Report of Research Results

Title: Bicycle accidents and the built environment- a case study in Chiang Mai

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Summary: This study firstly investigates the spatial distribution of bicycle accidents in the Northern Thai city of Chiang Mai, at the same time examines how its built environments contribute to and facilitate bicycle accidents by scrutinizing the architecture and urban design characteristics surrounding the bicycle accident hotspots. The findings are then used to develop a series of design guidelines that suggest how bicycle orientated urban design and architecture can help to reduce the number of bicycle accidents and contribute towards a safer built environment for cycling.

The main findings from the first phase of the study established 7 bicycle accident hotspots in the city that experienced 3 or more bicycle accidents between 2007 and 2015. 6 of these hotspots are located in the centre of the city, all of which are situated in traffic intersections, and straddle major public venues. Crucially, the accident hotspot analysis identified 2 ways in which the built environment could contribute to bicycle accidents; firstly through active ways, in which the lack of cycling infrastructure and safety measures to protect cyclists, and the lack of traffic calming measures to control the speed of motor-vehicular traffic, together with the presence of physical obstructions such as road-side parking, lamp-posts and trees. Secondly through a passive way, such as the presence of digital billboards that are attached to the façades of major buildings that face the bicycle accident hotspots. The analysis has found multiple devices in existence in 5 out of the 7 accident hotspots. The findings suggest they could become potential hazards for cyclists since they could act as visual distractions for cyclists and other road users.

The design guideline in phase 3 generated 3 main strategies that respond directly to the findings in the crash site analysis in phase 2. These design suggestions were reviewed by an expert panel and together with the design suggestions, the findings recommend: Creating practical and separated cycling routes that allow for safe crossing of traffic junctions; readapting and improving existing motor-centric infrastructure into bicycle orientated cycle-infrastructure; and integrating future cycling infrastructure with urban architecture and repositioning of digital billboards. Together these design suggestions demonstrates how cycling accidents in the context of Chiang Mai could be reduced through the application of bicycle orientated urban and architectural design, at the same time improving the safety of cycling in the city.

Aim of Research: This study comprises three main objectives. Firstly (1), it investigates the spatial distribution of bicycle accidents in Chiang Mai city, in order to highlight major bicycle accident hotspots from 2007-2015. The result aims to respond to the following questions: where in the city do bicycle accidents most frequently occur? And on what type of roads do bicycle accidents occur? The second objective (2) is to survey the surrounding built environment in each of the accident hotspots, in order to find out: If and how the architecture and urban design of the site contributed towards the accident, and if there are any preventative measures in place to protect cyclists? The final objective (3) is to use the findings from phase 2 to generate a series of design guidelines that respond to the question of: how can built environments that experience frequent bicycle accidents be redesigned and readapted to make them safer for cyclists? The results of the overall study aim to provide an alternative perspective of the study of bicycle accidents, the findings can be used to demonstrate that the built environment can and does play a critical role in the manifestation of bicycle accidents, and as a consequence, how better bicycle orientated urban and architectural design can be applied to help reduce the number of bicycle accidents to contribute towards a safer built environment for cycling in.

Methods of research and progression: For the first phase of the study, which was to investigate the spatial distribution of bicycle accidents, high bicycle accident locations (hotspots) were identified using Geographical Information Systems (ARCGis 10.3.1). The geo-locations of bicycle accidents were mapped according to latitude and longitude coordinates translated from questionnaire surveys that were conducted from 530 local club cyclists in Chiang Mai. The questionnaire contained 19 questions that were categorised into 2 parts; the former was designed to capture the background of each of the cyclists; while the latter focused on gathering data on bicycle accidents, such as location, time, injury and collision with what other type of road users. The sampling groups were chosen through the snowball sampling method, which enabled the study to reach a significantly wider participant target group of local club cyclists. Only feedbacks with named road locations were used in the survey. For this study, high bicycle accident locations (hotspots) were determined to be locations that contain 3 bicycle accidents or more between 2007 and 2015.

For the second phase, which was to examine the bicycle accident hotspots in detail, a team of 6 assistant researchers independently surveyed and documented each of the bicycle hotspots. The purpose of the survey was to analyse the characteristics of the built environment in each of the hotspots that could potentially contribute to and facilitate the manifestation of bicycle accidents. A survey table was created in order to standardise and enable the researchers to examine the specific factors and elements in each crash site (*see table 1*). The elements the researchers were looking for on each of the accidents sites were separated into 3 categories: infrastructural; presence of safety measures for cyclists; and architectural and urban design elements. The first category include factors such as location of the crash site, either mid-block or junction; type of road, either major or minor; flow of traffic, one way or 2 ways; changes in roadway slope; presence of pavements; presence of bus-stops; presence of road-side parking; presence of traffic lights; the number of traffic lanes; and the number of approaches to traffic junctions. The second category includes factors such as cycle lanes; speed bumps; advanced bicycle stops; central reservation. And the final category includes factors such as building typologies in the accident site; building heights around the crash sites; distance from buildings to streets; visual obstructions; physical obstructions; and major architectural features. After each survey session the researchers met and compared their observations in order to resolve any disputes or misinterpretations. The field observations were conducted individually throughout the month of September, 2015, from Monday to Friday between 9am and 4pm.

For the final phase, the study organised a design competition for architecture and planning students in Chiang Mai in order to develop a series of design guidelines. The design competition took place in October, 2015. A total of 42 students participated from 2 main universities in Chiang Mai; Chiang Mai University and Rajamangala University of Technology Lanna (RMUTL), Chiang Mai. Each of the student teams was given a specific bicycle accident hotspot to work on and a detailed brief which outlined the findings of the study in both phases and that which they must follow. The duration of the competition was from the 20th of October, 2015 to 1st of November, 2015. Each of the student teams submitted 2 A1 presentation boards on the presentation day, where a panel of 5 specialists was invited to evaluate each of the design guidelines. 3 winning proposals were chosen as a result of the evaluation process. The evaluation panel includes a governmental officer in charge of design and implementation of cycling lanes and bicycle infrastructure in Chiang Mai from the Municipality office; the president of the Chiang Mai Sunday Cycling Club; and 3 urban designers with expertise in cycling infrastructural design. The evaluation criteria were: crash site and problem analysis; solving problems; safety; practicality; design; and innovation.

Results of Research: The study initially planned to collect bicycle accident data from 3 different sources: The Highway Agency; The Royal Thai Police and local hospital traffic accident records, with the hope of extracting geographical location of bicycle accidents, which could then be used to visualise their spatial patterns. However, the initial findings from phase 1 found that local hospital accident records in Chiang Mai do not indicate the geographical location of bicycle accidents. Furthermore, data regarding bicycle accidents was found to be lacking in both the Royal Thai Police department and The Highway Agency. As a result, the study employed questionnaire surveys to capture bicycle accident data instead.

Using the questionnaire survey, a total of 240 accidents were recorded. The findings established in total 19 bicycle accident locations across Chiang Mai (*see table 1*). Of these 19 sites, 7 sites were found to contain 3 or more bicycle accidents between 2007 and 2015. 6 of the hotspots are found to be located in the centre of the city, only 1 is situated outside the city (*see fig. 2*). Unsurprisingly, all of the hotspots (100%) are situated at major traffic intersections. Figure 2 shows the Kernal Density Map (KDM) of the pattern of the bicycle accident hotspots. Green spots indicate locations of bicycle accidents and the green to red gradient map highlights the density of bicycle accidents in specific areas of the city according to the hotspot locations (*see Fig. 2*). Interestingly, as the KDM shows, all the hotspots are located outside the periphery of the historical centre of Chiang Mai, and 5 out of the 7 hotspots straddle major public venues. Other interesting findings gathered from phase 1 regarding bicycle accidents in Chiang Mai found that 65.2% (156) of bicycle accidents occur between 6-9am and 6-9pm; 49.6% (119) of bicycle accidents involved collisions with motorcycles; 63.3% (152) of the victims of these accidents did not need hospital treatment; and 40.8% (98) of accidents took place on main roads in the city.

SITES	SITE NAME	X	Y	A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	B1	B2	B3	B4	B5
SITE A	Kad Tanin Junction	98.985	18.806	1	N	Y	N	Y	N	Y	Y	N	Y	Y	14	4	N	N	N	N	N
SITE B	hiangmai ram hospital corn	98.978	18.796	3	N	Y	Y	N	N	Y	Y	N	N	Y	15	3	N	N	N	N	Y
SITE C	Rincome Junction	98.968	18.801	3	N	Y	Y	N	N	Y	Y	N	Y	Y	16	4	N	N	N	Y	Y
SITE D	Nonghoi intersection	99.007	18.758	1	N	Y	Y	N	N	Y	Y	N	N	Y	18	4	N	N	N	N	Y
SITE E	Somphet market	98.993	18.792	1	Y	N	Y	N	Y	N	Y	N	Y	N	3	1	N	N	N	N	Y
SITE F	lanna hospital	98.992	18.812	1	Y	N	Y	N	Y	N	Y	N	Y	N	5	2	N	N	N	N	Y
SITE G	Phucome Junction	98.96	18.805	4	N	Y	Y	N	N	Y	Y	N	Y	Y	20	4	N	N	N	N	Y
SITE H	Racha peurk junction	98.933	18.739	3	N	Y	Y	N	N	Y	Y	N	N	Y	24	4	N	N	N	N	Y
SITE J	Nawarat Bridge (east side)	99.004	18.788	3	N	Y	Y	N	N	Y	Y	Y	Y	Y	16	4	N	N	N	N	N
SITE K	Thepae Gate	98.994	18.788	1	N	Y	Y	N	N	Y	Y	N	Y	Y	8	4	N	N	N	N	Y
SITE L	Greenland Resort Entrance	98.965	18.828	1	Y	N	Y	N	N	Y	Y	N	N	N	6	1	N	N	N	N	Y
SITE M	Suandok Gate Intersection	98.978	18.789	3	N	Y	Y	N	N	Y	Y	N	Y	N	8	4	N	N	N	N	Y
SITE N	Panthip Junction	99	18.781	4	N	Y	Y	N	Y	N	Y	Y	Y	Y	15	4	N	N	N	N	N
SITE P	Tompaiyom Market	98.961	18.791	1	N	Y	Y	N	N	Y	Y	Y	Y	Y	6	4	N	N	N	N	Y
SITE Q	Train station Junction	99.016	18.786	1	N	Y	Y	N	N	Y	Y	N	Y	Y	7	3	N	N	N	N	N
SITE R	Huay Ting Tao	98.945	18.866	2	Y	N	N	Y	N	Y	Y	N	N	N	2	N/A	N	Y	N	N	N
SITE S	Wing 41 Intersection	98.963	18.787	1	N	Y	Y	N	N	Y	Y	Y	Y	Y	4	3	Y	N	N	N	N
SITE T	Chiangmai Zoo Entrance	98.948	18.841	1	N	Y	N	Y	N	Y	Y	Y	Y	N	6	3	N	N	N	N	N
SITE U	700 years Stadium	98.965	18.84	2	Y	N	N	Y	N	Y	Y	N	Y	N	2	N/A	Y	Y	Y	N	N

A0- NUMBER OF BICYCLE ACCIDENTS; A1- Mid-block (yes/no); A2 Junction (yes/no); A3- Major road (yes/no); A4- Minor road (yes/no); A5- One way (yes/no); A6- 2 way (yes/no); A7- Pavement/pedestrian walkway (yes/no); A8- Bus stop (yes, no);
A9- Road-side parking (yes/no); A10-Traffic lights (yes/no); A11-Number of traffic lanes (#); A12-Number of approaches into junction (#); B1- Traffic calming measures (yes/no); B2- Cycle lanes (yes/no); B3- Speed bumps (yes/no); B4- Advanced bicycle stops (yes/no)
B5- Central reservation (yes/no)

***Table 1**, results from the bicycle accident hotspot site analysis. The 7 hotspot locations are indicated in red.*

In phase 2, the detailed analysis of the bicycle accident hotspots has revealed a number of different spatial characteristics in each of the bicycle accident sites (see *Table 1*). On the one hand, the hotspot analysis suggests that in each of the hotspots contain active factors that are contributing towards bicycle accidents. These active factors include the lack of cycling orientated infrastructure and safety measures in place to protect cyclists (found in 7 out of 7 hotspots), such as cycle-lanes, advanced bicycle stops and cyclists' crossings; and secondly through the absence of traffic calming measures such as speed bumps to reduce the speed of motor vehicular traffic (found in 5 out of 7 hotspots). Furthermore, physical obstructions such as motor-vehicles and motor-cycles parked on roadside, advertising boards, lampposts and trees were observed in 5 out of the 7 accident hotspots.

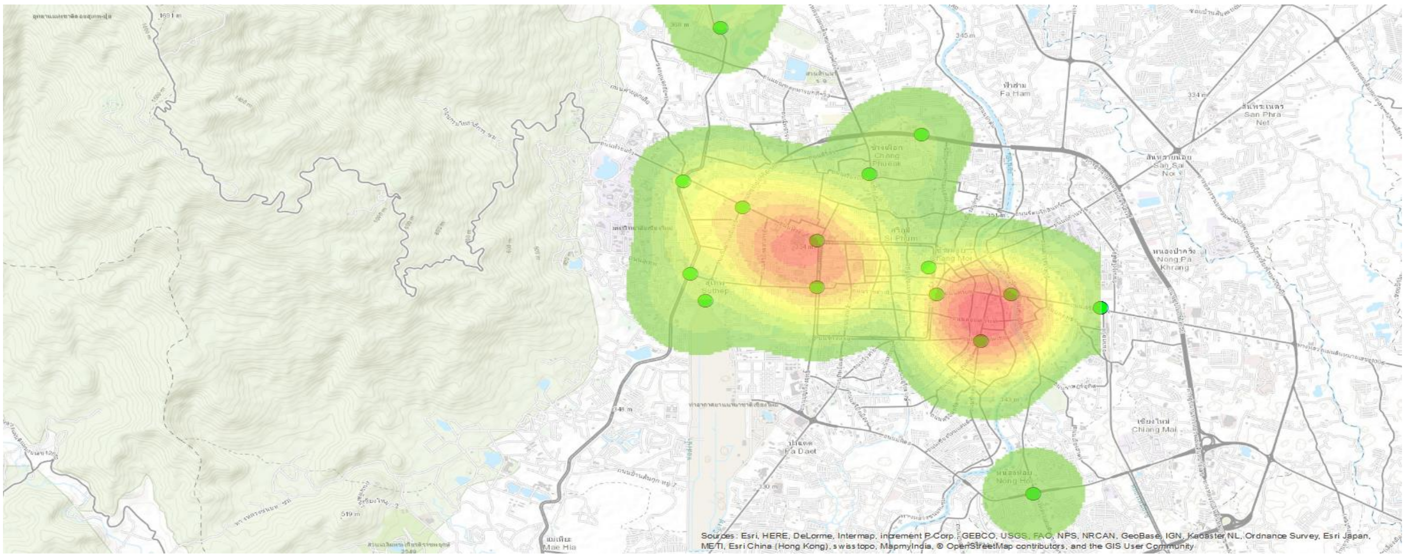

***Figure 2**, Kernal Density Map of the bicycle accident hotspots; illustrating the spatial patterns of bicycle accidents in the city of Chiang Mai*

On the other hand, the study also found that the built environment could be passively contributing towards bicycle accidents from the effects of digital billboards. These digital devices were found in 5 out of the 7 hotspots, and are often large and are either attached to facades of public buildings around the crash site, or as stand-alone objects located at the intersection. In all of the hotspots containing digital billboards, multiple devices were recorded in operation. The findings suggest digital billboards could potentially act as visual distractions for cyclists as well as other road users such as motor-vehicle drivers and motor-cycle riders, causing momentary loss of concentration when being observed, and as a consequence becoming potential hazards that facilitate bicycle accidents.

Based on the findings from the second phase of the study, the crash site recordings clearly demonstrate that the built environment is both actively and passively contributing towards bicycle accidents. Therefore, the design guidelines produced in phase 3 that intend to reduce the number of cycling accidents and improve the safety of cycling in the city must focus on not only providing practical cycling orientated infrastructure for cyclists, which is intended to tackle the active elements, but also the wider built environment that can passively contribute towards the manifestation of bicycle accidents. Thus the design guidelines can be categorised into 3 main strategies:

1) Creating practical and separate cycling routes that allow safe crossing at traffic junctions.
As the study has found in all of the bicycle hotspots there is currently no existing cycling infrastructure or other safety measures such as cycling routes that protect cyclists from motor-vehicular traffic. Thus the priority of the design guidelines suggest developing protected and separate cycling routes through complex and busy traffic intersections with a minimum width of 1.5m- 1.8m (Pujinda, 2013). For example in Phu Come Intersection, a canal runs under and across the centre of the traffic intersection, design guideline 1 proposes creating a cycling route beginning from the approach of the junction that could run continuously under the intersection and along the canal path. This would not only create a safe passage for cyclists to cross the intersection, but at the same time helping to improve the overall urban landscape around the canal (*see fig. 4*).

2) Readapting and improving existing motor-centric infrastructure into bicycle orientated cycle-infrastructure.
Readapting existing infrastructure for cyclists is a cost and time effective measure to protect cyclists from motor-vehicular traffic and to develop a bicycle orientated infrastructure. Design guideline 2 suggests using one of the traffic islands in Suandok Gate junction as an example, where the traffic island could be readapted into a cyclist crossing point and shelter. At the same time the island can be transformed into a landscaped garden, which can double up as a resting place or refuge for passing riders who are seeking shelter (*see fig. 5*).

3) Integration of future cycling infrastructure with urban architecture and repositioning of digital billboards.
The third design guideline proposes a series of strategies in which future cycling infrastructure can be integrated into interior of architecture spaces as well as the exterior, helping to improve convenience and accessibility of cyclists. For example in Rin Come intersection, future cycling routes could be extended into the interior of buildings surrounding the intersection, allowing cyclists to ride directly from street level to the top floor of the building. At the same time, bridges and cycling path can then connect from building to building, bypassing the traffic junction below altogether. The third design guideline also responded to the passive elements such as digital billboards, it suggests a repositioning of these devices to an alternative location in the junction that poses less distraction for road-users, and also to a lower gradient so that it’s most visible only at the intersection when the traffic stops, and lastly by integrating them with the traffic warning signal system so that they only operate when the warning signal is red (*see fig. 3*).

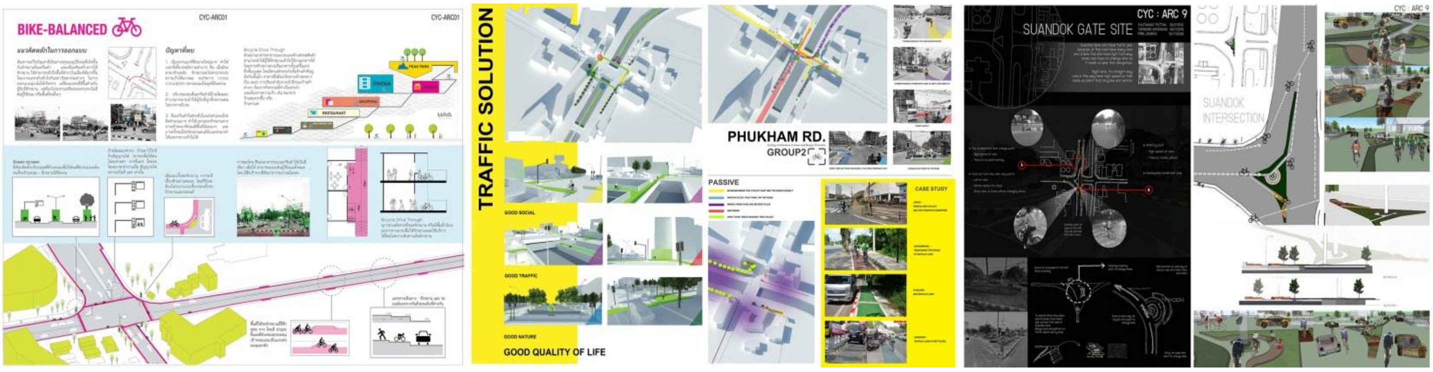

Fig. 3- Above left: *Design suggestion for Suan Dok Intersection.* ***Fig.4- Above Middle:*** *Design suggestion for Phu Come Intersection.* ***Fig. 5- Above right:*** *Design suggestion for Rin Come Intersection.*

Future study: The study has produced a multitude of findings, both expected and unexpected results that clearly demonstrates the role our built environment could play in the manifestation of bicycle accidents. One interesting finding of the study is the presence of digital billboards that were observed at most of the bicycle accident hotspots. Further detailed analysis and controlled tests would need to be carried out in order to determine the exact effects these electronic devices have on the behaviour of motorists and cyclists, and to determine the consequences of their application in complex and busy traffic intersections.

Means of official announcement of research results: We foresee this study will produce 2 main publications: (1) Spatial distribution of bicycle accidents in Chiang Mai using GIS; we will target the following journals for publication: Accident Analysis and Prevention; Journal of Safety Research or Journal of Transport Geography; and (2) Bicycle accidents and the built environment- how urban design and architecture play a part-a case study in Chiang Mai and recommendations; we aim to submit the results for publication in: JARS (Journal of Architectural Research, Thammasat University).

References: **Pujinda, P**. *Handbook of physical design supporting bicycle use*. Bangkok: Thaicyclingclub. (2013)