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Study on the separated bus lanes effectiveness in city centres

A case study in Edinburgh and Bialystok

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Abstract

Purpose – Under deteriorating conditions of travelling in urban areas, especially city centers, prioritization of public transport is one of the main ways of its enhancing. In developed countries sophisticated control traffic systems are being implemented while in developing countries such solutions due to implementation cost are very rare. The purpose of this paper is to assess public transport operational effectiveness under diverse operational schemes present in two similar in size and traffic characteristics cities. The assessment is based on average journey times and speeds during peak and off peak hours.

Design/methodology/approach – The methodology includes measurements and estimates of bus rides through in-field measurements in Edinburgh, UK and in Bialystok, Poland. In-field evaluations have been conducted using average speed and travel times. The data were collected by utilizing a portable GPS data logger that allowed monitoring and recording bus position along tested streets in one second intervals. Traffic optimization in Edinburgh is provided by separated bus lanes and control urban traffic system while in Bialystok the only prioritization is supported by bus lanes. The research areas in Edinburgh and in Bialystok covered streets in city centers and adjacent districts.

Findings – The findings show large operational potential in developing separated bus lanes in city centers of developing countries when due to cost they cannot afford implementing advanced ITS solutions. The introduction of bus lanes should be proceeded even at the expense of individual users. It has been found that well developed road network in city center with separated bus lanes can provide operating speed at comparable levels to speed of buses operating along lower volume corridors.

Originality/value – The comparison of bus lanes working under different traffic management conditions was carried out. Conducted analyses showed great potential of proper planning strategy of road network development toward the improvement of public transport performance.

Keywords ITS, Separated bus lanes, Public transport priority, City center, Urban traffic control system

Paper type Research paper

Introduction

The continuous increase in car usage has lead to the development of road congestion in most developed cities. This phenomenon has also been present in developing countries since cars became more easily accessible goods. Urban areas and especially city centers characterize with very high traffic volumes and commonly suffer from congestion which in turn severely decreases the quality of transport service. Local authorities all

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This paper has been published in a conference proceedings publication by WASD in 2015.

World Journal of Science, Technology and Sustainable Development
Vol. 12 No. 4, 2015
pp. 257-268
Emerald Group Publishing Limited
2042-5945
DOI 10.1108/WJSTSD-06-2015-0033

over the world (Mulley, 2011; Xinchen and Wanjing, 2013; Zyryanov and Mironchuk, 2012) have to deal with the phenomenon of congestion by different means, trying to either limit urban center's roadway space for individuals or to implement bus prioritization. Since public transport is a key factor to account when dealing with traffic congestion problems local authorities tend to improve its attractiveness and performance by offering priorities to buses in order to reduce overall bus journey time and improve regularity as well as to enhance their reliability and attractiveness. Buses play an important role in public transport context because they can effectively use limited road space, carrying many more passengers than private cars for a given amount of road space. The main problem is that they usually share the road infrastructure with other traffic and are equally affected by congestion (Levinson *et al.*, 1973; Shalby, 1999; TCRP, 2010). Hence potential improvement of their operational conditions by implementation of bus priority measures arises. Among possible schemes such as bus gate, bus lanes, bus priority in traffic signalization, bus malls, etc., separated bus lanes become widely accepted and most used as a mean allowing overtaking occurring queues in peak hours, alleviating road congestion and reserving restricted road space in densely built-up areas.

A bus lane is generally a lane restricted to buses but depending on local solutions that restriction often does not apply to certain other vehicles. Dedicated bus lanes are typically applied on major routes or where traffic congestion may significantly affect reliability or may only be used to bypass a single congestion point such as an intersection. Bus lanes may also function as a contra-flow bus lane allowing buses to travel in the opposite direction to other vehicles. Bus lanes can operate as restricted lanes round the day or at certain times of the day only, usually during rush hours, allowing all vehicles to use the lane at other times. Lanes may be located immediately at the curb or in an offset configuration (Neves, 2006; Mulley, 2010).

In developed countries existing bus lanes are often enhanced by implementation of advanced traffic management (ATM) solutions to further improve the flow of vehicle traffic. Such an ATM system is present in Edinburgh (SCOOT). On the other hand in developing countries due to cost limitation, only a simplified solution instead of advanced systems are being introduced. Such a prioritization creating "green wave" along main arterials running through city center exists in Bialystok. However, that prioritization is not devoted to buses but to improve general vehicle traffic and is being activated only under heavy traffic presence during rush hours. Directional prioritization is further dependent on temporary traffic intensity.

For above mentioned the aim of this paper is to evaluate and assess public transport operational effectiveness under diverse operational schemes present in two cities.

Bus priority schemes in Edinburgh

In 2007 commission work was developed for plans for public transport priority schemes in Edinburgh. The scheme considered the potential for improvements in bus routes as well as other engineering measures in order to improve bus journey times. The first phase of the scheme comprised public transport infrastructure improvements at seven locations mainly at the southeast of Edinburgh. These were delivered as a whole package or as individual measures, dependent on available funding. It was also concluded that the most appropriate funding would be a combination of the Council's own capital funds and developers' contributions. Given available finance, a phased approach to the introduction of measures was recommended.

A review and an assessment of a range of possible implementation of bus priority schemes including guided busways were investigated and considered for implementation in Edinburgh city. The off-road unguided busways, bus lanes on-street with and without road widening and general bus priority measures were considered as most feasible. A range of specific bus priority options were considered and investigated for all routes and sections, including off-road busways, on-street bus lanes, local road widening and traffic signal priority. Investigation of the risks associated with the proposed route options in the study, such as land acquisition and securing statutory powers as well as the environmental impact and benefits were also considered.

Public transport and bus priority schemes in Bialystok

Bus priority schemes in Bialystok involve generally separated on-street bus lanes (with flow). First bus lanes have been established in the middle of the previous decade and were designed to bypass congested intersections. Presently the total length of separated lanes is 12.6 km. Since 2005 city authorities have been conducting redevelopment of the city road network focussing long-term strategy on public transport prioritization. It has resulted so far in replacement of 90 percent of bus fleet, putting in service ring road surrounding the city center in 2009 (the strategy foresees creation two additional rings in the five years' perspective to further relieve city center from individual traffic) and rebuilding main arterials adopting them into the increased traffic volumes. In the city center major traffic flows are handled by two arterials cutting the center from north to south and from west to east. First corridor with separated bus lanes in the city center was completed and put into operation along Kaczorowskiego Street in 2011. By the end of a year 2013 another bus lanes have been put into operation along two main arterials in the city center. Corridors with curb separated bus lanes are presented in Figure 1.

Methodology

In order to investigate impacts of bus lanes on bus vehicles performance best procedure is to compare data before and after bus lane implementation. The lack of available "before" data enforced different approach. It was attempted to select two corridors which are similar in terms of the traffic flow characteristics as well as the general geometrical characteristics. Driving data were collected by utilizing a portable GPS data logger that allowed monitoring and recording bus position along tested streets in one second intervals. The data were investigated on corridors where one corridor had a separated bus lane and the other one had no such a priority (corridor with mixed traffic). For detail study two single carriageways were selected in Edinburgh area whereas in Bialystok four dual carriageway corridors were chosen. To assess operational effectiveness of bus lanes located in Bialystok city center basic parameters describing driving cycle are compared with the same characteristics recorded along corridors located outside the center. Additionally to compare the performance of buses operating under traffic control system in Edinburgh with buses performance in similar in terms of traffic and geometric conditions in Bialystok a single carriageway street located in city center was chosen.

Edinburgh bus traffic corridors

A7 corridor

The A7 begins its course in central Edinburgh, at the A1/A7/A8/A900 junction at North Bridge as a non-trunk road before passing through the city's south-eastern suburbs. This part of the A7 was the former route of the A68 (the old A7 used to be what the A701/A772

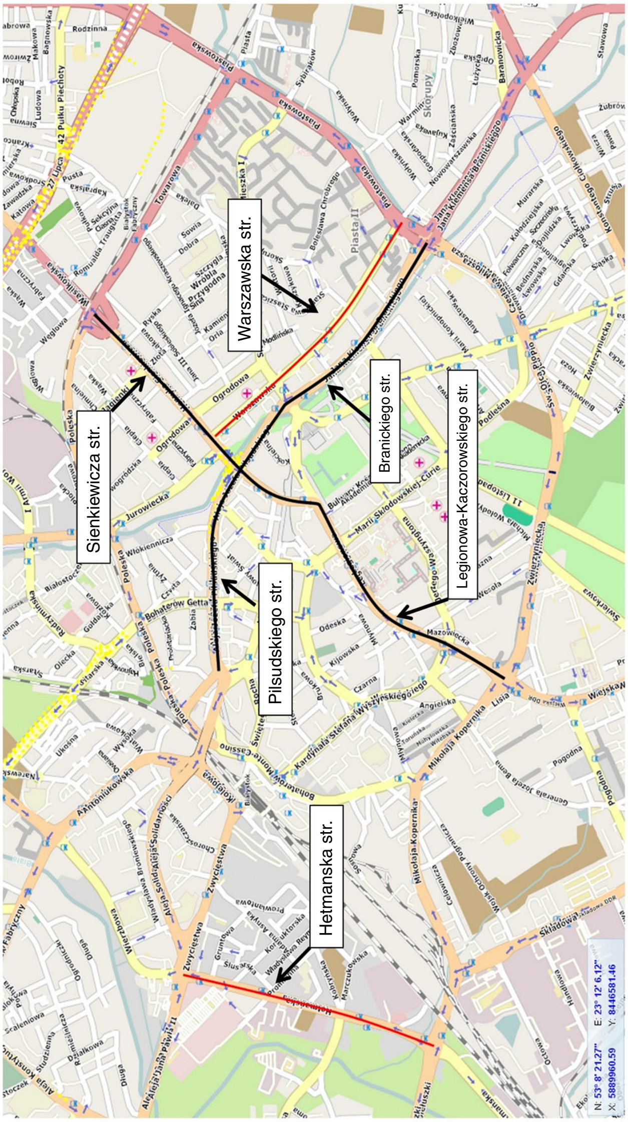

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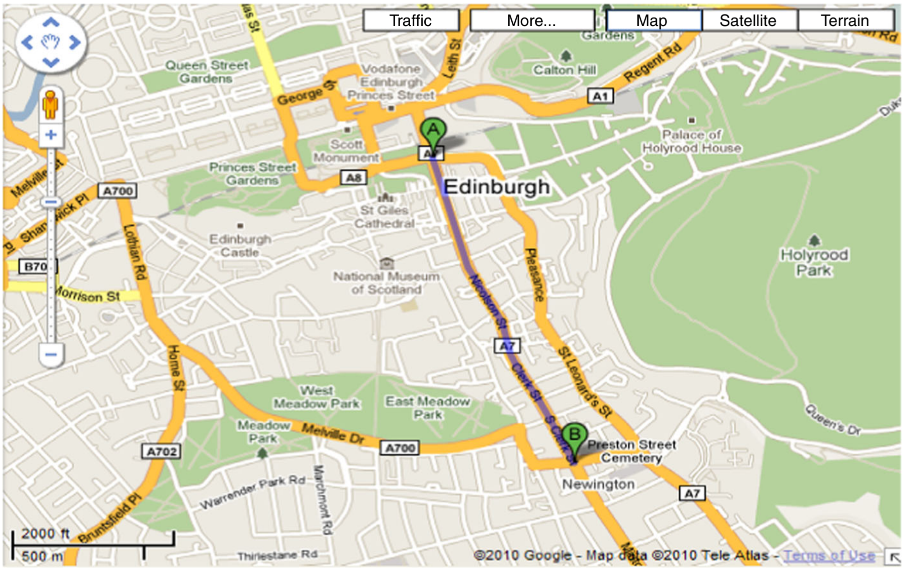
Figure 1.
Location of corridors with separated bus lanes in the city center of Bialystok

at Gilmerton is now). The measurements of driving cycle on the A7 started from North Bridge/Market Street's traffic signal to South Clerk Street/W Perston Street's traffic signal. The A7 corridor is a single carriageway; it has two lanes, one lane for buses and other one for all other type of vehicles. The length of the investigated corridor is approximately 1.45 km (Figure 2). Table I shows the characteristics of this corridor.

The corridor is very busy during the peak hours, because the investigated part has six signalised junctions. The corridor has seven bus stops inbound and eight bus stops outbound. It has six pedestrian crossings in both directions. The buses frequency are 57 inbound and 57 outbound. This corridor has ten bus routes for each direction.

A702 (corridor has no bus lane)

The A702 corridor starts as a primary route at the Tollcross junction in Edinburgh, and continues south until it meets the Edinburgh City Bypass (A720) on the city's outskirts. In the city is known as Home Street, Leven Street, Bruntsfield Place, Morningside Road, Comiston Road and finally Biggar Road. The route is a major commuter route for residents of Carlops, West Linton and Biggar who work in and around the Edinburgh area. The measurements of driving cycle on A702 started from Tesco Metro at the junction of Colinton Road with Morningside Road and continued onto the junction of



Source: Google maps

Figure 2. The A7 traffic corridor

The corridors Direction	Number of bus stops In	Out	Number of signalised junctions In	Out	Number of pedestrians crossing In	Out	Bus frequency/hr In	Out	Number of bus routes In	Out	Type of road In/Out	Number of lanes In/Out	Length of the corridor In/Out
A7 (bus lane)	7	8	6	6	6	6	57	57	10	10	Single carriageway	2	1.45 km

Table I. The characteristics of the A7 corridor

Comiston Road with Greenbank Crescent. The A702 corridor is a single carriageway; it has two lanes on both directions, both of the lanes are for all type of vehicles, and there is no lane dedicated for buses. The length of the investigated corridor is approximately 1.6 km (Figure 3). Table II shows the general characteristics of the corridor.

The corridor is very busy during the peak hours, because the investigated part has six signalised junctions. The corridor has seven bus stops inbound and five bus stops outbound. It has five pedestrians crossing in both directions. The buses frequency are 36 inbound and 36 outbound. This corridor has six bus routes for each direction.

Bialystok bus traffic corridors

Northsouth corridor (Sienkiewicza-Legionowa-Kaczorowskiego Street)

Those are the main arterials running through the city center (Figure 1). The total length of the corridor is 4.2 km. Sienkiewicza Street is a dual carriageway with originally two lanes in each direction but curb lanes have been transformed into bus lanes and thus the area for mix traffic was limited to one lane in each direction. Legionowa and Kaczorowskiego Streets are also dual carriageways but with three lanes in each direction; the curb lane is devoted only for buses so that two lanes remain for other type of vehicles. Characteristics of this corridor are presented in Table III.

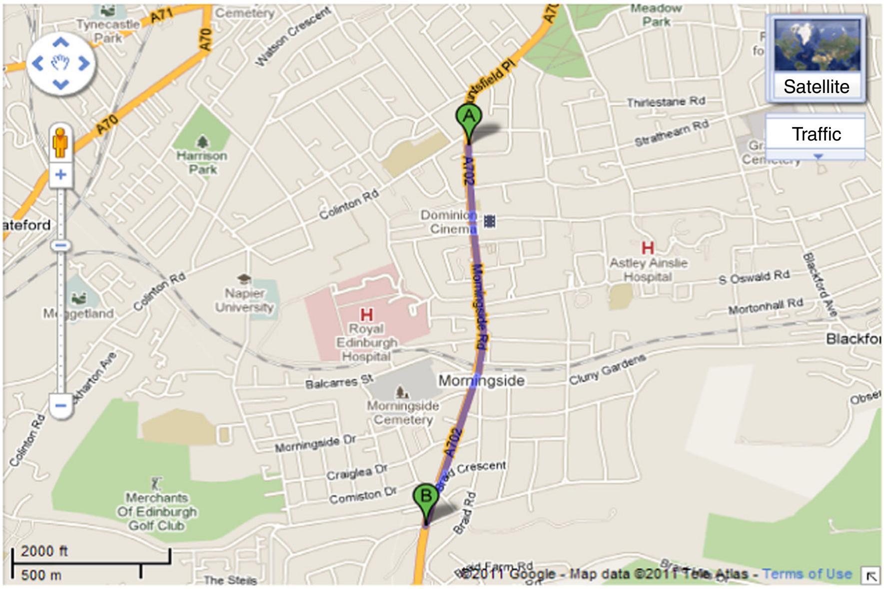


Figure 3.
The A702 corridor

Source: Google maps

Table II.
The characteristics of the A702 corridor

The corridors Direction	Number of bus stops In	Out	Number of signalised junctions In	Out	Number of pedestrians crossing In	Out	Bus frequency In	Out	Number of bus routes In	Out	Type of road In/Out	Number of lanes In/Out	Length of the corridor In/Out
A702 (mixed traffic)	7	5	5	5	5	5	36	36	6	6	Single carriageway	2	1.6 km

Westeast corridor (Piłsudskiego-Branickiego Street)

Piłsudkiego Street and Branickiego Street creates a main corridor on west-east direction in the city center (Figure 1). It is a dual carriageway corridor and the streets have been modernized from 2/2 cross section into 2/3 in order to introduce external lane devoted for buses. The total length of the investigated corridor is 3.3 km and it has three lanes in each direction with curb lanes devoted for buses. Table IV presents characteristics of the westeast corridor.

Hetmanska/Warszawska corridors

Hetmanska Street was chosen as a comparative corridor for northsouth and westeast corridors. This street is a dual carriageway located outside of the city center and it has three lanes in each direction with no dedicated lanes for buses. The measurements of driving cycles started from Hetmanska/Zwyciestwa's traffic signal to Hetmanska/ Popieluszki's traffic signal. The length of the route is 1.45 km. Warszawska Street was chosen to enable a comparison of a single carriageway operating under traffic control system in Edinburgh with a similar corridor in Bialystok operating without such a system. Warszawska Street is located in the city two-lane street for mixed traffic; its length is 1.56 km and Table V presents characteristics of those two corridors.

The corridors	Number of bus stops		Number of signalised junctions		Number of pedestrians crossing		Bus frequency/hr		Number of bus routes		Type of road	Number of lanes	Length of the corridor
Direction	In	Out	In	Out	In	Out	In	Out	In	Out	In/Out	In/Out	In/Out
Sienkiewicza	3	4	7	7	7	7	48	48	19	19	Dual carriageway	2	1.8 km
Legionowa-Kaczorowskiego	4	3	4	4	6	6	33	33	10	10	Dual carriageway	3	2.4 km

Table III. The characteristics of the northsouth corridor

The corridors	Number of bus stops		Number of signalised junctions		Number of pedestrians crossing		Bus frequency/hr		Number of bus routes		Type of road	Number of lanes	Length of the corridor
Direction	In	Out	In	Out	In	Out	In	Out	In	Out	In/Out	In/Out	In/Out
Pilsudskiego	3	3	3	3	4	4	45	45	11	11	Dual carriageway	3	2.2 km
Branickiego	3	2	2	2	3	3	27	27	8	8	Dual carriageway	3	1.1 km

Table IV. The characteristics of the northsouth corridor

The corridors	Number of bus stops		Number of signalised junctions		Number of pedestrians crossing		Bus frequency/hr		Number of bus routes		Type of road	Number of lanes	Length of the corridor
Direction	In	Out	In	Out	In	Out	In	Out	In	Out	In/Out	In/Out	In/Out
Hetmanska	3	3	2	2	4	4	21	21	5	5	Dual carriageway	3	1.45 km
Warszawska	2	3	1	1	6	6	13	13	3	3	Single carriageway	3	1.56 km

Table V. The characteristics of the westeast corridor

Analysis of the performance of buses on the corridors in Edinburgh

Table VI presents the data to be analyzed for the buses travelling on both corridors within Edinburgh city. From this we can see that there is a slight increase in journey time of 7.8 seconds for the off peak journey time when compared to the peak journey time on A702 corridor. This is, however, contrary to the average speed data whereby the traffic is flowing at an average of 0.4 km/hr faster in the off peak time period. The reasoning behind this discrepancy in the data is due to the fact that the route observed in the peak time period is in fact on average 84 meter shorter than the one examined in the off peak time period. When this is allowed for and the length of the off peak journey time is adjusted to have a same length as the peak journey and assuming a similar average speed we see that the overall journey time can be interpolated as being 351 seconds. This is in line with the expected results for the observations given that there will invariably be a reduction in overall traffic flows and passenger numbers during the off peak time period.

In case of A7 corridor the difference in average time during peak and off-peak hours is almost the same and does not exceed 4 percent. However comparing A7 and A702 corridors it is visible that the average speeds along A702 corridor are higher by 7.2 and 13.5 percent then the average speeds along A7 corridor during peak and off-peak hours, respectively. That reveals the fact that journey conditions on outskirts remain distinctly better than in the city center.

Analysis of the performance of buses on the corridors in Bialystok

From the data presented in Table VII we can observe that except of Sienkiewicza Street the average journey time during off peak periods is generally shorter when compared the peak time trips. However the differences in average speeds between those periods are not high and vary from 1.35 percent (Branickiego corridor) to 5.9 percent (Legionowa-Kaczorowskiego corridor). In case of Branickiego Street average travel

Table VI. Summary statistics of bus driving cycle parameters on corridors in Edinburgh

Route	Time	Average time (second)	Average speed (km/h)	Average length (meter)	Route	Average time (second)	Average speed (km/h)	Average length (meter)
A702 (no bus lane road)	08.00-09.00 a.m.	351	16.4	1,563	A7 (with bus lane)	354	15.3	1,482
	02.00-03.00 p.m.	359	16.8	1,647		365	14.8	1,474

Table VII. Summary statistics of bus driving cycle parameters on the corridors with bus lanes

Route	Time	Average time (second)	Average speed (km/h)	Average length (meter)	Route	Average time (second)	Average speed (km/h)	Average length (meter)
Sienkiewicza	08.00-09.00 a.m.	264	24.5	1,800	Legionowa-Kaczorowskiego (L-K)	368	23.5	2,400
	11.00-12.00 p.m.	354	18.3	1,800		347	24.9	2,400
Pilsudskiego	08.00-09.00 a.m.	349	22.7	2,200	Branickiego	176	22.5	1,100
	11.00-12.00 p.m.	332	23.8	2,200		165	22.2	1,100

speed remains at a constant level regardless the time of a day. Opposite situation appears in the case of Sienkiewicza Street where average speed recorded during off peak time (24.5 km/h) is almost 32 percent higher than average speed during the peak time period. This irregularity can be explained by signalised junctions and their coordination. Along the corridor all signalised junctions work in coordination which is being activated during the morning and afternoon peaks when traffic achieves a certain intensity. In the time between peak hours coordination is off and buses and commuters experience an increased number of forced stops and delays.

That influence and dependency of increased number of stops on average journey time, fluency and speed was also observed along corridors with no bus lanes. However, provided that the increased number of stops along corridors with priorities results from the presence of signalised junctions and lack of coordination then in case of corridors with no priorities the reason can lay in higher traffic intensity during peak periods as well as unlimited accessibility to those corridors. That in turn can lead to more dynamic driving when bus driver expecting difficulties on roads try to regain possible lost time on forced stops what can be observed in Figure 4. On collector streets running through residential areas in peak hours individuals join into the main traffic stream not only at junctions but also at a number of entering points what negatively effects traffic fluency.

Table VIII presents data gathered on corridors without bus lanes to be compared with corridors offering bus priorities. First average speeds on Hetmanska Street as could be expected are distinctly higher then on Warszawska Street. That results from the localization outside of the city center and the characteristic of a cross section. Essentially lower traffic intensity during off-peak hours allows to achieve distinctly higher average speeds. However, despite the fact that traffic intensity during peak hours in the city center area is higher than in outskirts the average speeds on corridors with bus lanes during peak hours are higher than values recorded on Hetmanska Street.

The estimation of driving fluency, essential from the point of view of reliability and punctuality of bus services, can be expressed by the difference in average speeds between peak and off-peak hours. Based on the data presented in Table VIII it can be concluded that the presence of bus lanes provides better driving fluency. In that case the differences in average speeds do not exceed 5.9 percent whereas in case of Hetmanska And Warszawska Streets those differences reach a value of 15 percent and 17.2 percent, respectively. The only exception applies to Sienkiewicza Street with a higher number of junctions.

Average journey speeds registered along all investigated corridors are presented in Figure 5.

Data presented in Figure 5 presents average speeds on examined corridors in both cities during peak-hours. First, we can state a significant difference in average speeds between dual and single carriageways. Corridors with higher number of driving lanes in each direction generally provide buses with better travel conditions and the average speed is higher by 6.8 km/h (41.4 percent) then speed recording along single carriageways. Second, analysing single carriageway corridors it occurs that the average journey speed along A702 corridor being managed by the traffic management system (SCOOT) is lower by 21 percent then the average speed on Warszawska Street during peak hours. During off-peak hours this difference is even higher and reaches 47.3 percent. It is also noticeable that a presence of a bus lane on A7 corridor is effective and the average speed on lower by 6.7 percent when compared to A702 corridor. During off peak hours that difference is even more distinct and rises to 11.9 percent.

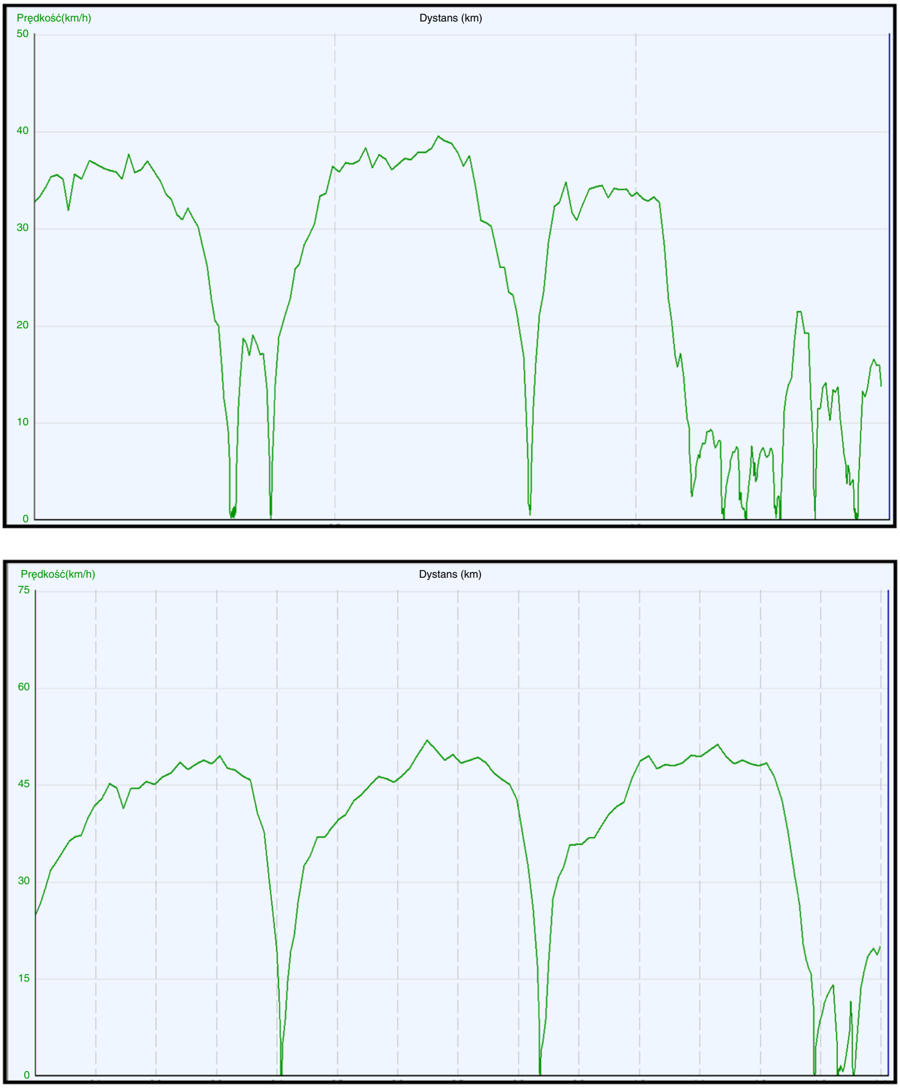


Figure 4.
Speed profiles along Warszawska Street

Notes: During (a) peak hour and (b) off-peak hour

Conclusions

The operational effectiveness of reserved bus lanes was evaluated in the paper. The effectiveness was primarily measured by an average journey time and speed. Different traffic and geometry conditions in terms of number of driving lanes and traffic management were taken into consideration.

Research results showed that the separated bus lanes in Bialystok are very effective and the average speeds on those corridors remain at comparable and higher levels when compared to the average bus speeds recorded on a reference street located away from the city center. However their effectiveness depends on a number of signalised intersections in relation to the overall number of driving lanes. During peak hours due to higher traffic intensity the average journey times are generally longer then during off peak periods and so the average speeds were higher in off peak hours with one exception recorded on Sienkiewicza Street. The data from that corridor showed a great potential in possible improvements of average journey speeds that can be ensured by proper traffic management and incorporation of efficient traffic management system.

However, research results from Edinburgh showed that the potential of ATM system may also be limited and not enough to ensure proper bus performance if traffic volume is very heavy.

Generally the data from Edinburgh A7 corridor showed that it is desirable and justified to favour public transport in crowded city centers over other vehicles even more extensively in order to provide for driving conditions comparable to those existing on the outskirts. The average speeds recorded on the A7 corridor in the city center with bus lane were at comparable levels to those recorded on the A702 with no bus lane.

However, comparing the average speeds in Edinburgh and Bialystok it can be concluded that the presence and operation of ATM system, under which the public transport is being operated in Edinburgh city center, may not be enough to ensure proper bus performance if traffic volume is too intensive. Considering the restrictions in roadway space in city centers that can be intended for separated/additional bus lanes further activities like limited accessibility for private users to city centers should be considered. On the other hand the outcomes from Bialystok show that the implementation of highly cost traffic management systems should be think deeply and also preceded by the analyses of implementation of other, more economic solutions. In some cases well-developed road network with separated bus lanes in city center can provide operating speed at sufficient level if signalised junctions operate in coordination.

Table VIII. Summary statistics of bus driving cycle parameters on the corridors with no bus lanes

Route	Time	Average time (second)	Average speed (km/h)	Average length (meter)	Route	Average time (second)	Average speed (km/h)	Average length (meter)
Hetmanska	08.00-09.00 a.m.	214	21.9	1,450	Warszawska	310	18.6	1,600
	11.00-12.00 p.m.	186	25.2	1,450		264	21.8	1,600

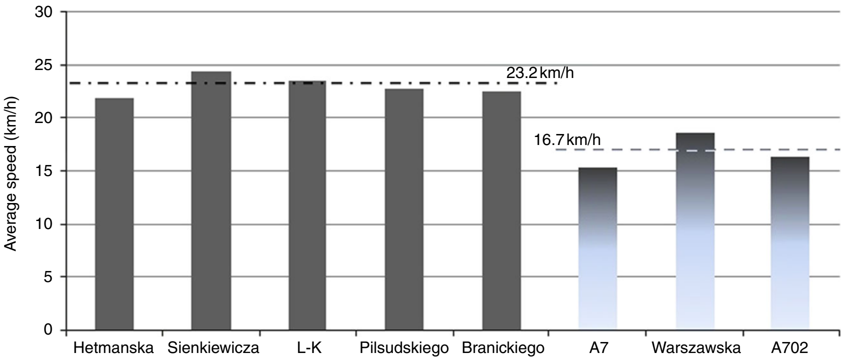


Figure 5. Average speeds along studied corridors during peak hours

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