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Development Traffic Volume Reduction Caused By Automatic Parking Barrier

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ABSTRACT

New developments, especially in urban areas are often considered as source of additional traffic volume. The paper is concerned with the extent of development traffic volume reduction resulting from the installation of automatic parking barriers at a shopping mall. Based on the hypotheses that, automatic parking barrier (APB) reduces peak hour development traffic volume significantly, a 'before and after' impact studies were carried out at a large shopping centre (Jusco) in Skudai town, Malaysia in 2007 and 2009 respectively. Jusco shopping mall has three gates (1, 2 and 3) in use for accessing and exiting the shopping premises. Proportional vehicle volumes emanating from the shopping premises at gates 1 and 3 connect directly to two collector roadways while those from gate 2 connect to an access one-way road. Gate 1 leads to a signalized 4 arm intersection. Gates 2 and 3 lead to highway links. Impact study shows that traffic flows at the gate 2 and 3 are small and negligible. Vehicle volume, speed, parking and traffic control mechanisms, parking and highway characteristics were surveyed and recorded. Studies were conducted at peak periods under daylight and dry weather conditions. Results show that indiscriminate vehicular discharge of about 12.67 vehicles per minute from gate 1 before the installation of automatic parking barrier was reduced significantly to 8.63 vehicles per minute after the installation of APB. Level of service along adjoining signalized roadway also improved significantly after the installation of automatic parking barrier installation. When natural traffic growths were factored into traffic flows, the level of service remained same. Consequently, the paper concludes that the extent of development traffic volume reduction resulting from automatic parking barrier installation is significant and useful.

Keywords: *Automatic parking barrier, development traffic, level of service, shopping mall*

1. INTRODUCTION

The provision of car parks is an integral part of transportation system; and the installation of parking barrier is often motivated by its positive contribution to road safety, traffic orderliness, and regulated discharge, and to an extent urban sustainability. Shopping malls are normally set up to promote the synergistic effects of having many different stores in one place, car parks are often provided to encourage family and out of location shopping. Car parks in turn act as storage and discharge outlets of vehicles onto adjoining road network.

In Malaysia, as often the case in many countries, the demand for car parks in urbanized areas usually outstrips supply because far too many cars are chasing far too few road spaces. With increase in demand for new developments, governments are able to control parking supply through the application of parking standards which define the maximum or minimum numbers of parking spaces to be applied to any new land use activity. Notwithstanding, development traffic (planned or unplanned) are often source of additional traffic volume. Whilst it is attractive and often necessary to promote the concept of shopping malls, account must be taken of additional traffic volume that they would generate in the short, medium and long term. To that extent, it would be useful to consider a parking control mechanism that allows for regulated vehicle discharge onto the highway.

Parking barriers (manual or automatic) are control mechanism often employed for parking lots, toll gates, railway crossings, commercial premises, apartment block access and other applications. Automatic parking barrier (APB) is composed of driver, electric system, arm and bracket. The control system is fitted with wiring terminals for ticket dispenser, remote controller, and ticket card. When a vehicle arrives at the entrance, the driver pulls out a ticket card from the dispenser triggering the parking barrier to rise up allowing the vehicle access into car park and down on clearance from barrier arm. Drivers simply repeat the entry steps at exit gate when leaving the premises. With the installation of functional automatic parking barriers, maximum vehicle volume discharge per gate can be computed and factored into existing traffic flows in the vicinity.

Skudai Town is a growing sub-urban area in Malaysia, where shopping centres are the main destination for shopping and other social activities. One of the shopping malls is named 'Jusco' (see figure1below). It is bordered by two urban collector roads, namely Jalan Perdagangan, Jalan Pendidikan and Jalan Pendidikan 1. Jusco shopping mall has approximately 31954m2 gross floor area with 762 (2m x 4m) parking bays occupying 19.1% of the gross floor area.. The parking bays are usually full at weekends, during peak and festive periods. At peak, it is not uncommon to find vehicles parked indiscriminately at any available space including pedestrian walkways and designated as emergency areas. The associated problems with indiscriminate parking are two folds; firstly, the issue of safety, car park rage and car fume pollution and secondly, uncontrolled vehicle discharge rate into adjacent roadways. Safety concerns were first raised in 2007 after the premier parking study was carried out at the shopping mall. In the study, installation of automatic parking barrier at all gates was strongly recommended. The main aim of installing automatic parking barrier is to prevent unauthorized access and facilitate orderly and timely vehicle discharge into adjoining roadways.

Figure 1. Shopping Mall

The key features of the automated parking barrier include; an extruded aluminium barrier arm and a highly visible control box that facilitate entry and exit into the car park with minimum inconveniences associated with processing time for authorized users. Once parking automatic barriers were installed at the shopping mall in 2009, the research group carried out an after- installation study. The mall has three gates; gate 1 leads to Jalan Perdagangan signalized intersection, gate 2 leads to Jalan Pendidikan 1 highway link and gate 3 leads to Jalan Pendidikan highway link. Initial studies suggest that gate usage levels during peak period are often about 80% (Gate 1), 5% (Gate 2) and 15% (Gate 3). Consequently, gate 1 is the most active and as illustrated below in figure 1, it leads to a signalized four-arm intersection. In any case, the paper is aimed at provoking debate on the extent traffic volume reduction resulting from automatic parking barrier control mechanism. Based on the hypotheses that, automatic parking barrier reduces vehicle volume discharge into adjoining roadways significantly; a 'before and after' impact study was carried out. The objectives of this study are to estimate the level of service along adjoining road to the car park 'before and after' the installation of automatic parking barrier; and also estimate the vehicle discharge rate 'before and after' the installation of automatic parking barrier during peak hours under daylight and dry weather conditions.

2. LEVEL OF SERVICE, DELAYS AND QUEUES

Level of service is often applied as benchmark for measuring roadway performance standard (7). This is a qualitative assessment of the quantitative effect of factors such as speed, volume of traffic, geometric features, traffic interruptions, delays and freedom to manoeuvre. There are six levels of service (A-F), with A rated as top and F as bottom. Highway Capacity Manual used speed / flow relationship to describe six level of service experienced by road users. As the level decreases so will the average speed and service quality: at level A the highest quality service occurs and motorists are able to drive at desired speed while at level F the lowest quality occurs with forced flow, stop-start and uncomfortable conditions Level B is a transition from level A to C because at level C even though the traffic may appear stable, it is more susceptible to congestion from turning movements and slow moving vehicles. At level D unstable traffic flow is approached with high overtaking demand that is virtually impossible to achieve at level E where perturbations in the traffic stream often trigger a quick transition to level F. In the study, volume speed and density relationship was used to estimate roadway capacity for Jalan Pendidikan at the pilot stage. In order to estimate capacity, flow and density was considered and represented by a quadratic equation. The flow (*q*) – density (*k*) relationship, (2) could be written as:

$$q = -\beta_o + \beta_1 k - \beta_2 k^2 \quad (1)$$

The average volume to capacity ratio of 0.5 or less at peak hour computed for this connector road suggests that the number of vehicles exiting from gate 3 would have insignificant influence on traffic flows. There are no on-street parking facilities available on these roads. Nevertheless, roadway capacity that is central to traffic analysis is worth mentioning briefly. It has often been loosely defined as the maximum number of vehicles passing a point or section on a roadway per hour under prevailing conditions. The definition recognizes the potential for substantial variations in flow during an hour, and focuses analysis on intervals of maximum flow. UK Department of Transport advice note TA79/99 (4) suggested capacities for different types of urban roads assuming a 60/40 directional split. It is noted in the advice note that highway network is composed junctions and links, and each of these components has its own physical characteristics that influence the maximum traffic flows that can be achieved. However, basic capacity for signalized intersections is defined in terms of the saturation flow rate, i.e., the capacity of the lane or approach assuming that the signal is green at all times. The saturation flow rate estimated using node based method relies on equation 2 below:

$$s = 3600 / h \quad (2)$$

Where:

s = saturation flow rate (veh/h),
h = saturation headway (s/veh), and
3600 = number of seconds per hour.

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Delay is computed using equation 3 below;

$$\partial = \frac{[c\,(1-\lambda)^2]}{[2\,(1-\lambda x)]} + \frac{\lambda^2}{[2q(1-x)]} - \left\{0.65\left(\frac{c}{q^2}\right)^{1}\!/_{3} \times x^{2+5\lambda}\right\} \quad (3)$$

Where,

∂ = Average total delay per vehicle on the particular approach of the intersection;
C = Cycle time (seconds);
λ= Proportion of the cycle that is efficiency green for the phase under consideration (g/C);
q = Flow (vehicle per second);
s = Saturation flow (vehicles per second of green); and
x = Degree of saturation (q/λs)

2.1 Development Traffic

Information about traffic volume is extremely crucial for transportation planning. It furnishes a basic scale of comparison, show relative importance of roads and also justifies highway improvement programs. Development traffics are planned or unplanned addition traffic loading on the network. Even though developments are trip generators, it must be emphasized that they merely attract trips produced elsewhere. Therefore, development traffic can also be construed as trip attraction. Trip attractions are an outcome of travel behaviour activities that changes relative to interest and choice. In sum, trip attractions are more inclined to exhibit dynamic characteristics compared to productions that are more or less static and predictable. This is so because the source of trip production is a finite element. In equation 4 below, it is assumed that zone attractiveness can be denoted by:

Ax = f (∂x, ßx, ŧx) (4)

Where; *Ax* is the attractiveness of traffic zone *x*, *∂x* is the distance from zone *x* to the centre of the city, *ßx* is the traffic advantage index, and *ŧx* is the acreage of each land use type. In practice, *ŧx* is determined by the travel distance and *ßx* determined from expert opinions. Of course there are errors produced by different public traffic modes and also subjective bias. Consequently, accurate values of attraction cannot be easily determined from Equation 4. In any case, trip attraction has long been considered as a major element in trip demand estimation. Many models have been presented for this purpose. Generally the models of trip-generation include variables which reflect the number of potential trip makers and the propensity of potential trip-makers to make a trip. However, none of the present models incorporate variables which reflect attraction factor. For example in equation 5, an additive functional form is assumed to exist between the factors which affect trip-generation and the number of trips generated.

$$T_i = \alpha_1 z_{1i} + \alpha_2 z_{2,i} + \alpha_n z_{n,} \quad (5)$$

Where, α_k are parameters of the regression function and $z_{k,i}$ is the value of the k[th] variable (such as income, automobile ownership, number of members in a household, and the like) for the *i* th zone. It can be argued that using multivariate regression to determine the number of trips generated by a zone is a simple matter when all the parameters of the regression function are known. Considering that human behaviour is unpredictable, regression technique at best would produce debatable outcomes.

Since development traffic volumes are merely trip attraction rates, it can be argued that parking barriers are useful control mechanism capable of regulating vehicle discharge into road networks.

3. SET-UP OF STUDY AND DATA

The study is on the extent of traffic volume reduction resulting from automatic parking barrier installation at Jusco shopping mall in Skudai, Malaysia. The aim is to explore the understanding of automatic parking barrier impact on highway traffic. The study was limited to a single site. Parking studies were carried out in 2007 (before installation of APB) and 2009 (after installation of APB) at gates (1, 2, 3), and adjoining roadways namely; Jalan Pendidikan, Jalan Pendidikan 1, and Jalan Perdagangan as illustrated below in figure 2 (drawn not to scale). Note that arrows indicate traffic flows; in the case of Jalan Pendidikan, the road has three lanes each direction with central median. Vehicles enter and exit the shopping mall from gate 3 using the flare lane. Gate 2 and 3 are about 20m away from adjoining roadways, while gate 1 is about 60m away from the signalised intersection at Jalan Perdagangan. The gates at 2 and 3 lead to Jalan Pendidikan 1 and Jalan Pendidikan. Jalan Perdagangan and Jalan Pendidikan are designated collector roads while Jalan Pendidikan 1 is a one-way access road with minimum traffic flow activities from the shopping mall. Generally, the shopping mall is fully fenced with about 5m set back from the roadways.

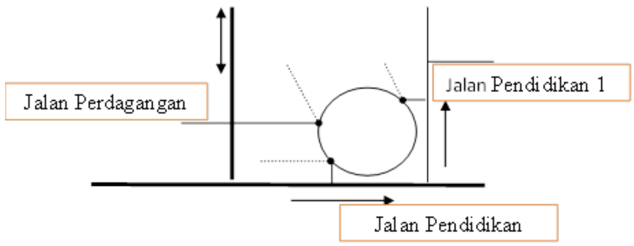

Figure 2. Setup of Impact Study

Observers were stationed at intersections and opposing gates 1, 2 and 3. Intersection geometric details, Demand flow, speed and actual green time per stage data were collected manually. Automatic parking barrier type, vehicle types, turning movements, vehicle speed and volume were surveyed. The node based method (see equation 2) was used to determine saturation flow and lost times at the signalised intersection opposite gate 1. Travel times for the third and thirteenth vehicle passing the stop line were recorded and used to compute saturation headway and loss time. Phasing sequence and actual green seconds per stage was surveyed and recorded. As illustrated below in figure 3, arm A is the Jusco traffic flow arm from gate 1, Arm D-B is Jalan Perdagangan, arm C is Jalan Perdagangan 2 (see figure 2). The automatic parking barrier installed at Gate 1 is approximately 60m away from the signalised intersection. Observers stationed at gates record entry and exit process time per vehicle so as to compute vehicle discharge rate per hour.

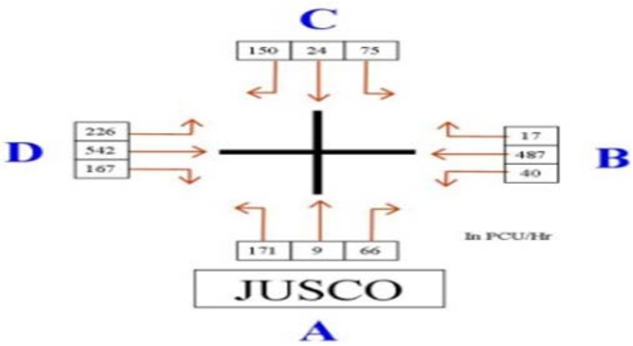

Figure 3. Traffic Flow at Jalan Perdagangan Intersection (read in conjunction with figure 2)

Sample size of 50 was used. Since the area enclosed by the shopping mall is privately owned, intra traffic flows though observed are of little concern to the study. Gross floor area, car park space area, proportion of vehicle volume per gate, parking area characteristics, traffic control mechanism, parking demand and supply were surveyed. Perimeter of the shopping mall, size and number of parking bays were manually measured; empirical data were then compared to that supplied by property owner and found to be accurate. Traffic flows and parking barriers aside, the background information for the 'before and after' studies are the same. This is useful in ascertaining that no layout advantage is enjoyed by either part of the studies. Although, traffic flows before the automatic parking barrier were surveyed in 2007 and not expected to change that much, nonetheless they were surveyed again in 2009 and updated accordingly. Studies were conducted during peak hours under daylight and dry weather conditions. It is pertinent that study be conducted during the dry season to eliminate the effects of rainfall and also restrict empirical survey to daylight so as to eliminate the effect of darkness or road lighting. The step wise approach to the study is shown below:

Step 1: Estimate the shopping mall characteristics

Step 2: Conduct volume and speed survey of adjacent roadways

Step 3: Use survey results to derive density, and then relate density to volume

Step 4; Use the relationship between volume and density to determine the critical density

Step 5; Plug the density into the volume and density relationship to determine roadway capacity

Step 6; Determine reference flow to capacity ratio and the corresponding level of service (LOS)

Step 7: Determine vehicle discharge rates at shopping mall APBs

Step 8: Adjust adjoining roadway flows to take account of volume discharge from APBs

Step 9: Compare before and after APBs results in order to estimate volume reduction

The characteristics of Jusco shopping mall is summarized as:

- Gross shopping mall area = 31954m^2
- Total car park area = 6103m^2
- No. of parking bays = 762
- Gate usage level = 80% - Gate 1; 15% - Gate 3; and 5% - Gate 2;
- Peak hour demand flow (pcu/h) = 683 (PM) 505 (Noon)
- Occupancy = 89.6% (PM) 66.3% (Noon)

4. FINDINGS AND DISCUSSION

When steps 2 – 6 were performed; volume to capacity ratios for Jalan Pendidikan and Jalan Pendidikan 1 were less that 50%. Hence both roadways were excluded from further analysis Vehicle arrivals and departures are shown below in table 1.

Table 1. Vehicle arrival and departure at shopping mall gates

Gate	Period	Before Installation of APB			After Installation of APB		
		Arr	Dep	Total	Arr	Dep	Total
1	12:00 13:00	231	175	406	183	224	407
	19:00 20:00	127	172	299	169	190	359
2	12:00 13:00	52	31	83	68	23	91
	19:00 20:00	70	89	159	21	66	87

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3	12:00 13:00	109	63	172	114	58	172
	19:00 20:00	77	87	164	65	43	108

Note: Arr – arrival, Dep. – departure, G – gate, P – Period

Automatic parking barriers at the gates have discharge capacity of about 8.63 vehicles per minute each at peak (say 500 vehicles per hour). From Table 1, Gate 1 noon has the worst scenario. Comparative arrivals and departures at gates 2 and 3 are small and their influence on adjoining roadway capacity is negligible. In any case, gate 2 leads to a one way road that can only be accessed from Jalan Pendidikan (see figure 2), thus many drivers use gate 3 to gain access into the shopping mall car park. Gate 3 has a dedicated flare lane for left turning movements along Jalan Pendidikan. The roadway has central median and an overhead bridge for pedestrians. It's easy to gain entry into the car park but circuitous to exit, hence most drivers use the gate 1. It can be mentioned in passing that gates 2 and 3 cannot be construed as intersections with Jalan Pendidikan 1 and Jalan Pendidikan respectively since they are mere set back entry and exit points of a private development. Therefore, Jalan Pendidikan and Jalan Pendidikan 1 roadways are taken as highway links and analyzed with equation 1. Jalan Perdagangan intersection is signalized. Although there may be internal queues and delays at these gates, they are private concerns. Since internal delays and queues generated in car parks will eventually empty onto the public roadways, it is imperative that control mechanisms are put in place to regulate their rate of discharge. Results for the turning movements at Jalan Perdagangan signalized intersection are shown below in table 2.

Table 2 Turning movements (PCU/hr) at Jalan Perdagangan Intersection

Ap	Total Flow Noon	Total Flow PM	Demand Flow (pcu/h) Noon			Demand Flow (pcu/h) PM		
			RT	ST	LT	RT	ST	LT
A	181	246	40	16	125	66	9	171
B	452	540	18	390	44	17	487	40
C	211	249	136	13	62	150	24	75
D	993	935	183	403	407	167	542	226

Note: RT-right turn, ST-straight, LT-left turn, Ap – approach arm

The automatic parking barrier is located at about 60m from the intersection arm A stop line. Gate 1 discharges vehicles into two lanes with dedicated lane for left turning movements. The 2009 traffic flows shown in table 2 are higher than the 2007 traffic flow and relied on for further analysis. Delays were computed for each arm of the intersection using equation 3 and subsequently level of service estimated from delays. Results are shown in table 3. As shown below in Table 3, before the installation of APB, the peak hour level of service at this arm is between D and F; after the installation of APB, level of service improved to C.

Table 3. Level of Service 'before and after' APB

ARM	BEFORE APB		AFTER APB	LOS PROJECTION		
	DELAY (s)	LOS	DELAY (s)	Year 2011	Year 2015	Year 2020
A – B	42.11	E	24.75	C	D	D
A – C	36.99	D	22.34	C	D	D
A – D	88.80	F	32.35	D	D	D

Note: APB – Automatic Parking Barrier, LOS – Level of Service

In sum, results show that after the installation automatic parking barrier at gate 1 traffic volume and delays at Jalan Perdagangan were reduced significantly. Level of service has improved from E, D, and F to C, C, and D respectively for the year 2009. Level of service was projected for 10 years assuming an annual traffic growth of 3%. The study has shown that level of service sustainability could be achieved with regulated vehicle discharge rates. Note that vehicle arrivals and departures are not the same as vehicle discharge rates. Vehicle arrivals and demands are parking demand at the shopping mall gates; whereas, vehicle discharge rate is a function of the adjoining roadway accessibility. Moreover vehicle arrivals and departures are measured internally with the attendant problem of roadway overspills associated with vehicle arrivals at shopping mall entrances. Vehicle departure queues are internal matters. In any case, before the installation of automatic parking barriers, discharge rate of about 12.67 vehicles per minute was computed. After installation, reduced discharge rate of about 8.63 vehicles per minute (34.2%) was computed. This is the parking barrier release rate from the time of vehicle arrival to the time of clearance from barrier arm stop line.

5. CONCLUSIONS

Based on the synthesis of evidences obtained from the study, it is correct to conclude that no lasting solution to the challenges of traffic overflows from shopping malls will be found unless that solution takes into account parking control mechanism at the gates. This study has shown that in cases where parking discharge into roadways are regulated by way of automatic parking barriers installation at gates;

- Vehicle volumes egress onto adjacent roadways are fixed and finite
- Influence of peak hour flows from shopping mall on adjacent roadways is minimized
- The assertion that parking demand from shopping mall will have overwhelming influence on qualitative roadway service is doubtful; especially in circumstances where traffic volume contributions from other sources in the immediate vicinity have been overlooked.
- Circulating flow within the shopping mall is a private property concern without direct influence on public highway
- As a result of regulated volume discharge, development hourly traffic volume was significantly reduced.

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He has worked with many local authorities in England including London Borough of Croydon, London Borough of Merton, Birmingham City Council, Surrey County Council and Coventry City Council. He has also worked with Amey / Mouchel Construction, Telford, Aspen Lewis Group (Rural Partners Ltd, Henley Homes, Berkley Homes and Cory Environmental Services). He was the Project Manager of JBE Consulting Ltd before career change to lecturing in 1999. He has taught and carried out research works at Obafemi AwolowoUniversity Ife Nigeria, Manchester College, Nigeria Building and Road Research Institute, University of Ibadan, Nigeria and Universiti Teknologi Malaysia where he is an associate professor and the head of road safety research group.

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