EXAMINING THE LEVEL-OF-SERVICE AND SPEED OF TRAFFIC CONTRAFLOW STRATEGY IN MALAYSIA

Nora Sheda Mohd Zulkiffli
Malaysian Institute of Road Safety Research (MIROS)
Email: norasheda@miros.gov.my

Rizati Hamidun
Malaysian Institute of Road Safety Research (MIROS)
Email: rizati@miros.gov.my

Siti Zaharah Ishak
Malaysian Institute of Road Safety Research (MIROS)
Faculty of Civil Engineering,Universiti Teknologi MARA, Shah Alam, Malaysia
Email: sitizaharah@miros.gov.my,

ABSTRACT

Daily traffic congestion has led to the implementation of contraflow operation in urban expressways in Malaysia since 2013 to ease traffic during rush hours. The contraflow operations utilize the inbound lanes as contraflow lanes to increase the total outbound traffic flow capacity. How effective of the contraflow operations to solve congestion problems in Malaysia is still had not been evaluated yet. The performance of the contraflow can be observed through an examination of the level of service (LOS) and speed at the specific stretch of the expressways. In this study, the LOS and speed at three urban expressways namely Kajang Dispersal Link Expressway (SILK Expressway-E18), Cheras-Kajang Expressway (Grand Saga-E7) and Shah Alam Expressway (KESAS-E5) were examined. The LOS of the normal and contraflow lane is a measure based upon the multilane expressway density capacity analysis. Result from analysis revealed that the implementation of contraflow lane would ease congestion. Unfortunately, it may give negative impact to the safety of road users by increasing the crash risk of a mixed-flow traffic travelling with different speed that only separated using plastic cones. The results of the 85th percentile speed indicated that vehicles were travelling at a high speed on contraflow lane. Hence, it is suggested the plastic cones used to separate traffic at contraflow are to be replaced by an appropriate separator such as non-fixed barrier by using suitable hardware, e.g. barrier transfer machine.

Keywords: Contraflow, level of service, traffic speed, urban expressways, rush hour congestion.

INTRODUCTION

Contraflow is a temporary traffic arrangement, usually part of the solution used to overcome congestion during rush hours of morning and evening. During the morning, the outbound lanes are then much more prone to congestion, while the inbound lanes are nearly empty. As in a contraflow condition the inbound lanes are reversed, more lanes are available to leave the congestion zone and road capacity increased (Knapper & Brookhuis, 2010). Wolshon and Meehan (2003) in their study that focused on the capacity stated that, road capacity increased about 50% when adopting the contraflow operation in four-lane road. In addition, the road that did not adopt contraflow during peak hour experienced more congestion compared to the road that applied contraflow (Hausknecht et al., 2011)

According to New Straits Times (2013), the implementation of contraflow at SILK expressway is beneficial to reduce the usual travelling time and increase the traffic flow during peak hours. The contraflow lane expected to reduce the usual travelling time from 28 minutes down to 7 minutes, and it is benefiting approximately 2,700 vehicles who are using the dedicated contraflow lane during peak hours.

Since the contraflow provided convenient to travel to the most of road users, drivers tend to increase their travel speed and seem it is hard to drive at low speeds (Dinh & Kubota, 2013). Stradling et al. in 2003 in a survey study found that most of the drivers agreed that manoeuvring their vehicle at a low speed (below 56 km/h) is challenging to them. Conversely, travelling with an increasing speed would increase the crash risk (Fildes & Lee, 1993; Nilsson, 2004). Not limit to the increase crash risk, increase in speed would also increase both the reaction distance, and the braking distance (Transport Roads & Traffic Authority, 2011). Reaction time indicated how long a driver takes to see, a process in the brain to realise danger and a process to react to the hazard (e.g. starting to apply brake). Whereas, the braking distance may refer as the vehicle travels while slowing to a complete stop. When a driver travelling with faster speeds, they required to react in between spotting and reacting to a hazard than a driver travelling at a slower speed. Thus, the high speed driver is more likely involved in the crash where they increased risk of losing vehicle control which, at higher speeds, cars becomes more difficult to manoeuvre.

The same concern rises when vehicles utilizing the contraflow in urban expressways. With an additional lane on the inbound lanes allocated to divert vehicle movement from the outbound lanes or vice versa, the vehicles tend to increase their speed. The free flow speed of the inbound and outbound vehicles that travelling on shared lanes on the expressway seems to be risky. Although the implementation of contraflow is expected to ease traffic congestion, monitoring of the traffic speed should be executed to see if the contra flow strategy giving adverse effect to traffic safety. Thus, this paper aimed to evaluate the contraflow lane operation strategy adopted at expressway in improving the traffic flow. This aim can be achieved by two objectives; the first objective is to identify the utilization of the contraflow lane (traffic capacity) and the second objective to compare the speed of vehicles travelling on the contraflow and normal lane. This study focused on three main expressways which adopted contraflow traffic management: Kajang Dispersal Link Expressway (SILK-E18), Cheras-Kajang Expressway (Grand Saga-E7) and Shah Alam Expressway (KESAS-E5).

LITERATURE REVIEW

Contraflow Practices and Configuration

In other countries practices, mostly divert traffic used for emergency evacuation people and goods during natural disasters such as floods, typhoon and hurricanes. Qazi et al. (2017) figure out various techniques are applied to reduce the evacuation time for a vehicle move from the danger area to safe places, including lane-based evacuation, vehicle routing, staged evacuation, contraflow operations, special signal timings and shoulder lane use. All of this evacuation route technique without intersections provides continuous traffic flow and reduces crashes.

Regarding to the contraflow lane configuration, Wolshon et al. (2001) has identified four configurations as in Figure 1. The most common lane reversal configuration used in the United States is all inbound lanes reversed in the outbound direction (refer Figure 1b) due to it is the most increases the capacity (i.e., vehicles per hour per lane) and the most with the least confusion (Pal et al., 2005, Wolshon et al., 2001). Meanwhile, the common contraflow lane configuration is normally practised in Malaysia (refer Figure 1 (c)) where one inbound lane reversed to an outbound lane.

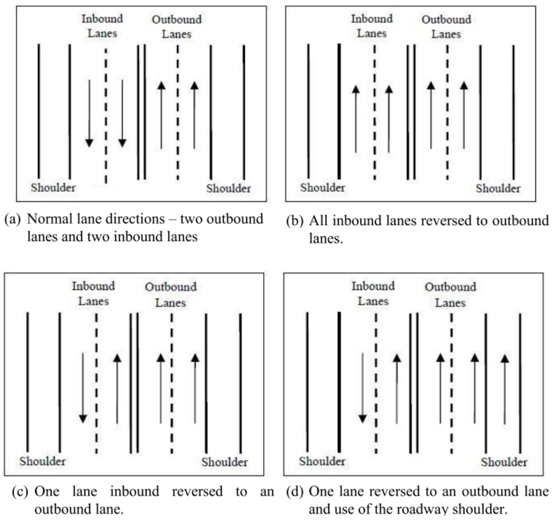

Fig. 1: Types of contraflow lane configurations (Wolshon et al., 2001)

The execution of the contraflow practices can be controlled by using several equipment or hardware's. In the United States, the overhead traffic light hardware for creating reversible lanes in Figure 2 (a) is commonly used (Hausknecht et al., 2011). While in many cities in United States, the barrier transfer machines (BTM), also known as the road zipper machine are used to transfer the non-fixed barriers to dynamically widen the road in one direction as shown in Figure 2 (b) (Hausknecht et al., 2011 and Rakhmawati, 2012). In Malaysia, traffic cones are used to demarcate the contraflow lanes (refer Figure 3) and the spacing between the cones are not uniform creating a large gap between one cone to another.

(a) Lane control lights (b) Barrier Transfer Machine

Fig. 2: Hardware for controlling contraflow lane in overseas (Hausknecht et al., 2011)

Fig.3: Traffic cones lane splitter at KESAS Expressway

Risk of Crash

Risk is a measure based on the potential for a crash or casualty to take place. Basically, risk a combination of two elements: the likelihood of a crash and the severity of that crash (Tuominen et al., 2006). Referring a book by Venkata (2011), there is evidence that lower speeds result in less collisions of lesser severity. Whereas, the faster the traffic speeds, the more collisions would have occurred. Research work by Finch et al. (1994), it was reported that every 1 km/h reduction in speed across the network, would result in a three percent drop in crash occurrence on residential and town centre roads.

The relationship between congestion and safety on expressways indicated that the likelihood of a crash associated with speed variable, which is a common indicator of unstable traffic conditions was found in a study by Marchesini and Weijermars (2010). Their study also mentions that the large differences in speeds between lanes and density variations also appear to make crashes more likely. Chang & Xiang, 2003; Zhou & Sisiopiku, 1997 found that high volume led to higher crash rates, however the severity of crashes is less. Whereas Lord et al. (2005) stated that crash rates decreased at high traffic densities. Additionally, Wang, Quddus and Ison (2009) examined did not find any relationship among congestion and crash frequency. None of the studies they looked at explicitly provided evidence on the influence of congested traffic conditions on crash rates (Marchesini & Weijermars, 2010). Furthermore, Innamaa et al. (2014) also found that on other research regarding two-lane roads, when hourly traffic volume increased, crash rates generally increased. On four-lane roads, crash rates were highest at hourly traffic volumes of 3600 to 4800 vehicles. However, on highways, crash rates increased with rising hourly traffic volume, and were highest at very low traffic volumes in both directions.

METHODOLOGY

Three main expressways involved are SILK, Grand Saga and KESAS Expressway. All these expressways are located in the state of Selangor. The methodology framework can be categorised into three major steps, i.e. identifying expressway, data collection, and data analysis.

Site Selection

Site selection consideration based on the expressway has used contraflow traffic implementation during peak hours. For SILK Expressway, the contraflow lane opened on weekdays from 7.00 am to 9.00 am after the Sungai Ramal Toll Plaza (KM 24.1) to KM 28.3 which is ending between the grade separated intersection at UNITEN and Serdang Hospital. Whereas, in the evening peak hours, open on weekdays from 4.30 pm to 6.30 pm from KM 28.3 to KM 24.1 consists of the total implementation length of 4.2 km.

The locations involved at Cheras Kajang Expressway during morning (direction to Kuala Lumpur) are from Batu 9 Toll Booth to Taman Segar, Taman Segar to Loke Yew and continued from Loke Yew to Dewan Bahasa, whereas, in the evening (direction to Kajang) only two locations are covered which are from Loke Yew to Taman Segar and Taman Segar to Batu 9 Toll Booth. The length of contraflow at Cheras Kajang Expressways is 13 km during morning peak hour. During evening peak, the contraflow is opened from Loke Yew to Toll Booth Batu 9 (11.7km).

The third location is KESAS Expressway, only implemented contraflow lane during morning peak hours started from KM 36.7 to KM 38.6 directions Shah Alam to Kuala Lumpur, consists of 1.9 km and opened for traffic from 6:45 am to 7:25 am and 8:00 am to 8:15 am.

Data Collection

Traffic volume and spot speed were the two data recorded for this study during the morning and evening peak hours. Traffic count surveys were conducted during three working days, either on Monday to Wednesday or Wednesday to Friday for morning (7.00 am to 9.00 am) and evening (4.30 pm to 6.30 pm). The day of data collection was chosen based on normal flow on weekdays (Tuesday/Wednesday/Thursday) and a different trend of volumes during a Monday or Friday. The traffic volumes were counted manually by trained observer on site at 15-minute interval and classified into the following six vehicle categories:

i. Passenger car
ii. Motorcycle
iii. Light vans
iv. Medium lorries (2 axles)
v. Heavy lorries (3+ axles); and
vi. Buses

The measurement of the vehicles' spot speed were performed using laser speed gun at the overhead pedestrian bridge located on the expressway. A minimum of 100 speed measurements were collected for the vehicle travelling on the contraflow and normal lane during peak hours.

Data Analysis

Data analysis consists of capacity analysis and speed analysis. Capacity analysis is conducted to determine the LOS of traffic facilities under different traffic flow conditions. The LOS is serve as a qualitative measure describing the operational conditions within the traffic stream. Prior to evaluating the existing traffic characteristics all counted vehicles were converted into a passenger car unit (p.c.u.) to account for the varying traffic composition. P.c.u. conversion factors based on JKR Arahan Teknik (Jalan) 8/86 guidelines were used as shown in Table 1.

Table 1: Conversion factors to P.C.U's

Type of vehicle	Equivalent Value in p.c.u's
	Urban standards
PASSENGER CARS	1.00
MOTORCYCLE	1.00
LIGHT VANS	2.00
MEDIUM LORRIES	2.50
HEAVY LORRIES	3.00
BUSES	3.00

An indication of the LOS is LOS A and F represent the best and worst operating conditions respectively. Based on Transportation Research Board (TRB, 2000), there are many methods available to calculate the LOS. For this study, calculation of LOS for multilane highways was chosen which required three steps as following:

Step 1: Determination of Free-Flow Speed

The determination of free-flow speed (FFS) can be conducted either using the field measurement method or estimation method. In this study, since vehicle speed is collected on site, the first method is applied. Therefore, the average (mean) of all passenger car speed measured at the site is used directly as the free-flow speed.

Step 2: Determination of Flow Rate

Two adjustments must be made to hourly volume counts or estimates to arrive at the equivalent passenger-car flow rate used in LOS analysis. The adjustments are applied using equation 1.

$$V_p = \frac{V}{PHF * N * f_{HV} * f_p} \text{ ……… (Equation 1)}$$

Where;
Vp = 15-min passenger-car equivalent flow rate (pc/hr/ln)
V = hourly volume (veh/hr)
PHF = peak hour factor
N = number of lanes
fHV = heavy vehicle adjustment factor
fp = driver population factor

Peak hour factor (PHF) for multilane highways has been observed to range between 0.75 to 0.95. Based on (TRB, 2000), where local data are not available, 0.88 is a reasonable to be used to estimate PHF for rural multilane highways and 0.92 for suburban facilities. In this study, the PHF is taken as 0.92. Equation 2 is used to determine the heavy vehicle adjustment factor.

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \text{ ……… (Equation 2)}$$

Where;
ET, ER = passenger-car equivalents for trucks and buses (T) and for recreational vehicles (RV) in the traffic stream (refer Table 2)
PT, PR = proportion of trucks and buses, and RVs in the traffic stream

Table 2: Passenger car equivalents on extended general highway segments

Factor	Type of Terrain		
	Level	Rolling	Mountainous
ET (TRUCKS AND BUSES)	1.5	2.5	4.5
ER (RVS)	1.2	2.0	4.0

Since there are no recreational vehicles in Malaysia, the PR and ER can be neglected. The driver population factor (fp) is typically set in the ranges between 0.85 to 1.00. In this study, the value is set to be 1.00.

Step 3: Determination of level of service
The level of service on a multilane highway can be determined directly from Figure 4 based on the free-flow speed (FFS) and the service flow rate (Vp) in pc/h/ln.

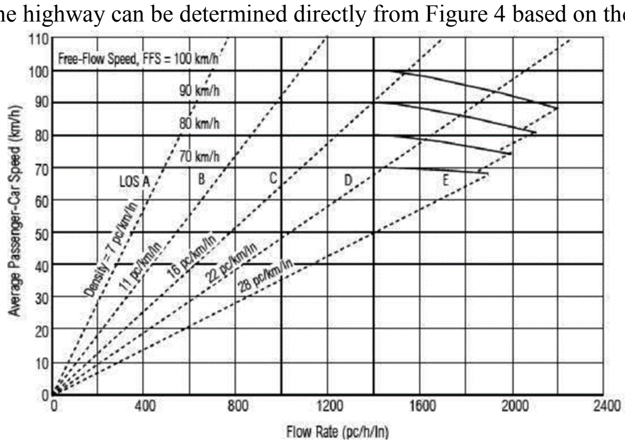

Fig. 4: Speed-flow curves with LOS criteria for multilane highways (TRB, 2000)

LOS criteria for multilane highways are defined in terms of density where the density can be calculated by using equation 3.

$$D = \frac{V_p}{S} \text{ ……… (Equation 3)}$$

Where;
Vp = flow rate (pc/hr/ln)
S = average passenger-car speed (km/h)

Whereas, speed data were using spot speed study. A spot speed study conducted at one point to collect speed data. The data were analysed by using the formula of 85th percentile where the speed percentiles are tools used to determine effective and adequate speed limits. The 85th percentile speed is the speed at or below which 85 percent of the vehicles drive on the road and this speed leads the most vehicles on the road consider safe and reasonable to drive on. According to Homburger et al. (1996), this percentile based on the assumption of 85 percent of the drivers is travelling at a speed they perceive to be safe. Whereas, the significant values were analyses using t-test analysis.

RESULTS AND DISCUSSION

The data obtained comprises the classified traffic volume at three expressways in Malaysia during contraflow strategy was conducted. Generally, the traffic volume trend on a normal lane at SILK and KESAS expressways is mostly influenced by the number of a car/MPV. A different trend observed at Grand Saga Expressway where the motorcycle is higher during the morning for normal weekday (Tuesday and Wednesday or Wednesday and Thursday). The traffic volume by different types of vehicles for the three expressways is summaries in Table 3.

Table 3: Traffic volume on normal lane

Expressway	Weekday	Normal lane (veh/h)							
		Motorcycle	Car/ MPV	Van	Lorry 2 axle	Lorry 3 axle	Bus	Others	Total
SILK (am)	Normal	7812	14341	3279	550	139	76	23	26220
	Mon/Fri	3478	6902	1512	274	36	34	23	12259
SILK (pm)	Normal	4955	10258	2172	691	138	64	23	18301
	Mon/Fri	2217	4847	1253	370	77	31	13	8808
GRANDSAGA (am)	Normal	15205	13328	2966	220	2	72	1	31794
	Mon/Fri	7800	7194	1565	162	2	35	4	16762
GRANDSAGA (pm)	Normal	8840	12727	3085	475	10	19	7	25163
	Mon/Fri	4512	6706	1138	282	8	16	0	12662
KESAS (am)	Normal	2565	10227	1939	551	235	53	0	15570
	Mon/Fri	1273	4975	869	244	100	21	0	7482
Total		58657	91505	19778	3819	747	421	94	175021

Table 4 provides the traffic volume on contraflow by different types of vehicles for the three expressways. Only the lighter vehicle is allowed to utilize the contraflow lane, includes the motorcycle, car/MPV, van and lorry 2 axle, except for Grand Saga Expressway which prohibit motorcycles from using the contraflow lane. A regulatory sign is posted to warn motorcyclist before approaching the start point of contraflow lane. Conversely, this regulatory sign was ignored by most of the motorcyclist. Traffic volume trends on a contraflow lane at each expressway are mostly influenced by the number of a car/MPV.

Table 4: Traffic volume on contraflow lane

Expressway	Weekday	Contraflow (veh/h)				
		Motorcycle	Car/MPV	Van	Lorry 2 axle	Total
SILK (am)	Normal	59	5318	957	38	6372
	Mon/Fri	27	2283	452	13	2775
SILK (pm)	Normal	90	3015	1777	130	5012
	Mon/Fri	43	2964	126	80	3213
GRANDSAGA (am)	Normal	396	2342	344	9	3091
	Mon/Fri	210	1135	72	8	1425
GRANDSAGA (pm)	Normal	204	3031	1384	78	4697
	Mon/Fri	11	1884	329	39	2263
KESAS (am)	Normal	0	1694	257	2	1953
	Mon/Fri	0	1088	37	3	1128
Total		1040	24754	5735	400	31929

The LOS for the three expressways on different days of the week through capacity analysis are presented in Table 5. Overall, the results indicated that the normal lane for all three expressways are currently operating in (LOS F) traffic conditions, except for the KESAS expressway which operating in LOS D on Monday/Friday. Traffic with the LOS F indicated a forced flow where speeds and volume can drop to zero where stoppages can occur for long periods. Minor disruption may be expected to cause serious local deterioration in service, and queues may begin to form. For the LOS D, traffic movement is severely restricted due to congestion as volume increased. However, the LOS D is considered the acceptable traffic conditions for design criteria in an urban area (Mohd Ezree, 2006). Whereas, the LOS at contraflow lane varies from LOS A to LOS E.

When compared the result of LOS from Table 5, contraflow lane on Monday/Friday had a better LOS than during a normal weekday, for example, at SILK expressway during the morning, the density of traffic flow is much better during Monday/Friday, although usually heavy traffic predicted due to the first day of the week start of school and ends of school besides the holiday break for weekend at certain states in Malaysia. This is indicated that contraflow strategy is in demand during the normal weekdays compared to Monday/Friday. Implementing contraflow as an alternative for traffic to divert their path seems useful since normal lane during peak hours experiencing very high density with LOS F. Looking for the density value for all three expressways, the Grand Saga expressway experiencing bad congestions as the density reaches up to 139 pc/km/ln on a normal weekday for the morning peak hour. At the same time, the contra lane provided at this expressway also experiencing higher density (24.2 pc/km/ln) with LOS E.

In the year ahead, the numbers of traffic on the roads keep increasing. Road widening or even new roads are expected cannot be compensated the traffic growth. Thus, to permanently improve mobility, the provided infrastructure or new implementation on road must be better utilised. The rush hour lanes (or contraflow) was provided to ease congestion during peak hour. Contraflow lane provided is observed help to ease congestion during rush hour in the morning and evening time. Even though the travel time is reduced by using a contraflow to reach the destination, but in term of safety, the implementation of contraflow can increase risk of collision.

Table 5: Result of density

Expressway	Weekday	Density (pc/km/ln)	
		Normal lane	Contraflow
SILK (am)	Normal	97 (LOS F)	17 (LOS D)
	Mon/Fri	36 (LOS F)	9.1(LOS B)
SILK (pm)	Normal	55 (LOS F)	16 (LOS C)
	Mon/Fri	33.3 (LOS F)	10.4 (LOS B)
GRANDSAGA (am)	Normal	139 (LOS F)	24.2 (LOS E)
	Mon/Fri	62.3 (LOS F)	5.3 (LOS A)
GRANDSAGA (pm)	Normal	98 (LOS F)	17 (LOS D)
	Mon/Fri	41.3 (LOS F)	7.1 (LOS B)
KESAS (am)	Normal	34 (LOS F)	4.1 (LOS A)
	Mon/Fri	17.4 (LOS D)	2.2 (LOS A)

Table 6 shows the 85th percentile speed for the three expressways at different period considering morning and evening peak. The result of the t-test indicated a statically significant difference ($t=-7.105$, $p<0.05$) in the normal lane during normal weekdays and Monday/Friday when comparing with contraflow lane. This is indicated 85th percentile speed of normal lane is different between contraflow lane. There is vehicle travelling with different speed, which indicate unstable traffic conditions for both normal and contraflow lanes.

Table 6: Result of 85th percentile speed

Expressway	Weekday	85th Percentile (km/h)	
		Normal lane	Contraflow
SILK (am)	Normal	68	71
	Mon/Fri	74	66
SILK (pm)	Normal	76	88
	Mon/Fri	76	72
GRANDSAGA (am)	Normal	49	67
	Mon/Fri	57	56
GRANDSAGA (pm)	Normal	71	65

	Mon/Fri	69	69
KESAS (am)	Normal	92	93
	Mon/Fri	91	85

In other country practice, they used a temporary plastic barrier to demarcate contraflow and inbound flow by using proper equipment. The equipment used to switch temporary plastic barrier quickly from one lane to the other (Schwietering & Feldges, 2016). The benefits of temporary plastic barrier are improved traffic safety and separating freeway traffic from contraflow lanes, as well as shorter interruption times and reduced labour costs (FHWA, 2002). Logically, the speed is higher at contraflow lane because of there is no access point in the contraflow lane as compared to normal lane which the conflict higher at normal lane. However, based on the experienced, drivers tend to slow down while using the contraflow lane due to cautious in case there was a vehicle travel on the wrong lane. This in line with concern highlighted by Wolshon (2002), the confusion among drivers is exists to those drivers unfamiliar with the contraflow operations, where they tend to entering the contra lane from the wrong direction. Furthermore, the head-on collision can be happening between the vehicle in contraflow and inbound lane. It also observed that there are situation cones were overturned into the inbound lane. The cones create hazards to vehicle or motorcycle which might cause them to accidentally run-off with it. Thus, it is vital for concessionaire upgrade the used of plastic cones to separate traffic. Since this is not a physical barrier, many head-on collisions might be occurred causing several mortalities. If a concessionaire upgrade to use temporary plastic barrier to segregate the contraflow lane, might increase the safety of road users.

In addition, the congestion started to occur at the termination point at the end point of contraflow lane. Thus, bottlenecks generate at the ending point of contraflow operations and can consequently cause congestion and crashes. Based on a study by Lim (2003) indicated that, merging congestion is likely to occur when traffic merges from two lanes into one lane and in this case, contraflow lane merges into the normal flow traffic. Under such situations, due to merging congestion can have occurred delay and decrease expressway capacity. Hence, efficient operations in terms of reducing delays and increasing traffic flow at contraflow termination points are critical and need further investigating.

CONCLUSION AND RECOMMENDATIONS

The implementation of contraflow lane that has been used daily in many expressways in Malaysia, especially urban network provides a quick solution to ease traffic during rush hours. Capacity analysis conducted in this study proved that the contraflow strategies are required to improve road capacity since most of expressway experiencing very high density. Nonetheless, high speed observed at the contraflow that only separated by using plastic cones would increase the risk of collision with inbound traffic from the opposite direction. Incident observed with overturned plastic cones would greatly create a hazard to traffic moving at a high speed on the expressway. Replacing plastic cones that used as a barrier to segregate traffic on contraflow with proper equipment such as BTM is highly recommended. It is imperative for a concessionaire to monitor these safety deficiencies of the contraflow lane and adhere to the recommendations given for a safer road user.

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