

Effectiveness of Various Ways of Providing Access and Service of Road Surroundings on Suburban Roads

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INTRODUCTION

The process of urban deglomeration, in which part of city populations migrate out of the city into the suburbs, has, over the last ten years led to strong growth of the suburbs. This has resulted in the construction of commercial and residential buildings alongside sections of national roads carrying traffic in and out of city. In most cases this development has direct access to the major road. The construction of residential buildings as well as commercial buildings in the immediate vicinity of major roads, without building service and local roads network is a frequent phenomenon in Central and Eastern Europe. Driveways to buildings are densely packed along such roads and can reach as many as 80 per kilometre, although the traffic during the day is very low. The traffic peak is in the morning peak when the flow of traffic into town is the heaviest. It causes overlapping of commuter and through traffic and leads to interruptions of traffic flow and deterioration of traffic conditions. Journey speed is reduced and greater delays extend journey times through urban areas. This phenomenon can be encountered not only in suburban areas, where it has the most adverse consequences, but also on those sections of roads that pass traffic through localities. The authors' research indicates that in Poland, some 35% of major roads length go through small communities (1). This state results from planning errors and poor regulations of land-use policy. Lack of adequate policies has degraded the parts of road network which have basic traffic function. This situation is further compounded by lack of network of express roads and motorways and inadequate development of road network transformation including construction of by-passes. One radical change would involve a hierarchical road network, though it is a costly and long-term challenge.

Following the arguments above, the authors undertook research. Their aim was to find out about the possibility of using less costly modifications of road networks and changes in the service of road surroundings to ensure an improvement in the conditions of through traffic in suburban areas and on roads passing through smaller localities. The issues concern sections of roads with a two-lane cross-section.

From among possible designs, the authors have chosen to investigate and present in the study the effectiveness of the following designs:

- Implementing an additional multifunctional median lane, specially signed and marked (also red surface) in the road cross-section,

- Construction of service roads with different locations of intersections merging traffic with the existing road (end or middle of a section).

The analysis focused on the impact of such changes on traffic efficiency and safety. The authors analysed journey speed, delay and platoon traffic on a uniform section of the road for different modes of service of road surroundings. Furthermore, the study presents the results of analyses covering the evaluations of:

- impact of access points density and level of their use on road traffic conditions,
- impact of driving through sections in built-up area on building platoon traffic,
- impact of change in the cross-section type on traffic conditions.

METHODS OF RESEARCH

In the available methods of evaluating traffic performance (2, 3) for two-lane roads no consideration is given in the traffic performance calculation procedures to specific features of sections passing through localities. The estimation methods of traffic performance used in practice take into account either sections outside the development (rural roads) or urban sections (arterials). Crossings through small or medium localities are substantially different than such sections, mainly with regard to the surroundings development and the way it is used. Consequently, it is difficult to use the results of calculation methods or research done in this area in other countries (4, 5, 6, 7, 8). The foreign bibliography quotes the results of simulation researches on arterial sections entering towns. This, however, can be used to a restricted extent only for the purpose of modelling individual components of road networks such as, for example, bus stops or pedestrian crossings (5). Few former researches on traffic conditions over the sections passing through localities focused on the analysis of average speed, headways and vehicle disturbances in the traffic flow. As shown in these researches, road surroundings development is of significant effect to vehicle traffic performance in passing small localities (1, 5, 9, 10, 11). However, the focus of such research is mainly traffic speed analysis with such measures as delays, platoon traffic share or journey speed (12) neglected, and the access impact on traffic performance not quantified.

Therefore, in order to analyse the effectiveness of various ways of providing access and service of road surroundings over suburban sections simulation was employed. On the grounds of such research conducted by means of road traffic simulation program VISSIM v.5.1, variability of journey speed, delays and platoon traffic share were evaluated. VISSIM software allows users to simulate traffic flow assignment along road sections of different cross section. The model used in the simulation program very well represents the behaviour of drivers passing small localities (13). The analyses were conducted on an adopted model section surrounded by a development, in which the length of the passage, number of lanes, number and type of access points were represented. The analyses also took into consideration traffic volumes on the major road and the traffic volume generated by access points.

For a case study analysis, a section of national road No 7 has been selected. The section is located in a Cracow suburban zone, and is ca. 800 m long, with a single roadway cross-section with an extra multifunctional median lane (fig. 1). The speed limit over the section is 50 km/h, density of access points is high (47 residential driveways, 4 commercial driveways and 2 intersections without traffic lights). Due to the close neighbourhood of a big city, the intense local traffic over the section in question overlaps with through traffic. The average daily volume over the analyzed section is ca. 19000 veh/24h, and in the peak period ca. 1400 veh/h, in the road cross-section. For the purpose of simulation, traffic volumes on the driveways and on the intersections were measured. It has been found that each residential driveway generates ca. 1 veh/h and each commercial driveway generates ca. 8 veh/h. For the intersections, the traffic volume from the measurements has been provided. On the grounds of empirical survey, vehicle attributes have been defined in the model, vehicle speeds in free flow (on the basis of an empirical speed distribution function) and the type of vehicle: heavy vehicles and passenger cars. Traffic measurements used to calibrate the model were made in three cross-sections, i.e. at the beginning, at the end and in the middle of the section. The traffic model has been properly calibrated, consideration given to the empirical measurements of journey time. In the model it was assumed that there is no possibility of overtaking or passing other vehicles. The majority of the model parameters were adopted as default values except the gap between vehicles, minimum gap between vehicles ensuring the minimum braking distance of 2 m, speed for turning relation from 5° km/h (for individual driveways) to 20° km/h (for intersections). The measuring points in the model were located minimum each 100 m, and generation cross-sections for the major road were located outside the impact of the analyzed section. As a result of the simulation several

measures of effectiveness such as the journey time of through urbanised area, as well as journey speed, delay and departure headways between vehicles were determined. The analyses were made for varying traffic volume levels on the major road, as the main goal was to observe the variations in the measures of traffic performance in case of growing volume of vehicles. Traffic volume variations ranged within $400 \div 1,600$ veh/h for one direction of traffic, which is a value close to the road section capacity.



FIGURE 1 View of the beginning of the model road section. Cross-section with additional multifunctional median lane

In the simulation research on the effectiveness of various ways to provide for the road surroundings accessibility and service, analyses were made for the following situations (fig. 2):

scenario 0 – cross-section with an additional multifunctional median lane for road surroundings service and two separate additional lanes for turning left on the intersections. Lack of access control over the entire length of the analyzed section.

scenario 1 – this is a solution with an additional multifunctional median lane excluded over the entire length of the locality. Turning left manoeuvre is performed from the driving straight on lane. Separate lanes for turning left on the intersection are only on the direction with right of way. Analysis of such scenario was made in order to compare the impact of changed cross-section type on the performance of vehicle traffic.

scenario 2 – elimination of the existing access points while constructing service roads along the road section in question. Traffic volume formerly generated on the driveways has been redirected to side entries of one intersection with shifted entries located in the centre of the locality. Additional lanes for left turning are separated on the intersection.

scenario 3 - elimination of the existing access points while constructing service roads along the road section in question. Traffic volume formerly generated on the driveways has been redirected to side entries of two intersections with shifted entries located on the ends of the locality and serving the service roads. At both intersections, additional lanes for turning left have been provided on the direction with right of way.

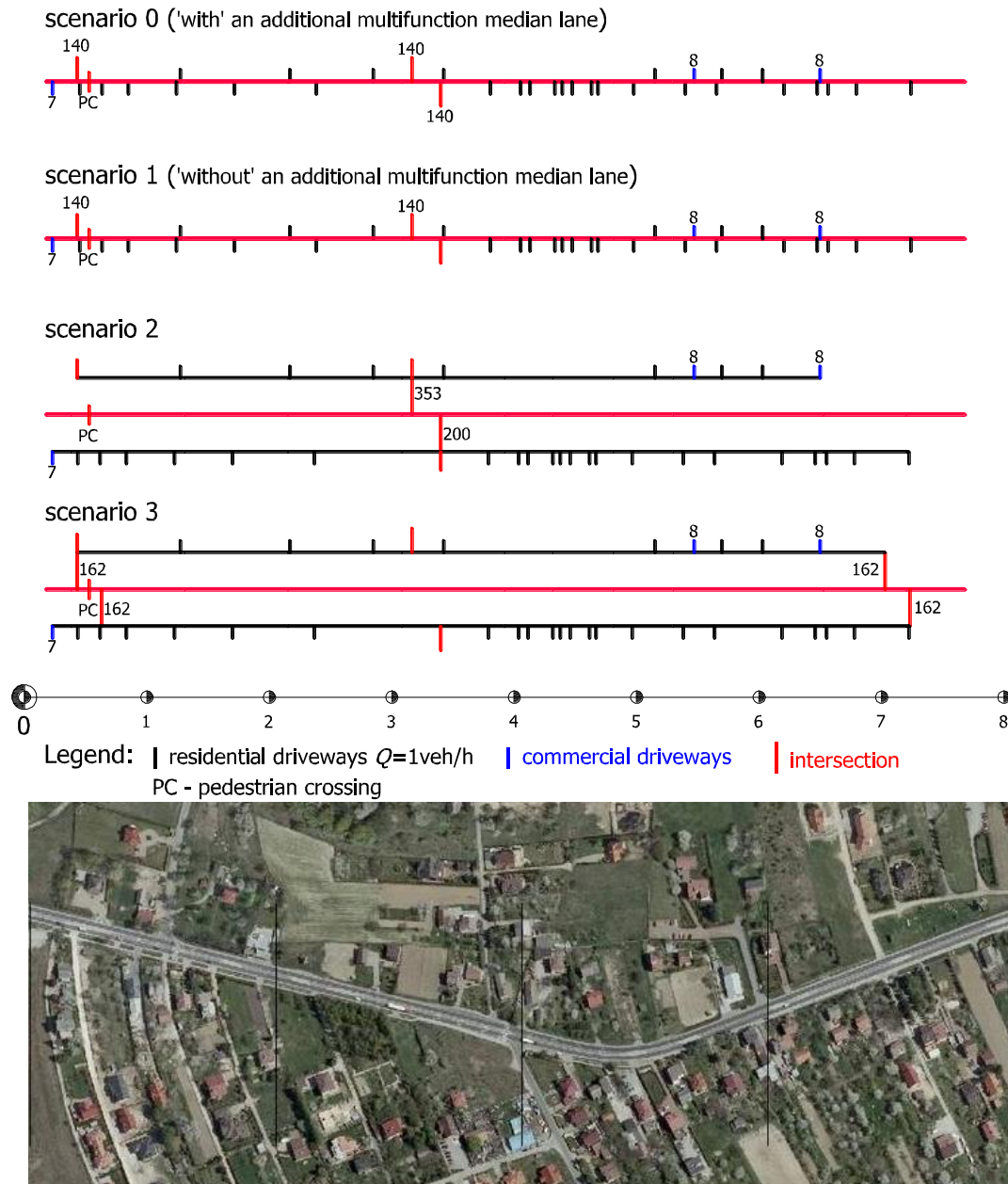


FIGURE 2 Diagrams of modification scenarios provided for the simulation research. View of the of the model road section (14).

SIMULATION RESEARCH OF TRAFFIC PERFORMANCE MEASURES

At the first step of the simulation research the analysis was performed on the journey speed, which is the quotient of the length of the road section investigated to the time of covering it. With this aim in view analysis was done on the profiles of average local speed in relation to the manner of the road surroundings being serviced. On the basis of the results, speed profiles were prepared that showed variations in the local speed over the analyzed section length for various levels of traffic volume, with differentiated driving directions. Fig. 3 illustrates the speed profile for traffic volume of 1,600 veh/h for each scenario of the solution of road surroundings service for one of the two directions analyzed. The highest values of local speeds appear in scenario 3, and are as high as 60 km/h, which is over 15 km/h more than in the other solutions. For the other scenarios, the shapes of speed profiles are close to each other, and the local speeds achieved are small. Table 1 presents the values of journey speeds on a given road section in relation to traffic volume and road surrounding service version adopted. The most significant increase of journey speed, as compared with scenario 0, is observed for the solution with service roads and two intersections located on the road section ends. The average journey speed is then by 5.7 km/h higher than in the starting scenario and by 8 km/h higher than in

scenario 1 (before reconstruction) for the traffic volume of 1,600 veh/h/lane (fig. 4). Up to the traffic volume of ca. 1,000 veh/h/lane the scenarios with service roads are comparable, and the journey speed is by ca. 2.2 km/h greater than for the scenario with an additional multifunctional median lane. The introduction of access control significantly affects the journey speed.

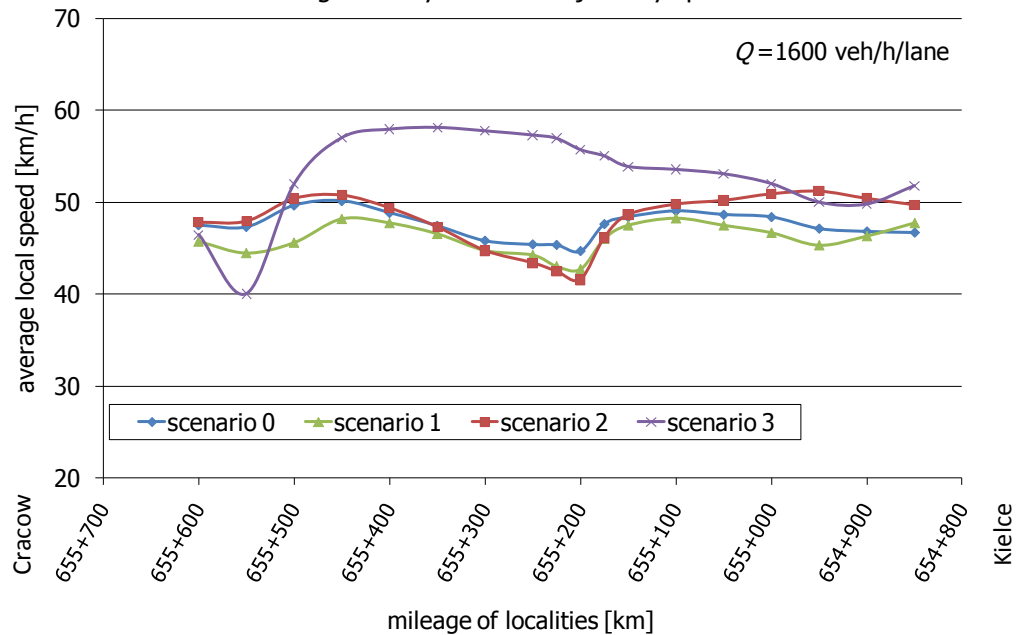


FIGURE 3 Profiles of average local speed on Cracow – Kielce direction for each scenario, with traffic volume of 1,600 veh/h/lane

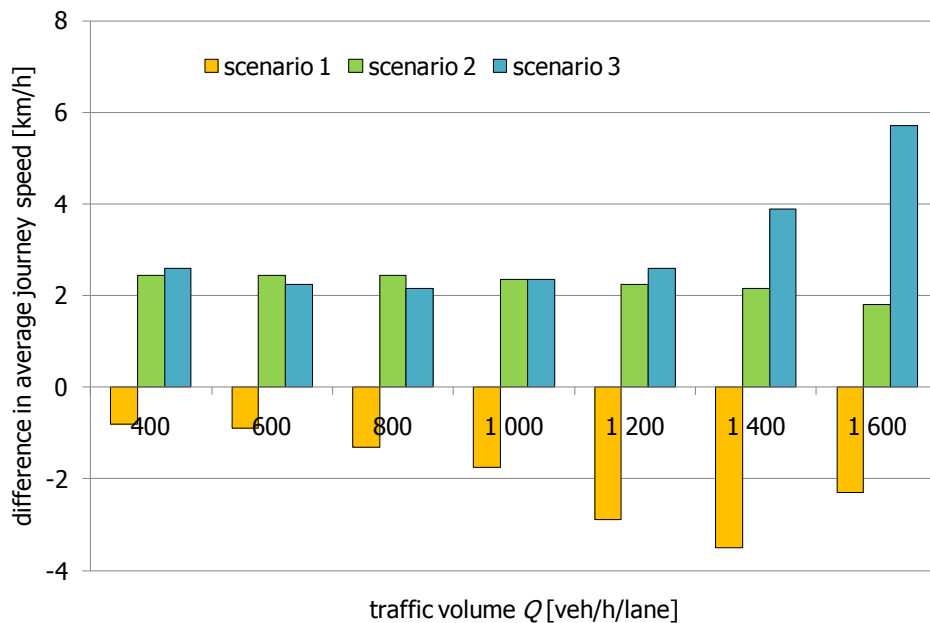


FIGURE 4 Differences in the values of average journey speed, depending on traffic volume for each scenario as compared with scenario 0.

What was analysed next were delays when covering the investigated road section. The delays define the amount of time lost by each vehicle covering the given road section as compared with the time of covering the section at the speed in free flow. A delay is the extra time needed to pass the locality, including any traffic disturbances appearing over the built-up area length, e.g. intersections, driveways, pedestrian crossings and traffic volume.

Fig. 5 illustrates the results of simulation research concerning the delays. They show the delay in a particular cross-section during passing, accruing from the section beginning for each scenario on both directions, with traffic volume of 1,600 veh/h/lane. The biggest time delays are definitely those for the solution with no access control and no additional multifunctional median lane. For the other

scenarios, the delays after the analyzed section has been covered are comparable, the differences are ca. 1.5 sec/veh.

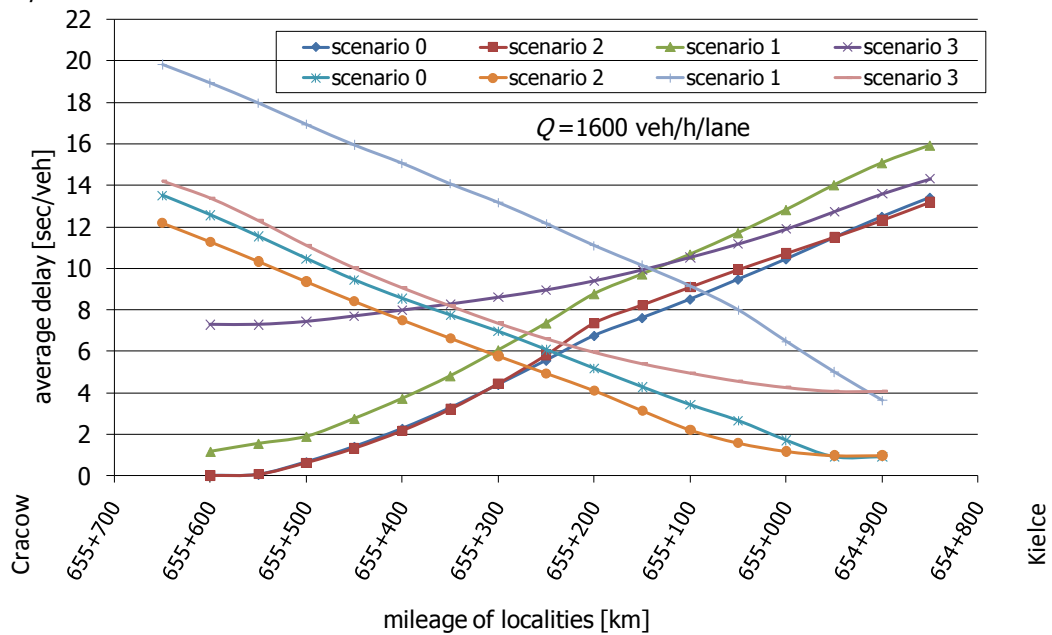


FIGURE 5 Variability of delays over the section length for each scenario in both directions, with traffic volume of 1,600 veh/h/lane

In driving over the analyzed section of ca. 800 m – depending on the driving direction and the surroundings service solution – the driver's average delay is $5 \div 20$ sec/veh, depending on the actual traffic volume.

The most significant delays in covering the analysed section are for scenario 1, irrespectively of the actual traffic volume. Scenario 3 turned out to be the most favourable, wherein disturbances occur only within the intersections on the built-up area ends. Average delays for this scenario range within $4.8 \div 15.7$ sec/veh. The analysis of the differences in delay values as compared with scenario 0 (fig. 6) allows us to state that for the scenarios with access control and with an additional multifunctional median lane (scenarios 0, 2, 3) a change in traffic volume has a minor impact on such delays. It is the effect of no disturbances caused by vehicles turning left.

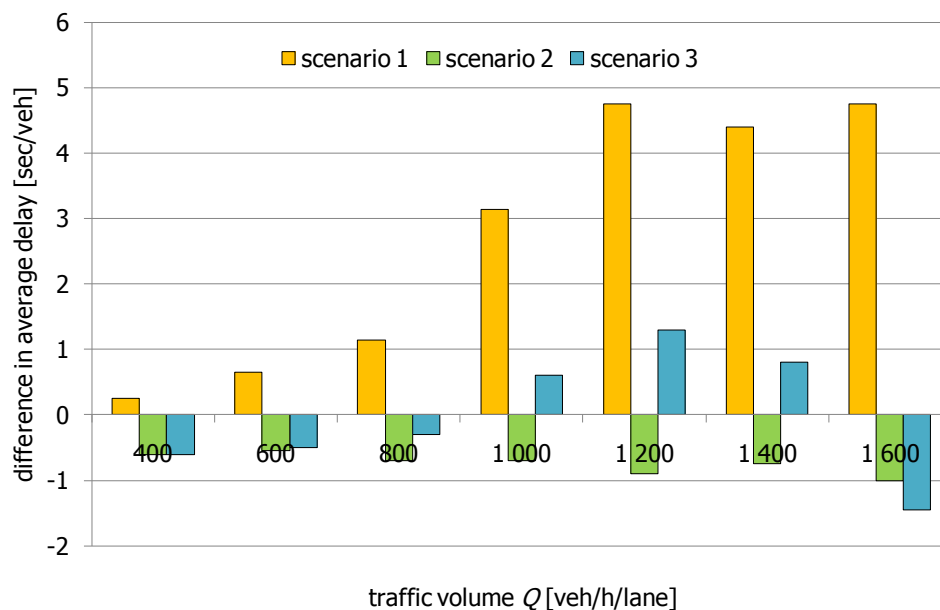


FIGURE 6 Differences in the values of average delays, depending on traffic volume for each scenario as compared with scenario 0

Another possible measure of traffic performance is the share of platoon traffic. Intersections, numerous residential and commercial driveways and the resulting traffic disturbances on the major road - these are factors which easily induce formation of vehicle platoons. Platoon traffic formation is affected by the length of a section with speed limit, as well as by density of access points - on two-lane sections, because overtaking manoeuvres are impossible. When analyzing the platoon traffic it was assumed that whenever the time interval between neighbouring vehicles is less than 3.6 sec, they are moving in platoon traffic.

When driving over a model section of a small length (ca. 800 m), platoon traffic is dependent mainly on the traffic volume on the direction of the major road. Since there are few residential driveways, and since there is an additional multifunctional median lane, the access points have but minor effect on platoon traffic share.

Variations of platoon traffic share for each scenario of cross-section solution and the volume of 600 veh/h/lane and 1,600 veh/h/lane are shown in fig. 7. Irrespectively of the actual volume and driving direction, differences in platoon traffic share for various scenarios are only minor. After driving ca. 300 m from the intersection, the platoon traffic percentage is stabilized accounting for ca. 80%, since there are no major factors which would affect the journey conditions. Average share of platoon traffic for the volume of 600 veh/h/lane accounts for 50%, while for the volume of 1,600 veh/h/lane there is a growth in this value to 90%.

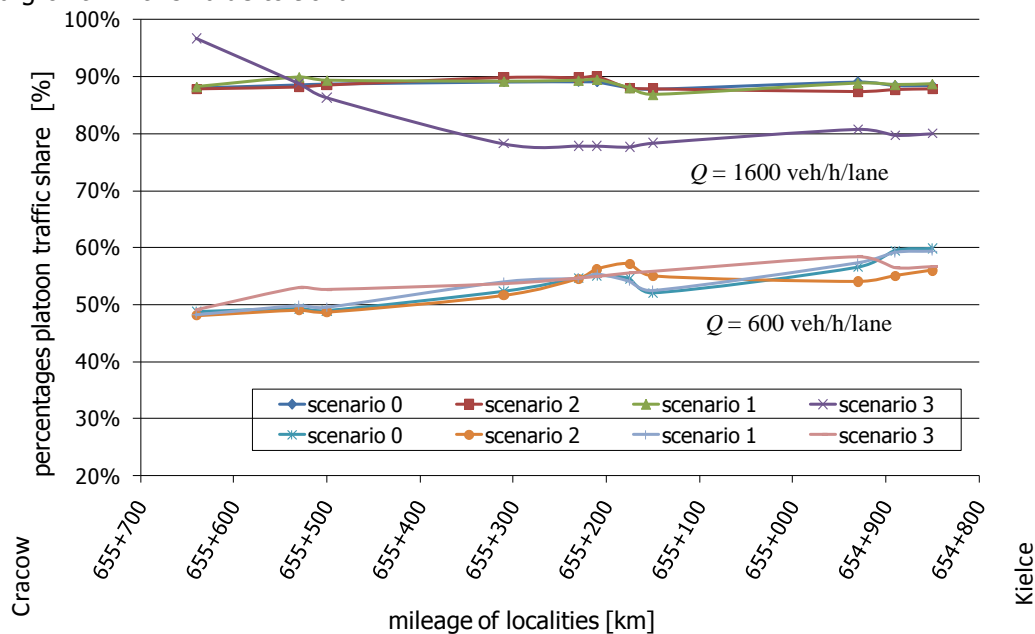


FIGURE 7 Variations of platoon traffic share over the analyzed section length on Cracow-Kielce direction for each scenario, with traffic volume of 600 veh/h/lane and 1,600 veh/h/lane

The difference in average percentages of platoon traffic between the scenarios for different volumes is insignificant. On the basis of these data it can be stated that what affects platoon traffic share is the distribution and type of access points over the section length as well as the traffic volume they generate rather than the mode of the area surrounding service. It can be seen that with traffic volumes up to 800 veh/h/lane the biggest share of platoon traffic is for scenario 3. The situation in this case changes for volumes over 1,000 veh/h/lane, when platoon traffic share is the smallest, which is related to the effect of intersections on the ends of the section (platoon traffic dispersion after the intersection is exited) (fig. 8).

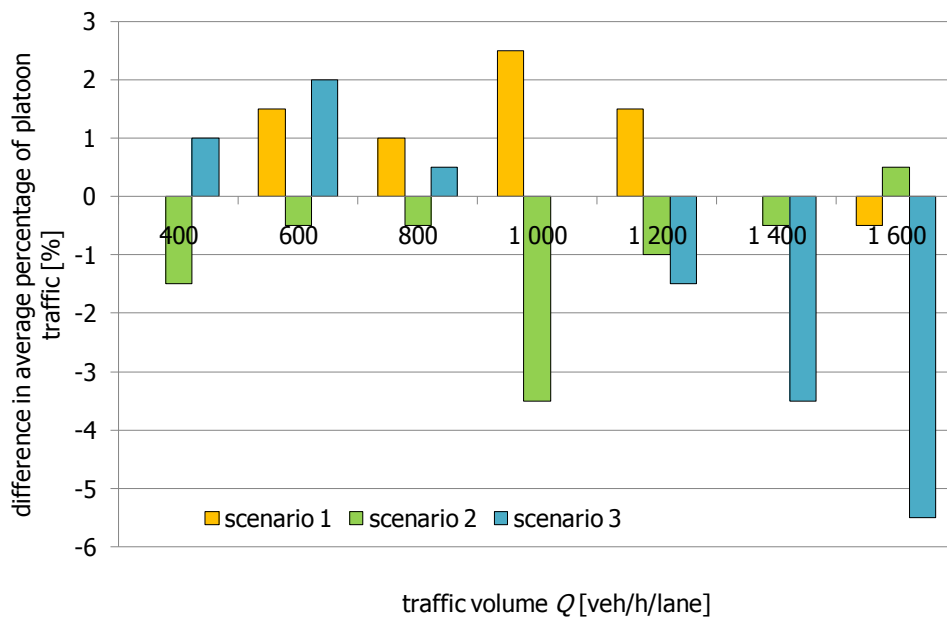


FIGURE 8 Differences of the values of average percentage of platoon traffic depending on the volume for each scenario as compared with scenario 0

In Table 1 the results for traffic performance measures included in the analyses of road network modifications for all scenarios have been listed.

TABLE 1 Results of simulation based traffic performance analyses for various scenarios of road network modifications

volume [veh/h/lane]	average journey speed [km/h]				delays [sec/veh]				share of platoon traffic [%]			
	scenarios				scenarios				scenarios			
	0	1	2	3	0	1	2	3	0	1	2	3
400	58.9	58.2	61.4	61.6	5.5	5.8	4.9	4.9	54,0	54,0	52.5	55,0
600	57.7	56.8	60.1	59.9	6.7	7.4	6.2	6.2	64,0	65.5	63.5	66,0
800	55.9	54.7	58.4	58.1	8.1	9.2	7.4	7.8	73,0	74,0	72.5	73.5
1 000	54.5	52.7	56.8	56.8	9.4	12.6	8.7	10,0	79,0	81.5	75.5	79,0
1 200	52.9	49.9	55.1	55.5	11.3	16,0	10.4	12.6	84,0	85.5	83,0	82.5
1 400	51.0	47.5	53.1	54.9	13.5	17.9	12.7	14.3	88.5	88.5	88,0	85,0
1 600	48.8	46.5	50.6	54.5	16.8	21.5	15.8	15.3	91.5	91,0	92,0	86,0

MODIFICATION OF ROAD SURROUNDINGS SERVICE BY USING ADDITIONAL MULTIFUNCTION MEDIAN LANE

One of the main factors affecting traffic performance when passing through localities is the relation between turns and development, the relation which disturbs through traffic over built-up section. Consequently, an analysis has been made of a cross-section modification from two-lane with paved shoulders (scenario 1) to a section with a multifunction median lane (scenario 0) (figs 1 and 9).

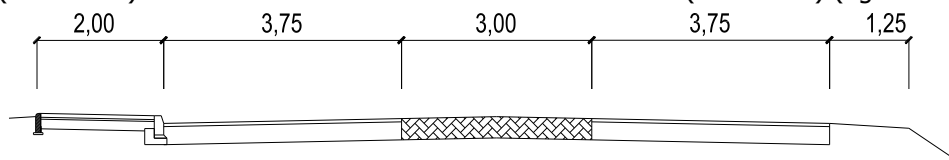


FIGURE 9 Cross-section with additional multifunctional lane (15)

The cross-section with an additional multifunctional lane on roads passing through localities is usually introduced together with traffic calming measures (narrowed sections, traffic islands in the middle, lane staggering). Initial, standard 14.0 m wide paved part of the road allows to construct two $3.50 \div 3.75$ m wide lanes and $3.00 \div 3.50$ m wide median lane (fig. 9). Median lanes are used as a space where vehicles wait for both left turning and joining the traffic. Mid-islands on median lanes prevent left turning manoeuvres on this lane and, additionally, function as a kind of refuge enabling pedestrians to crosswise. Cross-sections reconstruction and another use of paved shoulders requires widening of cross section top to add facilities for pedestrian traffic. The above design is gaining popularity and has been tested to assess its safety and traffic efficiency (15).

Replacing the cross-sections with bituminous shoulders with cross-sections with multifunctional median lane resulted, on six analysed road sections, in decreasing the number of collisions by ca. 29% and their casualties by ca. 31%. The safety improvement resulted from, for example, reduction of values of speed quantile 85% amounting to $2.3 \div 12.7$ km/h. Moreover, the number of potential collisions of vehicles turning from the superior road and vehicles heading straight has decreased as well (cases of driving into the back of a vehicle) (14).

The use of an additional multifunction median lane results in better traffic performance due to fewer disturbances on the major road. For the analyzed section, starting from the traffic volume of ca. 1,000 veh/h/lane there was a decrease in average delays by ca. 5 sec/veh (33%) as compared with the scenario with such lane not provided (scenario 1 – before the cross-section modification) (fig. 10).

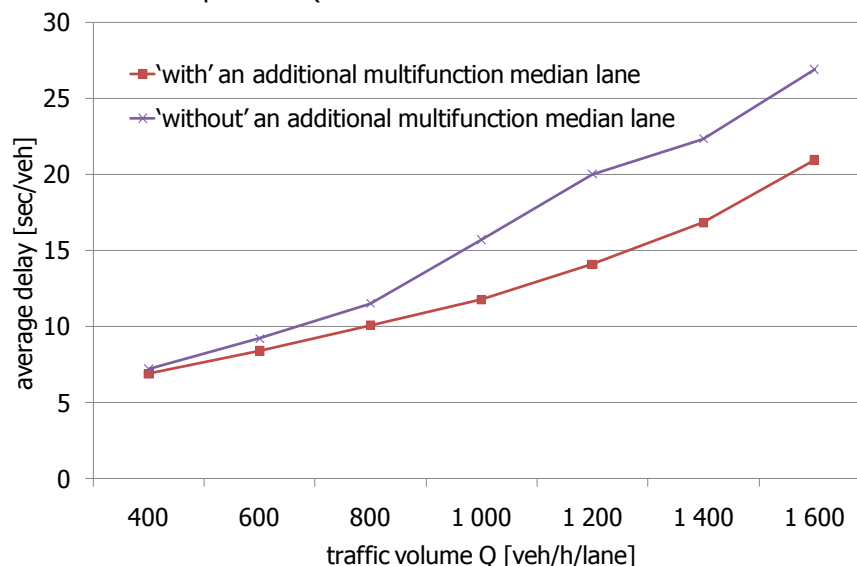


FIGURE 10 Impact of traffic volume on delay depending on traffic volume for a road cross-section 'with' and 'without' an additional multifunction median lane

RESULTS

On the basis of simulation research, the following conclusions were drawn:

- Using service roads connected with major road by means of two intersections located on the section ends (scenario 3) results in a substantial improvement of traffic performance. It is due to no disturbances occurring when driving over the section between two intersections. At the same time, high average journey speeds are achieved, over 53 km/h, irrespective of traffic volume, as well as low average delays (up to 20.4 sec/veh/km).
- A single intersection in the section centre servicing the entire local traffic (scenario 1) gives no rise to any substantial improvement of journey conditions, such intersection, resulting in vehicle platoons formed and in a decrease of average local speed.
- Modification of road surroundings service is of insignificant effect on platoon traffic percentage, irrespective of traffic volume. Both the type and location of access points in small communities determine the level of increase in the share of platoon traffic in a stream of vehicles alongside their length.
- The impact of residential driveways on delays and journey times is not significant. Only at volumes in the range of 2,000 veh/cross-section and traffic volumes on residential driveways exceeding 60 veh/h (60 driveways per 1 km), a noticeable impact of these driveways on road traffic performance can be observed.
- Significant effect of cross-section type on traffic performance. With the cross-section modified from two-lane with paved shoulders to a cross-section with an additional multifunction median lane, there is a decrease in average delays by ca. 5 sec/veh, i.e. by 33% (starting from 1,000 veh/h/lane).
- Apart from the analyses of road traffic performance, the authors also investigated road traffic safety using the "before and after" method for sections with a modified cross-section, i.e. after a multifunctional median lane was added. On the basis of the analyses on six sections modified by the multifunction median lane added, it has been found that the number of crashes and their victims was substantially reduced. It is related to the simultaneous drop of speed in free flow as compared with the section with paved shoulders.

CONCLUSIONS

On the basis of the analyses of the effectiveness of various types of service of road surroundings on suburban road sections the following conclusions can be drawn:

- models of estimation of traffic performance presented in the study indicate that any reconstruction of a road system accumulating over 15 residential driveways to one cross-section per kilometre of the road in passing through small localities improves traffic performance and reduces accident risk (1);
- use of a multifunctional median lane, particularly in cases where traffic volume exceeds 1,000 veh/h/lane in the cross-section leads to a marked improvement of road traffic performance and traffic safety. Therefore, such modification shall be promoted, especially when space required to construct service roadways is not available;
- traffic performance and safety are most affected by the length of road section with buildings. For that very reason, the proportion of such sections in the total road network should be reduced by promoting housing development along local road networks;
- analysis of traffic performance shows that on road sections with access control missing it is most advantageous to provide for such control by constructing service roads connected to the road by intersections located on section ends. Should providing a full control be impossible, it is recommended to use a section with multifunction median lane.
- The solution that is most economically effective and applied most frequently in Poland is modifying road cross-section by an additional median lane. Construction of service roads, despite some advantages, is undertaken only in cases when it is enforced by road technical condition standard.

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