OUTLOOK 2015

12

WORLD ASSOCIATION FOR SUSTAINABLE DEVELOPMENT

STUDY ON THE PUBLIC TRANSPORT OPERATION EFFECTIVENESS UNDER DIVERSE ROAD AND TRAFFIC CONDITIONS: LESSONS FOR SUSTAINABILITY?

WAFAA SALEH*

Edinburgh Napier University, UK

Transport Research Institute,
Edinburgh Napier University,
Edinburgh, Scotland, UK
E-mail: w.saleh@napier.ac.uk

ROBERT ZIOLKOWSKI

Bialystok University of Technology, Poland

Faculty of Civil and Environmental Engineering,
Department of Road Engineering,
Bialystok University of Technology,
45A Wiejska Street, Bialystok 15-351, Poland
E-mail: robert.ziolkowski@pb.edu.pl

ABSTRACT

Purpose: Under deteriorating conditions of travelling in urban areas, especially city centres, prioritisation 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 paper aims to assess public transport operational effectiveness under diverse operational schemes present in two 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, England and in Bialystok, Poland. In-field evaluations have been conducted using average speed and travel times. The data were collected by utilising a portable GPS data logger that allowed monitoring and recording bus position along tested streets in 1 sec intervals. Traffic optimisation in Edinburgh is provided by separated bus lanes and control urban

*Corresponding author

traffic system while in Bialystok the only prioritisation is supported by bus lanes. The research areas in Edinburgh and in Bialystok covered streets in city centres and adjacent districts.

Findings: The findings show large operational potential in developing separated bus lanes in city centres 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 centre 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 towards the improvement of public transport performance.

Keywords: separated bus lanes; public transport priority; ITS; city centre; urban traffic control system.

INTRODUCTION

The continuous increase in car usage has lead to the development of road congestion in most of developed cities. This phenomenon has also been present in developing countries since cars became more easily accessible goods. Urban areas and especially city centres characterise with very high traffic volumes and commonly suffer from congestion what in turn severely decreases the quality of transport service. Local authorities all over the world (Mulley, 2011; Xinchen and Wanjing, 2013; Zyryanov and Mironchuk, 2012) has to deal with the phenomenon of congestion by different means trying to either limit urban centre's roadway space for individuals or to implement bus prioritisation. 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 arise potential improvement of their operational conditions by implementation of bus priority measures. Among possible schemes such as bus gate, bus lanes, bus priority in traffic signalisation, 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 (Mulley, 2010; Neves, 2006).

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 South East 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 focusing long-term strategy on public transport prioritisation. It has resulted so far in replacement of 90% of bus fleet, putting in service ring road surrounding the city centre in 2009 (the strategy foresees creation two additional rings in the five years' perspective to further relieve city centre from individual traffic) and rebuilding main arterials adopting them into the increased traffic volumes. In the city centre major traffic flows are handled by two arterials cutting the centre from north to south and from west to east. First corridor with separated bus lanes in the city centre 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 centre. Corridors with curb separated bus lanes are presented in Figure 1.

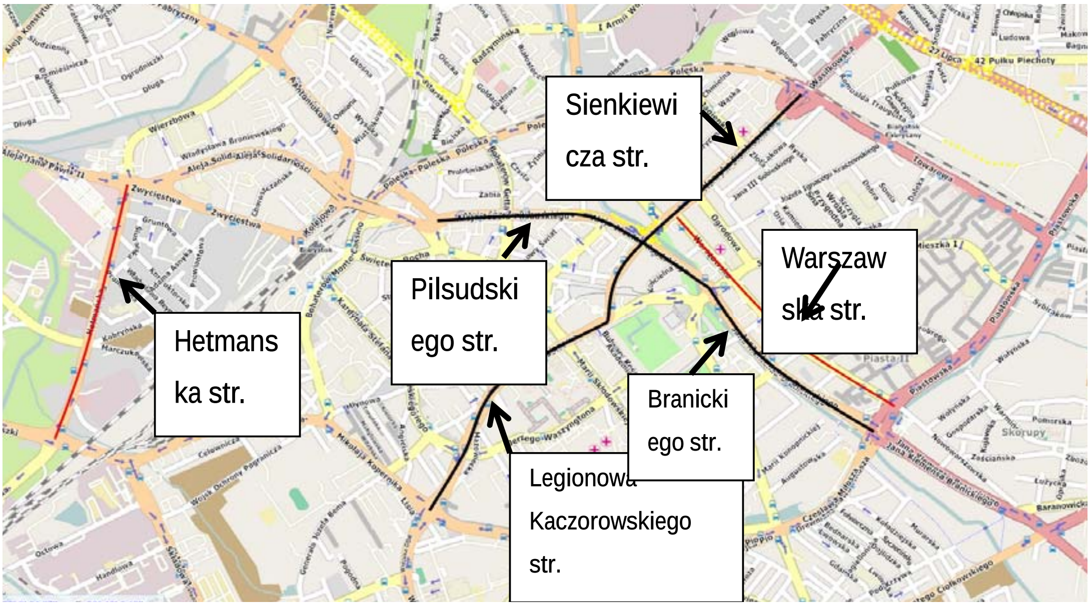


Figure 1 Location of corridors with separated bus lanes in the city centre of Bialystok

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 was investigated on such traffic corridors of which one corridor had a separated bus lane and the other one had no such 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 centre basic parameters describing driving cycle are compared with the same characteristics recorded along corridors located outside the centre. 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 centre 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 at Gilmerton is now). The measurements of driving cycle on the A7 started from North Bridge/Market Street's traffic signal to South Clerk St/W Perston St'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 1 shows the characteristics of this corridor.

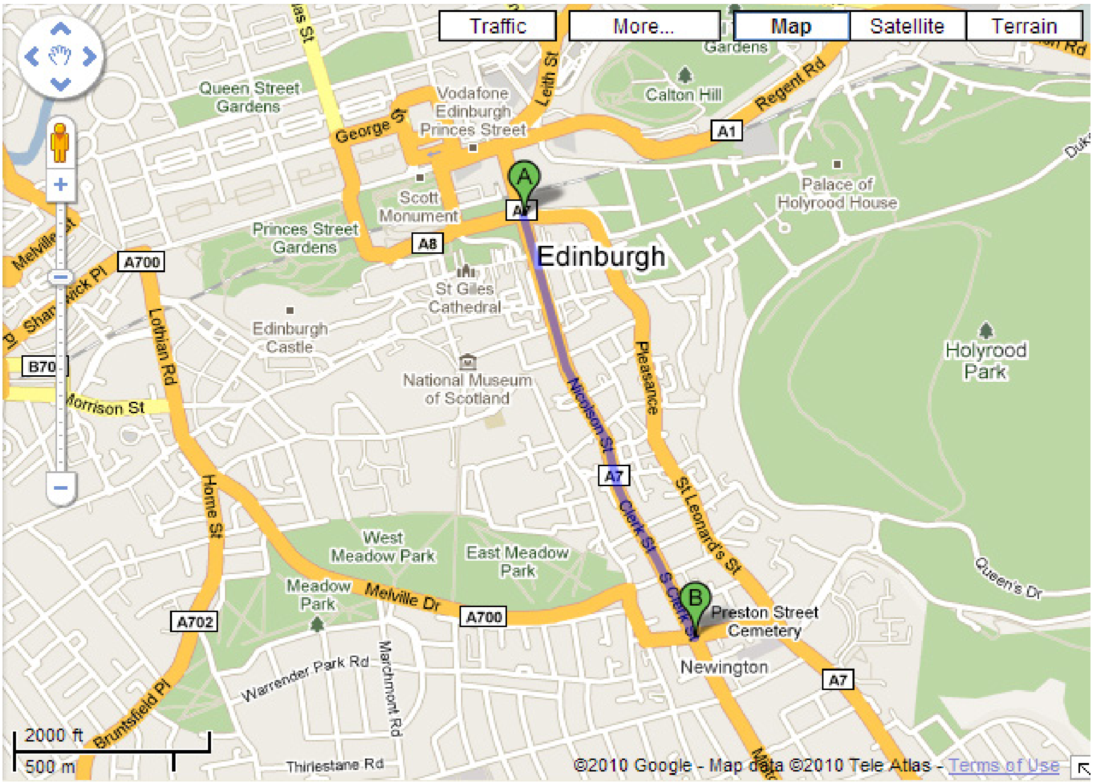
The corridor is very busy during the peak hours, because the investigated part has six signalised junctions. The corridor has seven bus stops inbound and eight bus stops outbound. It has six pedestrian crossings in both directions. The buses frequency are 57 inbound and 57 outbound. This corridor has 10 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

Table 1 The characteristics of the A7 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*
A7 (Bus lane)	7	8	6	6	6	6	57	57	10	10	Single carriageway	2	1.45 km



Source: Google Maps.

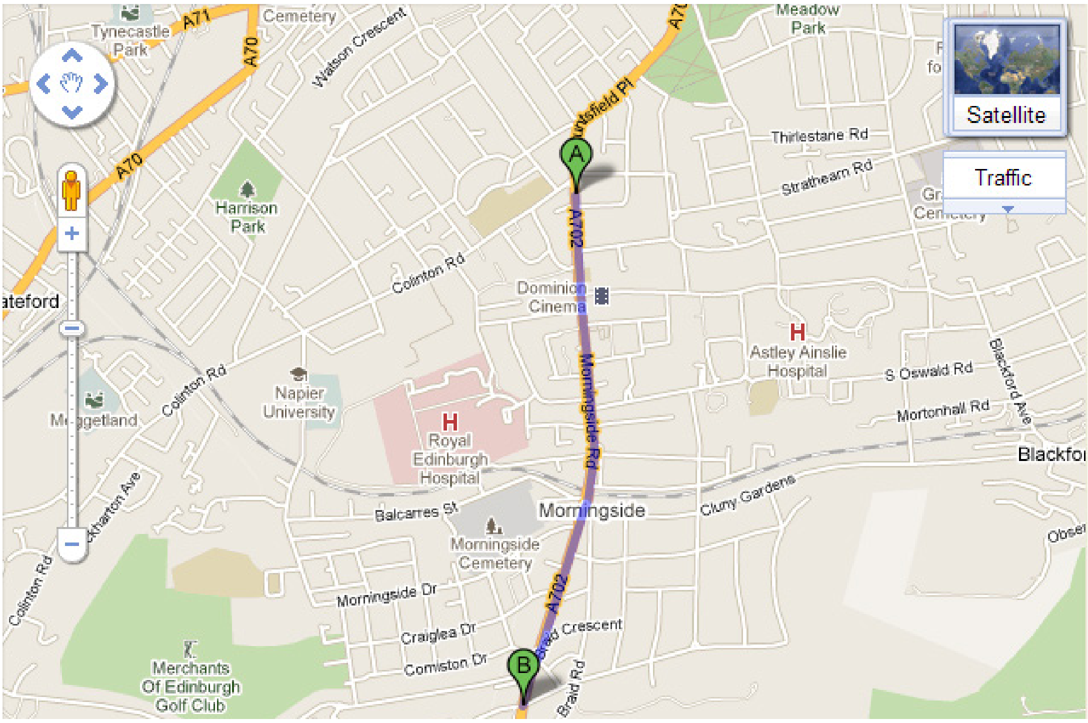
Figure 2 The A7 traffic corridor

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 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 invest igated corridor is approximately 1.6 km (Figure 3). Table 2 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.

Table 2 The characteristics of the A702 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*
A702 (Mixed traffic)	7	5	5	5	5	5	36	36	6	6	Single carriageway	2	1.6 km



Source: Google Maps.

Figure 3 The A702 corridor

BIALYSTOK BUS TRAFFIC CORRIDORS

Nort-south corridor (Sienkiewicza-Legionowa-Kaczorowskiego St)

Those are the main arterials running through the city center (Figure 1). The total length of the corridor is 4.2 km. Sienkiewicza St. 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 3.

Table 3 The characteristics of the north-south 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*
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

West-east corridor (Piłsudskiego-Branickiego St)

Piłsudkiego St. and Branickiego St. creates a main corridor on west-east direction in the city centre (Figure 1). It is a dual carriageway corridor and the streets have been modernised 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 4 presents characteristics of the west-east corridor.

Table 4 The characteristics of the north-south Corridor

The corridors	*Number of bus stops*		*Number of Sig nalised junctions*		*Number of pedes-trians crossing*		*Bus fre-quency/ 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

Hetmanska/Warszawska corridors

Hetmanska St. was chosen as a comparative corridor for north-south and west-east corridors. This street is a dual carriageway located outside of the city centre 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 St. 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 St. is located in the city two-lane street for mixed traffic; its length is 1.56 km and Table 5 presents characteristics of those two corridors.

Table 5 The characteristics of the west-east corridor

The corridors	*Number of bus stops*		*Number of Sig nalised junctions*		*Number of pedes-trians crossing*		*Bus fre-quency/ 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

ANALYSIS OF THE PERFORMANCE OF BUSES ON THE CORRIDORS IN EDINBURGH

Table 6 presents the data to be analysed 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 sec 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 82 m 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 sec. 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.

ANALYSIS OF THE PERFORMANCE OF BUSES ON THE CORRIDORS IN BIALYSTOK

From the data presented in Table 7 we can observe that except of Sienkiewicza St. 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% (Branickiego corridor) to 5.9% (Legionowa-Kaczorowskiego corridor). In case of Branickiego street average travel speed remains at a constant level regardless the time of a day. Opposite

Table 6 Summary statistics of bus driving cycle parameters on corridors in Edinburgh

Route	Time	Average Time (Sec)	Average Speed (Km/h)	Average Length (Meter)	Route	Average Time (Sec)	Average Speed (Km/h)	Average Length (Meter)
A702 (no bus lane road)	8.00–9.00 AM	351	16.4	1563	Princes St (bus only road)	286	14.2	1091
	2.00–3.00 PM	359	16.8	1647		224	19.4	1206

Table 7 Summary statistics of bus driving cycle parameters on the corridors with bus lane

Route	Time	Average Time (Sec)	Average Speed (Km/h)	Average Length (Meter)	Route	Average Time (Sec)	Average Speed (Km/h)	Average Length (Meter)
Sienkie-wicza	8.00–9.00 AM	264	24.5	1800	Legion-owa-Kaczo-rowskiego	368	23.5	2400
	11.00–12.00 PM	354	18.3	1800		347	24.9	2400
Pilsud-skiego	8.00–9.00 AM	349	22.7	2200	Branick-iego	176	22,5	1100
	11.00–12.00 PM	332	23.8	2200		165	22.2	1100

situation appears in case of Sienkiewicza street where average speed recorded during off peak time (24.5 km/hr) is almost 32% 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. In the time between peak hours coordination is off and buses and commuters experiences an increased number of forced stops (Figure 4).

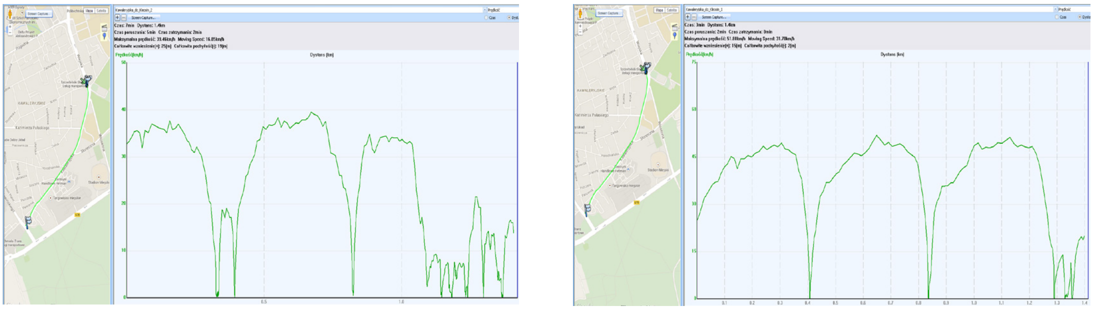


Figure 4 **Speed profiles along Warszawska St during a) peak hour and b) off-peak hour**

That influence and dependency of increased number of stops on average journey time 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. Both streets are collector streets and run through residential areas so in the peak hours individuals join in the main stream not only at junctions but also in a number of entering points what negatively effects traffic fluency. Table 8 presents data gathered on corridors without bus lanes to be compared with corridors offering bus priorities. An average journey speed was higher in off peak hours then in peak hours by 15% in case of Hetmanska St. and by 17.2% in case of Warszawska St. Average journey speeds registered along all investigated corridors are presented in Figure 5.

Table 8 **Summary statistics of bus driving cycle parameters on the corridors with no bus lanes**

Route	*Time*	*Average Time (Sec)*	*Average Speed (Km/hr)*	*Average Length (Meter)*	*Route*	*Average Time (Sec)*	*Average Speed (Km/hr)*	*Average Length (Meter)*
Hetmanska	8.00–9.00 AM	214	21.9	1300	Warszawska	310	18.6	1600
	11.00–12.00 PM	186	25.2	1300		264	21.8	1600

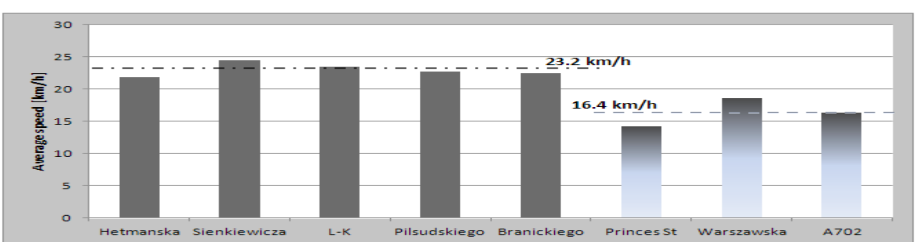


Figure 5 **Average speeds along studied corridors during peak hours**

Data presented in Figure 5 shows average speeds on examined corridors in both cities. Firstly, 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 an average speed is higher by 6.8 km/hr (41.4%) then speed recording along single carriageways. Secondly, analysing single carriageway corridors it occurs that average journey speed along Princes St. which is under the traffic management system (SCOOT) is lower by almost 30% then average speed on Warszawska St. It can be stated that under adverse traffic conditions even sophisticated traffic management system which control most of the city centre traffic signals may not be enough to achieve speed at satisfactory level.

Also comparing average speeds along Princes and A702 corridors it is revealed that disadvantageous geometric conditions in the city centre may have worse influence of public transport functionality then high volume of traffic.

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 average speed on corridors remain at comparable level with the average bus speed on recorded on a reference street located away from the city centre. However their effectiveness depends on traffic volumes and number of signalised intersections in relation to the overall number of driving lanes. During peak hours due to higher traffic intensity average journey times are generally longer then during off peak periods and so the average speed was higher in of peak hours with one exception recorded on Sienkiewicza St. case shows a great potential in possible improvement of average journey speed and limitation that can be ensured by proper coordination of the following signalised intersections.

Research results from Edinburgh A7 corridor show that it is desirable to favour public transit even more extensively over other vehicles especially in city centres due to the basic role of public transport in the city. Considering the limitations of roadway space that can be designed for separated bus lanes even sophisticated traffic management system may not be enough to ensure proper bus performance if severe traffic volume will not be limited. It is rationale to maintain the bus speed at reasonable level in order to improve the reliability of bus service.

REFERENCES

Levinson, H.S., Adams, C.L. and Hoey, W.F. (1973) *NCHTP Report 143: Bus Use of Highways: Planning and Design Guidelines*, Transportation Research Board, National Research Council, Washington, DC.

Mulley, C. (2010) ‘No Car Lanes or Bus Lanes-which is best?’ *Traffic Engineering and Control*, Vol. 51, pp.433–439.

Mulley, C. (2011) *No Car Lanes or Bus Lanes: Which Gives Public Transport the Better Priority? An Evaluation of Priority Lanes in Tyne and Wear*, Institute Transport and Logistics Studies, The University of Sydney.

Neves, J.M.G.R.V. (2006) *The Impacts Of Bus Lanes On Urban Traffic Environment*, Universidade do Porto.

Shalby, S.A. (1999) ‘Simulating performance impact of bus lanes and supporting measures’, *Journal of Transport Engineering*, Vol. 109, pp.247–255.

TCRP (2010) *Bus and Rail Transit Preferential Treatments in Mixed Traffic: A Synthesis of Transit Practice*, Transportation Research Board, Transit Cooperative Research Program, Washington, DC.

Xinchen, Y. and Wanjing, M. (2013) 'Influence of access traffic on the operational effectiveness of bus lanes and main Road', *13th International Conference on Transportation Professionals. Procedia – Social and Behavioral Sciences*, Vol. 96, pp.1648–1658.

Zyryanov, V. and Mironchuk, A. (2012) 'Simulation study of bus lanes and bus signal priority strategy', *Procedia – Social and Bahavioral Sciences*, Vol. 48, pp.1464–1471.

BIOGRAPHICAL NOTES

Wafaa Saleh is a Professor of Transport Engineering at the Transport Research Institute/ School of Engineering and the Built Environment at Edinburgh Napier University. Her research and teaching areas include transport modelling, travel demand forecasting, modelling travel behaviour, transport and the environment, transport safety, transport management in developing countries and traffic engineering. Her first degree is in Civil Engineering and her Master and PhD are in Transportation Engineering and Modelling. She Chairs the Travel Demand Management (TDM) Symposium and teaches on Napier's MSc in Transport Planning and Engineering and on a number of undergraduate programmes.

Robert Ziolkowski is an Assistant Professor at Bialystok University of Technology, Department of Road Engineering. He finished postgraduate study in "Chosen aspects of traffic safety and environmental protection in road design" and was interning at Transport Research Institute, Edinburgh Napier University. He is a Member of Polish Association of Engineers and Technicians of Transportation and was a representative of Bialystok Municipality in RTD Framework Programme on SMART NETS Signal Management in Real Time for urban traffic NETworks. His research areas include traffic safety and engineering, speed management, ITS.