witosa - Zakopiańska - Grota-Roweckiego - (Pychowicka Route); The route will consist of 4 road tunnels with a total length of approx. 2.0 km, and the Witosa - Zakopiańska section will also include the construction of a parallel tram line,
- Pychowicka Route - a southwestern section, about 2.0 km long, with the following route: Grota-Roweckiego - Tyniecka - Księcia Józefa - (Zwierzyniecka Route); The route will include the construction of a new bridge on the Wisła (Pychowicki Bridge) with a length of about 0.5 km,
- Zwierzyniecka Route - western section about 4.2 km long, with the route in relation: Księcia Józefa – Armii Krajowej; this is the most difficult and the most expensive part of the 3rd ring road to be completed, the element of which will be the tunnel under Wzgórze Św. Bronisława with a length of about 2.5 km and depth at the lowest point reaching almost 100 meters.



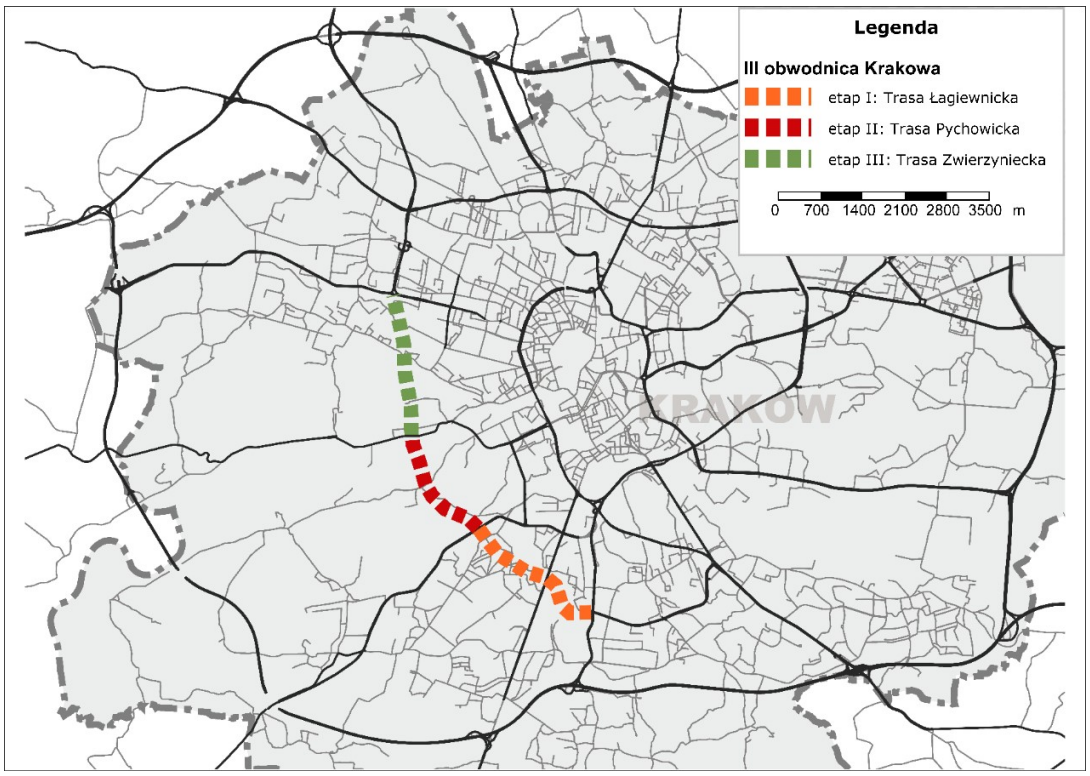
1. The target concept of shaping the Krakow road system - 4 ring roads supplemented with radial road connections (source: [1])

The above sections of the 3rd ring road will be implemented in a standard GP class road with increased technical parameters, aimed at ensuring high traffic flow: 2x3 section (between nodes) and 2x2 (within nodes), adaptation of the 3rd beltway to speeds of 70-80 km / h, limited availability and connection to the existing road system via two-level nodes.

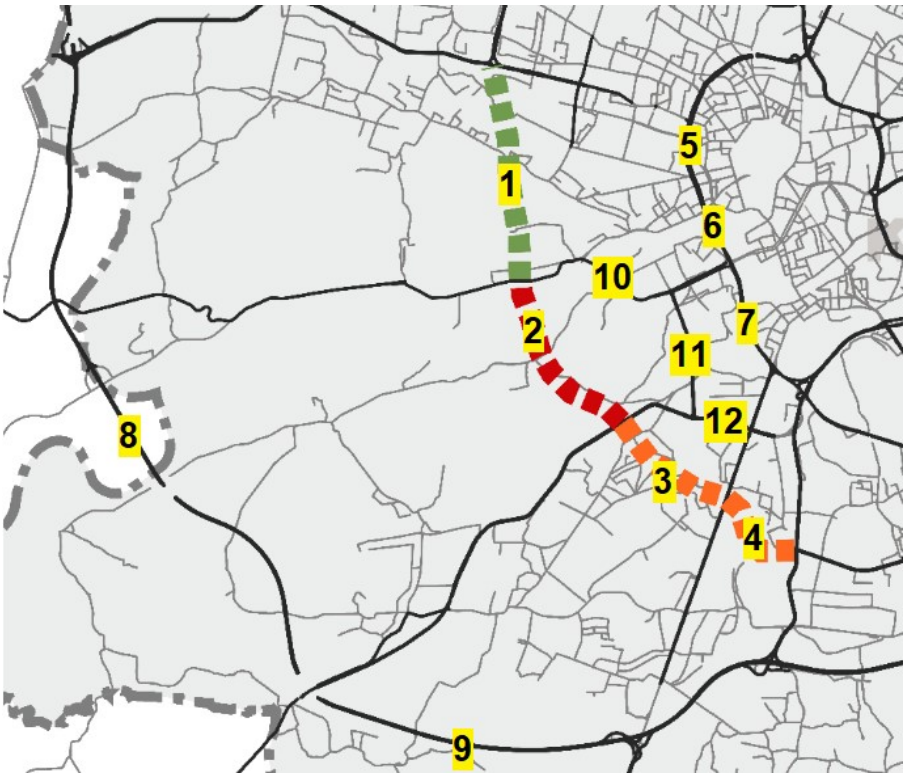
Completion of the above sections of the 3rd ring road is intended to significantly improve the quality of travel in the western part of Krakow and reduce the traffic flow on alternative road connections - especially the 2nd ring road. The project is to be implemented in stages: on July 18, 2018, the first fragment, ie the Łagiewnicka Route [9], began, the construction cost of which is estimated at approx. PLN 800 million. On the other two sections (Pychowicka and Zwierzyniecka Routes) preparatory and design works are underway, and their construction according to strategic documents of the city [10] should theoretically be completed by 2030. The cost of construction of these two sections is initially estimated at about PLN 2 billion [11], but due to the scale of the investment and the necessary engineering solutions (new bridge over the Wisla, tunnel drilling using the deep method, etc.) it seems to be a low value and in fact it may turn even several times higher.

Tools and assumptions for simulation analyzes - Kraków's transport model

The analytical work will be carried out using the Krakow Movement Model (KMR) [6], developed as part of the Comprehensive Traffic Research implemented in Krakow in 2013. [7] It is a macro-simulation model that maps the transport system in the area of Krakow and neighboring poviats, created with the help of PTV VISUM [4]. The forecasting model developed for 2025 will be used for analyzes – figure 2 and 3, taking into account forecast assumptions regarding the demand model (changes in physical activity) and the network model (investments and changes in the transport system) in the KMR area.



2. The forecast model of the Kraków transport network in 2025, with the stages of the western part of the third ring road being marked out (source: own elaboration based on [6])



3. Marking of cross-sectional points analyzed in simulation works

In the prognostic network model for 2025, it was assumed that until that time, among others, the most important road projects:

- closing the 4th ring road, i.e. construction of eastern (S7) and northern (S52) sections of express roads around Krakow,
- construction of radial connections between the 4th and 3rd ring roads: Balicka Route, Skawińska Route, Wolbromska Route, extension of Al. 29 November and al. Okulicki (roads in section 2x2 or 2x3),
- supplementation of radial connections between the 3rd and 2nd ring road – Milosza Street (course: Wit Stwosz – Doktora Twardego - Opolska), transfer of Księcia Józefa Street (mileage: Most Pychowicki - Zwierzyniecki Bridge),
- extension of Igołomska Street(DK 79) in Krakow to the section of 2x2.

The forecast model of demand includes assumptions regarding the number and relation of travels that result, among others, from forecasted changes in the functional and spatial structure, overall mobility growth and (for transit traffic) traffic growth in correlation with the GDP forecast. Due to the relatively short time horizon of the analysis, however, far-reaching changes were not assumed in the travel connection compared to the existing state model (i.e. for 2018) - hence the total increase in the number of trips by 2025 is around 10-15% (on internal journeys) and 15-20% (on destination-source and transit journeys).

The simulations were carried out for the morning rush hour (7:30 - 8:30). For the demand model thus developed, the total number of trips (motorized) at the morning peak amounts to approx. 201,000. (travel / hour), and the division of transport tasks in the reference variant (non-investment) in internal traffic is at the level of 48.2% for individual transport and 51.8% for collective transport. In each of the variants, identical assumptions regarding the demand model were taken into account and simulation was carried out in accordance with the full four-minute procedure, i.e. generation of travel, spatial distribution of travel, division of transport tasks and distribution of traffic to the network. The final result of the four-radio

model is the distribution of traffic to the network (i.e. the result of interaction between the travel model and the network model), hence the assumed investment changes in the network model should have a bearing on the received image of the transport system operation in the simulation process.

The following variants (scenarios) of road network development were defined in the analytical work:

- W0 - a non-investment reference variant,
- W1 (Ł) - investment option, 1. stage of construction of the 3rd ring road (Łagiewnicka Route),
- W1 (PŁ) - investment variant, 2nd stage of construction of the 3rd ring road (Łagiewnicka Route and Pychowicka Route) – figure
- W1 (ZPŁ) - target investment variant: 3rd stage and completion of the construction of the western part of the third ring road (Łagiewnicka Route, Pychowicka Route and Zwierzyniecka Route).
- the following assumptions were made in the parameterization of the aforementioned sections of the 3rd ring road:
- throughput: 2000-2500 hours/hour (main carriageways) and 700-1000 vehicles/hour. (switchboards) in the direction of
- speed in free traffic: 70-80 km/h (main carriageways) and 50 km/ h (switchboards),
- technical and functional class: GP.

Results of simulation analyzes - changes in the road network in subsequent stages of the western sections of the 3rd Krakow ring road

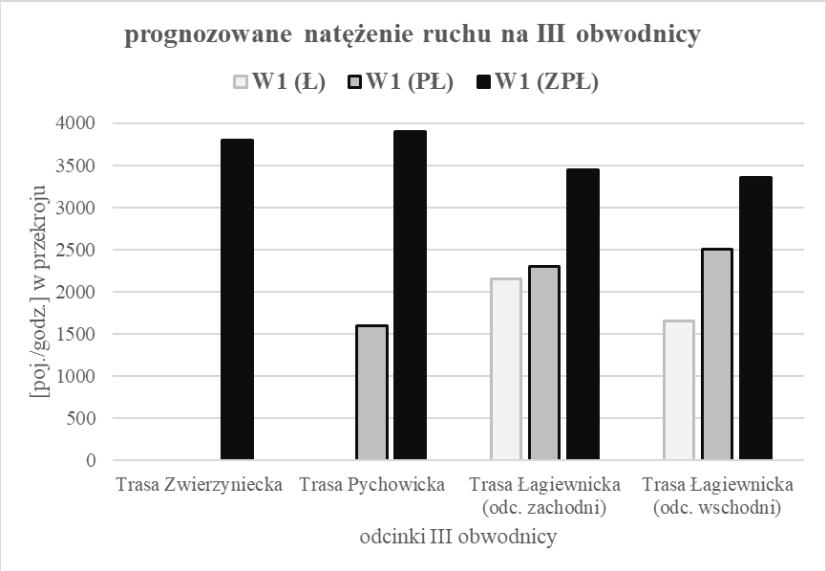
On figures 4 – 8 and in the tables 1 – 2, the simulation results for the analyzed scenarios of the implementation of subsequent stages (western sections) of the 3rd Krakow ring road are presented. The assessment was made mainly in terms of the total parameters of the transport system functioning in the city, the network effect of the analyzed investments, the forecasted load of new and existing road sections and potential changes in the flow of traffic flows in the Kraków road network.

Tab. 1. Simulation results - predicted traffic volume on the analyzed sections of the Kraków road system (forecast at the moment of putting the investment into use)

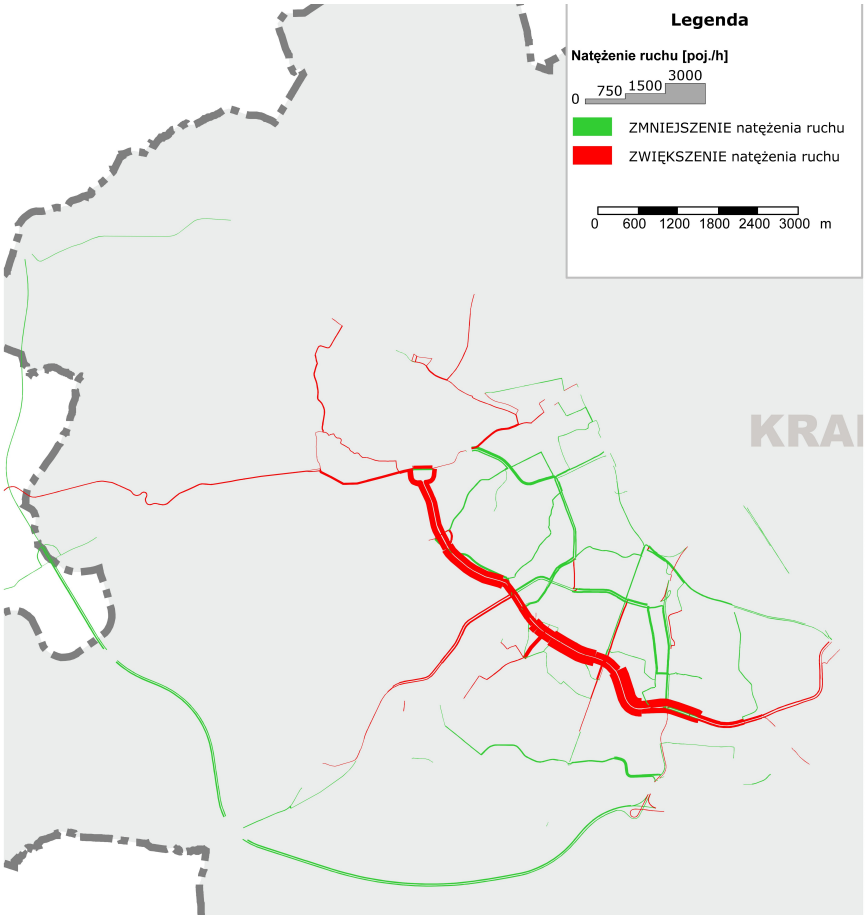
Traffic intensity [capacity/hour in cross-section]- 2025 simulation variants			W0	W1(Ł)	W1(PŁ)	W1(ZPŁ)
			non-investment	investment - stage 1.	investment - stage 2.	investment - stage 3.
III ring road	1.	Zwierzyniecka Route	(lack)	(lack)	(lack)	3800
	2.	Pychowicka Route (bridge)			1600	3900
	3.	Łagiewnicka Route: West side		2150	2300	3450
	4.	Łagiewnicka Route: West side		1650	2500	3350
II ring road	5.	al. Mickiewicza (AGH)	4050	4050	4000	3550
	6.	Dębnicki Bridge	4450	4400	4350	3900
	7.	al. Konopnickiej	3950	3950	3800	3500
IV ring road	8.	A4: bridge on the Wisla	4250	4250	3950	3450
	9.	A4: Sidzina – Zakopiański	4200	3900	3850	3600
area of Dębniki, Ludwinów estates	10.	Zwierzyniecki Bridge	1300	1350	750	1050
	11.	Kapelanka Street	2700	2800	2400	2200
	12.	Brożka Street	1950	1450	1400	1500

Tab. 2. Simulation results – summary of functioning parameters for the road network

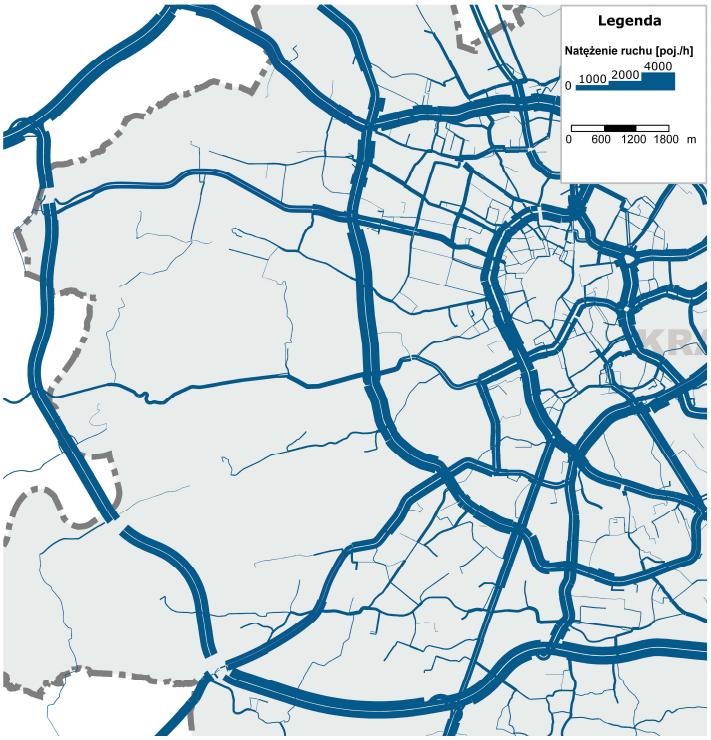
simulation scen arios - 2025		number of city trips - individual transport (PrT)	modal split – PrT's participation in motorized city trips	operating parameters of the road network - the entire network (KMR)		average speed-KMR	average travel time - KMR
		[vehicles/h]	[%]	[vehicles.-km]	[vehicles – h]	[km/h]	[min]
W0	non-investment	78760	48,2%	962215	20050	48,0	15,3
W1 (Ł)	investment - stage 1.	78910	48,3%	963464	19967	48,3	15,2
W1 (PŁ)	investment - stage 2.	79055	48,4%	963926	19857	48,5	15,1
W1 (ZPŁ)	investment - stage 3.	79630	48,8%	962283	19477	49,4	14,7



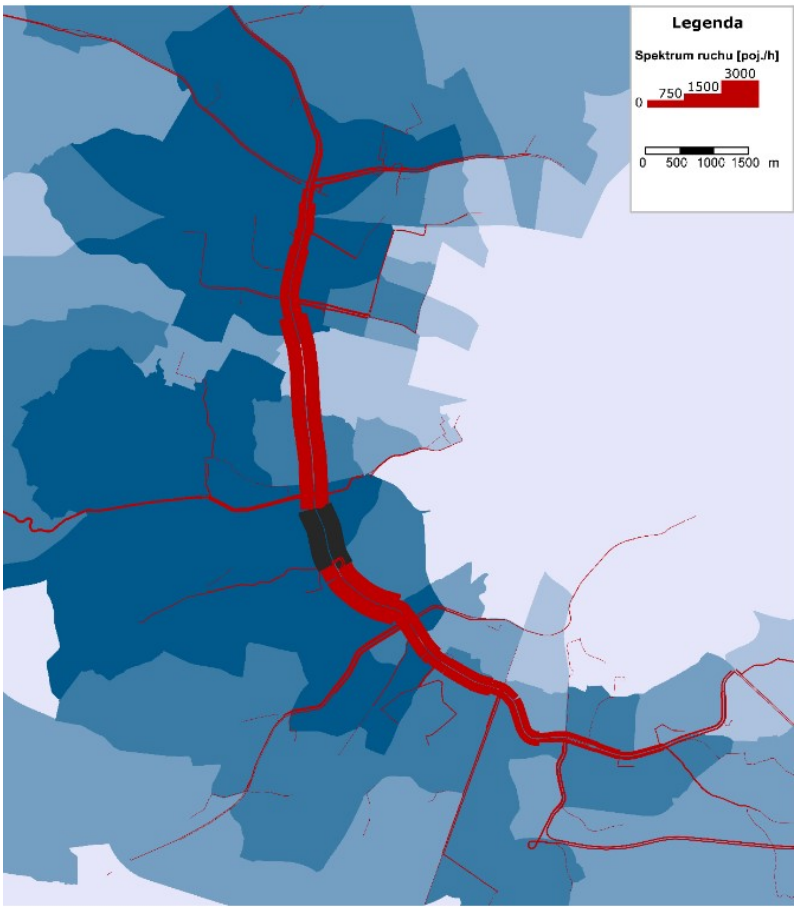
4. Simulation results - forecasted increase in road traffic on the III ring road as its subsequent stages in the western part of the city (forecast at the moment of putting the investment into use).



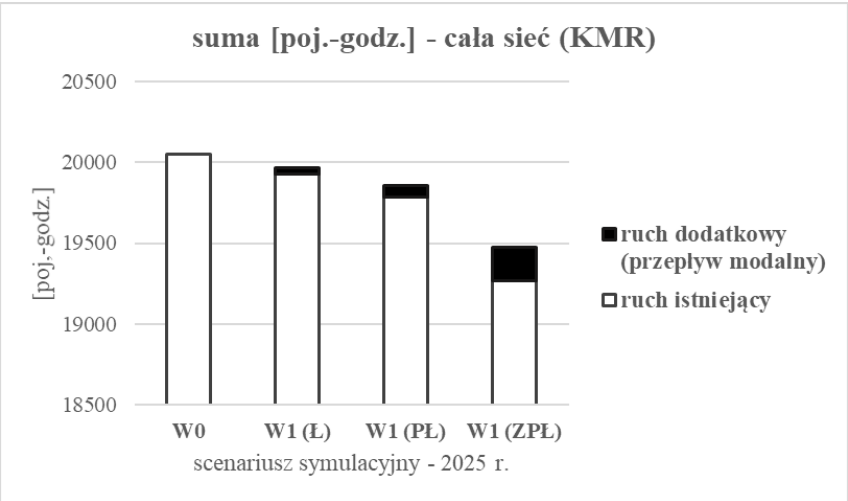
5. W1 variant (PŁ) - forecasted changes in the flow of traffic flows in the road network after the implementation of the 2nd stage (Pychowicka Route), in relation to the non-investment W0 variant



6. W1 variant (ZPŁ) - forecasted distribution of traffic flows in the Kraków's road network after handing over the entire western part of the 3rd ring road for use



7. W1 variant (ZPŁ) - spectrum (bundle) of road traffic in the cross-section of the Pychowicki Bridge after completing the third stage of the 3rd ring road (Zwierzyniecka Route)



8. Simulation results - changes in the total time spent traveling throughout the entire road network covered by the KMR model (i.e. the sum of vehicle-hours)

In the first stage of the investment implementation, i.e. option W1 (Ł), the implementation of the Łagiewnicka Route brings some visible changes in the functioning of the road network, but they are limited to the southern areas of the city. The forecast traffic load of a new section of the route falls within the range of approx. 1600 - 2200 vehicle / h. the summit and this movement are mainly related to the area of adjacent districts (Ruczaj,

Łagiewniki, Kurdwanów, and to a lesser extent Bieżanów and Prokocim). The results of the simulation show that this is related to a certain reduction in traffic on several alternative road connections (streets: Brożka, Tischner, Zawiła, Kamieńskiego), where the traffic intensity decreases by no more than several hundred vehicles (in an hour). Despite the limited network effect on the scale of the city, one can observe some improvement in the parameters of car travel - the average travel speed increases by 0.3 km/h in comparison with the W0 variant.

In the second stage of the analyzed investment, i.e. variant W1 (PŁ), further construction of the Pychowicka Route leads to a certain increase in the impact of the corridor III of the ring road. The use of the Łagiewnicka Route increases, where the traffic reaches approx. 2,500 vehicles / hour. in cross-section, while traffic flows on the new section are already lower - on the Pychowicki Bridge, it is approx. 1500 vehicles/hour. As the results of the simulation show, on the III ring road, there are additional flows of traffic from the districts of Ruczaj, Skotniki, Zwierzyniecka, and Salwator, while the inflow of traffic from the north is clearly limited by the terrain barrier and the lack of further passage through the Wzgórze Św. Bronisławy. In comparison with the W0 variant, some traffic decreases can be observed in the area of Dębniki and Ludwinowa (streets: Kapelanka, Kobierzyńska), and what is important - the most pronounced decrease in traffic can be observed on the Zwierzyniecki Bridge (almost by half). The flow of traffic flows north of the Grunwaldzki Roundabout and in the area of the city center of Krakow remains unchanged. In this variant, the traffic conditions in the network are further improved and the average speed of car travel in the whole of Krakow increases by 0.5 km / h (compared to the W0 variant).

In the final version of W1 (ZPŁ), the target shape of the entire western corridor III of the beltway, i.e. the completion of the Zwierzyniecka Route, brings much more visible changes in the road network, and the effects of the investment are much greater in the scale of the whole of Krakow. The corridor III of the ring road becomes one of the most-loaded road sections in Krakow and the entire traffic volume ranges from approx. 3300-3500 vehicles/hour in section (Łagiewnicka Route) up to almost 4,000 vehicles/hour (Pychowicka route and Zwierzyniecka route). The new section of the Zwierzyniecka route is characterized by high use in many trips carried out in the city, and the use of previously completed sections of the 3rd ring road is clearly increasing. As a result, the entire western section of the 3rd ring road is the basic communication axis in travels between major districts in the north and in the south of Krakow. There is also a synergistic effect and an increase in inflows from radial connections from the city center (i.e. from the 2nd ring road), as well as from peripheral areas (from the IV ring road). Benefits in the scale of the entire Krakow are clearly larger than in scenarios W1 (Ł) or W1 (PŁ): the average speed of travel increases by 1.4 km / h in comparison with the W0 variant. This means shortening the average travel time by approx. 0.7 minutes for each vehicle in the model area, and in total - a decrease by approx. 600 vehicle-hours.The simulation results for the W1 (ZPŁ) scenario show a more visible takeover of traffic through the 3rd ring road from many alternative connections - also appearing on further parts of the road network: II beltway (Aleje Trzech Wieszczów, Dębnicki Bridge), IV ring road (A4 motorway) and connections radial and tangential (Balicka Route, Czarnowiejska Street). Importantly, these decreases are usually not higher than 500-800 vehicles per hour in the section - especially it can be noticed that the traffic along the II beltway is still high, where it fluctuates between 3000-3800 vehicles/h, and in addition to the W1 (PŁ) scenario, the use of Zwierzyniecki Bridge in car journeys is improved.

Summary

The results obtained in the conducted simulation works seem to coincide with the expectations related to the implementation of the western part of the third ring road in the area of Kraków. The construction of the road will introduce major changes in the conditions of

travel in the city's road network, and its consequences will become more and more distinct as the subsequent stages of investment are put into use. As the forecasts show, the implementation of the III ring road concept will bring both visible benefits in the scale of the entire Krakow, but what is important - it may also result in some negative effects. Among the conclusions drawn from simulation works, the following aspects are worth emphasizing in this context:

- The implementation of the first two stages of the 3rd ring road, i.e. the Łagiewnicka Route and the Pychowicka Route, will bring some improvement in the travel conditions on the network, but these benefits will be relatively small in the scale of the city: for example, the forecasted increase in the average speed of travel by car is approx. 0.3-0 , 5 km/h. The network effect of the new sections of the 3rd ring road will be limited to the southern and south-western areas of the city, where the road system is relatively well developed - and in a sense they will "compete" with existing road connections with good levels of freedom of movement (e.g. outflow from the Zwierzyniecki Bridge and Kapelanka St. to the Pychowicka Route in the W1 (PŁ) scenario). However, without further continuation of the route to the north, it will be impossible to solve the key problems of the city's transport network, i.e. exhausted capacity on sensitive road corridors (II ring road, crossing the Wisla) and communication barrier in the western part of Krakow (no crossing through the Sowińca Range and Wzgórze Św. Bronisławy).
- Implementation of the concept at the final stage, i.e. after completion of the Zwierzyniecka Route, introduces fundamental changes to the city transport network and significantly increases the benefits from the implementation of the III beltway concept. The increase in the average speed of travel in the target variant W1 (ZPŁ) is higher, ie by almost 1.5 km/h compared to the non-investment variant W0, and despite the increase in the number of car trips, the total time spent traveling (by about 600 so-called vehicle -hours on the scale of the model). This confirms that the completion of the entire western III beltway route is necessary to fulfill the assumed postulates - it allows the creation of a basic communication axis in the western part of Krakow, which visibly affects the improvement of accessibility and travel parameters in many travels between the northern and southern areas of the city. As the results of the simulation show, the devotion of the Zwierzyniecka Route has a synergistic effect in the context of the increase in the use of the other two sections of the 3rd ring road, and consequently, the whole string also becomes one of the most-loaded sections in the road and street network of Kraków.
- Based on the conducted simulation analyzes, it can be preliminarily stated that completion of the entire 3rd ring road is crucial to increase (and obtain the proper degree) effectiveness of the investment sections being completed. As the simulation results show in the indirect scenarios W1 (Ł) and W1 (PŁ), the use of the new sections of the III ring road (measured by traffic) is at a visibly lower level than the assumed transport capacity, and their use in trips made in Krakow is quite limited - and only further connection in the northern direction strengthens the importance of these sections in the road network. For example, the forecasted traffic on the Pychowicki Bridge increases from 1,600 vehicles/h. 3900 hours/hour immediately after the construction of the Zwierzyniecka Route, which with the assumed parameterization of the model means an increase in its use from around 35% to over 80%. However, it should be noted that making a more detailed assessment of investment effectiveness would be possible after a more detailed economic and financial analysis
- However, the forecast results provide other important reasons for further directions of development of the Kraków transport system, which should aim at limiting some of

the negative aspects (effects) of the implementation of the new sections of the 3rd beltway. While this route will allow creating an alternative road connection without taking into account the center, in the W1 (ZPŁ) scenario it can be observed that the traffic reduction on the 2nd ring road is really small with respect to the W0 variant, and in the rush hour it decreases by no more than 500-800 vehicles/ hour in section. This means that in the face of leaving significant reserves of the road system inside the 3rd ring road, they will be filled again by additional (excited) car trips resulting from the shift of physical activity from other travel routes, time periods and means of transport. It should be noted that the investment impact on the division of transport tasks in Kraków will be much higher after completion of the entire III beltway: if for the indirect scenarios W1 (Ł) and W1 (PŁ), the forecast takeover of transport from public transport to individual transport is at the level of 0.1% and 0.2% of urban travel, respectively, in the W1 (ZPŁ) target scenario the modal flow increases to about 0.6% of all city trips. With a high probability, it can be said that as a result, the improvement of travel quality will be small and the level of road congestion in the city center will remain at a similar level as before, which will reflect the well-known paradox of the so-called Lewis-Mogridge [2], [3].

- The above-described dependencies indicate that it will be necessary to take further measures aimed at limiting the capacity of the road system in the area of the III beltway and focusing on the development of more efficient forms of transport in this area - in particular, public transport (e.g. narrowing of the 2nd ring road and the construction of a tram line in its corridor). Only such actions, in connection with the construction of the 3rd ring road, will allow achieving a lasting and effective reduction of the nuisance of car traffic in the city center of Krakow. It will also be part of the postulate of long-term shaping of the Kraków transport system in a sustainable and possibly effective manner.
- Conclusions may also be important in the context of the capacity of the surrounding Krakow road system and the identification of potential critical points and so-called bottlenecks. While the cross-section of the new sections of the 3rd ring road may not pose a risk in the context of capacity depletion, its transport capacity - and the general level of freedom of traffic in the road network - will be conditioned mainly by the capacity of nearby interchanges and access roads. The forecasted changes in the flow of traffic flows indicate, among others on increase of traffic intensity on further sections of III ring road (Witosa, Opolska) - where road congestion may occur due to the lower efficiency of intersections located there with traffic lights - as well as on already (already highly mobile) torsional relations within the Ofiar Katynia roundabout. Movement activity on the exit roads in the external area of the 3rd ring road (e.g. Radzikowskiego, Grota-Roweckiego, Zakopiańska, Herberta) will be intensified, which indicates that another critical factor may be transported capacity in torsional relations between these road sections and the 3rd ring road. An important role will also be played by the phenomenon of interlacing traffic flows on inter-node sections of the III beltway, which during rush hour may result in a marked deterioration of travel speed and the level of freedom of movement (this mainly applies to the Łagiewnicka Route).
- It should also be emphasized that the analysis results presented above should be treated as a "bottom" range of forecasted traffic volumes, and after some time the actual traffic volumes on the III ring road are likely to be even higher. It results, among others from a relatively short time horizon of analysis (2025), however - which is a typical phenomenon for investment projects in urban areas - in the following years after the investment has been put into use, the initial improvement of traffic conditions

may result in a further increase in traffic generation and the emergence of so-called excitation movement [8]. As the experience of analogous investment projects shows (e.g. Siekierkowska Route in Warsaw [12]), the additional increase in traffic only in the first few years can reach even 50-100% of the original traffic volume. Therefore, it is necessary to extend the analyzes with a long-term forecast of the effects of investments, which may eventually show quite different results in terms of effectiveness assessment after taking into account long-term changes in the travel model.

Source materials

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