The Performance Evaluation of the Application of the Environmental Adaptation Concept on A Collector Road in KKU, Thailand

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Abstract: A collector road in Khon Kaen University, Thailand equally serves both traffic movement function and land use access function. While the road is heavily used by pedestrians, it critically suffers from pedestrian accident risk, adverse traffic environmental impacts and amenity problems. A number of vehicles normally travel at hazardous speeds and rarely slow down and stop to allow safe crossing. The Environmental Adaptation Method (EAM) concept was consequently applied to manage and mitigate the pedestrian-vehicle conflicts problems. The activity profile (number of pedestrians per hour per 100 m.) was rearranged in correspondence with the improved speed profile by modifying several road physical characteristics other related facilities and landscape. Two occasions of physical improvements of the collector road performed technically well in reorganizing the vehicle and pedestrian interactions. However, the recent road modification (the second-improvement) showed lesser degree of success in calming the traffic speed while traffic volumes increased dramatically.

Key Words: Traffic Calming, Environmental Adaptation, Sharing the Main Streets, Collector Road

1. INTRODUCTION

As the economics growth and land use development in urban areas continuously increase, travel demand also rises up in response to the enhancement of individual income, car-ownership and car utilization. Therefore, passenger car dependency is obviously the main mode of urban transportation. In addition, economic and land use development can expeditiously accelerate urbanization and sub-urbanization. (Hayashi, 1996) Unavoidably, traffic congestion, road accidents, adverse environmental impacts and global warming and climate change crisis become more pronounced and clearly perceived.

Khon Kaen University (KKU) is located in the northwestern part of Khon Kaen city situating in the middle of the northeastern region of Thailand, approximately 450 km. apart from Bangkok. The campus covers around 900 hectares and has more than 50,000 residents including academia, students, supporting staff members and others. Location of KKU campus is not too far from the city center. Its primary location together with the development of the university and Srinagarind Hospital, the largest regional hospital in the northeast, has caused the change of urban area in vicinity of the campus. There are several communities surrounded the university mostly located in the north, west, and south of the campus. The rapid growth of these communities has affected the change of activities system in the area. Mid-rise apartments, shops, restaurants, food stalls, and other related activities have taken place to serve high demand from university staffs, students, and local residents. The area has become one of the densest areas of the city. However, since the northwest side of Khon Kaen City is considered a large enclosed area with incomplete and inefficient existing street networks, those living in this area have limited access to main roads. KKU campus eventually has become the main access for local residents to connect with other parts of the city. Local residents both within and outside the area have used main roads in KKU campus as a shortcut to Mitrapharp Road. and Maliwan Road. resulting a heavy through traffic in main campus.

Within KKU campus, the north side of campus or of academic zone was designated as main residential and services area for students and staffs. A pedestrian and bike routes was planned to link this residential and service zone with academic zone. The pedestrian axis was planned to pass through area of main library, complex building, and dormitories. Besides, public transport serving population within the campus has passed the frontage of complex building and main library. Pedestrians, therefore, are expected to be dense in this zone, especially during the day when students come to classes.

KKU campus, though is an academic area, it is comparable to a small town with various uses of land and buildings. The pattern of movement within the campus therefore corresponds to the pattern of activity system. Roads within KKU campus mostly are minor roads and collector streets associated with moderate traffic roads or local routes with low speed design, frequent access points, and access to buildings. Because the principle of road hierarchy based on the “functional classification” of the road itself and on the relationship between mobility and access, problems usually arise when these two dimensions of mobility and access do not correspond to each other as well as when the “intended” function conflicts with the “perceived” one (Marshall, 2005). In case of the main road in KKU campus, the adverse traffic environmental impact have occurred because of the mismatch between the mobility of the road and the area it served as well as the conflict between the physical characteristics and the function of the road.

Regarding to the system of road hierarchy in the campus, the main road in KKU campus is considered as a collector road. It has low to moderate capacity to carry traffic from minor streets within campus as well as from those in surrounded communities to the main system of arterial roads and highway. Meanwhile the road has passed through academic and student service zone that are location of various significant buildings such as main library, Complex Building or student service center, sport and recreation center, dormitories, and academic building of Faculty of Sciences and of Faculty of Agriculture. The road, therefore, intensely serves both motorized and non-motorized street users particularly in the area in front of Complex Building and main library where non-motorized street users are quite high especially during the day.

Moreover, the hostile physical characteristic of the main road encouraging the driver to speed up is one of various factors that cause the area of academic and student service zone the accident-prone area of the campus. In order to alleviate the adverse traffic environmental impact on this collector road in KKU campus, the Environmental Adaptation Method (EAM) with the concept of sharing main street was carried out, in correspondence.

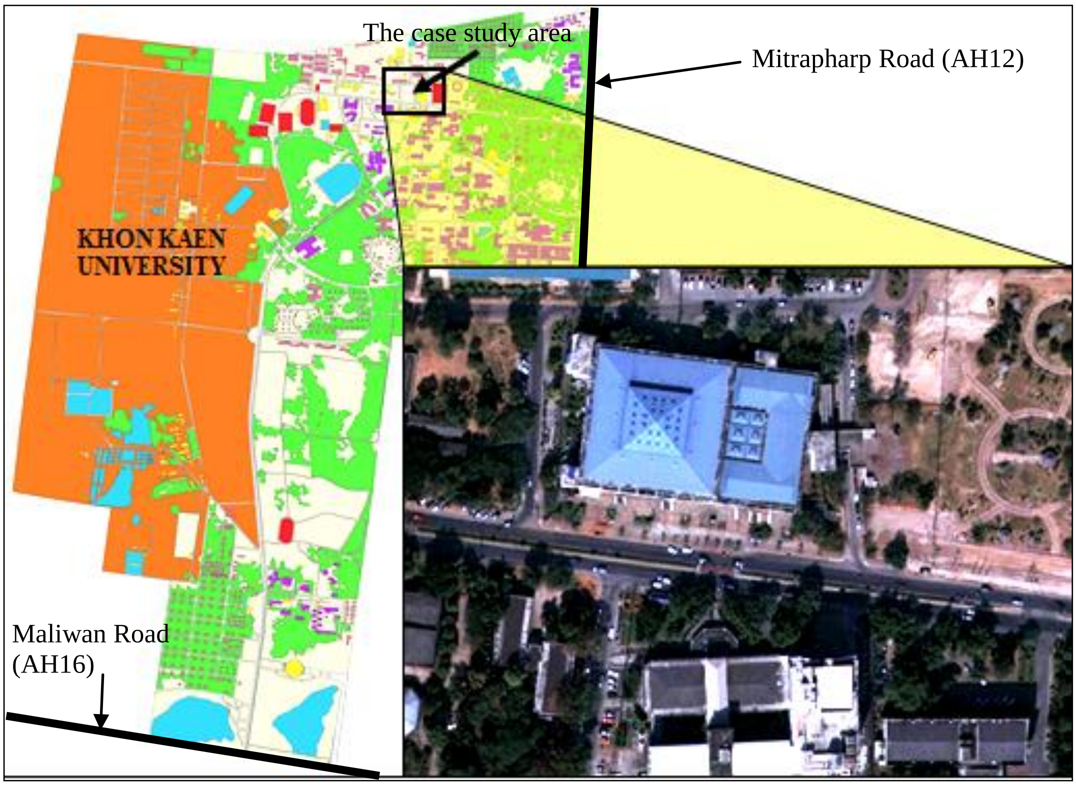


Figure 1. A collector road in front of the complex building in Khon Kaen University: The case study area

The collector road in front of the complex building (see Figure1) is an important route in KKU and has been used as the short cut between two highways, Mitrapharp road and Maliwan road located at the boundary of campus. The conflicts between pedestrians and vehicular movements on the KKU collector road have been critically recognized and urgently needed to be resolved. To alleviate the pedestrian and vehicle interactions and enhance the concepts of the Environmental Adaptation Method (EAM) (RTA, 2000) was initially applied in the case study area. Two occasions of real improvements of the collector road were performed to the vehicle and pedestrian conflicts.

The main objectives of this research are as follows: (i) to examine and analyze the severity of pedestrian accident risk in an area of high pedestrian movements along a collector road in front of the complex building in the KKU and (ii) to apply, implement and evaluate the applications of environmental adaptation concept to rearrange the vehicle/pedestrian conflicts on this road. This paper describes the following elements: (i) introduction; (ii) research methodology; (iii) transport/land use/environment interactions; (iv) traffic calming strategies; (v) the environmental adaptation concept; (vi) the analysis of pedestrian accident risk and pedestrian safety; (vii) the characteristics of the collector road in front of the KKU complex building; (viii) the applications of the environmental adaptation concept; (ix) data collection; (x) result analysis and (xi) conclusions.

2. RESEARCH METHODOLOGY

The interactions between pedestrian crossings and vehicle movements on a collector road in front of the KKU complex building were mostly pronounced as pedestrian accident risk, traffic environmental impacts and amenity problems. Based on the ESM method and the Song et al's model, the pedestrian accident risk was relatively critical. EAM was consequently applied to resolve the problems. The following description will explain the important steps of the application process of the EAM (RTA, 1999) and Figure 2 also shows flow chart diagram of the process.

Problem identification: Based on comprehensive field surveys and data collections of traffic and land use characteristics, a collector road in front of the KKU complex building has been suffered from pedestrian accident risk, traffic environmental impacts, amenity and esthetic and land scape problems.

Study area specification: A collector road, a divided four-lane road with 1.5 meters median width and narrow footpath (as shown in Figure 1 and 4) in front of the complex building is functioning as the main street in KKU. In addition, the adjacent road network and surrounding land use on both sides of the road were also taken into account.

Objectives and strategies identification: The main objectives of this research is to improve road and land use physical characteristics to reduce conflicts between pedestrian maneuverings and vehicles movements (therefore pedestrian accident risk) and to improve the environmental and amenity quality. Once objective was identified and corresponding strategies were also developed. This developed strategies will affect the data collection process.

Performance criteria identification: Prior to actually conduct a details investigation of the project. The performance criteria must be identified, selected and employed to assess and evaluate the outcome of proposed alternatives.

Data collection and analysis: The following road and land use characteristics data of a collector road in front of the complex building, adjacent road network and surrounding land use, mid-block and intersection traffic volume, Origin and Destination (O-D) traffic data, traffic speed, pedestrian crossing maneuvering were collected. The details of this data collection will be discussed in section 9.

Developing alternatives of measure schemes: Measure scheme alternatives will be developed in an integrated fashion. Therefore, different control, design and construction measures as suggested in RTA (1999) will be carefully selected and incorporated as set of different alternatives to be proposed for implementation. The details of the selected and applied alternative were explained in section 8.

Selection of the appropriate alternative: The different alternative were proposed and compared in correspondence to the achievable and measurable set up objectives. For each alternative, the comparisons on the performances outcomes of both the do nothing (existing) situation and the different proposed alternatives were conducted. Then, the appropriate alternative was selected for actual implementation. In this research, ESM, Song's model and other methods were adopted to assess the pedestrian accident risk performance. In addition, the micro-simulation modeling approach was systematically applied to assess the several performance outcomes (in terms of average and total (accumulative) vehicle travel time, average and total (accumulative) pedestrian trip time, combined network average and total (accumulative) trip time) of the existing and the proposed alternatives (Klungboonkrong and Woolley, 2003).

Implementation and monitoring: The selected alternative was actually implemented. Based on the performances criteria, the comparisons of between the before implementation (existing) situation and the implemented (the first implementation) alternatives were systematically conducted. Subsequently, the next implementation by the responsible KKU organization was subsequently executed. The details of the before-, the first- and the second-implementations and their associated performances were briefly summarized in section 10.

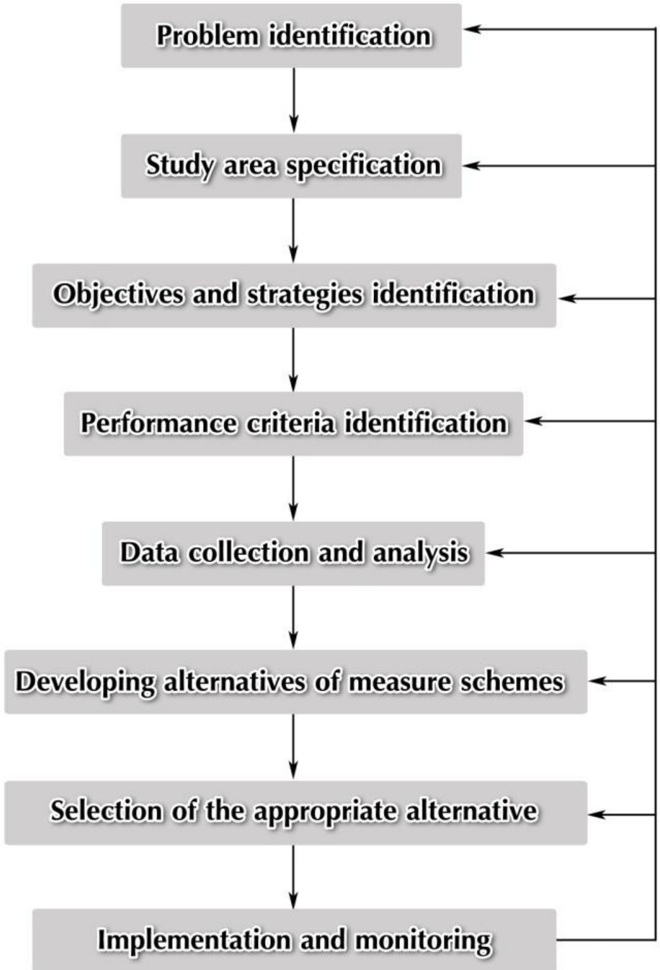


Figure 2. Flow chart diagram of the application process of the EAM concept

3. TRANSPORT/LAND USE/ENVIRONMENT INTERACTIONS

Transport/land use/environment interactions have long been accepted as a fundamental constituent of urban design and planning (Westerman, 1990). To achieve the primary objectives of the sustainable transport development, the understanding of the interactions is crucially indispensable and potentially leads to the ability to appropriately manage these interactions. The nature of such interactions varies significantly with the level of geographical scale. Westerman (1990) classified the transport/environment interaction into three levels including macro, meso, and micro levels. In this research, only the micro level was emphasized and hence the rearrangement of the conflicts between vehicle movements and road frontage-related activities are essentially key issue of the paper. The conflict consists of two important components: friction and impacts. The friction represents the influences of environment, land use, and frontage related activities (e.g. vehicle parking, crossing pedestrians, vehicle entering driveways, etc.) on the road traffic performances. Conversely, the impact is the effect of road traffic on abutting land use, environment, and the frontage activities along the road (e.g. crossing ability, pedestrian safety, noise, etc.) (Westerman, 1990).

AUSTROADS (1998) classified transport/environment typology at the micro level according to the relative importance and the function of a road and its adjacent environment into three primary categories as illustrated in **Figure 3.** Since the classification is relevant to the analysis of transport/environment interrelationship on the collector road, the transport/environment interactions and the type II corridors of which both traffic movement function and frontage access function are equally important.

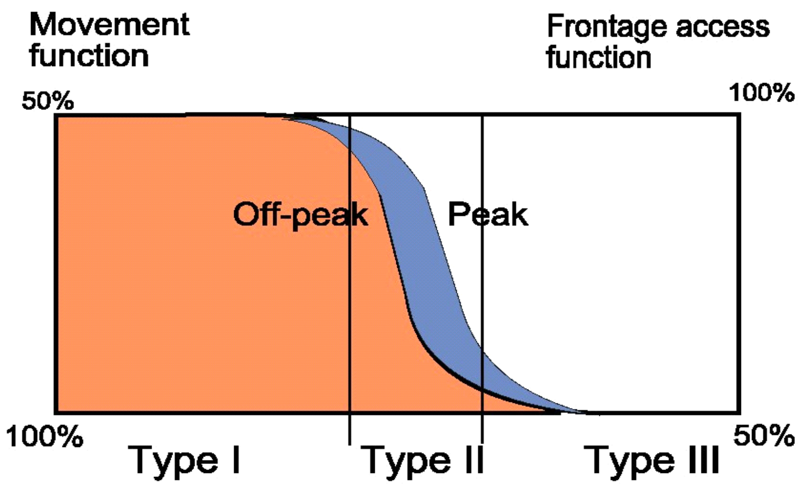


Figure 3. The classification of the transport/environment typology (AUSTROADS, 1998)

4. TRAFFIC CALMING STRATEGIES

'Traffic Calming' holds different meanings for different groups of people. In a broad sense, Hass-Klau (1989) has defined traffic calming as *'the combination of transport policies intended to alleviate the adverse environmental, safety, and severance effects that motor vehicles continue to impose on both the individual and society at large.'* When suitable road functional classes are appropriately defined (Brindle, 1989), the suitable traffic calming schemes are subsequently established and employed to encourage and reinforce the intended road functional classes.

Brindle (1991) classified traffic calming strategies into three different levels. Level I is the consequences of actions to control traffic speed and mitigate the impacts at local level where traffic volumes, levels of service, and network capacity are not a primary concern. One of the traffic calming strategies is the Local Area Traffic Management (LATM). Level II traffic calming strategies refers to the consequences of actions to control traffic speed and alleviate its impacts on traffic routes where traffic volumes, levels of service and network capacity are or may become a main concern. One example of the strategies is the Environmental Adaptation Method (EAM). Finally, level III strategies emphasize on the consequences of actions to reduce traffic levels and citywide impacts at the broader scale. An example of such strategies is Travel Demand Management (TDM).

Brindle's classification shows that different traffic calming scales are not only heavily associated with differences of geographical scope, but with the differences of the transport/environment interactions as well. Therefore, distinct measures are needed for different traffic calming levels and the suitable measures for one level may not necessarily be applicable to others. The collector road in front of KKU complex building emphasized on both traffic function and land use access function. Moreover, the areas along this collector road are residential and educational areas that are highly sensitive to the traffic induced effects. To manage the transport/environment interactions along this road, the level II of traffic calming strategies is reasonably suitable. Consequently, the EAM was adopted and applied.

5. THE ENVIRONMENTAL ADAPTATION METHOD (EAM)

EAM developed by Professor Hans Westerman (RTA, 2000) is the methods to modify the physical and land use characteristics of the roads in response to the needs of users by process of land use planning and transportation policy. It aims to provide safety, efficient traffic operation, amenity, and cost-effectiveness to all road users. EA focuses on the management of the conflicts between vehicles movements and pedestrian activities along sub-arterial roads, collector roads and the likes.

EAM must be conducted in an integrated approach involving with modification of street function and/or activities along the road. This approach is related to the alteration of road and/or activity function, the design and management of road space and its corresponding traffic, and the design and management of the frontage landscape. The following process is the heart of the application of the EAM (RTA, 2000): (i) gathering all pedestrian-oriented activities into a 'core zone' and directing all vehicle-oriented activities to a 'transition zone'; (ii) integrating all control measures to reduce traffic speed and/or minimize traffic volume in a core zone (to the target (the 85^{th} percentile) speed of 25-35 km/h) and in a transition zone (to 40 km/h); and (iii) improving the quality of street and streetscape within study area by modifying the landscape, road space, and road frontage (RTA, 2000).The EAM process was illustrated in Figure 4. The key factors influencing the design and planning for the EAM are the changes in road function, vehicle speed, traffic flow, through traffic, heavy vehicles, frontage activities, pedestrian behaviors, road reserve width and so on. Design for EA can be reflected in the selection of design, construction and control measures in the way that they are integrated to achieve the primary objectives (RTA, 2000). EA has been successfully applied and implemented in many projects in Australia (O'Brien, 1994; AUSTROADS, 1998 and RTA, 2000).

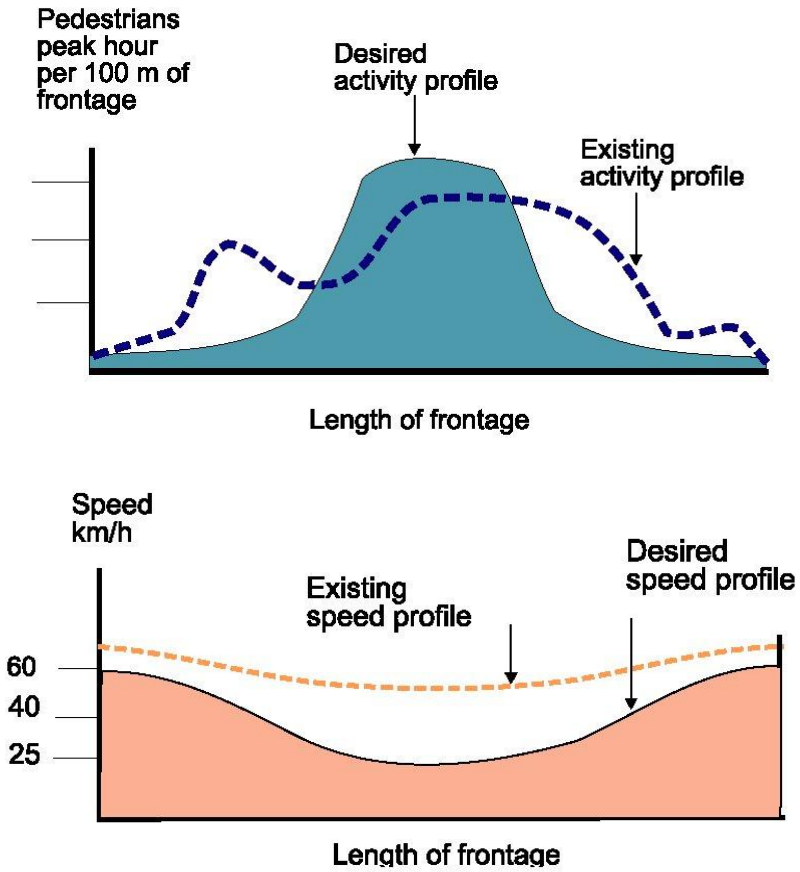


Figure 4. Activity Profile & Speed Profile
(RTA, 2000)

6. PEDESTRIAN ACCIDENT RISK AND PEDESTRIAN SAFETY

6.1 Environmental Sensitivity Methodology (ESM)

Singleton and Twiney (1985) established the Environmental Sensitivity Method (ESM) as a simple and practical tool to assess the Environmental Sensitivity (ES) of road sections caused by road traffic. The ESM assumes that the physical and land use characteristics of a particular road section can be utilized to determine the ES of that road. The road network in the study area was firstly divided into a number of homogenous links. Then the road physical and land use data relevant to the contributing factors for pedestrian safety were collected. The measured values of each contributing factor for pedestrian safety were compared with the corresponding measuring scales and the score of each factor could be assigned accordingly. For pedestrian safety, all derived scores of each factor were used to determine the ES index in terms of low, medium, and high level by using an established system for combination. (Singleton and Twiney, 1985). Based on the existing road and land use physical conditions in each improvement period and ESM, the rating score of pedestrian safety of a collector road in front of KKU complex can be assigned as high. If “Availability of Pedestrian Facilities” is “Yes” and “Walked Road Width” is “Wide” and “Footpath Width” is “Narrow”, then the ES index for Pedestrian Safety is “High” (Klungboonkrong, 1999).

6.2 Pedestrian Accident Risk Model

Recently, pedestrian accident risk models were developed by Song et al (1993a) based on several comprehensive sets of traffic, pedestrian, and pedestrian accident data collected in Sydney, New South Wales, Australia. Song et al's model is a behavioral probabilistic model based on Bayes' theory and can potentially be used to predict the level of pedestrian accident risk when attempting to cross a road at mid-block locations in urban areas. Song et al (1993b) recommended that the maximum acceptable level for vehicle-pedestrian accident risk limit is 2×10^{-5} per year and also found that pedestrian accident was rarely observed under the pedestrian risk level of 1×10^{-5}. Based on the finding, Klungboonkrong (1999) suggested the subjective rating scores for pedestrian accident risk as follows: low ($R = 0\text{-}1\times10^{-5}$); medium ($R = 1\text{-}2\times10^{-5}$); and high (R is greater than 2×10^{-5}). According to the Song et al's model, the pedestrian accident risk computed for the before improvement period is equal to 2.18×10^{-5} that can be classified as "high" score. This finding indicates that the collector road is potentially suffering from the pedestrian safety problem.

7. THE CHARACTERISTICS OF A COLLECTOR ROAD IN FRONT OF THE KKU COMPLEX BUILDING: (BEFORE IMPROVEMENT CONDITIONS)

A collector road in front of the KKU complex building is a divided four-lane road with two lanes in each direction and each lane is of 3 meters wide. The median width is approximately 1.5 meters, and the footpath with is narrow (see **Figure 5**). While the pedestrians randomly cross and usually walk on footpath along the road, the road has been more pronounced as having severe pedestrian accident risk and adverse amenity problems. This is because the road carries relatively high traffic volumes and those vehicles normally travel at high speed and rarely stop or even slow down to allow pedestrians to cross safely at the existing crossing. The collector road is surrounded by residential areas on one side and KKU main library, ICT building and other educational areas (e.g. Faculty of Science, Faculty of Agriculture and others) on the other side. Therefore, high number of KKU staff members and students usually cross this road section daily.

Figure 5. The before improvement conditions of a collector road in front of the complex building

8. THE APPLICATION OF THE ENVIRONMENTAL ADAPTATION CONCEPT

According to KKU master plan, the whole campus was planned and designed based on the concept of "livable campus." It is the kind of campus that encourages and accommodates various activities including enhances quality of lives all at once. Khon Kaen University is similar to a small town where people work, live, study, trade, or loosen up and enjoy themselves. The campus' public realm (e.g., park, small plazas, open space, and streets) provides a structure that enable campus to be livable. Making university campus environmentally healthy and safe requires high consideration and careful planning and design, especially the design of public domain.

A university campus as a small town could be livable with development concept of smart growth and compact city. What "smart growth" and "compact city" concepts have in common is the opposition against the urban sprawl and automobile-based development. Whereas the former emphasizes the development in the environs of public transport, biking and walking, the latter focus on livability, better access with less traffic, open spaces, and development in built-up area. Both concepts though could be approached variously, has some principles in common especially in the issues of street network, street design, and public streetscape. According to smart growth principles, straight and far street vista causes driver to speed thus street spaces should be designed so that driver can feel effectively enclosed (Duany, Speck, & Lydon, 2010). Besides, more eye contact between pedestrians and drivers are necessary to create Safe Street. Since KKU campus is comparable to a small town as well as student service zone to a small neighborhood, the concept of traffic calming and sharing the main street is suitable for adaptation the main street in KKU. The main purpose is to reduce conflict between motorized and non-motorized street users by reducing traffic speed and alerting drivers when approaching academic and student service zone. Planning and design considerations for environmental adaptation are as follows:

- Reduce the width of traffic lane by increasing the width of median.
- Create the feeling of efficient enclosure to driver by using street tree with spreading form so that space at crossing point is efficiently enclosed. (Unfortunately, the concept of street tree is overlook when the project took place.)
- In addition to warning sign, rough street pavement was used to reduce speed of vehicles before entering the core zone.
- Change the physical characteristics of area surrounded student service zone by redesigning streetscape (e.g., connected sidewalk, shading trees, street sign, etc.) to create the “walk able” zone
- According to KKU master plan, the axis of main pedestrian and bike route in academic zone was planned to cross KKU’s main road at the core zone so that the entire campus is physically unified.

More detail of environmental adaptation of the main street are shown in Table 3. In addition, it should be remarked that the process of EAM of the main street in KKU campus was done with high level of public opinion. Informations of EAM and design was disseminated through open sources such as university’s radio channel, web site, advertising boards, and brochures. The main objective of the adaptation is to reduce accidental risk due to pedestrian-vehicle conflict as well as increase amenities of the campus especially in student service zone.

The results of pedestrian accident risk, pedestrian safety analysis, and field surveys indicated that there is high risk of accident during pedestrian crossing maneuverings. The EA concept was applied to manage pedestrian safety problems. The activity profile (number pedestrians per hour per 100 m) is rearranged in accordance with the modified speed profile by changing several road physical characteristics and landscape. Two actual improvements were completed as shown in **Figure 6.** The summary of the details of road physical and land use characteristics during the before improvement period, the first improvement period and the second improvement period were also presented in **Table 3.**

(a) Before Improvement

(b) The First Improvement

(c) The Second Improvement

Figure 6. The road and land use physical characteristics of the study area during before and after applying the EA concept

Table 3. The road physical characteristics during the before-, the first- and the second- improvements

Road physical and land use adaption	Before Improvement	The 1st Improvement	The 2nd Improvement
Core zone and transition zones	No Core zone and transition zone	Core zone 40 m. Transition zone 80 m. (on both sides)	The same as the 1st Improvement
Speed hump length at core zone	Level asphaltic concrete road surface without speed hump	Brick-paver speed hump is 40 m. long at the core zone. Speed hump side slopes are 7 percent and 15 cm. high.	In west-bound direction, two asphaltic-concrete speed hump of 82 m. and 15 m. long at core zone and transition zone, respectively. In east bound direction, one asphaltic concrete speed hump of 82 m. long at core zone. Speed-hump side slope are 7 percent and 10 cm. high.
The effective road width and the median and footpath width	Footpath width of 2.5 m. Road width of 9.0 m. in each direction the median width of 1.5 m.	Widening the median with from 1.5 m. to 2.0 m.; widening footpath width to at least 3.0 m. and reducing the road width to 6.0 m. in each direction.	The same as the 1st Improvement
Bus stop locations	In west bound direction, bus stop location is situated at the location prior the pedestrian crossing	Relocating the new bus stop location in the west bound direction. Beyond the speed hump location	The same as the 1st Improvement
Pedestrian crossing control at mid-block location	Raised median of 1.5 m. wide	Planting bush trees (Bougainvillea) along the median (transition zone), expect for the core zone.	The same as the 1st Improvement
Warning the driver and riders to reduce their running speeds	No warning	Installing rumble strips and changing the texture of road surface to brick pavement at the intersection prior to the improvement area	No rumble strips and the texture of road surface to asphaltic pavement at the intersection prior to the improvement area

9. DATA COLLECTION

(a) Physical data surrounding KKU Complex Building

To produce the case study area map, all physical data concerns different infrastructures such as road alignment, median, footpath, bus stop locations, traffic management schemes, abutting buildings, and other facilities surrounding the complex building were surveyed and collected.

(b) *Traffic Volume*

Traffic counts at the mid-block locations and intersections in the study area were observed and collected according to predefined vehicle classifications and flow directions. The numbers of vehicles were collected during morning peak hour period (7:00-10:00) and afternoon peak hour period (15:00-18:00) and during off-peak period (11:00-14:00) of one selected working day.

(c) Origin and Destination (O-D) Data

To obtain an O-D data of all trips, the license plate survey was carried out. Some vehicles were collected during the peak hour (7:30-8:30) at every point of entry and exit. Types of vehicles recorded were motorcycle, passenger car, small truck, medium truck, heavy truck, small buses and big buses.

(d) Traffic Speed

Laser gun was adopted to measure vehicle travelling speeds during the morning and afternoon peak and off-peak periods.

(e) Pedestrian Crossing Maneuvering

The pedestrian crossing maneuvering data were collected in 5 designated zones (Zone A, B, C, D and E) during the morning and afternoon peak hourly periods and off-peak period previously mentioned. Each zone is approximately 40 m. long and the total length of the concerned road section is 200 m. (See Figure 7). Pedestrian crossing movements were observed and recorded in terms of number of pedestrians per 100 m. per hour and number of jaywalkers and jay runners were also considered.

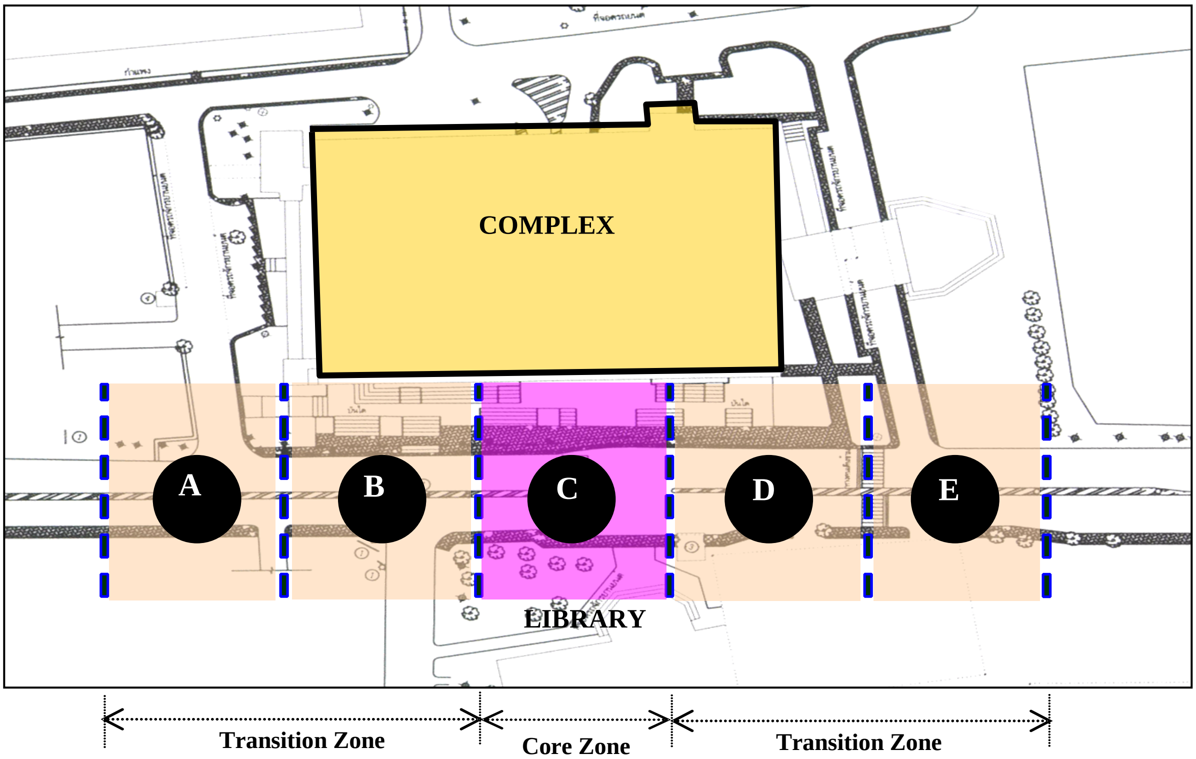


Figure 7. Five zones of pedestrian crossing data collection

10. RESULT ANALYSIS

The road physical conditions, road networks, origin-destination data, traffic volumes, speeds, composition, pedestrian movements, jay walkers and jay runners were observed and collected during the before- and the first- and the second-improvement periods. The results indicated that in one observed working day, the total number of pedestrian crossings in the morning and afternoon peak periods were generally similar. However, the traffic volumes observed in the morning peak period was slightly greater than those in the afternoon peak period. Thus, the further analysis is solely concentrated on the vehicle/pedestrian interactions at the core zone (C) in the morning peak period.

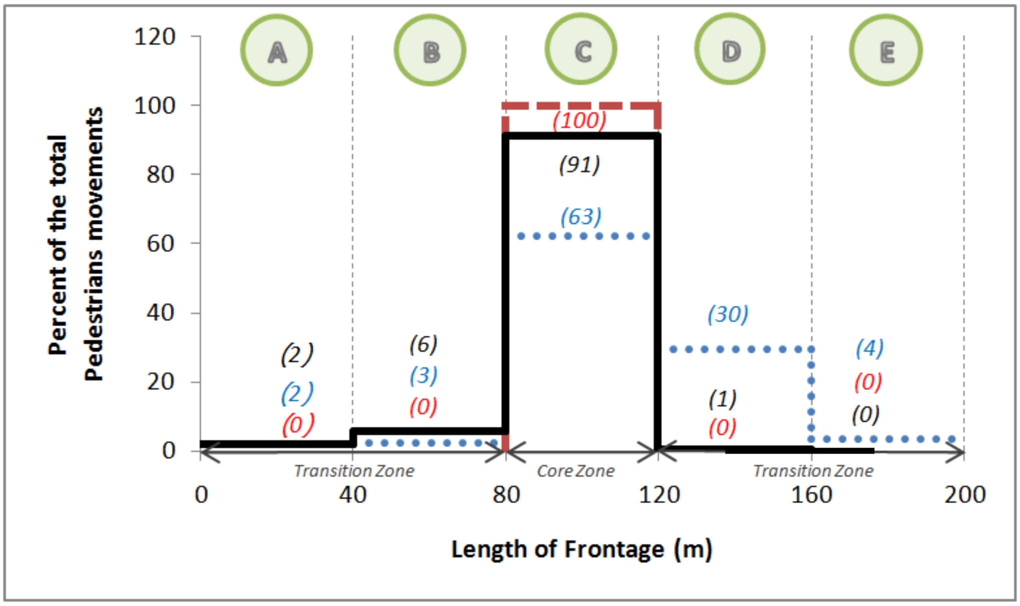
In the before-improvement period at the core zone (C), the traffic flows (collected during 7:30 and 8:30 AM) in the east-bound, west-bound and combined both directions were 577, 610 and 1,187 passenger cars per hour, respectively, while in the first improvement period, the traffic volumes the east-bound, west-bound and combined both directions were 790, 812 and 1,602, respectively. In the second improvement period, the traffic volumes in the east-bound, west-bound and combined both directions were 833, 921 and 1,754, respectively. In the first and second improvement periods, the morning peak hourly (combined both directions) volumes were considerably greater than that in the before improvement period. This was possibly because during the first and the second improvement periods, the certain amount of through traffic attempted to avoid traffic congestion on the existing road network and use the collector road as the short-cut route.

Figure 8 illustrated the speed profile collected during 7:30 and 8:30 AM in the core zone (C) and the transition zones (A, B, D and E) during the before-, the first- and the second-improvement periods. In the before-improvement period, the 85th percentile speeds in the core zone were 54.8 km/h and 45.0 km/h in the east- and west-bound directions, respectively, while in the first-improvement period, the 85th percentile speeds in the core zone were 31.0 km/h and 30.6 km/h in the east- and west-bound directions, respectively. Interestingly, in the second-improvement period, the 85th percentile speeds in the core zone were 43.0 km/h and 38.7 km/h in the east- and west-bound directions, respectively. It could be concluded that based on the 85th percentile speeds (in both directions) in the core zone, the first- and the second- improvements could potentially reduce traffic speeds dramatically. The results indicated that the installed a speed hump (in the first-improvement period) can effectively reduce the hazardous speed (in the before- improvement period) to the safer target speed interval (25-35 km/h). McLean et al (1995) implicitly noted that if a car hit a pedestrian at the impact speed of 50 km/h, the probability of survival is only 7%. However, if the impact speed is reduced to 31 km/h, the probability of survival is greatly raised to 99 %. However, the effectiveness of the improvement in the second-improvement period was lesser than that of the first-improvement period, because of the construction of speed humps during the two improvement periods were physically different in terms of the type of road surface and their physical characteristics (side slopes and heights).

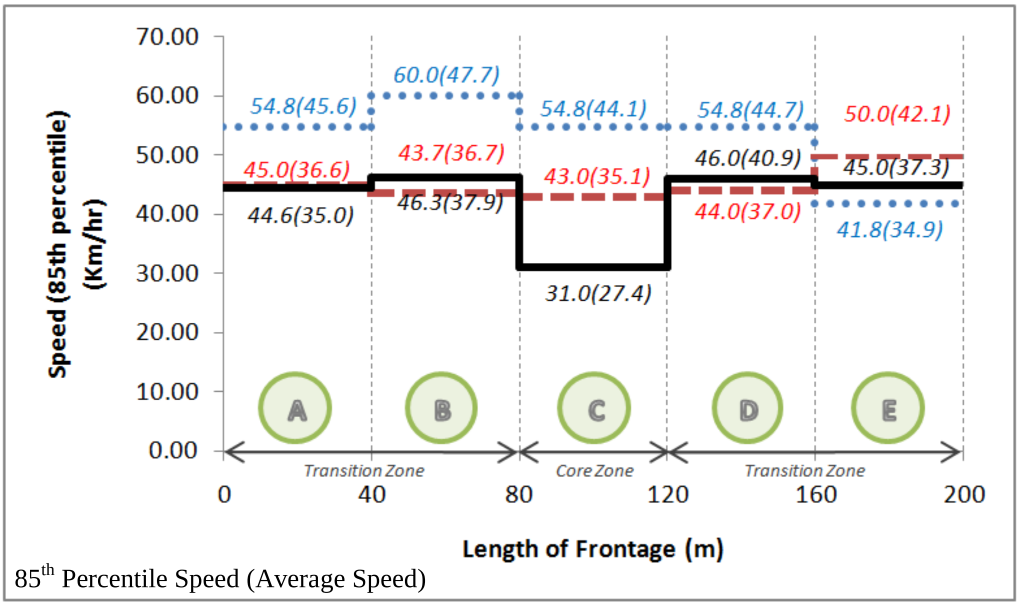
Figure 8 also illustrated that the pedestrian crossings maneuverings (activity profile) collected during 7:30 and 8:30 AM in the core zone (C) and the transition zones (A, B, D and E) during the before-, the first- and the second-improvement periods. These pedestrian crossings were classified into walking and running maneuvering. As shown in Figure 7, the percentage of the pedestrian crossings in core zone (C) was increased from 63% (in the before- improvement period) to 91% and 100% in the first- and the second-improvement periods, respectively. In the transition zone (D), the percentage of the pedestrian crossings was reduced from 30% (in the before-improvement period) to only 1% and 0% in the first- and the second-improvement periods, respectively. In other remaining zones, the percentages of the pedestrian crossings were very low and relatively unchanged during those periods. The results clearly shown that the principal achievement of the applications of the EA concept in gathering as many as pedestrian crossings in core zone (with lower target speeds) and minimizing such crossings in transition zone (with high traffic speeds).

(a) East-bound direction

Activity profile



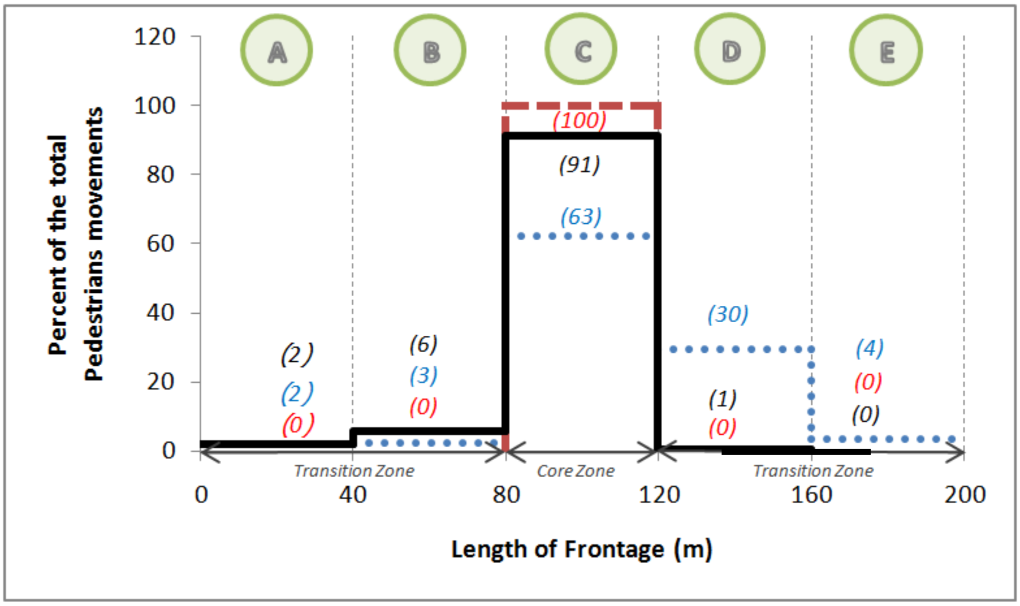
Speed profile



Before Improvement
1st Improvement
2nd Improvement

(b) West-bound direction

Activity profile



Speed profile

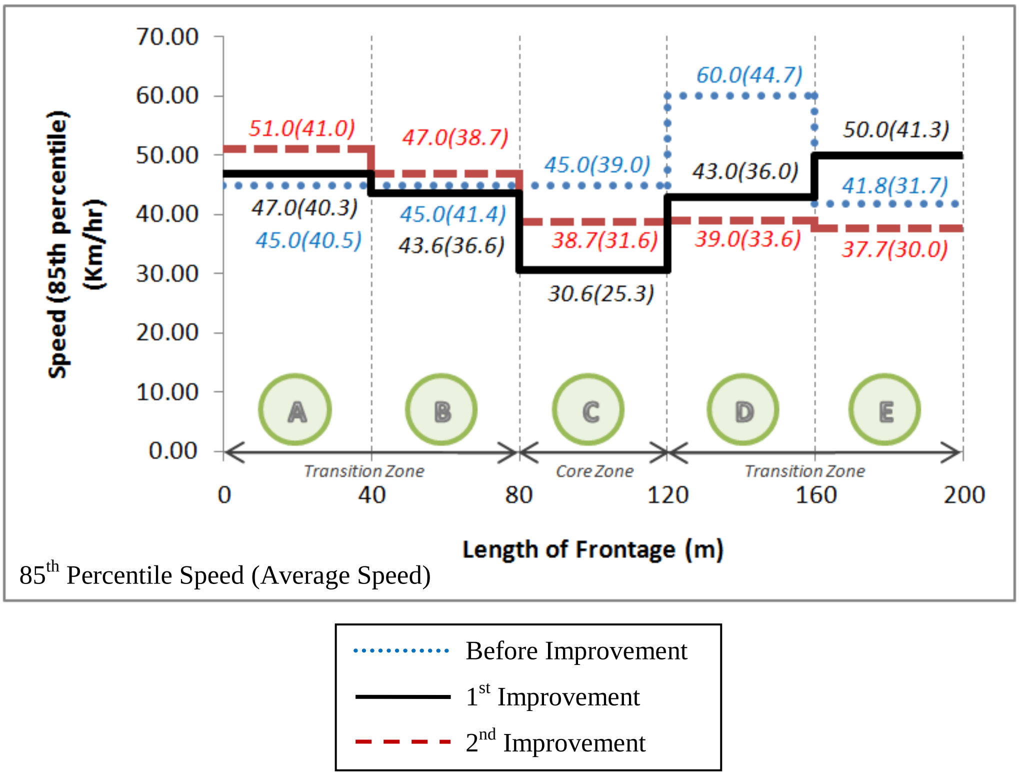


Figure 8. Activity profiles and speed profiles by traffic directions during the before-, the first, and the second-improvement periods

The comparative evaluation in various performance aspects (during the before-improvement, the first-improvement and the second-improvement periods) was summarized in Table 4. The percentage of jay runners in core zone was slightly reduced from 28.0 % (in the before-improvement period) to 25.6 % and 24.0% (in the first- and the second-improvement periods, respectively). The rating score of the ES index for pedestrian safety was improved from *'high'* (in the before-improvement period) to *'medium'* (in both the first- and the second-improvement periods). Based on the Song et al's model, pedestrian accident risk for both the before-improvement and the first- and the second-improvement periods is calculated as 2.18 x 10^{-5} (high risk) and 1.51 x 10^{-5} (medium risk) and 2.04x10^{-5} (high risk), respectively. It should also be noted that even though the traffic volumes in the first- and the second-improvement periods considerably increased, the pedestrian accident risk is safer than that in the before-improvement period. This is because the vehicular speed is reduced dramatically according to the installation of a speed hump and time required to cross the shorter effective walked distance of approximately 12.0 m. (post) compared to 18.0 m. (pre) for pedestrians was decreased dramatically. However, it is important to note that based on the calculated pedestrian accident risk, the pedestrian safety during the second-improvement period performed lesser degree of success compared to the first-improvement period. Based on the extensive people interviews, the perceived safety, esthetics, and landscaping aspects were significantly improved.

Table 4. The comparative evaluation of various performance aspects

Objective	**Performance Indicators**	**Level of achievement of the project**			
		Before Improv.	**1^{st} Improv.**	**2^{nd} Improv.**	**Remarks**
Reduction in conflicts between pedestrians and vehicles	-Traffic volume in core zone (veh/h)	1,187	1,602	1,754	Average in both directions.
	-Vehicle speed (85^{th} percentile in core zone (km/hr)	50	31	42.1	Average in both directions.
	-Pedestrian crossings in core zone (ped./h/100 m)	625	696	695	Average in both directions.
	-Jay runners in core zone (%)	28.0	25.6	24.0	Average in both directions.
	-ES for pedestrian safety	High	Medium	Medium	Based on ESM concept
	-Pedestrian accident risk	2.18 x 10^{-5}	1.51 x 10^{-5}	2.04 x 10^{-5}	Based on Song's model
Improvement in quality of the environment	-Footpath width (m)	2.0	3.5	3.5	
	-Median width (m)	1.5	2.0	2.0	
	-Effective Crossing distance (m)	18.0	12.0	12.0	

11. CONCLUSIONS

The conflicts between pedestrians and vehicle movements on a collector road in front of the KKU complex building were recognized as problematic and required the suitable traffic-calming scheme to alleviate the problem. According to the ESM method and the Song et al's model, the pedestrian accident risk in that area was critical. The EAM was consequently applied to the case study area. Based on the conducted field surveys, the applications of the EAM could potentially and effectively mitigate the traffic accident risk, maintain the environmental and amenity quality and enhance the acceptability of the affected stakeholders in terms of esthetics and landscaping. This concept can also be applied to other similar situations. The improved collector road performed technically well in reorganizing the vehicle and pedestrian conflicts. The EAM is an innovative and effective measure to manage potential pedestrian-vehicle interactions on a collector road. The recent road modification (in the second-improvement period) showed lesser degree of success in calming the traffic speed while traffic volumes and pedestrian crossings increased dramatically. It should be noted that although the EAM can potentially be applied to other sub-arterial or collector roads under similar road environment, the physical characteristics of road and adjacent environment must carefully be designed and constructed.

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