THE EVALUATION OF LOCAL AREA TRAFFIC MANAGEMENT ON ACCIDENT RATES

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Abstract: Significant safety problems exist on local streets. Local Area Traffic Management (LATM) has been used to deal with the problems with the primary purpose of improving safety and benefiting residents. Researchers have argued about the safety benefits that are brought from various schemes. This paper describes the evaluation of safety benefits resulting from a case study of LATM schemes in metropolitan Adelaide, South Australia. A rigorous method of evaluation that was developed by Fairlie and Taylor (1990) was employed for the study. GIS ArcView was used for detailed accident data analysis. The devices employed in the schemes bring the benefit of reducing speed, but it does not necessary offer the direct accident reduction potential. The acceptance of a scheme by the local community is the key element for a scheme to be implemented.

Key Words: Local Area Traffic Management (LATM), safety benefit, accident rate

1. INTRODUCTION

Significant safety problems exist on local streets. In terms of traffic accidents, it was estimated that about 25 percent of all urban injury accidents occurred on local streets with the most vulnerable groups (pedestrians and cyclists). It was especially the young and the elderly who were at the highest risk (Andreassen, Hoque and Young, 1984; Samdahl and Daff, 1986; Affum and Taylor, 1997). To improve local area traffic conditions and reduce the accident rates, the development of an acceptable and suitable LATM scheme has become an important concern for traffic engineers and safety administrators. The basic purpose of Local Area Traffic Management (LATM) is to control the movement and speed of traffic in residential areas to discourage through traffic, minimise traffic accidents and improve the level of environmental amenity. LATM involves the use of various techniques and traffic devices. However, it is impracticable to discourage all through traffic from all streets in a residential area, because of historical reasons, the functions of some collector/arterial roads and local streets are in a mixed manner. The introduction of LATM for one area may generate a serious effect on an adjacent area. Therefore, the use of LATM should be carefully planned, tested and evaluated. Apart from the mentioned problem, in many cases, once an LATM scheme had been implemented, no evaluation process was followed. There has then been no feedback about the effectiveness and impact of the scheme on the defined objectives.

This paper aims at reporting an investigation on traffic accident rates, with a rigorous evaluation method that was used to assess the safety benefits after the LATM schemes were introduced. A case study was conducted in metropolitan Adelaide, South Australia, in the suburb of Beaumont. In the LATM benefit evaluation, before and after studies were employed to compare the accident rates for the treated area and the control area in a disaggregated network level. The performance of traffic in the area was also measured and compared in the before and after periods. The study indicated that the success of a scheme is not only measured on the basis of the safety benefits and of the achievement of residential amenity, but is also based on the acceptance of the scheme by the local community. If a LATM scheme is not accepted by the local community, it is impossible to be implemented, even it may bring out the safety benefits to the area.

2. PRINCIPLES IN UNDERTAKING LOCAL AREA TRAFFIC MANAGEMENT

Safety problems on local streets have been perceived for some years. Brindle (1983 cited in Fairlie and Taylor, 1990) emphasised the magnitude of safety problems on local streets. He found that data from overseas and Australia have shown that up to 33 per cent of urban casualties typically occurred on local streets. Samdahl and Daff (1986) reported that 25 to 35 per cent of total casualty accidents occurred on local streets in NSW between January 1982 to June 1984. Affum and Taylor (1997) supported these findings and claimed that about 25 per cent of urban injury accidents occurred on local streets. An obvious characteristic of the safety problems on local streets is that higher number of accidents involve vulnerable road users like pedestrians and cyclists, especially the young and the elderly who are at the highest risk (Andreassen, Hoque and Young, 1984; Samdahl and Daff, 1986; Affum and Taylor, 1997).

LATM schemes are primarily used to deal with these safety problems on local streets, and to benefit residents. The main reasons for implementing LATM schemes are: to decrease noise and intrusion into residential environments; to shift unnecessary traffic; to reduce excessive speed; and to reduce accident numbers and severity. Therefore LATM schemes gain the goal of providing local communities with improved safety and amenities.

The results of overseas and Australian studies were summarised by Brindle (1984) who concluded that LATM programs in existing local street networks would generally be expected to produce significant improvements in local safety, in particular, child safety should greatly be improved. This claim was supported by two studies. A German study yielded a 44 per cent reduction in accidents in treated areas and a study in Unley (South Australia) reported a 56 per cent reduction in injury accidents and a 42 per cent reduction in total accidents after a 12 month period in which an LATM scheme had been implemented. Searles (1986) reported in a Swindon study that suggested that it was feasible to have an overall accident reduction of between 10 per cent and 15 per cent, with reduction in pedestrian accidents being substantially greater.

Despite the fairly strong evidence that supports focusing on the accident problems of local areas, the significant level of safety improved by LATM on local streets is not supported by all researchers. Andreassen and Hoque (1986) questioned the high expenditure on LATM schemes, while there were not enough funds that could be implemented for treatment on arterial roads for many of the blackspots. They also questioned how much benefit LATM scheme would produce, when compared to the benefits of implementing a road safety countermeasure on arterial roads. Some researchers raised that many of the traffic management devices used in LATM failed to deal with the accident problems occurring on local street network (Andreassen and Hoque, 1986; Fairlie and Taylor, 1990).

3. THE SAFETY EVALUATION PROCESS FOR LATM SCHEMES

The evaluation of a safety project is normally undertaken after examination of the changes of accident frequency and severity over a period of time and some related issues following the implementation of a countermeasure or a scheme. It is a process conducted to ascertain whether and how effective a countermeasure or a scheme has brought about the desired result of improvement of road safety and if it has reached the objectives. The techniques of the evaluation have been discussed by a number of researchers (Affum and Taylor, 1997; Ogden,1996; Fairlie and Taylor, 1990; Brilon, 1988; Searles, 1986).

In general, three techniques, cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis, have been used widely in the evaluation of accident countermeasures. But these techniques are not suited in the evaluation of LATM schemes due to some difficulties, which was indicated by Fairlie and Taylor (1990):

> '*(a). there is a large degree of interaction between all traffic phenomena, so that it is difficult to attribute a particular effect to a specific countermeasure, (b). definition of the physical area influenced by a given traffic or environmental measure is difficult, and (c). environmental measures have effects on other urban functions besides traffic safety*'.

They suggested that evaluation should take place not only at the location of the countermeasure, but also over the full area where side-effects can be expected. A more relevant approach to evaluating the safety benefits of an implemented scheme was pointed out by involving a detailed disaggregate analysis of accident data within the area for before and after periods compared with an appropriate control area. Some researchers also argued that a short period (after a LATM scheme was implemented) is not suitable for an effective evaluation of LATM schemes. (Nicholson, 1986; Brilon, 1988; Fairlie and Taylor, 1990; Affum and Taylor, 1997).

Brilon (1988) detailed a study methodology he developed, using three years of before-period and after-period accident data to evaluate safety benefits of area-wide LATM schemes in several German cities. The methodology used a pilot test in a residential area where a number of treatments had been implemented. The analysis was based on the accident statistics from police authorities (including minor damage accident). Each accident was concerned in terms of its type, causes and consequences, as well as the local situation at the time of its occurrence. The results of the analysis indicated that the most significant reduction of accidents occurred in the areas where the most intensive treatments were applied, in spite of all treated areas showing significant reduction. There were slight decreases in accidents on arterial roads, but slight increases in accident in neighbouring areas. The figures showed the vulnerable road users (children, pedestrians and cyclists) had benefited most from the treatments. It also suggested that the 'bottlenecks' had an increase in accidents with minor damage primarily collisions with oncoming traffic.

Fairlie and Taylor (1990) provided a detailed evaluation of safety benefits of LATM in two local areas in Sydney, on the basis of a methodology that they developed for area-wide accident analysis. Accident data of a three years after-period was required as the critical test. LATM schemes were implemented with a dense coverage of devices. Accident data were based on Police Accident Records. The accident analysis considered all network elements, road user groups, time periods and accident severities. The results of the analysis showed that in both treated areas, direct safety benefits had been produced at the internal intersections, with significant reductions in non-injury accidents and total accidents. On the other hand, there was no accident reduction apparent on the external road network. The study found that many of the traffic management devices used extensively in LATM failed to solve the dominant types of accidents occurring on local streets.

It can be seen that a complete evaluation of an LATM scheme should include the analysis of a broad range of factors which may be affected by the implementation of the LATM scheme. Such as: frequency, severity, type and pattern of accidents; traffic volumes and vehicle speeds; traffic noise and emission level; and resident attitudes concerning safety, speed, volume, intrusion and environment.

4. CASE STUDY

4.1 Study Methodology

The methodology adopted for the evaluation of the LATM schemes was first proposed by Fairlie (1989) and later by Fairlie and Taylor (1990). It also has a similar basis to that developed by Brilon (1988). It is a rigorous method which compares the accident frequencies of a certain before and after period of a treated area with a control area (non treated area) using the Chi-square test on the contingency table to overcome the problems of low accident numbers and regression to the mean effect. The main features, according to Fairlie and Taylor (1990), are as below:

- a desirable minimum of three years of before and after period data (accident and traffic network data) is required
- a suitable control area close to the study area
- study and control areas' networks which are defined as a connected set of nodes (junctions) and links (street sections) respectively
- accident data which are analysed in a format that allows the comparison of before and after data for a range of factors, including frequency and severity of accidents, road user categories (e.g. car, cyclist, pedestrian, etc), Road User Movements (RUMs), the time of day of the accidents and Light conditions
- 'like' categories are grouped together (e.g. all internal links, all internal intersections, etc) to deal with the problem of small and dispersed accident numbers that normally encountered in local areas. These results are then compared with the control area. The approach may be used for 'like' treatments (e.g. all intersections treated with roundabouts, all links treated with speed humps, etc)

The steps involved in this method are outlined in sequential order as below:

1. Identify suitable LATM and control areas. These schemes should have before and after period accident data, ideally with a minimum of three years duration and LATM devices implemented on an area-wide basis. The control area should have similar features to that of the treated area but no form of traffic management schemes implemented during the study period.

2. Visit relevant personnel responsible for developing and implementing each candidate scheme, including traffic engineering consultants, council officers and engineers. Obtain all the relevant data for the scheme.

3. Carry out a field inspection of each candidate scheme to observe the location, appearance and operation of each device and get a 'feel' for the traffic conditions, abutting land use, etc.

4. Determine which candidate LATM areas satisfy the conditions for further study and then identify suitable control areas.

5. Obtain accident data from the relevant authorities, sufficient enough to give for a period of about three years before and after the implementation of the schemes for both LATM and control areas.

6. Classify the LATM and control areas into a series of numbered nodes (or intersections) and links, and internal and external network. The external network comprises the surrounding arterial or sub-arterial roads and the internal network comprises the streets within these arterial roads.

7. List the following accident details for each node and link in both LATM and control areas for each year; date of accident; time of accident; accident type; road user movement (RUM) code; travel directions (node only); location along links (links only); vehicle/road user category; and severity of accident.

8. Collate the following accident details for each link and node for both the LATM and control areas to give the accident history of each node and link for the period: accident severity; accident type; vehicle/road user category; time of accident and light condition

9. Determine the implementation dates for the LATM and after allowing time for a settling-in period, collate and summarise relevant accident details as listed above for before and after periods.

10. Check to ensure that the data has been collated correctly.

11. Collate and analyse before and after data for each node and link for both LATM and control areas for the following categories: internal links; internal nodes; external links; external nodes and the interactions between them.

12. Collate and analyse before and after data for LATM and control areas on an area-wide basis (ie. group all internal and external intersections and links).

13. Collate and analyse before and after data for each category of traffic management devices used for the LATM areas (for example all data for intersections that have thresholds, all links that have speed humps etc).

14. Collate and analyse for both LATM and control areas accident details by type of accident, severity, vehicle and road-user categories and time categories for both internal and external road networks disaggregated as stated above.

15. Perform statistical analyses using Chi-square contingency table tests to assess the significance of accident changes for before and after periods.

The Chi-square statistic is calculated as below. On the basis of the null hypothesis that there is no difference between the before and after data, consider the following two-row contingency table, in which there are 'n' columns corresponding to 'n' levels of the accident variable under consideration. 'B_i' is the frequency of before period accidents and 'A_i' is the frequency of the after period accidents in accident category 'i':

						Row sum
Before	B_1	B_2	B_3	....	B_n	R_B
After	A_1	A_2	A_3	....	A_n	R_A
Column sum	C_1	C_2	C_3		C_n	T

Then the Chi-square statistic is given by Equation (1):

$$\chi^2_{n-1} = \frac{T}{R_B}\sum_{i=1}^{n}\frac{1}{C_i}\left[B_i - \frac{C_i R_B}{T}\right]^2 + \frac{T}{R_A}\sum_{i=1}^{n}\frac{1}{C_i}\left[A_i - \frac{C_i R_A}{T}\right]^2 \qquad (1)$$

with (n-1) degrees of freedom.

For each level of the variables in the table the difference in accident frequencies between the two periods is compared using the approximated chi-square statistic given by Equation (2) with one degree of freedom (Leeming,1963, cited in Affum, 1996).

$$\chi^2 = \frac{\left[B_i - A_i\right]^2}{C_i} \qquad (2)$$

Road accident data analysis is one of the major tasks in the evaluation of a LATM scheme. There are several methods that can be used to present this process. GIS ArcView was employed for all the accident data analysis because it provides great accurate and efficient capabilities in integrating various databases and graphic displays.

4.2 Case Study Area

Case study area was selected in the suburbs of Linden Park, Hazelwood Park, St Georges, Glen Osmond and Beaumont, Burnside, in Adelaide, South Australia. The LATM and the control areas are shown in Figure 1. The LATM area is a predominant residential area with two schools and is surrounded by three main roads. The control area is selected with the similar characteristics to the treated area. It is mainly a residential area with two schools as well. The devices included in the Beaumont scheme were road humps (watts profile road humps with or without protuberances) and one roundabout which spans five streets as shown in Figure 2. The prime motive of the LATM scheme was to limit through traffic and to reduce the traffic speed of all the streets in the area, thus increasing safety and improving the amenity. The installation of devices commenced in March 1991 and was completed in April 1991.

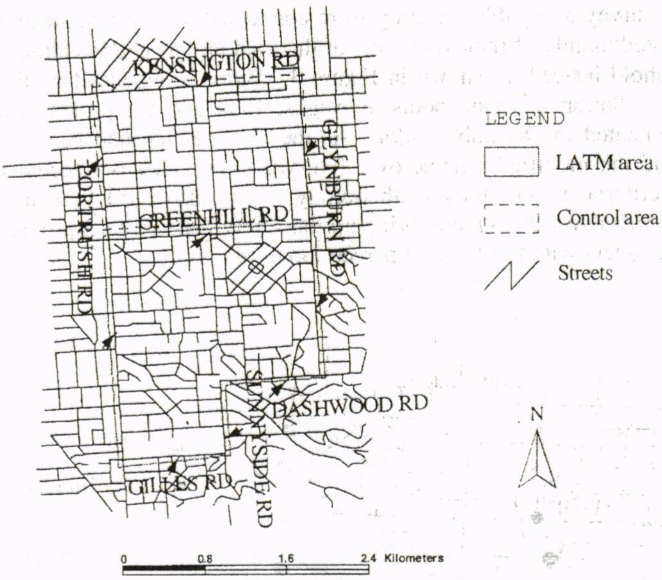

Figure 1. Locations of the study area and control area

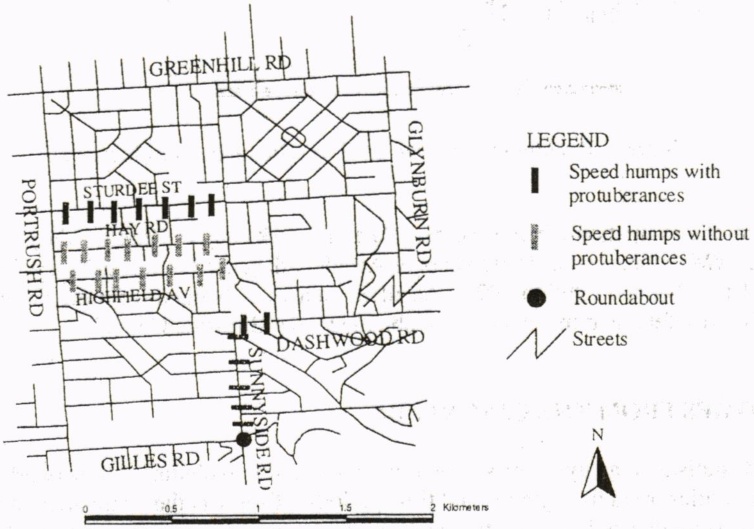

Figure 2. Beaumont LATM scheme devices locations

The Beaumont scheme is a good example of the importance of residents' opinions to the scheme. The LATM scheme was modified due to the residents strongly opposing the road humps after one year of implementation, in spite of the scheme being supported by the residents at the planning stage and the beginning period of its implementing (the questionnaire survey and public meeting were conducted at different stages). The modified scheme consisted mainly of removing most of the road humps and installing roundabouts and an entry threshold instead, as shown in Figure 3. Work commenced on the removal of the humps and installation of roundabouts in August 1994 and the project lasted five months being complemented in December 1994. As the first scheme had been implemented over three years and the modified scheme over five years, this area is selected for a study as it matched the criteria of the study methodology. It is also used in comparing these two schemes on which one was to really bring up the safety benefits to the area, the result of the technique assessment with the result of perception of the residents.

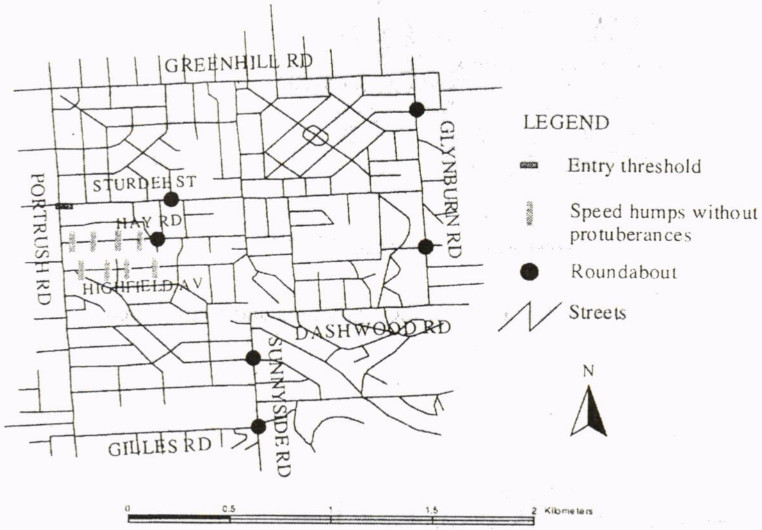

Figure 3. Beaumont modified LATM scheme devices locations

Data used in the evaluation include accident data, network data, traffic flow data, traffic speed data and LATM devices data. Three years of Accident data used in the areas are from 1988 to 1991, 1991 to 1994 and 1995 to 1998. Accident data was obtained from the South Australia Office of Road safety, and the others were obtained from Burnside Council.

5. OUTCOMES FROM THE CASE STUDY

A detailed statistical analysis was given in Xu (1999), including all network elements, accident severities, road user groups and time periods. Table1 is the summaries of the overall evaluation results that indicate the frequencies of accidents by severity category for external links and intersections, internal links and intersections in the three time periods. Some statistically significant differences were found in some groups. The LATM internal links emerged the most reduction in total accident frequency in all the disaggregated networks after implementing the LATM scheme. Table2 is the frequency of accident types in the whole area. It indicates a significant reduction in hit parked vehicle accident in the LATM area after the scheme was implemented.

Table1. Summary of Accident Frequencies and Severities

Location	Severity	LATM Area			Control Area		
		1988-90	1991-94	1995-97	1988-90	1991-94	1995-97
Internal Links	Fatal	N/A	N/A	0	N/A	N/A	0
	Injury	4✦	0✦	3	2	2	2
	PDO	33*	16*	28	21	27	28
	Total	37*	16*	31	23	29	30
Internal Intersections	Fatal	N/A	N/A	0	N/A	N/A	0
	Injury	2	3	5	2	3	2
	PDO	15	19	11	15	11	16
	Total	17	22	16	17	14	18
External Links	Fatal	N/A	N/A	1	N/A	N/A	0
	Injury	9	3	7	6	4	4
	PDO	69✦	66	43✦	41	39	30
	Total	78✦	69	51✦	47	43	34
External Intersections	Fatal	N/A	N/A	1	N/A	N/A	0
	Injury	18	16	13	18	17	21
	PDO	108✦	147✦	115	98	105	102
	Total	126✦	163✦	129	116	122	123

Note: *-statistically significant change at 95% confidence level.
✦- statistically significant change at 95% confidence level but found to be statistically insignificant when compared with the other area.
N/A - not available
PDO - property damager only

Table2. Summary of Frequency of Accident types

Accident type	LATM Area			Control Area		
	1988-90	1991-94	1995-97	1988-90	1991-94	1995-97
Head on	2	3	1	1	3	1
Hit fixed object	14	17	11	4✦	11	12✦
Hit parked vehicle	41✦	25✦	34	17	20	18
Hit pedestrian	2	1	7	3	5	4
Rear end	106	113	93	81	67	72
Right angle	50	53	48	39	43	57
Right turn	11	12	8	26	29	14
Side swipe	28	40	24	28	26	25
Other	4	6	1	4	4	2

Note: ✦- statistically significant change at 95% confidence level but found to be statistically insignificant when compared with the other area.

5.1 Beaumont Scheme

The Beaumont scheme produced significant safety benefits for the internal links. It had statistically significant reductions in property damage only (PDO) and accident frequency when compared with the control internal links based on severity. The injury accidents were also significant reduced (100%) after the implementing of the scheme, although the reduction was not statistically significant when compared to the control area. This could be concluded probably as a result of the reduction in speeds, which was brought about by the implementation of the scheme.

The reductions on external links and internal network were perceived. However, the reductions were not found in the internal intersections, external intersections and external network in spite of the increase in accidents found to be insignificant when compared with the control area. The result of no accident reductions occurred in the internal intersections possibly due to only one roundabout and that no other form of devices was applied to the internal intersections.

Hit parked vehicle accidents, the most frequent type of accident on the LATM internal links and internal network, were significantly reduced when compared with the control area. It could be mostly ascribed to the installation of the speed humps as they were the main devices employed in the scheme. The results obtained from recorded accidents which occurred in the vicinity of the devices showed the speed humps had a significant reduction in this type of accident. The extensive installation of speed humps could be a result of changing drivers' behaviour in reducing speeds.

5.2 Beaumont Modified Scheme

The Beaumont modified scheme totally failed in bring safety benefits to all levels of the networks. In spite of some reduction in accidents observed in these networks, they were mostly found to be insignificant when compared to the control networks.

The results indicate that the removal of the speed humps reduced safety benefits on the internal links, and the use of roundabouts instead of speed humps as the LATM devices did not bring the safety benefits in the internal intersections as well as the internal network. This result is found to be different from the results of studies by some researchers (Fairile and Taylor,1990; Affum, 1996), in which they found the roundabouts produced excellent results in reducing accidents for internal intersections. The result obtained from this study probably is due to that not many devices were applied to the internal intersections.

There were no reduction in Hit parked vehicle accidents, but an increase in Hit pedestrian accident even though it was insignificant on the LATM internal links. This was also the result of increase in accidents in the vicinities of the remained speed humps. All of these were probably due to the changing of drivers' perception of humps and increase in speeds as a result of removing most of the speed humps. The internal intersections recorded a significant increase in Right turn accidents when compared with the control area. This was possibly due to the increase in speeds and carelessness.

Two LATM schemes' evaluation results indicate that internal and external network with different characteristics of traffic operations, in terms of flow speed, traffic flow rate and road conditions, lead to different accident patterns in the two networks.

- For both the LATM and the control areas, the most frequent accidents were hit parked vehicle on the internal links, right angle in the internal intersections and rear end on the external links and intersections.

- Most of the accidents occurred on the internal network were during the day time, off peak hours and week days.

- About 10% to 18% of injury accidents occurred on the internal networks except the modified Beaumont LATM internal network that experienced a 27.4% of total injury accidents in the area.

- The internal networks recorded an average 80% of the accidents were involved with motor car sedan, station wagon, utility and panel van accidents, and about 4% involved with motor cycle, pedal cycle and pedestrian accidents. The rest of the accidents were involved with truck, bus, pole, post, other fixed object and other unknown types of vehicle accidents.

The devices employed in the schemes were roundabouts, speed humps and entry threshold. Roundabouts recorded a significant reduction in PDO and total accidents, but an increase in injury accidents. It shows that the roundabouts were effective in resolving the rear end, right angle and side swipe accidents which normally occurred on the internal intersections.

Speed humps showed totally different results regarding safety benefits in the two schemes. The Beaumont modified scheme had the result which failed to reduce for all types of accidents and increased in accidents with hit fixed object, hit parked vehicle and right angle. However the speed humps in the Beaumont scheme recorded a significant reduction in PDO and total accidents but a slightly increase in injury accidents. They also showed a significance in resolving the hit parked vehicle accidents which is the most frequency accident occurred on internal links. The different results indicate that speed humps do not offer direct accident reduction potential, rather influence it indirectly, through drivers' perception of overall travelling conditions on the streets with the general speed reduction. The results also indicate that intensive installation of speed humps would generally bring safety benefits for the areas while installation on a few streets with a few speed humps do not change drivers behaviour. On the other hand, the speed humps appeared to generally reduce speeds and they also seemed a good control device for traffic volumes.

Entry threshold employed in the Beaumont modified scheme did appear to reduce accidents and did not increase any new types of accidents. However, as there was only one implemented in the scheme, it would be meaningless to draw a conclusion.

This case study indicates that the effect of the scheme on the external network is limited, and also it does not necessarily reduce accidents on the internal network. It is very important to select a suitable scheme and associated devices which are employed on the internal links and internal intersections to produce the best effect on changing drivers' driving behaviour and modifying the flow pattern, and hence, to reduce potential accidents. If the primary goal of implementing a LATM scheme was not concerned with safety problems, the likely result would be that no safety benefits were obtained from the implementing of the scheme.

The available traffic flow data from the Beaumont LATM area on 62 locations of the streets showed that total traffic movements on these streets in the after implementation of the LATM scheme period were about 20% lower than the before period, and were further down a 15% in the after implementation of the modified scheme period. The result indicates that the two schemes had nearly the same successful level in controlling traffic volume. The total three year accidents in the three periods in the internal networks were 92, 73 and 105 respectively. They could be translated to that the after implementing of the LATM scheme period had a 20.6% reduction in total accidents, but the after implementing of the modified LATM scheme period had a 14% increase in total accidents compared to the before period. This indicates that the accident rate (accidents/vehicle volume) before and after the initial LATM scheme periods were the same, which means that the LATM scheme did not offer the accident reduction potential. The accident rate after the modified LATM period was higher than the before period, which means the modified scheme did actually offer more accidents to the area. Therefore, from the safety benefits measured by the accident rate (accidents/vehicle volume) point of view, both schemes were unsuccessful and the modified scheme was even worse.

In-depth questionnaire surveys and public meetings were applied in the Beaumont LATM area through out the whole process from the proposal of the traffic management plan to after implementing the modified scheme. The different options of LATM schemes were asked to obtain opinions from the public. The LATM scheme obtained support by 75% of total respondents before its implementation. After one year of its implementation the result of a questionnaire survey appeared that 74% of the total respondents were not satisfied with the scheme and strongly asked for the removing the speed humps, although the facts were that it did bring the benefits of improving the amenity by reducing speed and through traffic. The above safety evaluation results also showed that the accidents were reduced in the area brought by the scheme. The modified scheme was accepted by the community after one year of its implementation. This indicates that if the technique assessment result of a LATM scheme is different from what perceived by the local community, the scheme would be unsuccessful. Therefore a well designed LATM can make residents feel safer and more comfortable even though the actual assessment result is not matched with their perception.

6. CONCLUSION

This study attempted to evaluate the safety benefits for local area traffic management schemes based on two schemes. A rigorous method that was developed by Fairlie and Taylor (1990) was employed for the study. GIS computer program ArcView was used for detailed accident data analysis. A number of conclusions and recommendations may be drawn from the study as follows:

- The effect of the scheme on the external network is limited, and a LATM scheme does not necessary reduce accidents on the internal network. If the primary goal of implementing a LATM scheme was not concerned with safety problems, the likely result would be that no safety benefits are obtained from the implementing of the scheme. A correctly designed LATM scheme should have direct safety benefits by effectively reducing identified accidents, getting the best effect in changing driver's driving behaviour and modifying the flow pattern.

- A detailed disaggregate analysis of accident data in different network levels can clearly identify the safety problems. It gives a clear picture of whether or how much the benefits bring from the scheme at the different network levels. It also gives a clear idea for possible future studies to deal with these problems and to help improve the effectiveness of future LATM schemes . A three years accident data is desirable for such an evaluation.

- Roundabouts are a good device for reducing accidents and are also effective in resolving rear end, right angle and side swipe accidents. However they increase injury accidents which are not supposed by its functions. There may should be a further study for finding the possible reasons. Speed humps produce different results in dealing with accidents. The study indicates that speed humps do not offer direct accident reduction potential, rather than influence it indirectly, through drivers' perception of overall travelling conditions on the streets with general speed reduction. Intensive installation of speed humps may bring safety benefits for the area while installation on a few streets with a few speed humps possibly do not change drivers behaviour.

- Speed as a major contributing factor to many of the accidents is recognised by most of the researchers. It is also a main contributing factor to most of the accidents occurring on local streets. To create a safe residential environment, reduction in speeds should be priorly considered. The effective physical speed control devices have contributed to such an environment. Roundabouts are effective for speed control and are acceptable to residents. Speed humps are also effective for speed control but are not necessary accepted by residents as a reason of damaging cars.

- Safety benefits measured by the accident rate (accidents/vehicle volume) may produce different results. Therefore it can be suggested that accident rate (accidents/vehicle volume) can only be used as a supplement information for evaluation.

- A well designed scheme should not only have real safety benefits and an improvement of residential amenity, but also be accepted by the local community. Otherwise it will be impossible to be implemented.

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