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GENETIC ALGORITHMS FOR DYNAMIC CONTRAFLOW PROBLEM

Ampol KAROONSOONTAWONG
Lecturer, Department of Civil Engineering
King Mongkut's University of Technology Thonburi
126 Pracha-Utit Road, Bangmod, Thung-Khru
Bangkok, 10140, Thailand
Fax: +662-427-9063
E-mail: ampolk@gmail.com

Abstract: This paper deals with the dynamic lane-based contraflow problem in daily peak- period traffic management application. The problem is NP-hard, so a genetic algorithm with the simulation-based user-optimal dynamic traffic assignment is adopted to solve larger-size problems. The decision variables are reversibility indicator variables, reversal starting times, reversal durations, and redesigned numbers of lanes for candidate link pairs. Three GA variations are proposed: GA1, GA2 and GA3. They employ time-dependent congestion measures from previous solution in their decoding procedures with increasing degrees of randomness. The three algorithms are compared on two test networks. From the experiment, GA3 outperforms the other algorithms on both test networks under the solution quality criterion.

Key Words: Contraflow, Genetic Algorithm

1. INTRODUCTON

Contraflow strategy (also known as capacity reversibility) is a traffic management method, which essentially accommodates the unbalanced traffic flows between two driving directions on a congested roadway section during daily peak periods. Early researchers (1-2) focused on reversible left-turn lanes used in the direction of the peak flow. The effectiveness, feasibility and safety issues are discussed in (3-4). (5) described the current state in planning and engineering practices. (6) indicated that the capacity reversal strategies were not popular because of implementation issues: costs, safety and control. Over the past years, the literature on contraflow emergency evacuation has considerably been increased, especially in the U.S., due to natural and man-made disasters. Current contraflow evacuation plans exist for at least ten states in USA (7). (8) and (9) provided comprehensive reviews on this topic. Since the contraflow strategy becomes more popular mainly for the emergency evacuation, the previously described implementation issues should partially be resolved. Thus, the contraflow for daily traffic management may be re-considered as a workable option, especially for the urban cities with available contraflow emergency evacuation plans.

Essentially, the practicality assumptions are made in this paper, so that the potential of dynamic lane-based contraflow in decreasing TSTT can be explored and demonstrated. The practicality assumptions include acceptable cost, viable safety policy, sufficient manpower, signage and potential of blockage actions, which are required to divide a multi-lane roadway segment.

This paper proposes a time-varying lane-based capacity reversibility model based on the user-optimal dynamic traffic assignment for daily peak-period traffic management. The model embeds a traffic flow theoretical model, namely, the cell transmission model (CTM) (10) that can capture traffic realisms such as shockwaves and spillovers. Since the proposed model is NP-hard, it cannot efficiently be solved to obtain a globally optimal solution. A global optimization method that can overcome the local optima is suitable to this problem. Three variations of genetic algorithms are proposed, and the performances of the three algorithms are compared.

2. LITERATURE REVIEW

Due to the space limit, only relevant literature review is provided. The proposed formulation is developed on the basis of the works by (8, 11, 12). Tuydes and Ziliaskopoulos (11) formulated the system-optimal dynamic traffic assignment (SODTA)-based capacity reversibility problem as a linear program (denoted by SODTA-CR), which propagates traffic based on the CTM to better represent vehicle-level movements, to capture spatiotemporal changes in disaster conditions, and to enable optimal capacity reversibility calculation. SODTA-CR has a major drawback on the continuous capacity redistribution variables that allow an unrealistic fraction-of-lane solution. Tuydes (8) proposed three extensions of SODTA-CR: lane-based capacity reversibility (SODTA-LCR), total-or-nothing capacity reversibility (SODTA-TCR), and budgeted capacity reversibility (SODTA-BCR). SODTA-LCR addresses the drawback of SODTA-CR by using integer redistribution variables (i.e. lane-based reversibility). The criticisms of SODTA-LCR are on the cost of the street divisions and the risk in assigning contradicting flows on the same highway. The SODTA-TCR was developed to address these criticisms by allowing either whole road segment reversibility or none. SODTA-TCR is a restricted version of the SODTA-LCR, which in turn is a restricted version of SODTA-CR. SODTA-BCR accounts for the limited resources for the operation and construction of the contraflow interchange segments such as the required number of police patrol cars to block the intersections at the beginning, end and along the reversed segments.

SODTA-CR, SODTA-LCR, SODTA-TCR and SODTA-BCR have two major assumptions.
First, these models assume that drivers fully follow the central instructions on the system-optimal evacuation paths assigned to different drivers. Thus, these models can be single-level because the drivers and the evacuation manager share the same objective in minimizing total system travel time (TSTT). Second, the capacity reversibility is unchanged (static) over the simulation period, so the models cannot determine the optimal starting time and duration of reversibility. Xie et al. (9) proposed a bi-level model for the combined lane-based capacity reversibility and crossing elimination problem. The model is bi-level in order to capture different objectives between the roadway manager (minimize TSTT) and the drivers (minimize individual travel time). In other words, (9) assumes drivers do not receive instructions from the roadway manager, and behave in user-optimal manner. Xie et al. (9) also assumes static reversibility. A usual drawback of these analytical models is high computational time due to its analytical nature, so it cannot be employed for actual urban networks. Tuydes and Ziliaskpoulos (12) proposed a tabu-based heuristic to address this deficiency. The heuristic was developed based on the dual analysis results of the analytical study. (9) developed a Lagrangian relaxation-based tabu search.

Our proposed model is bi-level and allows lane-based capacity reversibility, similar to (9).
However, our model allows time-varying reversibility with different reversibility durations for various candidate link pairs, so that the optimal starting times and the optimal reversibility durations for candidate link pairs can be determined for daily peak-period traffic

management. In our solution method, we employ the dual analysis results from (11) in developing decoding procedures for the proposed genetic algorithms. Note that the proposed formulation and algorithms can also be applied to evacuation planning when drivers are assumed to behave in a user-optimal manner.

3. PROBLEM DEFINITION

Tuydes (8) formulated the SODTA-based static lane-based capacity reversibility problem as a mixed integer program (SODTA-LCR). We extend SODTA-LCR to become a mixed-zero-one continuous linear bi-level program (BLP) for the combined UODTA and time-varying lane-based capacity reversibility problem (TVLCR). The proposed model is denoted by BLP-TVLCR. Due to the space limit, the formulation is only briefly described. The upper-level problem minimizes the total system travel time (TSTT) subject to the time-varying lane-based capacity reversibility constraints and the UODTA (the nested program), which was developed by (13). The model determines an optimal capacity reversibility policy (i.e. starting times, reversibility durations, and numbers of reversed lanes) for all candidate link pairs. We do not allow the total link reversibility by setting the minimum number of lane for each direction to one, so that the network connectivity problem is not resulted. Over the simulation period, the lane reversal is allowed at most once for each candidate link pair. Two-way streets are considered in the formulation. However, for a one-way street, an artificial link with zero capacity can be added in the opposite direction to represent the reversibility potential (8). In this way, the total network capacity remains the same although the number of links in the augmented network may be increased.

4. SOLUTION METHOD

BLP-TVLCR is a mixed zero-one continuous linear bi-level program, which is NP-hard (14). Since the underlying analytical UODTA is replaced by the simulation-based UODTA in the proposed approach, it allows us to obtain a near-global optimal solution. The metaheuristic is suitable for NP-hard problems, and can overcome a local optimum and potentially discover a global optimum given sufficient computational time. In this paper, the genetic algorithm (GA) is adopted due to its evident efficiency and effectiveness in literature.

There are three sets of decision variables for each candidate link pair i - i^* in BLP-TVLCR: reversibility starting times ($time\_start_{i-i^*}$), reversibility durations ($duration\_reversal_{i-i^*}$), and the numbers of lanes in both driving directions after reversibility (mod_ $num\_lanes_{i-i^*,\ k}$ for driving direction k=1 and 2). An additional decision variable for each candidate link pair i-i^* is created: the reversibility indicator variable (allow_reversal$_{i-i^*}$). The indicator variable is equal to one if the reversibility is allowed for the candidate link pair and equal to zero if the reversibility is prohibited. The reversibility indicator variable is employed, so that the premature convergence of genetic algorithm can be avoided.

We propose three variations of genetic algorithm, denoted by GA1, GA2 and GA3. They are developed based on problem-specific knowledge. The three GA variations employ the UODTA module in the Visual Interactive System for Transport Algorithms (VISTA) (15) to evaluate different time-varying lane-based capacity reversibility strategies for larger-size problems. The UODTA module in VISTA is a departure-time-based version of the simulation-based UODTA approach using a mesoscopic simulator based on an extension of CTM, to propagate traffic and satisfy capacity constraints. The implicit assumption is that drivers have perfect information and can divert to alternate paths if it reduces travel time.

In our implementation, duplicated links

corresponding to candidate links are added to the network, and time-based capacity factors associated with these candidate and duplicated links are employed to represent various capacity reversibility strategies. For example, a candidate link pair is link (A, B) and link (B, A) (i.e. from node A to node B and from node B to node A, respectively), and the first direction is arbitrarily assigned as A to B, and the second direction is from B to A. The duplicated links (A', B') and (B', A') are added to the network such that (A', B') is a copy of (A, B) and (B', A') is a copy of (B, A). To incorporate different time-varying lane-based capacity reversibility strategies, a set of time-based capacity factors associated with each candidate link is employed. A capacity factor, which is ranged between 0 and 1, indicates the proportion of the original link capacity for a candidate link during a time period. To illustrate, links (A, B) and (B, A) are two-lane roadways, and a time-varying lane-based capacity reversibility strategy states that the link (A, B) should have three lanes during the second hour of the three-hour simulation period (in other words, a lane should be reversed from the second direction to the first direction during the second hour). Then, from 0 to 3600 seconds and from 7201 to 10800 seconds (i.e., during the first hour and the third hour), the capacity factors of the original links (A, B) and (B, A) are equal to one, and the capacity factors of the duplicated links (A', B') and (B', A') are equal to zero. This implies no capacity reversibility in the first hour and the third hour. From 3601 to 7200 seconds (i.e., during the second hour), the capacity factors of (A, B) and (A', B') are equal to respective 1 and 0.5, and those of (B, A) and (B', A') are equal to respective 0.5 and 0. This implies three lanes in the first direction (i.e., an original two-lane roadway and a lane reversed from the coupled link) and one lane in the second direction (i.e., an original two-lane roadway becomes a one-lane road).

4.1 Development of GA1, GA2 and GA3

In the development of GA1, GA2 and GA3, the problem-specific knowledge of BLP-TVLCR is heuristically taken from the dual variable analysis of the analytical SODTA-CR in (11), which was employed in the tabu-based heuristic approach for the evacuation contraflow problem (12). The relationship between the dual variable of the lower-level program and the upper-level objective in BLP-TVLCR is not known, but it may be approximated by the analysis of the single-level system-optimal counterpart.

The dual variable analysis of the SODTA-CR is the optimal capacity reversibility assignment principle, which is briefly described here. Over the analysis period, the total marginal cost of reversing one more unit of capacity in the direction of one cell will have the same marginal cost as that of reversing in the direction of the coupled cell (15,18). These dual variables are non-zero only when the corresponding constraints are binding (i.e., the storage or flow capacities are fully used). (8) approximates the marginal costs of reversing a unit capacity in a link by a congestion measure: the total number of times over the analysis period that link capacities are used at the maximum levels. This congestion measure implicitly assumes that all dual variables contribute equally. Although it is a strong assumption, this congestion measure is more accurate than other measures such as link flows (8).

In this paper, the modified congestion measure is determined as follows. To account for time-varying reversibility, the analysis period (i.e., simulation period or *duration_sim*) is divided into many time slices where the duration of time slice is called sec*ond_per_slice*. For example, a ten-hour simulation period is composed of 60 ten-minute time slices (i.e., *duration_sim* =36000 seconds; sec*ond*_per_*slice* =600 seconds). The congestion measure of link i in time slice j is a binary variable $reach\_cap_{ij}$, which equals to one if it is congested, and zero otherwise. In time slice j, the traffic count per lane on candidate link i is calculated from the simulation-based UODTA flows:

$$link\_count\_per\_lane_{ij} = \frac{link\_count_{ij} + link\_count_{i'j}}{(cap\_factor_i + cap\_factor_{j'}) \cdot num\_lanes_i} \quad (1)$$

where $link\_count_{ij}$ = traffic count on original link i in time slice j

$link\_count_{i'j}$ = traffic count on duplicated link i' (the copy of link i) in time slice j

cap_factor_i and $cap\_factor_{j'}$= link capacity factors of link i and i'

num_lanes_i = original numbers of lanes of link i

If the traffic counts per lane on link i exceeds the factored jam density per lane during a time slice j, the variable $reach\_cap_{ij}$ is set to one, indicating the congestion on this link at this time slice$_j$. The jam density per lane is calculated from the link length divided by the vehicle length, and the factored jam density per lane is equal to the product of common jam-density factor (*jam_density_factor*) and the jam density per lane. In our experiment, we use the vehicle length of 20 feet, which is determined from the sum of the default vehicle length and distance headway. The jam density factor of 0.5 is employed in the experiment as we assume that at 50% of the jam density, the traffic flow reaches capacity. For each candidate link pair, the difference in the congestion measures over each time slice can be calculated, and this difference indicates the driving direction that should be assigned more lanes reversed from its coupled link during this time slice. For candidate link pair (i,i^*) , if the direction of link i is the first direction and that of link i^* is the second direction, then we define $diff\_reach\_cap_{i\text{-}i}{}^* = reach\_cap_{ij} - reach\_cap_{i^*j}$. Then, $diff\_reach\_cap_{i\text{-}i^*j}$ equals to – 1 (i.e., $reach\_cap_{ij}$=0 and $reach\_cap_{ij}$ = 0 ; or $reach\_cap_{ij}$ =1 and $reach\_cap_{i^*j}$ = 1), implying no reversibility should be adopted in time slice j.

The variable $FirstTimeSlice_{i\text{-}i^*}$ is the first time slice j with the non-zero value of $diff\_reach\_cap_{i\text{-}i^*j}$. and within the range of allowable starting time [$lb_{starttime}$, $ub_{startime}$]. here). GA2 is similar to GA1 except the $FirstTimeSlice_{i\text{-}i^*}$ is set to -1 if there is not such time slice. If $FirstTimeSlice_{i\text{-}i^*}$ is not equal to -1, the variable $NonZeroDiffReachCap_{i\text{-}i^*}$ stores the non-zero value of $diff\_reach\_cap_{i\text{-}i^*j}$. The variable $LastTimeSlice_{i\text{-}i^*}$ is the last successive time slice that has this same congestion-measure difference value; that is, the time slices j+1, j+2, $LastTimeSlice_{i\text{-}i^*}$ have the same congestion-measure difference value ($NonZeroDiffReachCap_{i\text{-}i^*}$) value as the time slice j ($NonZeroDiffReachCap_{i\text{-}i^*} = diff\_reach\_cap_{i\text{-}i^*j}$.).

GA1, GA2 and GA3 are developed based on the described problem-specific knowledge (specifically, $FirstTimeSlice_{i\text{-}i^*}$, $NonZeroDiffReachCap_{i\text{-}i^*}$, $LastTimeSlice_{i\text{-}i^*}$, which randomness. GA1, GA2 and GA3 determines the variable $allow\_reveral_{i\text{-}i^*}$ from the corresponding gene in the chromosome for link pair $i\text{-}i^*$, and checks the value of $FirstTimeSlice_{i\text{-}i^*}$. If $FirstTimeSlice_{i\text{-}i^*}$ is not equal to -1 (i.e. this link pair should have capacity reversibility), then the variable $allow\_reveral_{i\text{-}i^*}$ is unchanged; otherwise, $allow\_reveral_{i\text{-}i^*}$ is set to zero. GA1 determines the starting reversal time from $FirstTimeSlice_{i\text{-}i^*}$. GA1 employs $NonZeroDiffReachCap_{i\text{-}i^*}$ to indicate the driving direction to be improved; then, it deterministically adds a lane in that direction and decreases a lane in the opposite direction. GA1 allows the corresponding gene in the chromosome to determine the variable $reviable\_duration_{i\text{-}i^*}$ (i.e. randomness plays a role following two points. First, the variable *reviable_duration*$_{i\text{-}i^*}$ is determined from *LastTimeSlice*$_{i\text{-}i^*}$, *FirstTimeSlice*$_{i\text{-}i^*}$ and its lower and upper limits. Second, the redesigned numbers of lanes are determined from the corresponding genes in the chromosome for link pair $i\text{-}i^*$. GA3 is the combination of GA1 and GA2. GA3 determines the variable *reviable_duration*$_{i\text{-}i^*}$ in the same way as GA1, but determines the redesigned numbers of lanes in the same way as GA2. The genetic algorithm is briefly described next.

4.2 Genetic Algorithm

GA is an iterative procedure that maintains a population of candidate solutions to the objective function (*16-17*). Denote by Pop (k) the binary-string population from generation k. There are N_{POP} chromosomes (also called strings, individuals, structures or solutions) per a population, and let $fr^{(i;k)}$ represent chromosome i of length L in the population from generation k for all i = 1, 2, …, N_{POP}. Thus, the population from iteration k can be written as: $Pop(k) = \{fr^{(1;k)}, ..., fr^{(N_{POP};k)}\}$. Each chromosome $fr^{(1;k)}$ represents a vector of decision variables to the BLP-TVLCR, but the semantics associated with the vector is unknown to the GA. During each generation, the current population is evaluated, and a new population of candidate solutions is formed on the basis of this evaluation. This study modifies a C source code named GENESIS Version 5.0 (*25*) for the GA implementation. The formal algorithm of GA is shown below, followed by the descriptions of important components.

Genetic Algorithm (after (25))

Step 0: Set iteration counter k = 0. Initialize the binary-string population *Pop(0)*. Initialize the GA parameters: 1) population size; 2) crossover rate; 3) mutation rate; 4) total functional evaluations (total trials)

Step 1: Decode all binary structures into real numbers

Step 2: Evaluate the fitness values of all structures in *Pop (k)*:

$$fitness_i = \frac{Worst\text{-}TSTT_i}{Worst\text{-}Average\_current\_tst} \quad \forall i=1,\dots,N_{POP} \tag{2}$$

where *Worst* = the greatest value of TSTT which has occurred in the last 5 generations *Average_current_tstt* = average TSTT of the current population

Step 3: Collect a convergence measure and update the incumbent solution: The convergence measure is the best objective value found so far. Update the best solution found so far (incumbent solution) including *incumb_allow_reversal*$_{i\text{-}i^*}$, *incump_start_time*$_{i\text{-}i^*}$, *incumb_reversa_durationl*$_{i\text{-}i^*}$, *incumb_end_time*$_{i\text{-}i^*}$, *incumb_mod_num_lanes*$_{i\text{-}i^*,j}$, *incumb_cap_factor_original*$_{i\text{-}i^*,j}$, *incumb_cap_factor_duplicated*$_{i\text{-}i^*,j}$, *incumb_ FirstTimeSlice*$_{i\text{-}i^*}$, *incumb_ NonZeroDiffReachCap*$_{i\text{-}i^*}$, *incumb_ LastTimeSlice*$_{i\text{-}i^*}$ $\forall i\text{-}i^*$, $\forall j = 1,2$

Step 4: If the number of functional evaluations (trials) is greater than or equal to the total trials, terminate the algorithm. Otherwise, set $k = k$ +1, and go to Step 5.

Step 5: Select *Pop(k)* from *Pop(k-1)* by the SUS proportional selection.

Step 6: Perform mutation operation on *Pop(k).*

Step 7: Perform two-point crossover operation on *Pop(k).*

Step 8: Go to Step 1

.

Solution Representation

The appropriate representation for the variable *allow_revasal* $_{i\text{-}i^*}$ is binary; that for the variables smart_time $_{i\text{-}i^*}$ and *revasal_duration* $_{i\text{-}i^*}$ are real-valued; and that for the variables *mod_num_lane*$_{i\text{-}i^*,k}$ $\forall k$ =1,2 are integer. That is, the genetic structures are the vectors of mixed integers. Since the adopted genetic algorithm requires the binary string representation, the vectors of mixed integers have to be encoded into binary string structures. From the decoding procedures of GA1 to GA3 in Figures 3-5, *starts_time* $_{i\text{-}i^*}$ and *revasal_duration* $_{i\text{-}i^*}$ have to be within their allowable ranges; thus, the fractional variables (ranged between 0 and 1) can be employed instead of the real-valued variables. Also, *revasal_duration* $_{i\text{-}i^*}$ and *mod_num_lane*$_{i\text{-}i^*,k}$ $\forall k$ =1,2 can be determined by fractional variables (see Figures 3-5).

Encoding Procedure

For encoding procedure, the lower bound, upper bound and required precision of each decision variable must be specified. For BLP-TVLCR, all decision variables (genes) can be replaced by fractional variables that have the same lower bound (fr_i^{min} = 0) and upper bound (fr_i^{max} = 1). That is, the time-varying lane-based capacity reversibility constraint set is replaced by boundary constraints (i.e. a decision variable is determined by the corresponding fractional variable and feasible range). The fractional variables have the same required precision (*prec* after decimal point). The required bit (m) for each decision variable is determined from the equation (*16*): $2^{m-1}<((fr_i^{max}-fr_i^{min})\cdot 10^{prec}+1)\leq 2^m$. The required precisions of 2, 3, 4 and 5 correspond to the required bits of 7, 10, 14 and 17, respectively. We consider the required precision of 2 is sufficient ($m=7$). The total bits required to represent a solution (i.e. the length of a chromosome) are $Length = m\times N_{var}\times N_{clp}$, where N_{var} is the number of variables per candidate link pair; N_{clp} the number of candidate link pairs. N_{var} for GA1, GA2 and GA3 are respective 2, 2 and 3. N_{clp} in our two test networks are 12 and 14, respectively. Further, the GA implementation translates the binary structures into the packed bit arrays based on the octal number representation to maximize both space and time efficiency in manipulating structures (see further detail in (*25*)). The initial population is randomly generated to cover a wide domain range.

Decoding

After initializing the initial population and the GA parameters in Step 0, Step1 translates a binary string into a set of real numbers ($real_i$) corresponding to a set of decision variables (fr_i); then, fr_i is determined from $fr_i = \frac{real_i}{2^m\text{-}1}$ $\forall_i$ = 1,2,…,$N_{var}\cdot N_{clp}$, where $real^i$ is a real number corresponding to the binary string associated with the i^{th} decision variable. For BLP-TVLCR, there are only two constraint sets: time-varying lane-based capacity reversibility constraint and UODTA conditions. Recall that the former constraint set is replaced by the boundary constraints. Since (fr_i^{min} = 0) and (fr_i^{max} = 1), his decoding procedure always satisfies the boundary constraints. Also, since the UODTA is employed for functional evaluation, the UODTA conditions are always satisfied. Thus, the constraint handling, mostly based on the concept of penalty functions that penalize infeasible solutions, is not required.

Figure 1 shows the descriptions of parameters and decision variables. Figure 2 shows the sub-procedures employed in the decoding procedures for GA1 to GA3. Figures 3-5 shows the decoding procedures for GA1-GA3.

Description of Parameters

$lb_{starttime}$; $ub_{starttime}$ = lower bound; upper bound of feasible starting reversal time

$lb_{duration}$; $ub_{duration}$ = lower bound; upper bound of reversibility duration

$num\_lanes_{i-i^*,k}$ = number of lanes in driving direction k (=1 or 2) of the candidate link pair *i-i**

$sum\_lanes_{i-i^*} = num\_lanes_{i,1} + num\_lanes_{i,2}$

$sim\_duration$ = simulation duration

$second\_per\_slice$ =seconds per time slice used in calculating congestion measure

Description of Decision Variables

$allow\_reversal_{i-i^*}$ = capacity reversibility indicator variable for candidate link pair *i-i**

$start\_time_{i-i^*}$ = reversibility starting time for candidate link pair *i-i**

$reversal\_duration_{i-i^*}$ = reversibility duration for candidate link pair *i-i**

$end\_time_{i-i^*}$ = reversibility ending time for candidate link pair *i-i**

$mod\_num\_lanes_{i-i^*,j}$ =modified number of lanes after reversibility for driving direction j

$cap\_factor\_original_{i-i^*,j}$ =capacity factor for the original link in direction j of link pair *i-i**

$cap\_factor\_duplicated_{i-i^*,j}$ = capacity factor for the duplicated link in direction j of link pair *i-i**

Figure 1. Descriptions of Parameters and Decision Variables

Sub-Procedure $DetermineCapacityFactor(i-i^*)$ If $mod\_num\_lanes_{i-i^*,1} < num\_lanes_{i-i^*,1}$ $cap\_factor\_duplicated_{i-i^*,1} = 0$; $cap\_factor\_original_{i-i^*,2} = 1$ $cap\_factor\_duplicated_{i-i^*,2} = (mod\_num\_lanes_{i-i^*,2} - num\_lanes_{i-i^*,2}) / num\_lanes_{i-i^*,2}$ $cap\_factor\_original_{i-i^*,1} = mod\_num\_lanes_{i-i^*,1} / num\_lanes_{i-i^*,1}$ Else if $mod\_num\_lanes_{i-i^*,1} \geq num\_lanes_{i-i^*,1}$ $cap\_factor\_original_{i-i^*,1} = 1$; $cap\_factor\_duplicated_{i-i^*,2} = 0$ $cap\_factor\_duplicated_{i-i^*,1} = (mod\_num\_lanes_{i-i^*,1} - num\_lanes_{i-i^*,1}) / num\_lanes_{i-i^*,1}$ $cap\_factor\_original_{i-i^*,2} = mod\_num\_lanes_{i-i^*,2} / num\_lanes_{i-i^*,2}$
Sub-Procedure $RetrieveIncumbentSolution(i-i^*)$ $allow\_reversal_{i-i^*} = incumb\_allow\_reversal_{i-i^*}$ $start\_time_{i-i^*} = incumb\_start\_time_{i-i^*}$ $reversal\_duration_{i-i^*} = incumb\_reversal\_duration_{i-i^*}$ $end\_time_{i-i^*} = incumb\_end\_time_{i-i^*}$ $mod\_num\_lanes_{i-i^*,j} = incumb\_mod\_num\_lanes_{i-i^*,j}; \forall j = 1,2$ $cap\_factor\_original_{i-i^*,j} = incumb\_cap\_factor\_originial_{i-i^*,j}; \forall j = 1,2$ $cap\_factor\_duplicated_{i-i^*,j} = incumb\_cap\_factor\_duplicated_{i-i^*,j}; \forall j = 1,2$

Figure 2. Sub-Procedures for GA1-GA3

a) Variables for Candidate Link Pair *i-i** in GA1

$f_{i-i^*,1}$ =Reversibility indicator (1= reversibility is allowed; 0 = reversibility is abandoned)

$f_{i-i^*,2}$ =Reversibility duration

b) Decoding Procedure for Candidate Link Pair *i-i** in GA1

$allow\_reversal_{i-i^*} = 0$ if $f_{i-i^*,1} \in [0,0.5)$, 1 if $f_{i-i^*,1} \in [0.5,1.0]$.

If $FirstTimeSlice_{i-i^*} = -1$ (i.e., the evidence shows that reversibility is not necessary),

set $allow\_reversal_{i-i^*} = 0$.

If $allow\_reversal_{i-i^*} = 1$

$start\_time_{i-i^*} = FirstTimeSlice_{i-i^*} \cdot second\_per\_slice$

$reversal\_duration_{i-i^*} = lb_{duraton} + (ub_{duration} - lb_{duration}) \cdot f_{i-i^*,2}$

$end\_time_{i-i^*} = start\_time_{i-i^*} + reversal\_duration_{i-i^*}$

If $NonZeroDiffReachCap_{i-i^*} = 1$ (i.e., 1st-direction link will be increased by a lane),

$k = 1$ and $kp = 2$

Else if $NonZeroDiffReachCap_{i-i^*} = -1$ (i.e., 2nd-direction link will be increased by a lane),

$k = 2$ and $kp = 1$

If $start\_time_{i-i^*} \in [start\_time_{i-i^*}, end\_time_{i-i^*}]$,

$mod\_num\_lanes_{i-i^*,k} = \min\{mod\_num\_lanes_{i-i^*,k} + 1, sum\_lanes_{i-i^*} - 1\}$

Else

$mod\_num\_lanes_{i-i^*,k} = \min\{mod\_num\_lanes_{i-i^*,k} + 1, sum\_lanes_{i-i^*} - 1\}$

$mod\_num\_lanes_{i-i^*,kp} = sum\_lanes_{i-i^*} - mod\_num\_lanes_{i-i^*,k}$

$DetermineCapacityFactor(i-i^*)$ (see Figure 2)

Else if $allow\_reversal_{i-i^*} = 0$

$RetrieveIncumbentSolution(i-i^*)$ (see Figure 2)

Figure 3. Decision Variables and Decoding Procedures for GA1

a) Variables for Candidate Link Pair *i-i** in GA2

$f_{i-i^*,1}$ =Reversibility indicator (1= reversibility is allowed; 0 = reversibility is abandoned)

$f_{i-i^*,2}$ = Numbers of lanes in both driving directions after reversibility

b) Decoding Procedure for Candidate Link Pair *i-i** in GA2

Same as the Decoding Procedure in GA1 except that the determinations of $reversal\_duration_{i-i^*}$ and $\text{mod}\_num\_lanes_{i-i^*,k}$ are replaced by the following:

- $reversal\_duration_{i-i^*} = \max\{lb_{duration}, \min\{ub_{duration}, (LastTimeSlice_{i-i^*} - FirstTimeSlice_{i-i^*} + 1)\cdot second\_per\_slice\}\}$
- If $start\_time_{i-i^*} \in [start\_time_{i-i^*}, end\_time_{i-i^*}]$,

  $temp = \lfloor f_{i-i^*,2}\cdot(sum\_lanes_{i-i^*} - 1 - \text{mod}\_num\_lanes_{i-i^*,k} + 0.999999)\rfloor$

  $\text{mod}\_num\_lanes_{i-i^*,k} = \min\{sum\_lanes_{i-i^*} - 1,\ temp + \text{mod}\_num\_lanes_{i-i^*,k}\}$

  Else

  $temp = \lfloor f_{i-i^*,2}\cdot(sum\_lanes_{i-i^*} - 1 - num\_lanes_{i-i^*,k} + 0.999999)\rfloor$

  $\text{mod}\_num\_lanes_{i-i^*,k} = \min\{sum\_lanes_{i-i^*} - 1, temp + num\_lanes_{i-i^*,k}\}$

Figure 4. Decision Variables and Decoding Procedures for GA2

a) Variables for Candidate Link Pair *i-i** in GA3

$f_{i-i^*,1}$ =Reversibility indicator (1= reversibility is allowed; 0 = reversibility is abandoned)

$f_{i-i^*,2}$ = Numbers of lanes in both driving directions after reversibility

$f_{i-i^*,3}$ = Reversibility duration

b) Decoding Procedure for Candidate Link Pair *i-i** in GA3

Same as the Decoding Procedure in GA1 except that the determinations of $reversal\_duration_{i-i^*}$ and $\text{mod}\_num\_lanes_{i-i^*,k}$ are replaced by the following:

- $reversal\_duration_{i-i^*} = lb_{duraton} + (ub_{duration} - lb_{duration})\cdot f_{i-i^*,3}$
- If $start\_time_{i-i^*} \in [start\_time_{i-i^*}, end\_time_{i-i^*}]$,

  $temp = \lfloor f_{i-i^*,2}\cdot(sum\_lanes_{i-i^*} - 1 - \text{mod}\_num\_lanes_{i-i^*,k} + 0.999999)\rfloor$

  $\text{mod}\_num\_lanes_{i-i^*,k} = \min\{sum\_lanes_{i-i^*} - 1,\ temp + \text{mod}\_num\_lanes_{i-i^*,k}\}$

  Else

  $temp = \lfloor f_{i-i^*,2}\cdot(sum\_lanes_{i-i^*} - 1 - num\_lanes_{i-i^*,k} + 0.999999)\rfloor$

  $\text{mod}\_num\_lanes_{i-i^*,k} = \min\{sum\_lanes_{i-i^*} - 1, temp + num\_lanes_{i-i^*,k}\}$

Figure 5. Decision Variables and Decoding Procedures for GA3

Fitness Evaluation

After converting the chromosomes to the vectors of decision variables, the UODTA with the decoded time-varying lane-based capacity reversibility strategy is solved by the simulation-based UODTA module in VISTA. TSTT for each solution is used to calculate a fitness measure. The objective functional value is TSTT determined from the UODTA flows. For GA1 to GA3, various time-dependent congestion measures ($diff\_reach\_cap_{i-i^*,j}$, $FirstTimeSlice_{i-i^*}$, $NonZeroDiffReachCap_{i-i^*}$ and $LastTimeSlice_{i-i^*}$) are also determined from the UODTA flows.

Selection

A selection algorithm determines the actual number of offspring that each individual should receive based on its fitness (*18*). There are two parts in a selection algorithm: 1) determination of the individuals' expected values; and 2) conversion of the expected values to discrete numbers of offspring. The selection algorithm must maintain a constant population size while attempting to provide accurate, consistent and efficient sampling. The best selection algorithm is the Stochastic Universal Sampling (SUS) (*18*). SUS is analogous to a roulette wheel with N_{POP} equally spaced pointers, and each structure is allocated a portion of the roulette wheel proportional to the structure's relative fitness. A single spin of the wheel determines the number of offspring assigned to every structure, yielding N_{POP} winners. Then, the selection pointers are randomly shuffled, and the selected structures are copied into the new population. SUS can be based on two different measures: the objective function (TSTT) and ranking. The adopted measure is the TSTT. This proportional selection simply considers the TSTT as performance measure for each chromosome. Furthermore, DeJong (*19*) proposed the elitism concept, which is also used in this study. The elitist policy stipulates that the best individual always survives into the new generation. The elite individual is placed in the last position in the offspring population and is not changed through crossover or mutation.

Mutation

After the new population is selected, mutation is applied to the new population. Mutation helps GA search different neighborhoods. Each position is given a chance of *M_rate* to undergo mutation. *M_rate* is usually set less than 0.1 in either a fixed or a variable rate. This study employs a fixed *M_rate*. Mutation is implemented by treating the entire population as a linear array of positions. For each position, generate a random number between 0 and 1. If the random number is within *M_rate*, a random value is chosen from {0,1}, and the value of the position is overwritten by this random value.

Crossover

A crossover operator exchanges genetic materials among adjacent pairs of the first ($C\_rate \times N_{POP}$) structures in the new population. Note that the population is randomly shuffled in the selection procedure. The crossover can be implemented in a variety of ways, but there are theoretical advantages that the two-point crossover is better than other kinds (*19*). The two-point crossover operator treats the structures as rings, randomly chooses two crossover points, and exchanges the sections between these points (*17*). The segments between the crossover points are exchanged, given that the parents differ outside of the crossed segment. After crossover, if the offspring are different from the parents, then the offspring replace the parents. Given the same random seed, UODTA is not a noisy function, so structures that are identical to parents will not be marked for evaluation.

5. COMPUTATIONAL EXPERIENCE

We consider two multi-origin multi-destination test networks. The first is a small-size, hypothetical grid network, and the second is a larger-size network (the modified Sioux Fall network). We first describe the two test problems. Then, the performance comparisons of GA1, GA2 and GA3 on the two test networks are discussed.

5.1 Test Problems

Network 1

Figure 6a shows Network 1 composed of 9 nodes, 24 links. All links are 3-lane and 2 mile long with the free flow speed of 49.5 mile per hour (mph) and the capacity of 1,000 vehicles per hour per lane (vphpl). The simulation period is five hours. All 12 link pairs are candidate for time-varying lane-based capacity reversibility. We consider 20 O-D pairs (nodes 1, 3, 5, 7 and 9 are both sources and sinks). The O-D demands from node 5 to each of the other four sinks are 500 vehicle trips. The O-D demands from each of the four sources (nodes 1, 3, 7 and 9) to node 5 are 3250 vehicle trips. The other O-D demands are 1250 vehicle trips. Then, the total vehicle trips are 30,000. The static demands are distributed over the first 12 ten-minute time slices (i.e. first two hours) by the following weights: 0.05, 0.05, 0.05, 0.1, 0.1, 0.15, 0.15, 0.1, 0.1, 0.05, 0.05 and 0.05, respectively. Within each time slice, the demands are assumed uniformly distributed. The allowable ranges of reversal starting time and reversal duration are respective [1200 seconds, 5400 seconds] and [1800 seconds, 5400 seconds]. The TSTT of the original network is 6933.31 hours.

Network 2, Modified Sioux Falls Network

Figure 6b shows Network 2 composed of 24 nodes and 76 arcs. 14 link pairs with dashed red arrows are candidates for time-varying lane-based capacity reversibility. The network is the aggregated network of the city of Sioux Falls, South Dakota, used by many researchers in the literature. All links are 2-lane with the capacity of 1200 vphpl and the free flow speed of 49.5 mph. The link lengths can be determined from the distance scale in Figure 6b. We consider 33 O-D pairs. The total vehicle trips are 43,629. The static demands are distributed over the first 12 fifteen-minute time slices (i.e. first three hours) by the following weights: 0.05, 0.05, 0.05, 0.1, 0.1, 0.15, 0.15, 0.1, 0.1, 0.05, 0.05 and 0.05, respectively. The simulation period is five hours. The allowable ranges of reversal starting time and reversal duration are respective [1200 seconds, 9000 seconds] and [1800 seconds, 7200 seconds]. The TSTT of the original network is 3820.37 hours. It is noted that Network 2 is about two times less congested than Network 1 as the original TSTT of Network 2 is about half of that of Network 1.

5.2 Performance Comparison of Proposed GA Variations

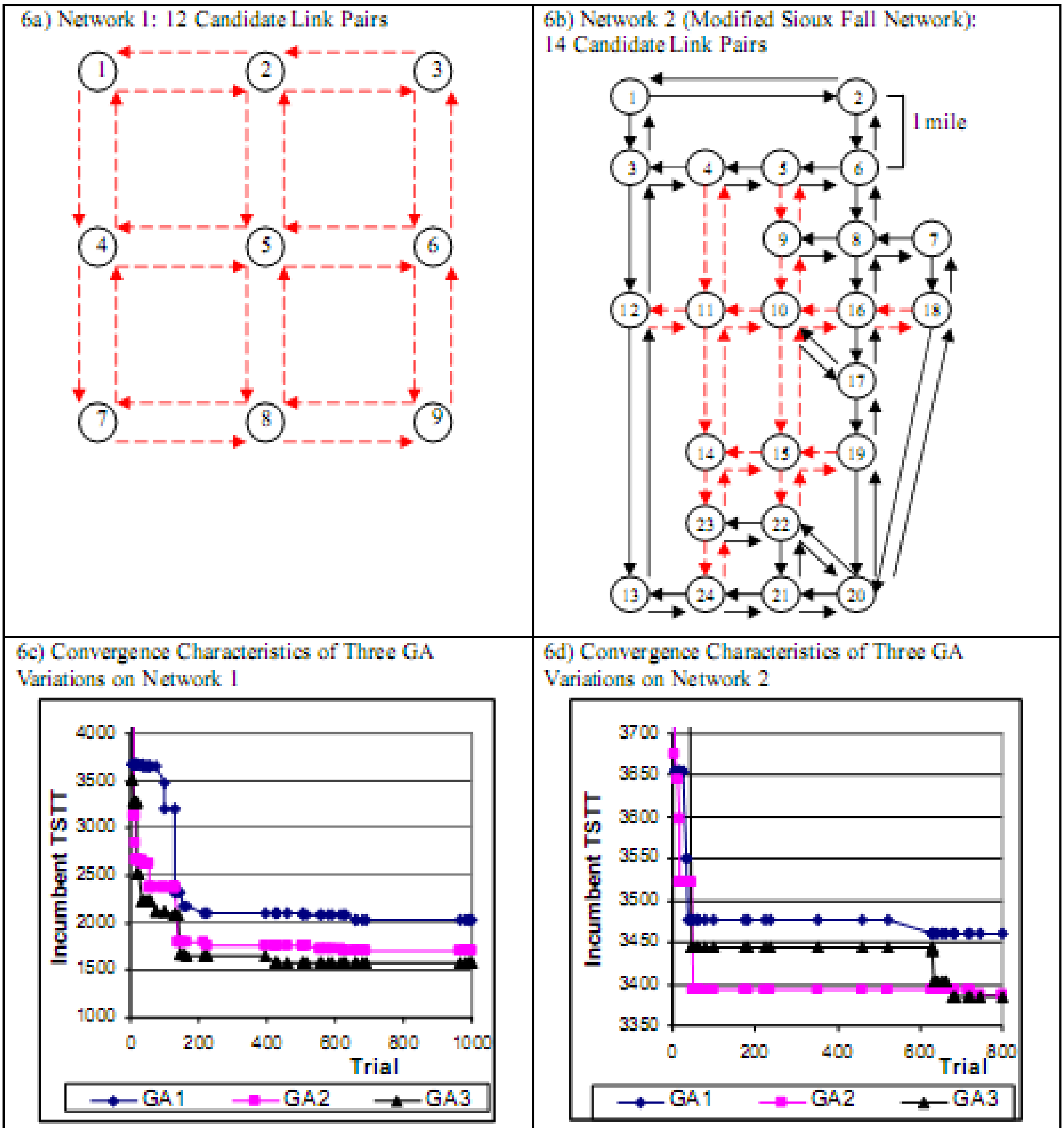
The success of GA applications essentially relies on the employed GA parameters, so a parameter calibration should be performed in order to obtain an optimal set of GA parameters. However, this is not a focus in this paper. The following GA parameters are employed for all GA runs: population size of 50, crossover rate of 0.6, and mutation rate of 0.001. Given the same parameter sets, the performance of the three GA variations can fairly be compared in terms of solution quality, convergence speed and computational time. All GA variations evaluate a solution by running the simulation-based UODTA and calculating TSTT. A generation of GA1, GA2 and GA3 may have different numbers of functional evaluations (trials), so we choose to compare the algorithm performance by the number of trials.

For Network 1, we run the three GA variations for 1,000 trials. Figure 6c shows the convergence characteristics of the three algorithms, and Figure 6e presents the results of the best solutions obtained from the three algorithms. In terms of CPU time, GA1, GA2 and GA3 consume approximately the same computational time. GA3 yields the best solution quality at trial 982: best TSTT= 1580.05 and % improvement from original TSTT = 77.21, where such percentage is calculated from the equation: % improvement = [(Original TSTT – Best TSTT)/Original TSTT]×100. Note that the higher % improvement means the better solution quality. GA2 yields the second best in terms of solution quality with the % improvement of

75.32 and yields its best solution at trial 992. GA1 provides the worst solution quality (% improvement = 70.67) and finds its best solution at trial 660. The best solution found on Network 1 by GA3 is described. From 12 candidate link pairs, five link pairs (56-65, 78-87, 14-41, 25-52, and 36-63) have no capacity reversibility, whereas the other seven link pairs (12-21, 23-32, 45-54, 89-98, 47-74, 58-85, 69-96) are adopted the following time-varying lane-based capacity reversibility strategy. The starting reversal times for the seven link pairs are 5400, 3000, 3600, 1800, 3600, 5400, and 1800 seconds, respectively. The reversal durations for the seven link pairs are 4200, 3600, 2400, 3000, 4800, 2400, and 4800 seconds, respectively. The numbers of lanes for the seven link pairs are 5-1, 2-4, 4-2, 2-4, 1-5, 2-4, and 2-4, respectively.

For Network 2, the three algorithms are run with the total trials of 800. Figure 6d presents the convergence characteristics of the three algorithms. Figure 6f shows the best solutions found by the three algorithms. In terms of CPU time, GA1, GA2 and GA3 spend about the same computational time. GA3 finds the best solution quality (% improvement = 11.41) at trial 679. GA2 is slightly worse than GA3 in terms of solution quality: % improvement = 11.34 and trial found=748. GA1 performs worst (% improvement = 9.40 and the trial found = 628). The best solution found on Network 2 by GA3 is described. From 14 candidate link pairs, ten link pairs (411-114, 910-109, 1112-1211, 1015-1510, 1011-1110, 1016-1610, 1114-1411, 1415-1514, 1423-2314, 1522-2215) have no reversibility, whereas the other four link pairs (59-95, 1618-1816, 1519-1915, and 2324-2423) are adopted the following time-varying lane-based capacity reversibility strategy. The starting reversal times for the four link pairs are 7200, 2400, 1800, and 4200 seconds, respectively. The reversal durations for the four link pairs are 6600, 4800, 6600, and 3600 seconds, respectively. The numbers of lanes for the four link pairs are 1-3, 3-1, 3-1, and 1-3, respectively.

Based on our limited experimental results, GA3 outperforms GA1 and GA2 on both networks which represent two congestion levels (Network 1 is smaller but two times more congested than Network 2) in terms of solution quality. The CPU times for the three algorithms are approximately the same. In terms of convergence speed, GA1 is best, whereas GA2 and GA3 are second and third best, respectively, on both networks. Among the three criteria, the solution quality is most important, so the three algorithms are judged based on this criterion, yielding GA3, GA2 and GA1 are best, second best and third best, respectively.



6e) Results of Best Solutions on Network 1

Algorithm	Best Obj. Value (TSTT)	%Improve from Original TSTT	Trial Found	CPU (hours)
GA1	2033.6	70.67	660	36.33
GA2	1711.1	75.32	992	37.83
GA3	1580.1	77.21	982	35.54

6f) Results of Best Solutions on Network 2

Algorithm	Best Obj. Value (TSTT)	%Improve from Original TSTT	Trial Found	CPU (hours)
GA1	3461.3	9.40	628	57.10
GA2	3387.3	11.34	748	55.00
GA3	3384.5	11.41	679	58.10

Figure 6. Test Networks and Computational Results

6. CONCLUSIONS

The genetic algorithm (GA) is adopted in this paper by majorly modifying three components of the algorithm: 1) solution representation, 2) encoding and decoding procedure, and 3) functional evaluation. The GA employs the existing simulation-based UODTA. The decision variables are starting times, reversal durations, and redesigned numbers of lanes for candidate link pairs. An additional decision variable for a candidate link pair is the capacity reversibility indicator variable, which is added in order to prevent pre-mature convergence of GA. Three GA variations are proposed, namely, GA1, GA2 and GA3. GA1, GA2 and GA3 are developed based on problem-specific knowledge with increasing degrees of randomness. The problem-specific knowledge is adapted from the dual variable analysis of the analytical model, and involves the time-varying congestion measures. The experiment is conducted to compare the performances of the three GA variations on two test networks: Network 1 (a small, more-congested network) and Network 2 (a larger, less-congested network). The performance comparison is considered on three criteria: solution quality, convergence speed, and CPU time. The algorithms are ranked based on the solution quality criterion. We found that GA3 performs best on both networks. The CPU times of the three algorithms are approximately equal.

The future research directions are the following. The formulation and solution method can indeed be applied to contraflow evacuation planning when user-optimal behavior is assumed. The formulation may be extended to account for the limited resources (or budgets) for the operation and construction of the lane-based capacity reversibility (similar to (*8*)). Alternative global optimization methods may be explored and compared.

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REFINING THE PERFORMANCE OF NEURAL NETWORK APPROACH IN MODELLING WORK TRI P DISTRIBUTION BY USING LAVENBERG-MARQUARDT ALGORITHM

Gusri YALDI
PhD Student
ISST-Transport Systems
University of South Australia
Adelaide, South Australia, SA 5001
Fax: +61 8 8302 1880
E-mail: Gusri.Yaldi@postgrads.unisa.edu.au

Michael A P TAYLOR
Professor of Transport Planning
Director – ISST
University of South Australia
Adelaide, South Australia, SA 5001
Fax: +61 8 8302 1880
E-mail: Michael.Taylor@unisa.edu.au

Wen Long YUE
Senior Lecturer, Program Director
ISST-Transport Systems
University of South Australia
Adelaide, South Australia, SA 5001
Fax: +61 8 8302 1880
E-mail: Wen.Yue@unisa.edu.au

Abstract: The Neural Network (NN) approach has been adopted in travel demand modelling since more than one decade ago. Especially in work trip distribution estimation, NN approach was reported to have poor generalization ability. It was found unable to satisfy the Production and Attraction constraints and there was no mechanism to enforce it. This paper will show a comparison of neural network models with different training algorithms and suggest the one that can overcome the aforementioned drawbacks. The NN model trained by using the Lavemberg-Marquardt Backpropagation (LMBP) algorithm generates work trip numbers with a statistically higher accuracy than the well-known and widely used gravity model. It can satisfy both constraints with a higher goodness-of fit than the doubly-constrained gravity model. Therefore, the use of LMBP algorithm is suggested as one of the mechanism to refine the NN performance and to satisfy the constraints for work trip number distribution forecast.

Key Words: Neural Networks, Work Trip, Training Algorithm

1. INTRODUCTON

The use of NN approach in modelling activities is growing fast and covering many disciplinesincluding transport systems. The literature suggests that NN were used in 13 categories of transport studies up to year 1990 where driver behaviour simulation studies had the highest percentage (Dougherty, 1995). However, recent investigation indicates a growing adoption of NN in travel demand modelling, dominated by Mode Choice (MC) studies.

Examples include the multilayer perceptron neural networks used by Cantarella & de Luca (2005), Hensher & Ton (2000), Carvalho et al. (1998), and Subba Rao et al. (1998) in mode choice studies. There is less application of NN approach in trip distribution compared to mode choice study. Black (1995) reported a study of spatial interaction modelling using NN focusing on commodity flows. The model is structured based on the doubly constrained gravity model (DCGM) and named as Gravity Artificial Neural Network (GANN). Mozolin et al. (2000) reported the use of NN for passenger trip distribution modelling. They used NN approach to model trip distribution which is also characterized by DCGM.

Neural Network is an intelligent computer system that mimics the processing capabilities of the human brain. It is a forecasting method that specifies output by minimizing an error term indicated by the deviation between input and output through the use of a specific training algorithm and random learning rate (Black, 1995; Zhang et al, 1998).

The performance of NN models is characterized by its important properties, such as learning algorithm, activation function, number of layers, number of nodes inside each layer, and learning rate (Teodorovic and Vukadinovic, 1998, Dougherty, 1995). The amount of dataset and the ratio for training, validating and testing is also important for the NN fitting performance (Carvalho et al., 1998). Among those properties, however, the training algorithm is the most critical one.

The properties of NN models, especially the training algorithms, which are inappropriately defined, can negatively impact the model results. Consequently, the model results will become inaccurate and imprecise. For examples are the studies by Mozolin et al. (2000) and Yaldi et al (2009b). The first study used the Quickprop algorithm, while the second study adopted the variable learning rate algorithm. Although those studies were based on different training algorithms, their findings are the same. The NN approach was found to have poor generalization ability. It was unable to satisfy the Production and Attraction constraints. Former studies seem also to have lack of statistical analysis regarding the performance of the NN approach in trip flow estimation.

Therefore, any efforts devoted to the development of a framework that can help the modeller in defining such properties can avoid the aforementioned drawbacks to occur. This study is then aimed at refining the performance of NN approach in estimating work trip numbers by using Lavenberg-Marquardt Backpropagation (LMBP) algorithm, as part of the above mentioned effort. A more comprehensive statistical analysis is provided to support the findings.

The LM algorithm is based on the Marquardt algorithm for non linear least squares which is incorporated into the standard Backpropagation (BP) algorithm. It is categorized as the standard numerical technique for minimization of sum of the nonlinear objective functions. While the standard BP is a steepest descent algorithm, the LMBP is an approximation to Newton's method. The key factor of this algorithm is the Jacobian matrix, where the optimization function is to minimize the function of connection weight vector. It was found that training the NN models by using this algorithm to converge in several cases where training by using other algorithms are failed to do so (Hagan and Menhaj, 1994).

A number of Multilayers feed forward neural network models were developed and trained by using Neural Network Tool in the MatLab software environment, version 7.0.1. In order to compare the performance of the LM algorithm, the models were also trained by using standard BP and variable learning rate algorithm with momentum (VLBP). Thus, the models are termed here as BP, VL and LM models respectively.

Each model was trained ten times; with epoch number is limited to 100 epochs. The results are compared and statistically tested by using the x^2 square and t-test. The results are also compared with the well-known doubly-constrained gravity model, calibrated by using Hyman algorithm

(Hyman, 1963). The comparison includes the goodness of fit in term of correlation coefficients (r) of Trip Production (rP), Trip Attraction (rA) and Trip Number (rTij) between observed and model outputs. The error level is also compared which is measured through the Root Mean Square Error (RMSE), and Standardized Root Mean Square error (SRMSE) between observed and estimated trip number generated by each training algorithm.

The results suggest that the LM models can satisfy the Production and Attraction constraints, with statistically insignificant variation of rP and rA between each experiment, as indicated by chi square test for correlation coefficient. In contrast, the BP and VL models have unstable performance, where the rP and rA fall within positive and negative one. There are significantly variations of correlation coefficient between each experiment.

Then, the neural network models are compared with doubly-constrained gravity model (DCGM) calibrated by using Hyman's algorithm (Hyman, 1969). The paired t-test suggests that the BP and VL models have a significantly higher average error (RMSE) than the DCGM. However, the same test suggests that the LM model has a significantly lower RMSE than DCGM. Besides, the last model has also a significantly higher goodness-of-fit of estimated trip number (rTij) than the DCGM model. Therefore, it can be suggested that the performance of NN model can be refined through the use of appropriate trainingalgorithm, which is the Lavenberg-Marquardt algorithm.

The rest of the paper will report the how the model are developed, input data, model output analysis and detailed comparisons. The discussion, however, will mainly in the model output, as the comprehensive discussion on the BP, VLBP and LMBP algorithms have been reported in Hagan & Menhaj (1994), and Phansalkar & Sastry (1994).

2. MODEL DEVELOPMENT

2.1 Model Structure and Training Process

The structure of the NN model is one of its important properties. Multilayer Feedforward Neural network is often used in the forecasting purposes. It commonly has three layers, namely the Input, Hidden and Output layers, and connected by non parametric values, known as the connection weights. Each layer consists of a number of very simple processing elements, called as neurons. The neurons in the first layer take the data into the network. It flows along the connections and is scaled by the value of connection weights. The output is computed by transferring the scaled input using internal transfer function, which is commonly a logistic function (Black, 1995, Dougherty, 1995).

Except for hidden layer nodes, the numbers of processing units are determined by the variables that construct the expected outputs. In the case of work trip distribution and analogue to doubly constrained gravity model, the Trip Flow (Tij) is a function of Trip Production(P), Trip Attraction (A) and Trip Length (D) as the deterrence factor. Therefore, there are three nodes at the input layer, while output layer has only one node (Figure 1).

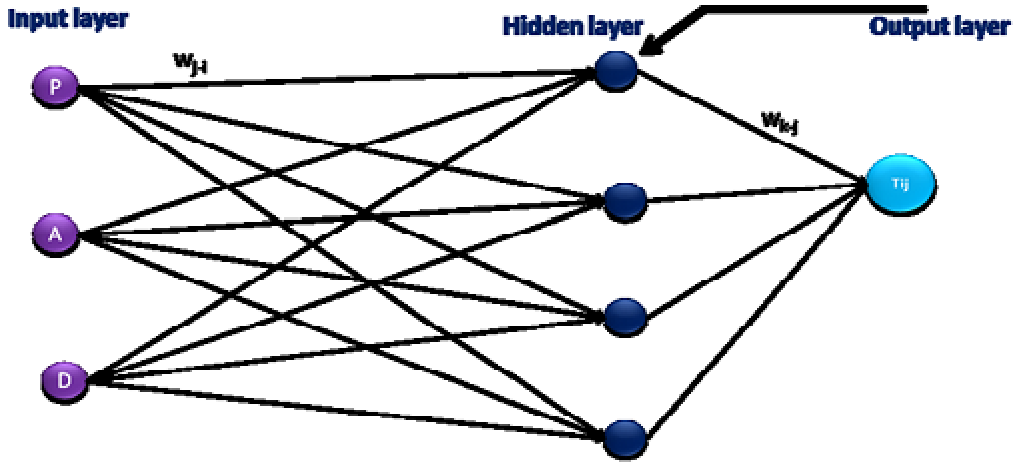

Figure 1. Proposed NN model structure

This study used a constant number of nodes inhidden layer as the former study by Yaldi et al. (2009b) indicated that node numbers in that layer is not a significant factor in NN model performance. It even can increase the error level as found in a study by Carvalho et al. (1998). Thus, the number of nodes in hidden layer was set to be ten nodes.

The training process is started from summation in the hidden layer nodes using the following equation.

$$O_j = \sum_i x_i w_i \quad (1)$$

Then, the Oj is squashed according to the activation function used in the network structure, in this case Logsig. Thus, the squashed output in hidden layer nodes (O'$_j$) is:

$$O^1_j{}_j = \frac{1}{1+Exp(-O_j)} \quad (2)$$

It is followed by the summation in the output layer node (O_k).

$$O_k = \sum_j O_j^1 w_{k-j} \quad (3)$$

Since the same activation function is used in the output layer node, the summation result in this layer is squashed according to the following equation.

$$O_k^1(T_{ij}) = \frac{1}{1+Exp\text{-}(O_k)} \quad (4)$$

The result is then compared with the target value (observed trip numbers/t_{ij}), and compute thedifferent (diff).

$$diff = t_{ij} - O_k^1(T_{ij}) \quad (5)$$

It is then compared with the threshold value (goal). If it is below the threshold value, than the training is stopped, otherwise the error (diff) is back propagated to the system in order to obtain the combination of connection weights that can generate results with error below the threshold value. This recursive process is undertaken using three different training algorthms, namely standard Back Propagation (BP), Variable Learning Rate Back Propagation (VLBP) and Lavenberg-Marquardt Backpropagation (LMBP). To simply the discussion, the models are termed as BP, VL and LM models respectively.

The LM algorithm was initially developed to accelerate the convergence of the standard BP algorithm. It is categorized as standard numerical technique for minimization of nonlinear least square function, and an approximation of Newton's method. It has the main functions as

$$V(x) = \sum e^2(\underline{x}) \quad (6)$$

$$\Delta(x) = -[\nabla^2 V(x)]^{-1} \nabla V(\underline{x}) \quad (7)$$

$$\nabla V(x) = J^T(x) e(\underline{x}) \quad (8)$$

$$\nabla^2 V(x) = J^T(x)\, J\,(x) + S(\underline{x}) \quad (9)$$

Where $\nabla^2 V(x)$ is the Hessian Matrix and
$\nabla V(\underline{x})$ is the gradient, and
$J(X)$ is the Jacobian Matrix.

Other technique is known as ad hoc method. Examples include variable learning rate, momentum, and rescaling variable algorithm. They are the extension of standard BP algorithm, which is based on the steepest descent algorithm, where the performance index is approximated by:

$$V = \sum e^2 \quad (10)$$

And the approximate steepest (gradient) descent algorithm is:

$$\Delta w^k(i,j) = -\propto \frac{a\bar{v}}{aw^k(i,j)} \quad (11)$$

Where α a is the learning rate. The main different of the above algorithm is in the method of minimizing the error, as indicated by equation (6) and (10). A comprehensive discussion of standard BP, VLBP and LM algorithm development and their application in several function approximation problems is available in Hagan & Menhaj (1994), and Phansalkar & Sastry (1994).

2.2 Data

The study used work trip data collected by the Transportation Agent of Padang City, West Sumatra, Indonesia. It was collected in 2003. There are 36 traffic analysis zones. Hence, there are 1296 samples for all nodes in input and output layers. The input data consists of Trip Production, Trip Attraction and Trip Length.

2.3 Transfer Function and Epoch Number

There are four common activation functions according to Teodorovic and Vukadinovic (1998), and two of them are Sigmoid and Linear functions. Sigmoid functions have often been used in different transportation studies, such as the studies by Mozolin et al. (2000), Carvalho et al. (1998), and Black (1995). Although the activation function is one of the main properties of the NN, there is no study specifically reporting the use of different activation functions and their impact on the network performance. The mathematical formulations of these functions are given below.

1. Tansing $\quad x = \frac{2}{1+\exp(-2x_0)} - 1 \quad (12)$
2. Logsig $\quad x = \frac{1}{1+\exp(-x_0)} \quad (13)$
3. Linear $\quad x = x_0 \quad (14)$

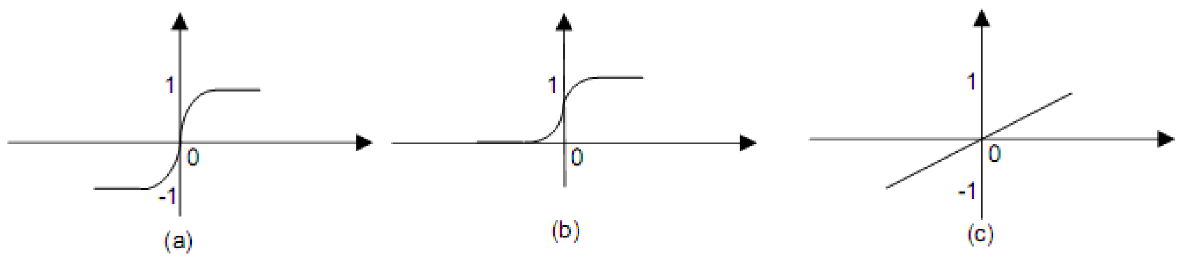

Figure 2. Common Activation Function

The first and second activation functions will squeeze the summation results in each node of the hidden and output layers based on the graphs depicted by Figure 2. The Tansig function will give results in the range [-1, 1] and for Logsig in [0, 1]. Meanwhile, the linear transfer function will not change the summation results and just transfers them after the summation process, and hence the outputs have no limits. With this knowledge, the selection of the activation function and the data normalization is a crucial decision. The following factors are considered in selecting the activation function:

1. The activation functions in the hidden layer must be able to capture the nonlinearity between input and output.
2. Different activation functions can be used in the hidden and output layers
3. Due to all the data being positive, the activation in the hidden layer must not allow the summation outputs to be negative values
4. The activation function in the output layer must ensure it does not generate negative outputs (estimated trips)

Based on the explanations above, Logsig is a suitable activation function in the hidden layer, as well as the output layer. Therefore, Logsig is used as the internal transfer function in both hidden and output layer. It is different from transfer function used in former study by Mozolin et al (2000), which used the Tansig/double sigmoid function. A study by Yaldi et al. (2009a) reported the impact of different activation function as mentioned above, toward the performance of NN prediction performance.

Maximum number of epoch was set as 100 iterations. It is based on our experience, especially for networks with validation sample; the training was always stopped with epoch below 100. It is expected that the over-fitting can be avoided by limiting the epoch number. It is a significantly lower number of iteration compared to former studies by Mozolin et al. (2000) and Black (1995), where the epoch number was up to 100000 and 150000 respectively. Therefore, a significantly lower training time can be expected in this study.

2.4 Modelling Tools and Statistical Tests

The model was developed using the Neural Network Tool in MATLAB software version 7.0.1. The initial weights for all layers were randomly selected by the software. The weights were updated after all of the data are used in the training (batch mode). Model performance was measured using Root Mean Square Error (RMSE).

To enable the statistical tests, the experiments are run for ten times for each training algorithm. There are four kinds of tests undertaken in these experiments, namely:

1. Paired/Match t-test (t*)
This test is used to measure the significant difference of average performance (RMSE) with different training algorithm and with DCGM model

2. One-Sample t-test (t**)
It is used to measure the significant difference of average performance (RMSE) among NN models and the DCGM

3. The Fisher Z transformation t-test
It is used to measure the significant difference of correlation coefficient (r) among NN models and the DCGM

4. Chi square (*x2*) test
It is used to measure the significant variation in the correlation coefficient among the ten experiments of NN model for within each model. All tests were conducted by using SPSS Statistic 17.0 software. The tests and analysis were

conducted at the calibration level only.

3. MODEL OUTPUT A NALYSIS AND DISCUSSION

3.1 Trip Production and Attraction Constraints

The details of the calibration results of work trip distribution numbers for different training algorithms are reported in Figures 3 and 4. The *x2* test result for measuring the variation among each experiment is described in Table 1. It can be seen that the BP and the VL models have a significantly unstable value of correlation coefficient, for both Trip Production (rP) and Trip Attraction (rA). The values lay between negative one positive one. The statistical test for these non parametric variables suggests that the variation is significantly high.

In the mean time, the LM models are reported to also have a fluctuation value of correlation coefficients for Trip production (rP) and Trip Attraction (rA). However, the *x*2 tests suggest that the variation is statistically insignificant. Therefore, there is strong certainty that training the NN model by using LMBP algorithm will tend to have almost the same value of correlation coefficients (rP and rA) for every experiment, as illustrated by Figures 3 and 4, as well as Table 1.

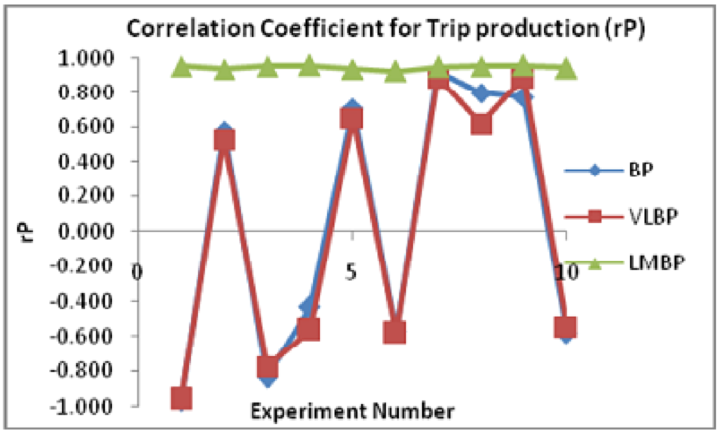

Figure 3. Correlation Coefficient for Trip Production

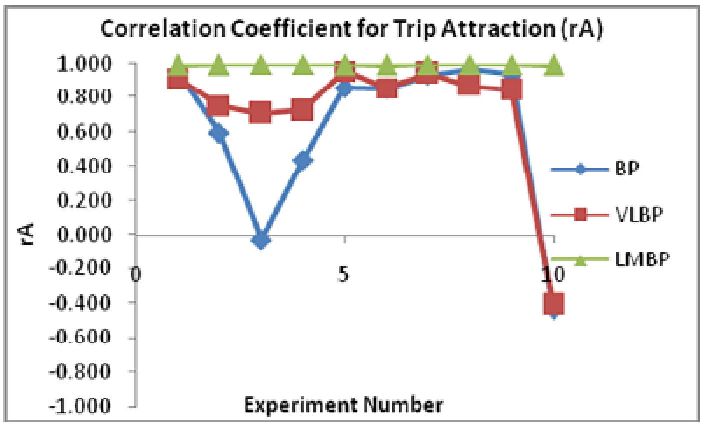

Figure 4. Correlation Coefficient for Trip Attraction

Table 1. Correlation Coefficients (r) for trips Production (rP) and Trip Attraction (rA)

Trial	BP		VLBP		LMBP	
	rP	rA	rP	rA	rP	rA
1	-0.966	0.957	-0.958	0.917	0.955	0.995
2	0.578	0.596	0.530	0.753	0.937	0.995
3	-0.832	-0.025	-0.774	0.707	0.956	0.996
4	-0.431	0.441	-0.564	0.725	0.959	0.996
5	0.710	0.859	0.652	0.955	0.938	0.996
6	-0.571	0.855	-0.579	0.858	0.927	0.995
7	0.920	0.934	0.888	0.946	0.950	0.997
8	0.800	0.965	0.619	0.872	0.956	0.996
9	0.775	0.941	0.888	0.845	0.958	0.996
10	-0.578	-0.431	-0.544	-0.406	0.945	0.995
$\chi 2$	400.724 (16.92)	217.250 (16.92)	377.356 (16.92)	126.919 (16.92)	3.140 (16.92)	1.775 (16.92)

Based on degree of freedom (n) of nine and level of confident (α) 0.05

3.2 Estimated Trip Number (rTij and RMSE)

The performance of each algorithm is calibrating he trip distribution numbers is reported in Table 2, and Figures 5 and 6. The NN models are also compared to the DCGM model, in order to assess their error level in term of Root Mean Square Error (RMSE) and goodness-of-fit (correlation coefficient/rTij).

The results of ten time experiments suggest that the goodness-of-fit of the BP model has the same trend as the VL model. Both models have a significant variation of correlation coefficients (rTij), and hence, there is high uncertainty in the model predictability performance. It is indicated by the values of *x*2 which are significantly higher than the critical one (Table 2). The t-test based on Fisher's Z transformation suggests that only the LM model has the ability to predict the patter of the trip distribution with goodness-of-fit (rTij) above the gravity model, calibrated by using Hyman's algorithm (Hyman, 1969).

Table 2. Correlation Coefficients (r) for estimated Trip (rTij) and RMSE

Trial	BP		VLBP		LMBP	
	RMSE	rTij	RMSE	rTij	RMSE	rTij
1	384	0.478	283	0.418	159	0.842
2	318	0.180	291	0.395	152	0.855
3	414	0.015	264	0.485	159	0.842
4	395	-0.025	312	0.159	158	0.841
5	384	0.314	281	0.435	154	0.853
6	299	0.333	276	0.421	154	0.851
7	408	0.698	214	0.704	160	0.839
8	396	0.736	230	0.676	159	0.841
9	370	0.663	241	0.632	159	0.841
10	493	-0.037	319	-0.003	161	0.844
$\chi 2$		1622 (16.92)		888.651 (16.92)		4.919 (16.92)
Gravity Model, RMSE (168), rTij (0.822)						
t-test*	13.001 (1.960)		9.542 (1.960)		-13.252 (1.960)	
t-test**		-27.719 (1.960)		-24.202 (1.960)		2.679 (1.960)

** Based on paired t-test with level of confident (α) 0.05, two tails*

*** Based on paired t-test for Fisher's Z transformation, with level of confident (α) 0.05, two tails*

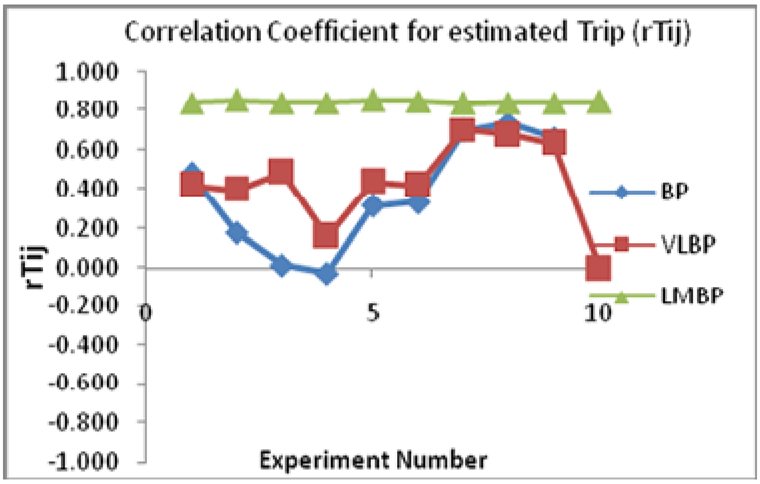

Figure 5. Correlation Coefficient for Estimated Trip

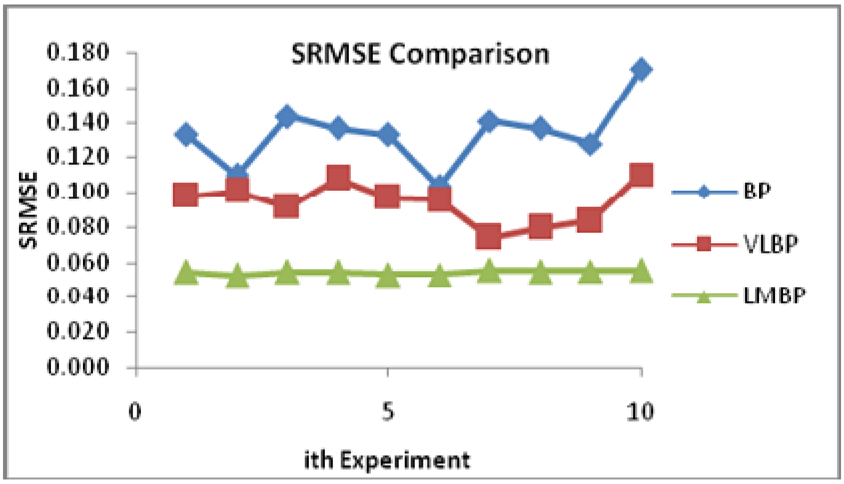

Figure 6. Standardized Average Error Level for BP, VLBP, LMBP

Then, the NN model trained by using LM algorithm is found to have a statistically significant higher rTij than this doubly-constrained gravity model, while the BP and VL models have an opposite performance. The same findings are also found with the error level (RMSE). Only the LM model has an average error level (RMSE) below the DCGM model, and it is statistically significant (Table 2). The BP and VL models have a significantly higher error than the DGCM model. It can be seen from Figure 6 that there is a major fluctuation in the results, indicating the same finding as study by Mozolin et al. (2000) (see Figure 7), as well as recent study by Yaldi et al. (2009b). Therefore, it can be suggested that the performance of NN approach in estimating the work trip number can be refined by using the LM algorithm, as indicated by the findings above.

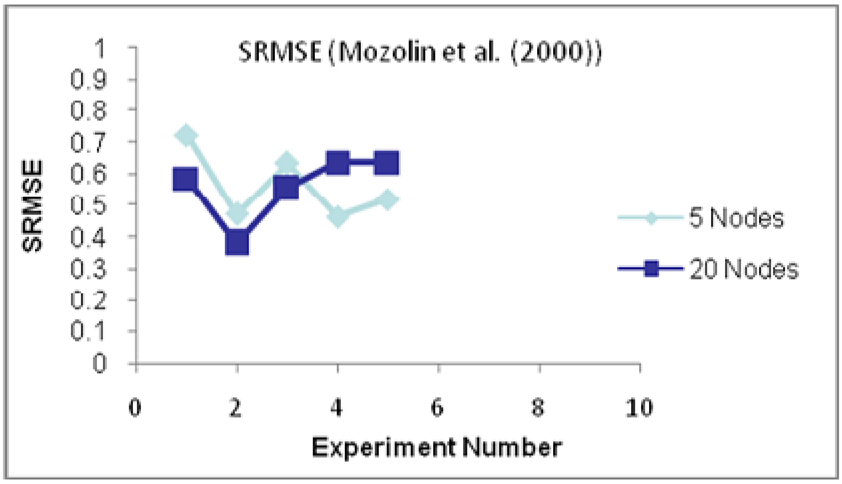

Figure 7. Standardized Average Error Level by Mozolin et al. Study (2000)

4. CONCLUSIONS AND RECOMMENDATI ONS

4.1 Conclusions

The performance of Neural Network (NN) approach is defined by at least seven properties, and the training algorithm is suggested as the most critical one. The findings from this study suggest that the Neural Network (NN) generalization ability in estimating the work trip distribution number and its ability to satisfy the Trip Production (P) and Trip Attraction (A) constrains can be refined by using the right training algorithm. Comparison on three different training algorithms, namely standard Backpropagation (BP), Variable Learning Rate Backpropagation (VLBP) and Lavenberg-Marquardt Backpropagation (LMBP) has indicated the only LMBP algorithm is suitable for work trip distribution calibration.

The statistical tests suggest that only LM models are found to have a significantly higher goodness of fit (rTij) and lower error level (RMSE) than well-know doubly-constrained gravity model. In addition, the LM models are able to satisfy both constraints, trip production (P) and Trip Attraction (A), and also have insignificant variation on its performance. The other two models, BP and VL, have an opposite results. Therefore, it issuggested that the performance of NN approach can be refined by using the LMBP algorithm.

4.2 Recommendations

Since the performance of the NN approach is dependent upon multi properties, it is suggested to conduct further research in regards to other properties. Further study can be also intended to investigate the relationship between each of its properties toward the performance of NN approach. Examples include the data normalization method and its relationship to the activation function in the output layer.

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TRAFFIC MITIGATION AT THE GOVERNMENT COMPLEX: PLAN AND OBSTACLES

Jittichai RUDJANAKANOKNAD
Lecturer
Department of Civil Engineering
Faculty of Engineering
Chulalongkorn University
Patumwan, Bangkok 10330 Thailand
Fax: +66-02-251-7304
E-mail: jittichai@hotmail.com

Wiracha SUKSIRIVORABOOT
Student
Department of Civil Engineering
Faculty of Engineering
Chulalongkorn University
Patumwan, Bangkok 10330 Thailand
Fax: +66-02-251-7304
E-mail: nokpednum_ple@hotmail.com

Wilawan SATTRAKULWONG
Student
Department of Civil Engineering
Faculty of Engineering
Chulalongkorn University
Patumwan, Bangkok 10330 Thailand
Fax: +66-02-251-7304
E-mail: pui_wl@hotmail.com

Abstract: This article presents traffic mitigation experiences at the new Bangkok Government Complex located on Chaeng Watthana Road in suburb Bangkok. The study shows that its location is in difficulty of traffic mitigation due to unplanned land use, street network, and limited public transportation. Nevertheless, two groups of traffic mitigation plans have been developed and implemented, i.e., 1) improvement of traffic network through constructing new roads and connections, expanding roads and intersections; and 2) traffic demand management for the government officials and visitors by adding more public transportation network, operating shuttle buses, and creating ridesharing programs. Ultimately, the mitigation plan is partially complete and considered to be unsuccessful due to several obstacles such as institutional barriers among stakeholder organizations, delay in constructions, land acquisition problem, etc. This plan and obstacles would serve as traffic mitigation lessons for Thailand’s infrastructure development in the future. operation, as it enables DOH to update the risk situation and improvement outcomes of the network.

Key Words: Traffic Mitigation, Traffic Management, Transportation Planning, Infrastructure Planning, Urban Transportation

1. INTRODUCTON

This article presents traffic mitigation experiences at the Government Complex Commemorating His Majesty the King’s 80th Birthday Anniversary, 5th December, B.E. 2550 (or abbreviated as “the Government Complex”) located on Chaeng Watthana Road, Laksi District in suburb Bangkok. To this end, the paper will present the limitations of why it is in difficulty of any traffic mitigation. Later, the details of proposed traffic mitigation plans will be explained. Lastly, the current mitigation results will be discussed to conclude the challenges and barriers in implementation.

The Government Complex is located on a crown land covering an area at the size of approximately 0.6 sq.km. in the central section of Chaeng Watthana Road between Vibhavadi Rangsit Road and Pracha Chuen Road. The Complex is separated into three sections, i.e., Zone A on the north side (for Courts and Ministry of Justice Building), Zone B on the south side (for other 24 government offices), and Zone C on the east side (for future expansion); see Figure 1 for the aerial view and zonings of the Complex. The Complex also includes Royal Thai Army Buildings (in the middle) as well as The Administrative Court (on the northeast side). The construction of the Complex was started since late 2005 until now (as of December 2009). However, some government agents have relocated to the Complex since August 2008. Once all offices have been relocated to the Complex (in early 2010), there will be approximately 18,000 working officers from 26 dwelling organizations as well as 7,000 visitors coming to the Complex every working day (Dhanarak Asset Development, 2009).

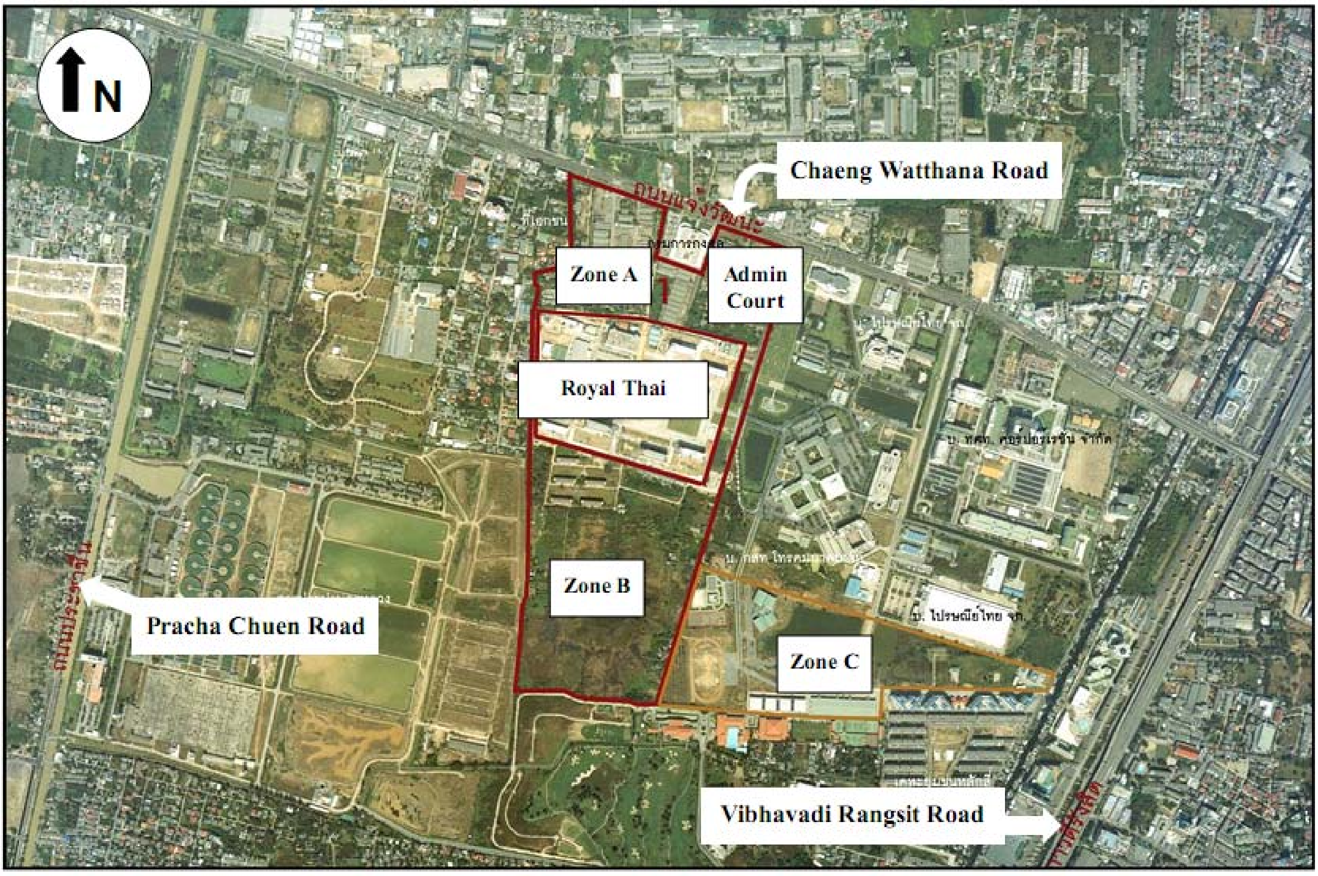

Figure 1. Aerial View of the Government Complex and its Zonings (Modified from DAD, 2009)

With its enormous project size that leads to high traffic demand, a significant traffic impact on Chaeng Watthana Road as well as neighborhood area is unavoidable. The Dhanarak Asset Development, Co., Ltd. (or abbreviated as "DAD"), the main organization who oversees the construction as well as manages the Complex, has realized this manifest impact and thus create several mitigation plans to alleviate the problems. Section 2 will show the limitation of traffic mitigation in this area. The details of mitigation plans as well as their progress and obstacles are described in Section 3. Lastly, the fourth and final Section contains concluding remarks and lessons learnt from these traffic mitigation experiences.

2. LIMITATIONS OF TRAFFIC MITIGATION

The Complex's location is limited to any traffic mitigation due to three main reasons as follows:

First, the area around Chang Watthana Road was unplanned to build any large infrastructure.

Figure 2 shows the "Tung Song Hong" covered space with an area ofv11 sq.kms that encloses by four main arterials, i.e., Chaeng Watthana Road on the north, Ngam Wong Wan Road on the south, Vibhavadi Rangsit Road on the east, and Pracha Cheun Road on the west.

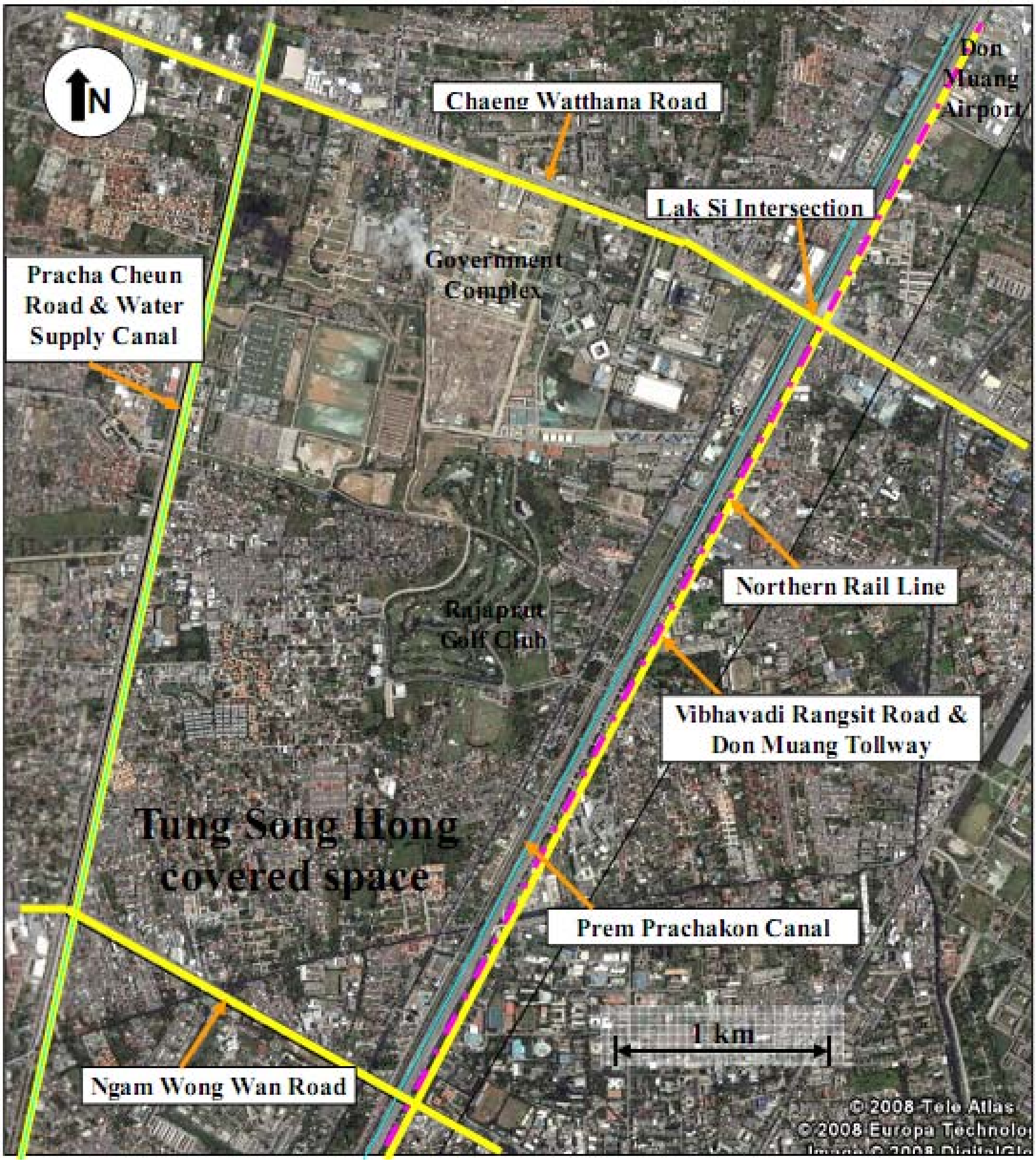

Figure 2. Limits of Traffic Mitigation for the Government Complex (Modified from DAD, 2009)

This large covered space had been ignored by the government and not planned to be urban area; however, in the last two decades, this covered space and its surrounding have been one of the fast-growing areas for population and employments. Several land developers built residential complexes with narrow independent two-lane roads, without 4-or 6-lane arterials connecting the area. They cannot connect roadways due to separated land ownership. The government's attempts to build any straight arterial road were failed since they would require lots of land acquisition from hundreds of land owners.

Secondly, four arterials surrounding the area are themselves main obstacles, i.e., 1) the Chaeng Watthana Road on the north side is the roadway with extremely high traffic volumes. There have been several land developments on the north side of this road including Muang Thong Thanee Complex – the northwest side of Figure 2. Also, the west side of this road just recently connected to the west-side region through the completion of Rama IV Bridge in 2006. 2) the east side is limited by Prem Prachakon Canal and Northern Rail Line, both were built in late eighteenth century. These impede the construction of any crossing roadway. In addition, the Vibhavadi Rangsit Road and Don Muang Tollway, large multi-lane freeways, bring the construction problem to an East-West crossing roadway since the roadway must be either high with long spans to cross, or underneath them. Furthermore, it was expected that the traffic on Vibhavadi Rangsit Road would be lessen due to the permanent closure of Don Muang Airport (ASDECON, 2006); however, the airport has not actually closed until now.

Thirdly, the area has insufficient and unreliable public transportation to serve commuters at the Government Complex. According to the government plan (OTP, 2008), there are only three neighboring mass transit systems: 1) Bangkok Bus Rapid Transit (BRT Line 2) – initially, Bangkok Government planned to connect the second BRT line from the Chatuchak Terminal to the inner of Government Center. Later, the plan was changed to connect BRT line via Chaeng Watthana Road only and run through Muang Thong Thanee Complex. However, BRT is a new project in Thailand and its service and efficiency could not be estimated at this time. Also, even the first BRT line has been on hold for several years due to many litigation as well as technical problems. 2) SRT Dark Red Line (Bang Sua-Rang Sit) – this project is now seeking companies qualified for the construction. It is expected to be completed in 2012. However, this Line does not pass Chaeng Watthana Road. The commuters who take this Line must transfer from Laksi Intersection Station to the Government Complex by using other modes. And, 3) MRT Purple Line (Pak Kret – Suvintawong) – this is one of the nine future mass transit lines according to the OTP plan. The project is the most direct one to the Complex but still in the public participation process. It is not expected to be constructed soon.

Besides the planned mass transit system, this area has only few bus lines since it is on suburb Bangkok and near the Bangkok border. The main public transit in this area is a public van, both legally and illegally, with high fares comparing with general MBTA bus lines. Also, the express Chao Phraya River ferries could not connect to the area with another travel mode since the Complex is about 8 km away of the Chao Phraya River.

3. TRAFFIC MITIGATION PLAN

Based on the limitations of the Government Complex area, there have been several proposed strategies to mitigate traffic and serve commuters. These strategies can be classified into two groups, i.e., roadway system improvement and travel demand management. The details of each strategy (according to DAD,

2009) as well as its progress are shown below.

3.1 Improvement of roadway system

DAD developed the roadway network within the Government Complex as well as outside network with the concept of multi-direction connections. Therefore, several entrances and intersections were proposed with some specified criteria, i.e., to avoid land acquisition from land owners and to divert from reserved areas (areas with high-rise buildings) as much as possible. DAD's plan of roadway expansion is shown in Figure 3.

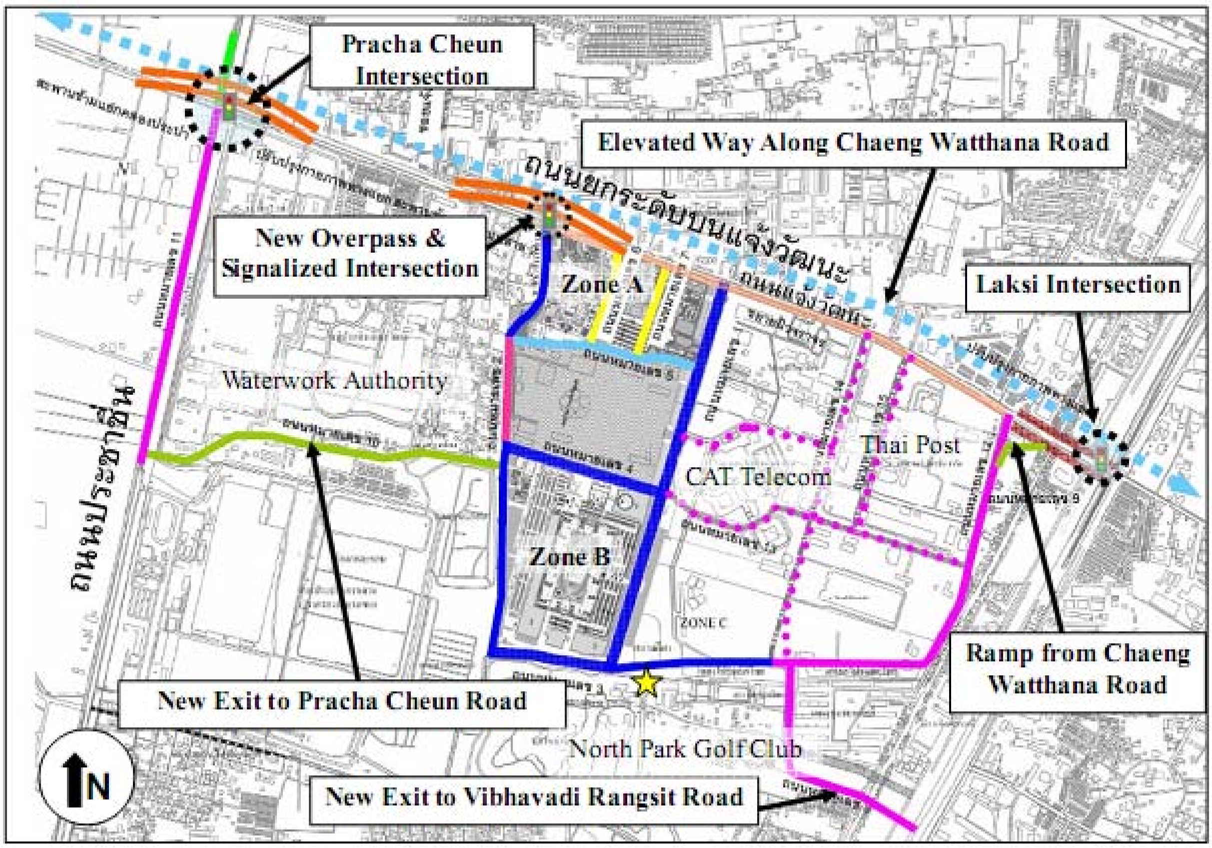

Figure 3. Proposed Roadway Network Expansion (Modified from ASDECON, 2006)

Building Internal Roadway System

Within the Complex, DAD constructed and expanded the existing roadways (dark blue, light blue and yellow lines in Figure 3). All blue and yellow roadway constructions were completed but they might not be opened yet since some connecting roadways are not finished. In addition, DAD tried to expand the roadways into adjacent areas, i.e., CAT Telecom and Thai Post, Co., Ltd., such that these connecting roadways can be alternatives to the main routes.

Proposing Connections to External Area

For connections to outside network, on the East side, DAD built the direct ramp from Chang Watthana Road and constructed the roadway to connect to the south side of Zone B. Also, on the southeast side, DAD plans to build a new exit road to the Vibhavadi Rangsit Road. This exit road's idea is still on hold since DAD could not negotiate with land owners. Also, even with land acquisition, the exit could not easily connect to the Vibhavadi Rangsit Road since it will have to encounter the Prem Prachakon Canal and the

Northern Rail Line (see Figure 2), which are main obstacles to connect to Vibhavadi Rangsit Road. Another possible option is to connect the roadway through the North Park Golf Club (at a "star" in Figure 3). This option seems reasonable but indeed very difficult since the Golf Club belongs to prestigious members and these members always vote against any activity that would disrupt their recreation activities.

On the West side, DAD planned to build an exit roadway to Pracha Cheun Road through the Waterwork Authority (See the Green Line in Figure 3). Nevertheless, the Waterwork Authority strongly rejected the idea since the new public road may affect the Authority's water quality since the Authority's crucial duty is to supply water through Bangkok. Later, the Authority allows DAD to build a road with the condition that the road must be elevated. However, an elevated road is too costly and requires land acquisition on the west side of the
Pracha Cheun Road since it has to build a bridge across the Water Supply Canal and the connecting ramp. Other option is to acquire the land on the south side of the Authority but this would affect hundreds of residents along the way also. Therefore, the idea of West side connection is currently on hold.

With these limitations, unless the new exit to Vibhavadi Rangsit Road is built; all traffic from the Government Complex must pass through Chaeng Watthana Road, via either Laksi or Pracha Cheun Intersection. Both intersections are currently oversaturated with average delays of more than 10 minutes during the peak hour even before the opening of the Complex.

Expanding Chaeng Watthana Road and Intersections

On the Chaeng Watthana Road, DAD has coordinated with the Department of Highways to expand the Road and its intersections. The major works are 1) building an overcrossing bridge at one of the main entrances to the Complex as well as setting up a signalized intersection under the bridge, 2) expand the westbound direction (southside) of the Chaeng Watthana Road from four to six lanes only between Lak Si intersecton and the Admin Court. The first item will be completed in mid 2010, while the latter was delayed due to contractor's operation and would be completed in late 2010.

Other Proposed Plan

Besides these plans, DAD has several long-term plans to mitigate traffic in the area. One of the plans is a large elevated roadway (the Dashed Light Blue Line in Figure 3) above Chaeng Watthana Road connecting Don Muang Tollway to the Sri-Rat Expressway (west side of Figure 3). This elevated roadway is definitely costly and might be conflicted with the MRT Purple line along the same route. Also, DAD has periodically asked Bangkok Government to build arterial roads within the Tung Song Hong covered space. However, it seems like the plan is still on the paper due to several land acquisitions and tight government budget.

3.2 Travel demand management

Based on an above discussion on the traffic mitigation by improvement of roadway strategies, all of these strategies are undeniably difficult, time-consuming, and expensive. Therefore, DAD also proposed a travel demand management plan to support them. The main objective of travel demand management strategies is to reduce automobile travels during the peak hours. These strategies as well as their progress are as follows:

Adding Public Transportation

DAD has coordinated with several public transportation operators including BMTA, Bangkok Bus Rapid Transit, Chao Phraya River Ferries, Co., Ltd. Nevertheless, these operators could not assist the Complex' commuters due to several below reasons:

The Bangkok Mass Transit Authority (BMA), the largest Bangkok bus operators, had initially agreed to add two more bus lines on Chaeng Watthana Road. However, these two lines could not go inside the Complex now since the construction of the overpass bridge as well as its underneath intersection is not completed. In addition, the BMTA is currently facing a bus shortage problem due to the delay on the controversial BMTA NGV Bus Plan.

Bangkok Bus Rapid Transit (BRT) initially plans to end the line inside the Complex and DAD has reserved a land for its terminal on the east side of Zone B. Later, BRT persuaded DAD to ask for a section of Zone-C land as a depot and maintenance center for the proposed BRT Line. However, DAD rejected the proposal and would like to reserve its land for future expansion. Additionally, since the commuters for the Complex are likely to be crowded only on weekdays with a little or no activity on weekends. Therefore, it might not be worthwhile for any bus or transit line to stay in the area since they have no revenue on the weekends. Ultimately, BRT changed its line to end at Muang Thong Thanee instead.

Chao Phraya River Ferry is one of the promising transit operators. Presently, the Ferry operates from Pakkret pier (the nearest pier from the Complex) to CBD in the morning with no service on the reverse direction. And in the afternoon, it operates only from CBD to Pakkret pier. This routing system does not work for commuting to/from the Complex since most government officials are living around CBD. The Ferry Company agrees to add more services given that the demand is stable and there is a reliable connection service between the pier and the Complex. Therefore, this option is still problematic and might be unsustainable.

Operating Internal Shuttle Bus Service

DAD has run five large air-conditioned shuttle buses to operate inside and around the Complex area. The main purpose of these buses is to assist traveling between Chaeng Watthana Road and Zone B area (1-km distance). The shuttle bus is costly but helpful for commuters who take BMTA buses or vans on Chaeng Watthana Road. Currently, the shuttle bus service is free and DAD has to absorb its cost. In the future, DAD planned to change its routing to cover the Laksi Intersection area and might include some condominiums or villages with a large number of commuters to the Complex.

Ridesharing Program

Since most government officials who relocated to the Complex have been living near their old officies in CBD, it is difficult for them to use public transportation to the Complex since it could take more than 90 minutes during the peak hours with multiple connections. Therefore, DAD tries to cooperate among organizations to develop ridesharing program in the Complex.

Rudjanakanoknad (2008) has studied the carpooling campaigns in Thailand and done experiment at the Complex by creating a carpool program for organizations. On October 2008, the Community Development Department and the Office of the Consumer Protection Board are the first two organizations who experienced the program. According to Rudjanakanoknad, et al. (2009a), 300 out of 600 carpool questionnaires were returned from these government officers and 30 people were grouped and set to share their cars to the workplace. Two months later, the depth interviews were conducted to evaluate the program outcome. It was found that only 9 of them are still sharing their cars. The survey shows that although most participants view that the program can save their travel costs and creates departmental interpersonal relationships in the organization. However, most officials are unpunctual and unwilling to forgo their privacy unless their organization leader fully supports and sponsors the program. Nevertheless, the carpooling idea is very new to Thai people and DAD still have to educate officers in the Complex as well as act as a media among dwelling organizations.

In addition to the carpool program, DAD has encouraged a buspool/vanpool organization within the Complex. Based on the DAD's questionnaires, officers would like to commute together in a bus or a van from several meeting points around Bangkok to the Complex. However, the multi-organization and service price are major obstacles. According to Rudjanakanoknad, et al. (2009b), buspool service is expensive since vehicles must be idle during regular working hours and the weekends. Also, buspool requires strong, synchronized, and punctual travelers. This may be successful for large adjacent organizations like CAT Telecom, or Thai Post, Co., Ltd. since the management at these organizations subsidizes approximately 75% of all buspool costs for their employees due to the pressure from their worker union. However, DAD and the Complex' government organizations have set no budget for this program since there is no Thai government policy to offer commuting incentives for its officers.

Managing Working-Hour Schedule

To reduce peak-hour traffic volumes, DAD proposed that organizations should slap the start and end of their working hours, e.g., some might start at 7:30am, while the others start at 8:30am, or 9:30am. Then again, this idea is hardly implementable for this multi-organization Complex. Each organization has its own duties with traditional time slots and DAD has no legal power to regulate them. For examples, all Court hearings and justifications usually happen synchronously in the morning period.

Parking Management

In the Complex, there are more than 10,000 on- and off-street parking spaces with about 8,000 in large parking structures. Currently, all parking is free but DAD has proposed a plan to charge a nominal parking fee at its parking structures once all organization are completely filled in mid-2010. The objectives of parking charges are: 1) to encourage officials to share their vehicles and use public transportation to the Complex, 2) to efficiently manage parking space, and 3) to optimize its revenue. Yet, the idea of parking charges has been strongly protested from officials. They believe that parking should be one of their welfare. It may be due to the reason that almost all government offices in Thailand are free of parking charges. It is doubtful whether the implementation of parking charge will ultimately be successful at this Complex.

4. CONCLUDING REMARKS

Although most of the aforementioned traffic mitigation strategies seem incomplete and unsuccessful, the Government Complex is arguably one of very few Thailand's government infrastructures with traffic mitigation plan. DAD has hired consultants and spent a large amount of budget and time to cover the plan. However, the traffic mitigation at the Government is very challenging due to these reasons:

- The location of the Complex in an unsuitable area with an unprepared land use and limited roadway expansion opportunities

- DAD is a state-enterprise organization, not a government agent. With this status, DAD has no legal power to enact the Eminent Domain law for much-needed land acquisition

- An institutional barrier among DAD and the organizations within the Complex as well as among organizations themselves make them very difficult to organize activities such as ridesharing, working-hour management, etc, together.

- The roadway construction and traffic-network expansion have been delayed. These should be completed before the first organization relocated to the Complex. After the officials start working, any construction is not easy since it involves traffic congestion and dust pollution.

Lastly, while traffic mitigation plan presented herein is site-specific and might not be applicable to other project sites. This article should serve as a valuable source for transportation engineers and traffic practitioners who might experience Thailand’s infrastructure development project in the future.

ACKNOWLEDGEMENTS

The authors would like to thank the Dhanarak Asset Development, Co., Ltd. (DAD) and the Project Management Consultancy and Construction Supervision Consultancy (PMSC) for helpful information and pictures in the report. In addition, the authors would like to thank Dr. Suwat Wanisubut who inspired the authors to write this article and gave valuable information regarding the project.

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IMAGE PROCESSING ANALYSES ON BICYCLE BEHAVIOR AT NEWLY INSTALLED BICYCLE-LANE IN JAPAN

Yui MIYAHARA
Graduate Student
Department of Logistics & Information Engineering
Tokyo University of Marine Science and Technology
2-1-6, Etchujima, Koto-ku, Tokyo, #135-8533, JAPAN
Fax: +81-3-5245-7366
E-mail: m095011@kaiyodai.ac.jp

Tetsuro HYODO
Professor
Department of Logistics & Information Engineering
Tokyo University of Marine Science and Technology
2-1-6, Etchujima, Koto-ku, Tokyo, #135-8533, JAPAN
Fax: +81-3-5245-7366
E-mail: hyodo@kaiyodai.ac.jp

Abstract: In this paper, we conducted surveys on traffic density and behavior of bicycle user such as mixed traffic conditions on bicycle lane. The video picture data of the bicycle lane was acquired for six continuous days. The behavioral data obtained from survey was analyzed by image processing. The purpose of this paper is to comprehend and discuss the actual conditions on bicycle lane such as the traffic density in certain time and direction and the behavior of the bicycle user. We were able to obtain enough suggestions from the image processing data. Especially, we focused on the analyses on the difference of the behavior of bicycle user by time and characteristics of bicycle movement by the weather etc.

Key Words: Bicycle-Lane, Image processing, Bicycle behavior

1. INTRODUCTON

A lot of people are using the bicycle for various purposes such as shopping, commuting, going to school, leisure, etc. Moreover, as it is environment-friendly (no emissions / noise), maintaining the bicycle running space contributes to the reduction of exhaust gas by about 300,000 tons as stated in the Kyoto Protocol target. Furthermore, a noteworthy level and the number of users like young individuals who get on it for the health maintenance and being fashionable increase every year in recent years. However, recently bicycle traffic accidents tend to increase from problems such as bicycle user's the recognition level, the moral degeneration, and bicycle running space shortage of a low traffic rule of the bicycle user. In Japan, most of the space (about 79,000km) assumed that the bicycle actually runs among the bicycle running spaces is a bicycle-pedestrian road, and only 3%(about 2,500km) of it is currently state in the space which the bicycle and the pedestrian such as bicycle lane are completely separated. Especially, the number of bicycle and pedestrian's contact accidents, because of bicycle user's and pedestrian running into each other, will increase on sidewalk in ten years by about 4.5 times (Figure-1). Thus, the necessity of the bicycle lane installation to which the bicycle and the pedestrian are completely separated has risen. In this paper, we conducted surveys on traffic density and behavior of bicycle user such as mixed traffic conditions on bicycle lane. The behavioral data obtained from surveys is analyzed by image processing. The purpose of this paper is to comprehend and discuss the actual circumstances on bicycle lane such as traffic density in certain time and direction and the behavior of the bicycle user.

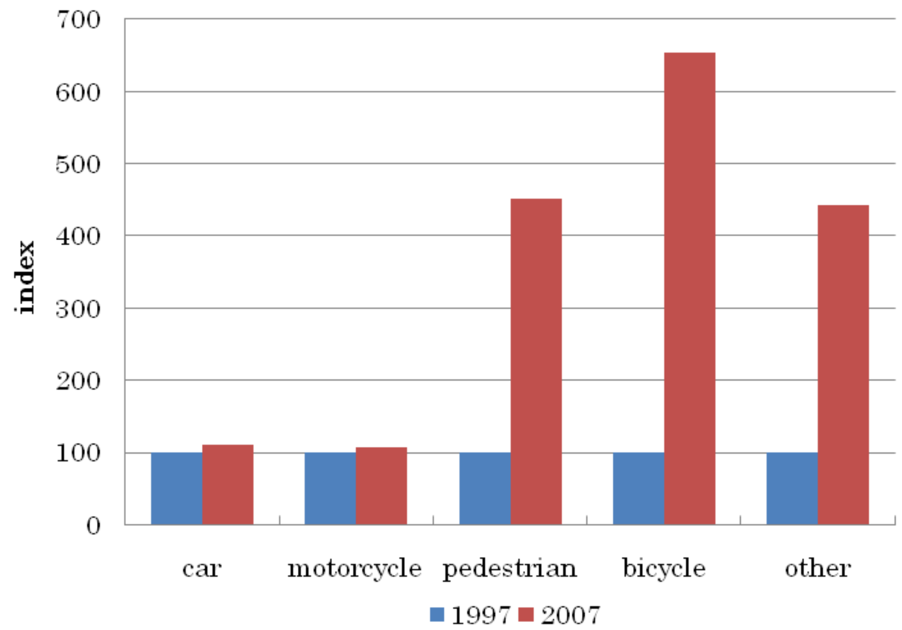

Figure 1. Accident number comparison in 1997 and 2007 according to the respective party
***Set the index of 1997 with 100**

2. CURRENT BICYCLE PLANNING IN JAPAN

2.1 98 Pilot Projects for "Development of Comfortable Space for Cycling"

The Ministry of Land, Infrastructure and Transport and the National Police Agency started 98 Pilot Project for "Development of Comfortable Space for Cycling" in urban areas in January, 2008. Phase 1 is from 2008 to 2009, and the body of project is local governments. Half of project cost is subsidized from the ministry, and total annual budget is about US$ 200 million.

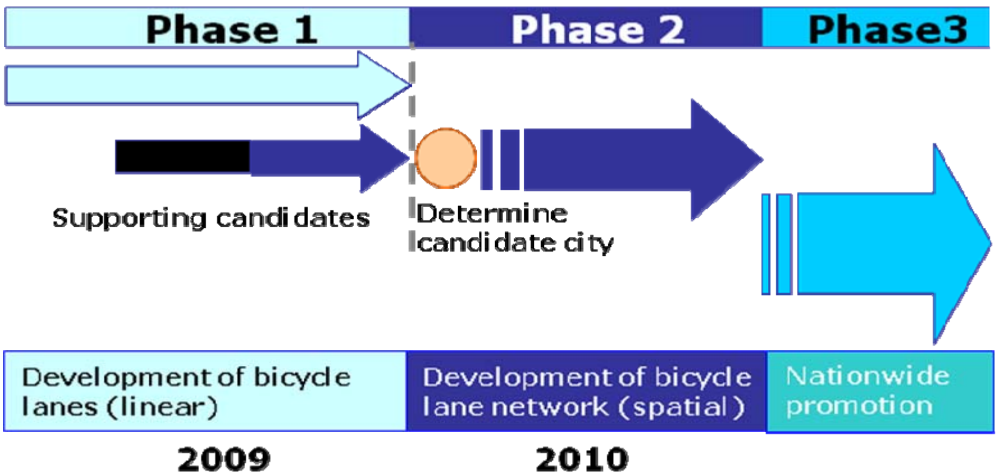

Figure 2. Summary of 98 pilots project

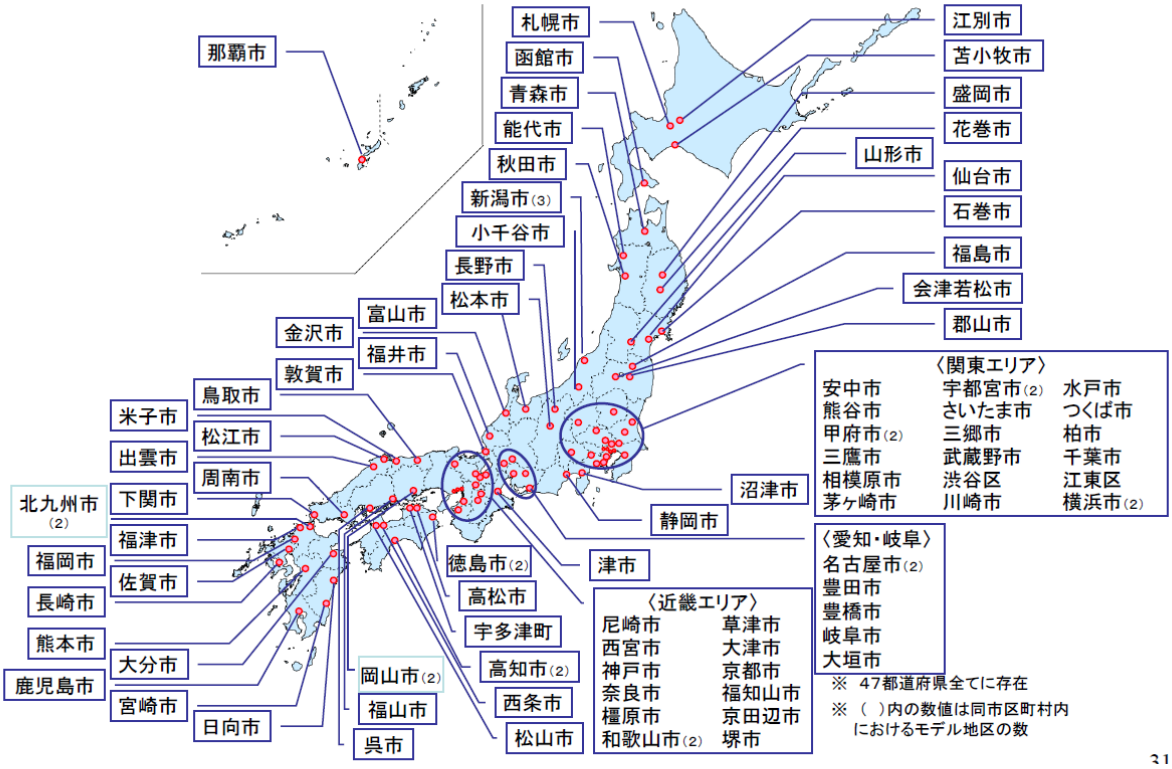

Figure 3. National map of 98 areas

2.2 Summary of Kameido-Bicycle-Lane

The installation of the bicycle lane that has been done in Kameido, Koto-ward, Tokyo that was completed by the end of March in 2008 is a typical case of the pilot project in 98 areas in the whole country. The bicycle lane installation completed in Figure-4 has dimensions of 2m width and about 1.2km along the side shoulder on both side of Keiyo road (the National Road No.14). In this paper, the image was acquired according to Table-1, and the analysis was done by image processing technique.

Figure 4. Kameido-Bicycle-Lane

Table 1. Details of shooting video

Term of shooting video	December 2nd (Tuesday) 12:00 to December 6th (Monday) 14:00, 2008
Acquired time	Total:146 hours (continuous)
Observed space	About 16m length in a bicycle lane

The direction of the bicycle running was digitalized as x axis and the perpendicular direction were digitalized as y axis. The path shown in Figure-5 was also digitized by setting coordinates affine converting the shot image diagonally in 0.2 seconds. However the video image was not able to be necessarily acquired in an ideal angle under the influences such as street trees and signboards within the range of the analysis object as shown in Figure-5. "Vitracom SiteView", image processing software made in Germany that the background difference function was equipped in the picture processing was used.

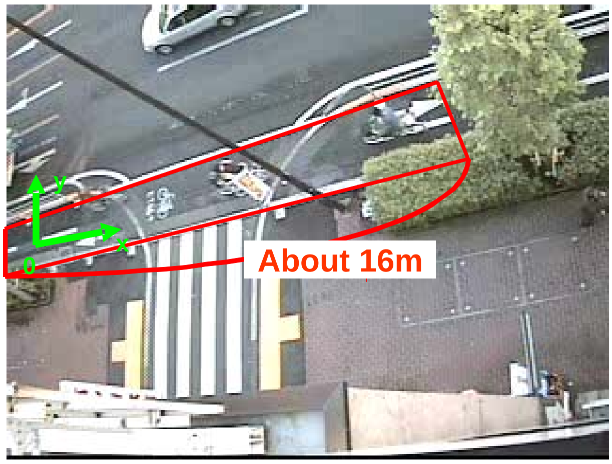

Figure 5. Acquired video image, range of analysis objects and coordinates setting

3. MEASURING BICYCLE BEHAVOR BY IMAGE PROCESSING

First, we examined video pictures on December 3rd (Wednesday) from 00:00 to 24:00 and December 5th (Friday) from 00:00 to 13:00 and from 14:00 to 24:00. Data from 13:00 to 14:00 on December 5th (Friday) and heavy rain had fallen in addition for three hours from 15:00 to 18:00. The volume of bicycles running was .

counted from the acquired video image. The counted data included and counted not only the bicycle lane for 24 hours on December 3rd (Wednesday) (from 00:00 to 24:00) but also the numbers of bicycles running on sidewalk. The result is shown in Figure-6. Though many of bicycle users ran on the sidewalk, 70-80% of them ran in the bicycle lane, that is, 200 bicycles per hour at most from 19:00 to 20:00

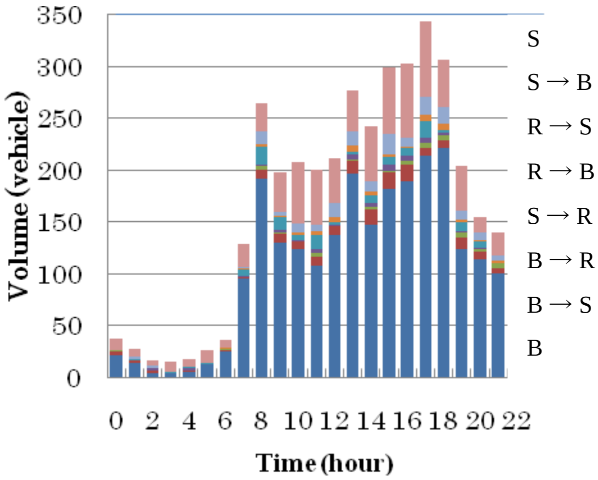

Figure 6. December 3rd (Wednesday, FINE)
S:Sidewalk B:Bicycle lane R:Roadway

We compared the date of the traffic density counted visually with the date acquired by image processing that is only on bicycle lane (Figure-7). Figure-7 shows that there is small traffic volume at midnight (from 00:00 to 07:00, from 23:00 to 24:00) and traffic density recognition by image processing was clear. However, only 60-70% of traffic was recognized at the commuting time (from 08:00 to 09:00) whose traffic was heavy, lunch time (from 13:00 to 14:00), and going-home time (from 16:00 to 20:00). This is because they one are recognized as one object when two or more bicycles come in succession. This time, it is thought that this problem was caused because pictures were taken diagonally.

We estimated the actual traffic density by using the data acquired by image processing on December 5th (Friday) and the ratio obtained by the traffic comparison on December 3rd (Wednesday) (Figure-8).

Figure-8 shows clearly that the traffic density on December 5th (Wednesday) when it was raining heavily from 15:00 to 18:00 decreases compared with the data on December 3rd (Wednesday) when was fine day. Especially, the traffic at the peak on December 3rd (Wednesday) was half of that on December 5th (Friday). Therefore, it is confirmed again that weather is a big influence on the bicycle use.

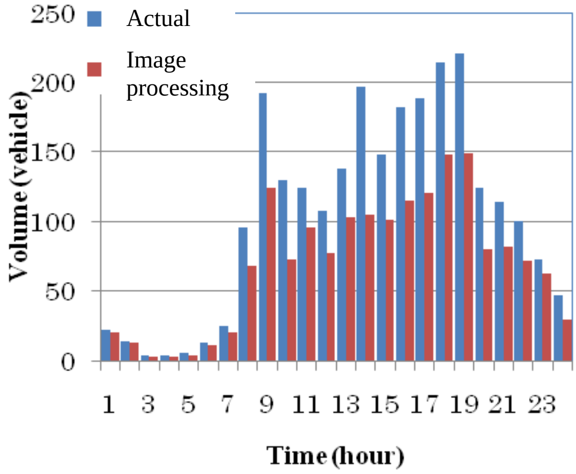

Figure 7. December 3rd (Wednesday, FINE)
Actual traffic volume and traffic counted by image processing

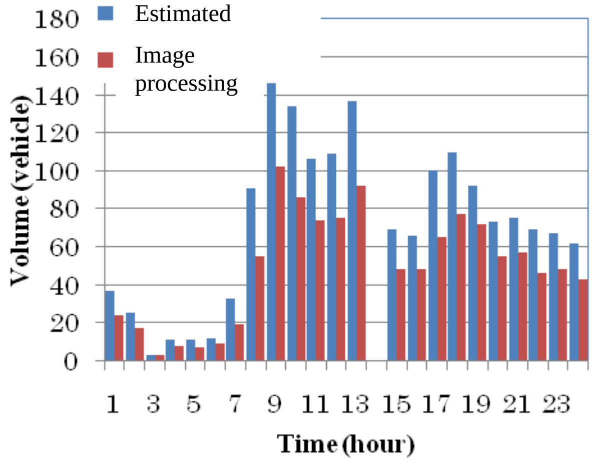

Figure 8. December 5th (Friday, RAIN)
Estimated traffic volume and traffic counted by image processing

4. ANALYSIS ON CHARACTERISTICS OF BICYCLE MOVEMENT

4.1 Velocity

The bicycle running speed was estimated from the acquired data by the image processing. Figure-9 is a velocity distribution that was obtained on December 3rd (Wednesday), Figure-10 is on December 5th (Friday). It shows that the average speed on December 3rd (Wednesday) is 12.8 km/h, standard deviation is 5.0 km/h, and a high-speed running has been comparatively observed. On the other hand, the average speed on December 5th (Friday) is 11.9 km/h, standard deviation is 5.5 km/h, therefore, it is understood that the rain influenced on decreasing the travel speed. As for the both days, 15-20 km/h was the most frequent speed, but the second frequent speed was different. For instance, the second frequent speed on December 3rd (Wednesday) was 20-25 km/h, and that on December 5th (Friday) was 10-15 km/h. Thus, it is clear to cause the difference in the running speed distribution of the bicycle still at fine weather and rain though there seemed to not be so many differences when the average speed is seen.

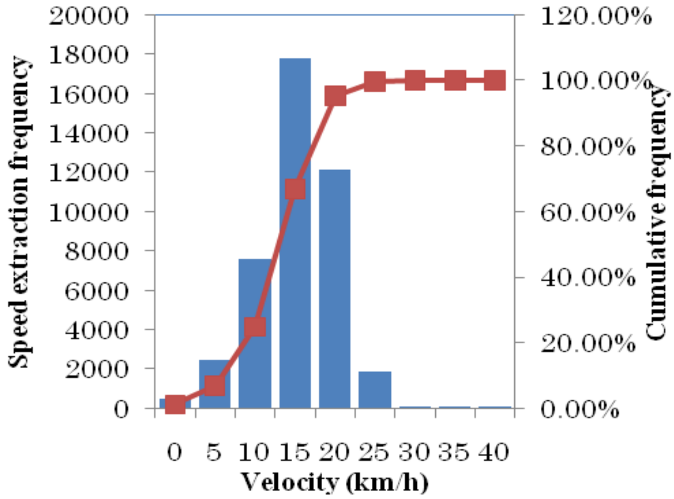

Figure 9. December 3rd (Wednesday, FINE)
Average: 12.8 [km/h], S.D.: 5.0[km/h]

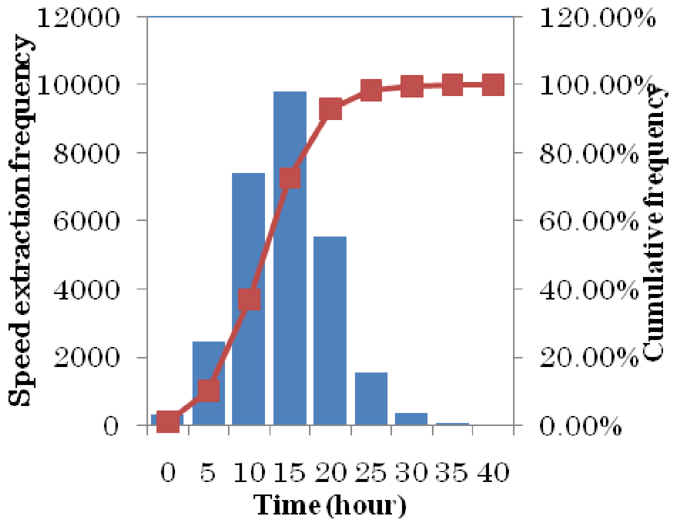

Figure 10. December 5th (Friday, RAIN around 4 PM)
Average: 11.9 [km/h], S.D.: 5.5[km/h]

4.2 Trajectory of Bicycle

Bicycle lanes installed in Kameido are two lanes, one side having 1m, and it is possible to run interactively in the bicycle lane. Left lane running is provided to the bicycle user, as indicated by the road marking. Then, the running rate of a left lane can be obtained by the image processing and the affine-transformation, dividing x coordinates by the width of 1m, and drawing the distribution of the frequencies of y coordinates. The results are shown in Figure11. - 14.

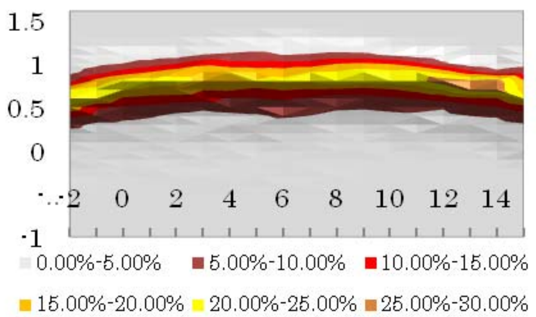

Figure 11. December 3rd (Wednesday, FINE) WEST → EAST

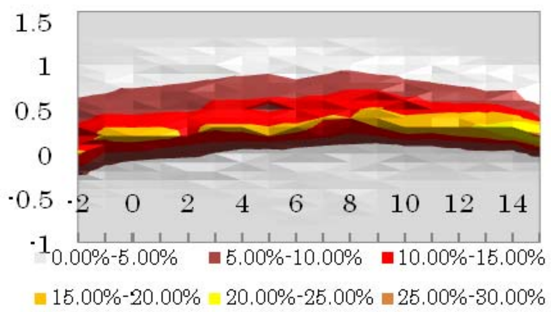

Figure 12. December 3rd (Wednesday, FINE) EAST → WEST

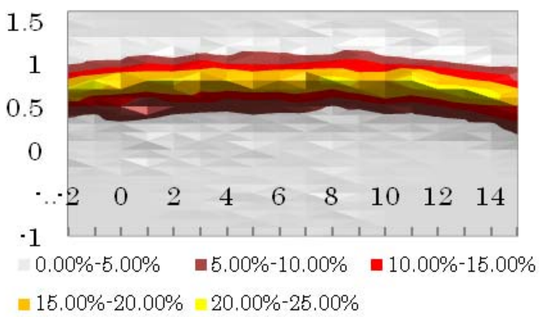

Figure 13. December 5th (Friday, RAIN) WEST → EAST

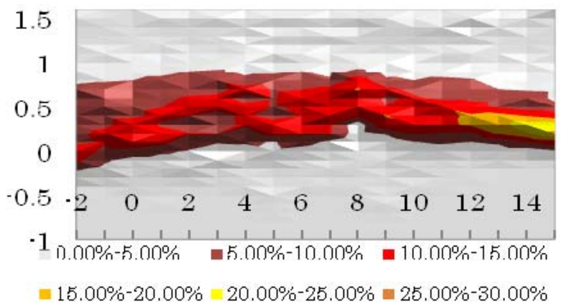

Figure 14. December 5th (Friday, RAIN) EAST → WEST

Figures represent that tendency to run on the left. Results also indicate that bicycle users who come from west (railway station) to east tend to run on the left. On the other hand, bicycle users who run in opposite direction tend to run on the left less than the former and the quality of later trajectory varies widely. It is assumed that the reason of these differences is because bicycle users try to get away from diagonal shoulder which is negative y axis in the figure and get close to the fence which is positive y axis in the figure. There are two evasive actions that to evade contact to the shoulder and to evade the collision with the opposed bicycle, and it is possible that a safe running is never done. Moreover, shoulder and the width of the bicycle lane should be reconsidered.

5. CONCLUSION

In this study, the video picture data was acquired for six continuous days for the bicycle lane installed in Kameido, Koto-ward, Tokyo and an enough suggestions were obtained from the image processing data. Especially, we focused on the analyses on the direction of the bicycle lane and time, and the running pattern in the bicycle lane, etc.

Our study shows that the bicycle lane in Kameido is currently an excellent example in the viewpoint of traffic and the transport speed in Japan. According to the trajectory of bicycles, however bicycle users who run on the roadway side tend to run on the left side, bicycle users who run in the opposite direction tend to run on the left side less than former. Therefore, it is thought that the improvement of the road surface condition is necessary such as setting up fences on the roadway side, etc. In the present study, we did not analyze the traffic that flows into the intersection in the station district, however the analysis in that area will be required since traffic density is very high.

In this study, we could shoot a video only from the diagonal angle because of the influences such as street trees and signboards. However, it is supposed that if the image was taken by certain way such as taking it right above, the data with high accuracy can be expected. We hope it would be possible to understand the characteristics of the bicycle behavior are valuable for planning bicycle lanes and their network system in urban areas.

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INFLUENCE OF ROAD DEVELOPMENT AND LAND COVER CHANGE ON URBAN HEAT: A CASE STUDY OF PATHUMTHANI, THAILAND

Pattapan SUKSA-ARD
Student
Faculty of Architecture and Planning
Thammasat University
Klong luang, Pathumtani 12121
Fax: +66-2-986-9605-6
E-mail: apattapan@yahoo.com

Pawinee IAMTRAKUL (Ph.D.)
Lecturer
Faculty of Architecture and Planning
Thammasat University
Klong luang, Pathumtani 12121
Fax: +66-2-986-9605-6
E-mail: apawinee@hotmail.com

Manat SRIVANIT
Lecturer
Faculty of Architecture and Planning
Thammasat University
Klong luang, Pathumtani 12121
Fax: +66-2-986-9605-6
E-mail: s.manat@gmail.com

Abstract: Currently, a phenomenon of urban heat island is the major concern of urban problem with the rising in average temperature of urban surface in different region. This phenomenon has also spread out while its urbanization. For an effectively and efficiency to alleviate its impact, this study attempted to investigate its evidence on the relationship between density of the roads and land cover result to an increasing in surface temperature. The application of urban heat analysis with the normalized difference vegetation index and land surface temperature was applied by the interpretation of satellite images. The result of analysis demonstrated the positive relationship between the expanding of land surface temperature and the occurring of urban heat island. This useful information could direct contribution to sustain the urban environment with both mitigation and adaptation effects to balance urban growth with the sustainable integration land use and transportation plan.

Key Words: Traffic Mitigation, Traffic Management, Transportation Planning, Infrastructure Planning, Urban Transportation

1. INTRODUCTON

Over the past decades, population growth and economic expansion has played a primary driver of land use change. This phenomenon has resulted to the urban area spreads out and leads to an urban sprawl. These effects of urbanized and urbanizing landscapes have exerted significant impact on degrading quality of life with environment problems. Among environmental issues associated with human activities, the urban heat island (UHI) effect has been one of the increasing concentrations of urban problem. It was commonly referred to the phenomenon of temperature differences between urban area and their surroundings. The different of temperature is determined in term of higher temperature in dense build up area and lower temperature in surrounding rural region. The effects are exacerbated by the human activity that generates heat as a result of road traffic, industry and domestic building. This problematic was turned to be serious environmental issue due to an increasing in air conditioning demand incorporating with the raise population levels. As a result, the magnitude and pattern of UHI effects have become major concern of many urban climate studies (Fei and Marvin, 2006). Urbanization including residential, commercial and industrial developments initiates one of the most dramatic human-induced on the change of a natural ecosystem: a natural landscape, often containing transpiring vegetation and a pervious surface, is converted to a built, largely impervious landscape made up of rigid, sharp-edged roughness elements. The introduction of new surface materials (such as concrete, asphalt, tiles, etc.) coupled with the emission of heat, moisture and pollutants dramatically change radiative, thermal, moisture, roughness and emissions properties of the surface and the atmosphere above (Roth, 2002). Urban heat island studies are generally conducted in one of two ways: (a) measuring the UHI in air temperature through the use of automobile transects and weather station networks and (b) measuring the UHI in surface (or skin) temperature through the use of airborne or satellite remote sensing.

This study selected Pathumthani, Thailand as a case study to perform the analysis of urban heat island. This research aims to mitigate the impact base on an in-depth analysis approach on the application of thermal remote sensing. This study also emphasized on the utilizing of the normalized difference vegetation index (NDVI) as the major indicator of urban climate and land surface temperature (LST) as the indicator of warmth level urban. The land use changed related to the surface temperature and normalized difference vegetation index can be derived from satellite base data by Landat5 the thematic mapper (TM) sensor data and Landsat7 the enhanced thematic mapper plus (ETM+) sensor data. Two dates of Landsat TM/ETM+ images, acquired in 2000 and 2004, were utilized to document the historical morphological changes in land cover and vegetation coverage and to analyze the relationship between these changes and those occurred in LST.

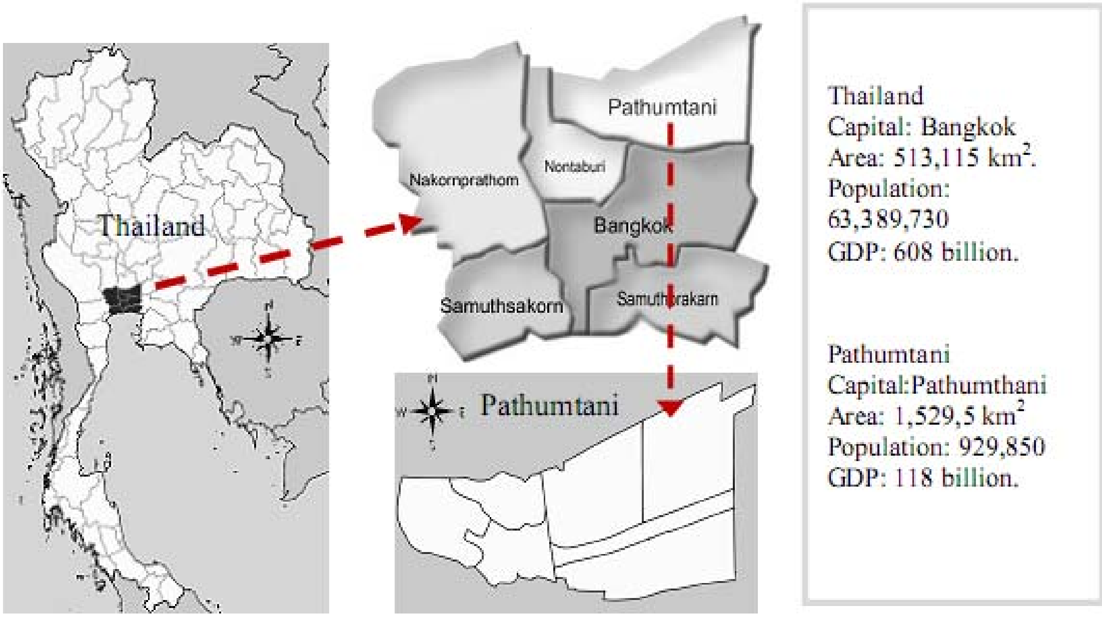
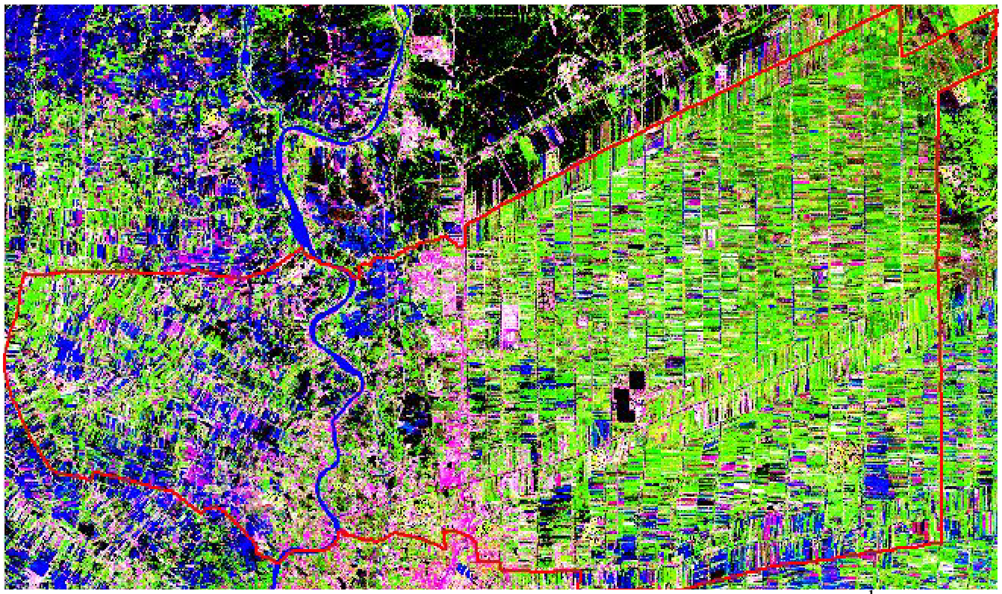
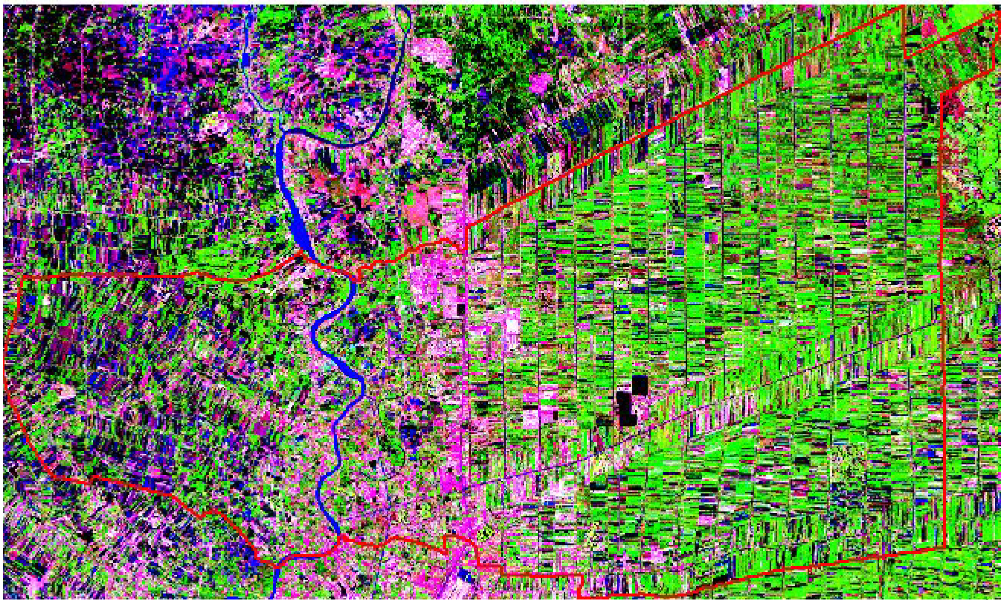


Figure 1. Study area (Pathumtani Province, Thailand)

Figure 1 demonstrates the location of study area that was selected due to the rapid urbanization of the site compared to other provinces in central region. Due to influx of population on the bed-town, it has resulted to an increasing in energy consumption, land use change and uncontrolled urbanization in the study area. Base on the application of analysis tool that previously mentioned, this study was able to assess the impact of roads on thermal environment by applying remote sensing and geographic information system (GIS) techniques. With the performance of analytical tool, this study allows for a measurement the impact of the changes in surface temperature and normalized difference vegetation index on urban heat island of the study area (Phatumtani province) between year 2000 and 2004 as depicted in Figure 2.



a. The thematic mapper (TM) sensor, November 2nd, 2000



b. The Enhanced thematic mapper plus (ETM+) sensor, December 15th, 2004

Figure 2. Landsat TM/ETM+ false color composite image (743:RGB) of Pathumthani
Source: Global land covers facility, 2009

2. CONCEPTUAL OF THE STUDY

As stated that the Urban heat island (UHI) is the phenomenon which represents the occurring of the higher surface temperature occurring in urban area than the surrounding rural region due to urbanization (Voogt and Oke, 2003). Heat island can be classified into different layers of urban atmosphere and various surfaces that can be divided into three categories. These classifications include the different layer that are canopy layer heat island, boundary layer heat island and surface urban heat island. The urban canopy layer extends upwards from surface to approximately mean building height; the urban boundary layer is located above the canopy layer. The surface urban heat island refers to relative heat of urban surface and surrounding rural region (Roth et al., 1989).

The step of land cover analysis can be analyzed base on the LST, NDVI and built up area data from satellite image (TM and ETM+). The step of analysis can be explained as follows:

2.1 Image pre-processing

Landsat data from two different years were obtained as a basis information for input into the further analysis. Landsat5 Thematic Mapper (TM) image acquired on November 2nd, 2000 and Landsat7 Enhanced thematic mapper plus (ETM+) image acquired on December 15th, 2004 were analyzed in this image pre-processing step. However, there is a point for consideration that the day-time for transient water stress may affect the radiant surface temperature.

2.2 Derivation of brightness temperature

Landsat satellites can be classified into two groups, based on sensor and platform characteristics. The first group Landsat 5 (L5), which carry the Thematic Mapper (TM) sensor. The TM sensor has a spatial resolution of 30m for the six reflective bands and 120m for the thermal band. Because there are no onboard recorders on these sensors, acquisitions are limitted to real-time downlink only. The second group consist of Landsat 7 (L7), which include the Enhanced Thematic Mapper Plus (ETM+) sensors, The L7 ETM+ sensor has a spatial resolution of 30 m for the six reflective bands, 60 m for the thermal band

Satellite TIR sensors measure radiances at the top of the atmosphere (TOA), from which brightness temperatures (also known as blackbody temperatures) can be derived by using Plank's law (Dash et al., 2002). It is assumed that the water vapor content of the atmosphere is constant for a relatively small region, so that the atmospheric condition could be considered as uniform, and the influence of atmosphere on radiance temperature could be neglected. Therefore, the at-satellite brightness temperature can be used to reflect the distribution of the surface temperature fields. It is recognized that the water vapor content does vary over time due to seasonality and inter-annual variability of the atmospheric conditions. It is not appropriate to directly compare temperature represented by the at-satellite brightness temperature between multiple time periods. Therefore, we focused on the UHI intensity and its spatial patterns across the study region on the image acquisition dates. UHI intensity is measured as the difference between the peak temperature found inside the urban area and the background rural temperature (Oke, 1987). In this way, the UHI effect can be measured for the individual thermal images and then compared between different time periods. The retrieval methods of brightness temperature from the TM and ETM+ images are different, which are discussed as follows.

1. Retrieval of Spectral radiance from the Landsat 5 TM images

Chen et al. (2002) proposed a method of deriving brightness temperature in two steps: First, the digital number (DN) of the Landsat TM thermal infrared band was converted into spectral radiance (Landsat Project Science Office, 2002):

$$L_\lambda = \frac{DN}{255} \times (L_{max} - L_{min}) + L_{min} \qquad (1)$$

Where λ L is Spectral radiance at the sensor's aperture [W/(m2 sr·μm)], DN is the pixel digital number for band 6, max L = 1.896 (mW/cm2sr·μm) and min L = 0.1534 (mW/cm2sr·μm).

2. Retrieval of Spectral radiance from the Landsat 7 ETM+ images

The Landsat 7 ETM+ 1G products were utilized for retrieving temperature in 2004. The approach to the retrieval of temperature was described in the Landsat 7 User's Handbook. The DNs of band6 were converted to spectral radiance by the following formula:

$$L_\lambda = \frac{(L_{max} - L_{min})}{QCA_{max} - QCA_{min}} \times (DN - QCAL_{min}) + L_{min} \qquad (2)$$

Where λ L is Spectral radiance at the sensor's aperture [W/(m2 sr·▯ m)], DN is the pixel digital number for band 6, max QCAL = 0 is Maximum quantized calibrated pixel value corresponding to max L , min QCAL = 255 is Minimum quantized calibrated pixel value corresponding to min L , max L = 17.04 (mW/cm2sr·μm) is spectral at-sensor radiance that is scaled to max QCAL and min L = 0 (mW/cm2sr·μm) is spectral at-sensor radiance that is scaled to min QCAL .

3. Brightness temperature computation

The thermal band data (Band 6 on TM and ETM+) can be converted from at-sensor spectral radiance to effective at-sensor brightness temperature. The at-sensor brightness temperature assumes that the Earth's surface is a black body (i.e., spectral emissivity is 1), and includes atmospheric effects (absorption and emissions along path). The at-sensor temperature uses the prelaunch calibration constants. The conversion formula from the at-sensor's spectral radiance to at-sensor brightness temperature is:

$$T_k = \frac{K2}{In\left(\frac{K1}{L_\lambda} + 1\right)} \qquad (3)$$

Where T_k is the temperature in Kelvin (K), K1 is the prelaunch calibration of constant 1 in unit of W/(m^2 sr·▯ m) and K2 is the prelaunch calibration constant 2 in Kelvin. For Landsat5 TM, K1 is equal to 607.76 W/(m^2 sr·μm) and K2 is equal to 1260.56 W/(m^2 sr·μm). For Landsat7 ETM+, K1 is about 666.09 W/(m^2 sr·μm) and K2 is about 1282.71 W/(m2 sr·μm) with atmospheric correction (Barsi et al., 2005). The final apparent surface temperature on Celsius (˚C) can be calculated the following equation:

$$T_c = T_k - 273.15 \qquad (4)$$

Where Tc is the temperature in Celsius (˚C), Tk is the temperature in Kelvin (K).

2.3 Computation of normalized difference vegetation index

Normalized difference vegetation index (NDVI) may be used as an indicator of biomass and greenness (Myneni etal., 2001; Boone et al., 2000; Chen and Brutsaert, 1998). When standardized, it may also be used as a method for comparing vegetation greenness between satellite images (Gillies et al., 1997; Weng and Lo, 2001). The index value is sensitive to the presence of vegetation on the Earth's land surface, and is also highly correlated with climatic variables, such as precipitation (Schmidt and Karnieli, 2000). In this study, NDVI were used to examine the relationship between LST and greenness. NDVI were calculated as the ratio between measured reflectance in the red and near infrared (NIR) spectral bands of the images using the following formula:

$$NDVI = \frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}} \quad (6)$$

Where RNIR and Rred are spectral reflectance in TM and ETM+ red and near infrared bands. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

3. METHOD OF STUDY

This study applied the spatial data collection to identify the urban heat that was generated by the density of roads development and land area change. The detail of method is demonstrated in Figure 3 as well as the steps that were used for analysis in this study can be explained in detail as follows:

1. Image preprocessing

The 2000 image was registered into 1: 4000 topographic maps of Patumthani province and Transverse Mercator geo-referenced. The TM image was then co-registered to ETM+ image and with the resulting root mean square values ranging from 0.13 to 0.24 pixels.

2. Classify land use pattern

Process evaluation of the area land cover was categorized by utilizing the landsat satellite image and separated or analyzed the information into 16 sections. A group of data can be separated into 5 sections, such as building space area, forest areas, agricultural areas and water areas. The result of land use can be classified and then be compared with aerial photography. Consequently, it can be calculated for proportion of each type of land use with their proportion in percentage.

3. Calculate LST, NDVI and Road density

Taking 7 band of satellite image to measure temperature and combine the 7 layers which were defined by the scope of study area. The calculations can be determine by using the formulas from equation, and then were input into the geographic information data (GIS) to determine the road layers and determine its density by using kernel function. Next step is the determination of the road density is as a fictional setting for further comparison.

4. Analysis of relationship

Due to the aims of this study is to identify the effect of changes in urban area that results to the changes in urban heat, thus this study employed data base on year 2000 and 2004 to input in the comparison process. Finally, the difference between the developed of area and undeveloped area can be simply compared.

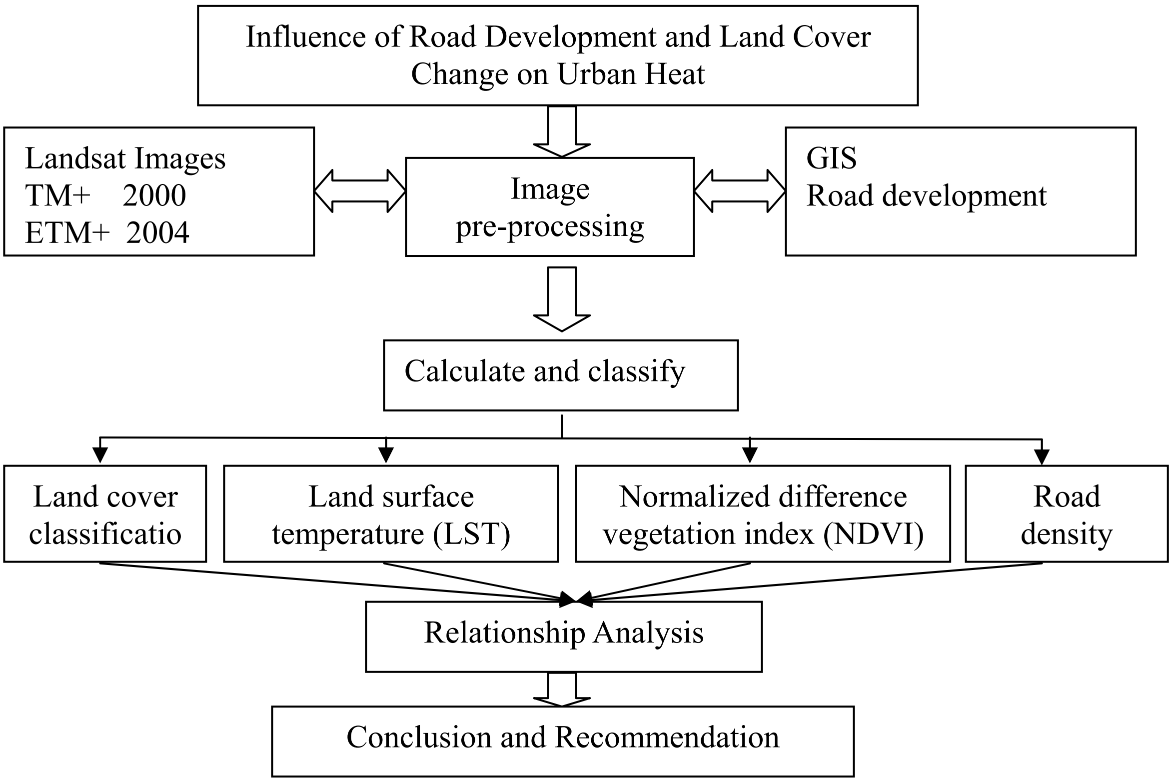


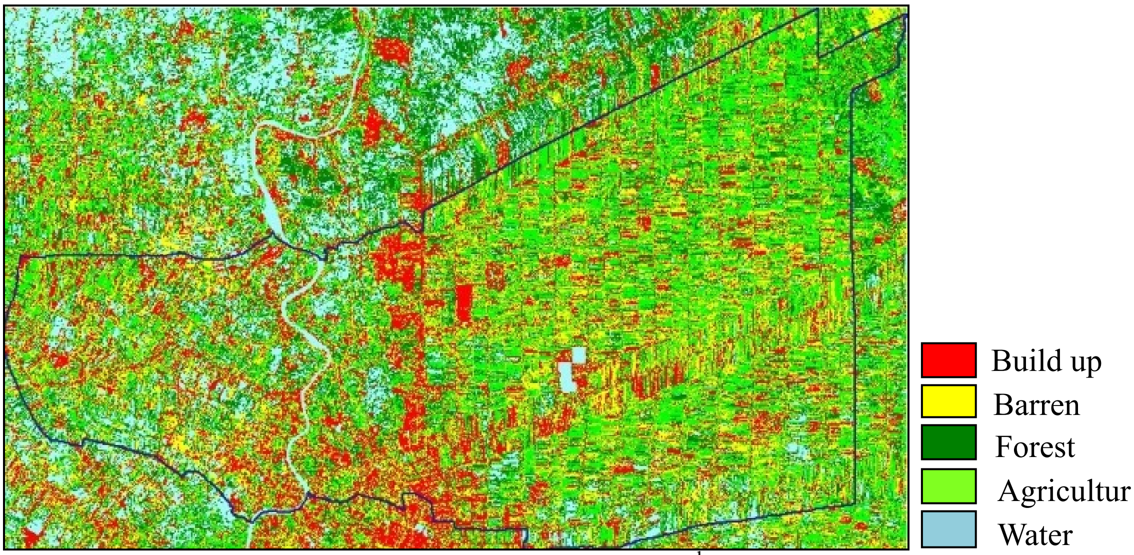
Figure 3. the flowchart of research methodology on this study

4. RESULTS OF ANALYSIS

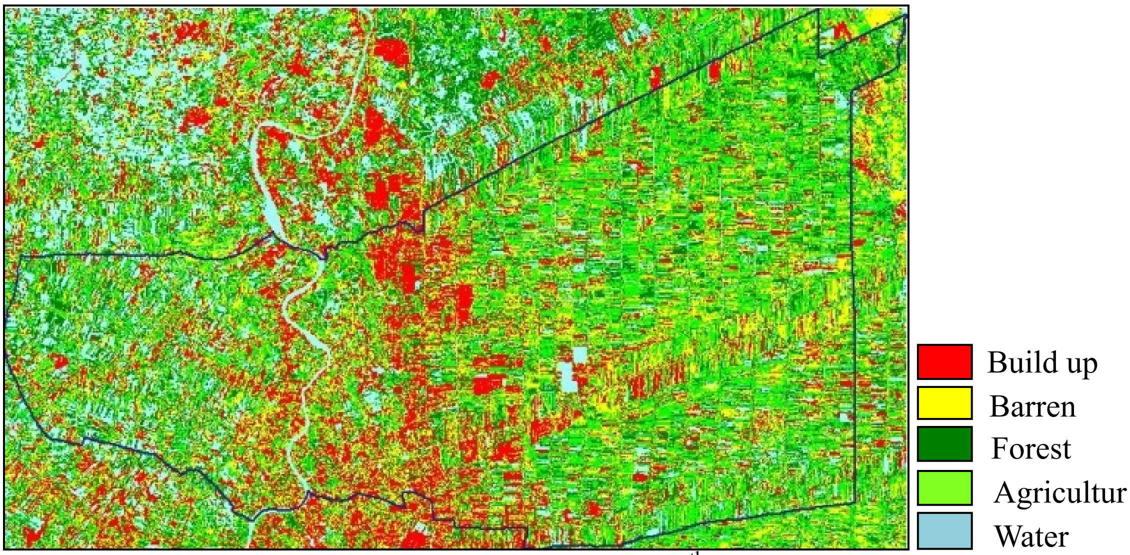
4.1 Land use pattern

The different pattern of build up area during the period between 2000 and 2004 can be determined in this study base on the applications of Land cover analysis. The result of analysis revealed that the border between the central urban area and the surrounding town is crystallizing shown the pattern of development, with one core center and sprawl towns. Beside, the pattern of changes for an emerging of barren and forest area is found to be lower fraction. Only a small proportion of the barren and forest area is shifted due to the rapid development, whereas the build-up area and agriculture area has been increasingly.

Figure 4 displays the different patterns of changes in an amount of area between 2000 and 2004. The central urban area is shown in rapid development with buildup area and it is adjacent to the site. It has been changed from barren and forest to agricultural which its distribution of land use and cover type between 2000 and 2004 can be displayed in Table1.



a. November 2nd, 2000



b. December 15th, 2004

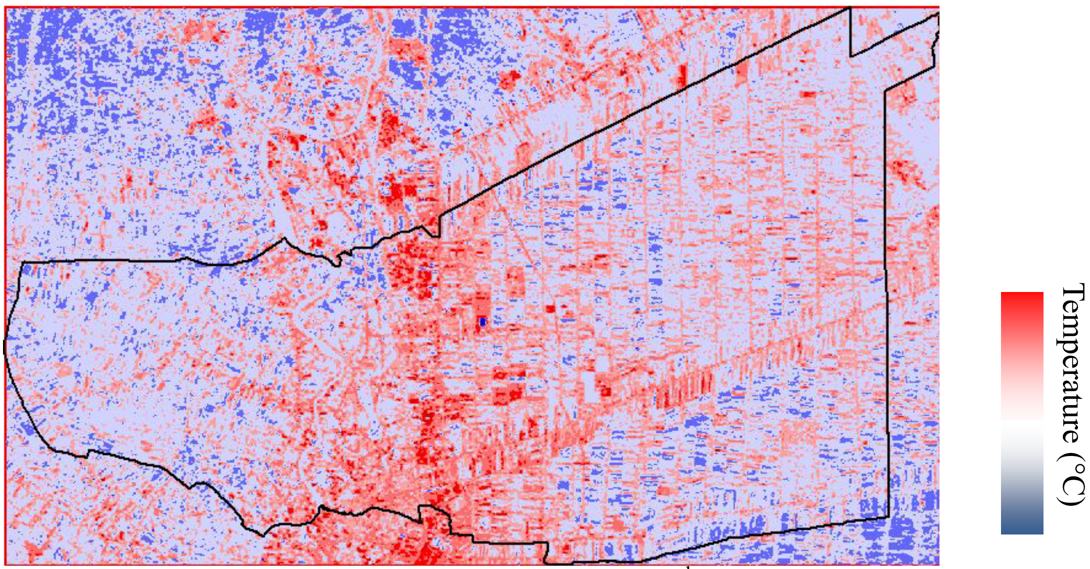
Figure 4. Characteristic of Land cover type study area (Pathumtani, Thailand)

Table 1. Land cover in 2000 and 2004

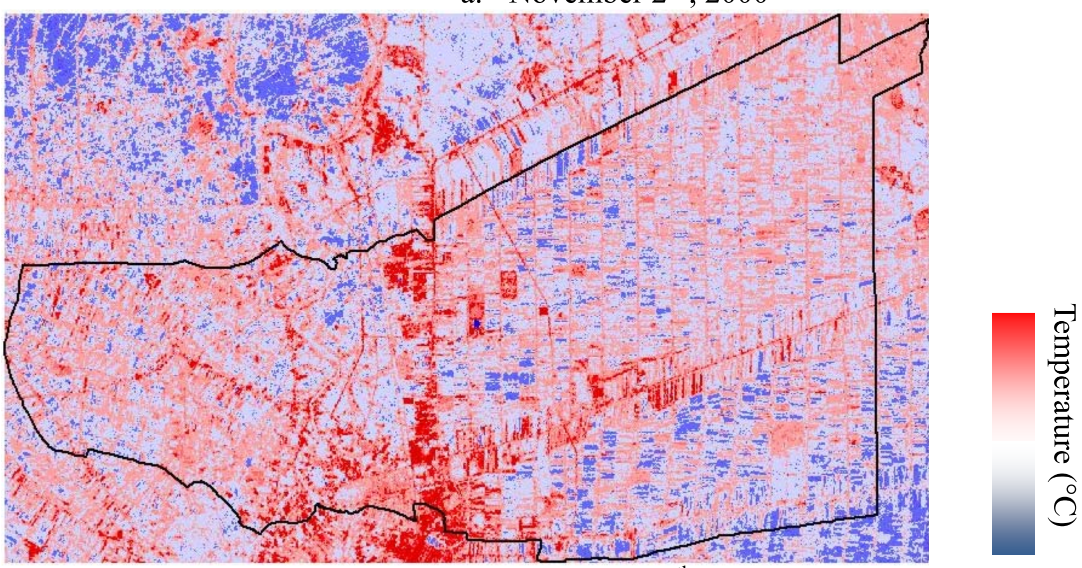
Land cover classes	Area, 2000 (km^2)	Ares, 2004 (km^2)
Build up area	483.53	491.13
Barren	581.73	551.22
Agriculture area	684.59	698.59
Forest area	527.05	508.33
Water	392.39	418.44

4.2 Relationship between LST and NDVI

The summarization of LST characteristic can be illustrated into two years as shown in Table 1. The 2000 image land surface temperatures ranges from 18.50 °C to 30.73 °C, with an average of 21.28 °C. The 2004 image land surface temperature ranges from 24.43 °C to 35.56 °C, with an average 27 °C. The standard deviation on LST2000 was lower than that of LST 2004. Figure 5 shows the increasing in the temperature of the study period in 2000. It was found that the areas with higher surface radiant temperature were mainly located in central urban area and major towns with the traffic on road network. Compared to the LST map in 2000, the extent of LST map in 2004 has shown the increasing trend significantly. With the urban growth, the extent of urban heat island dramatically expanded from the inner cycle highway to outer one, linking the sub urban areas.



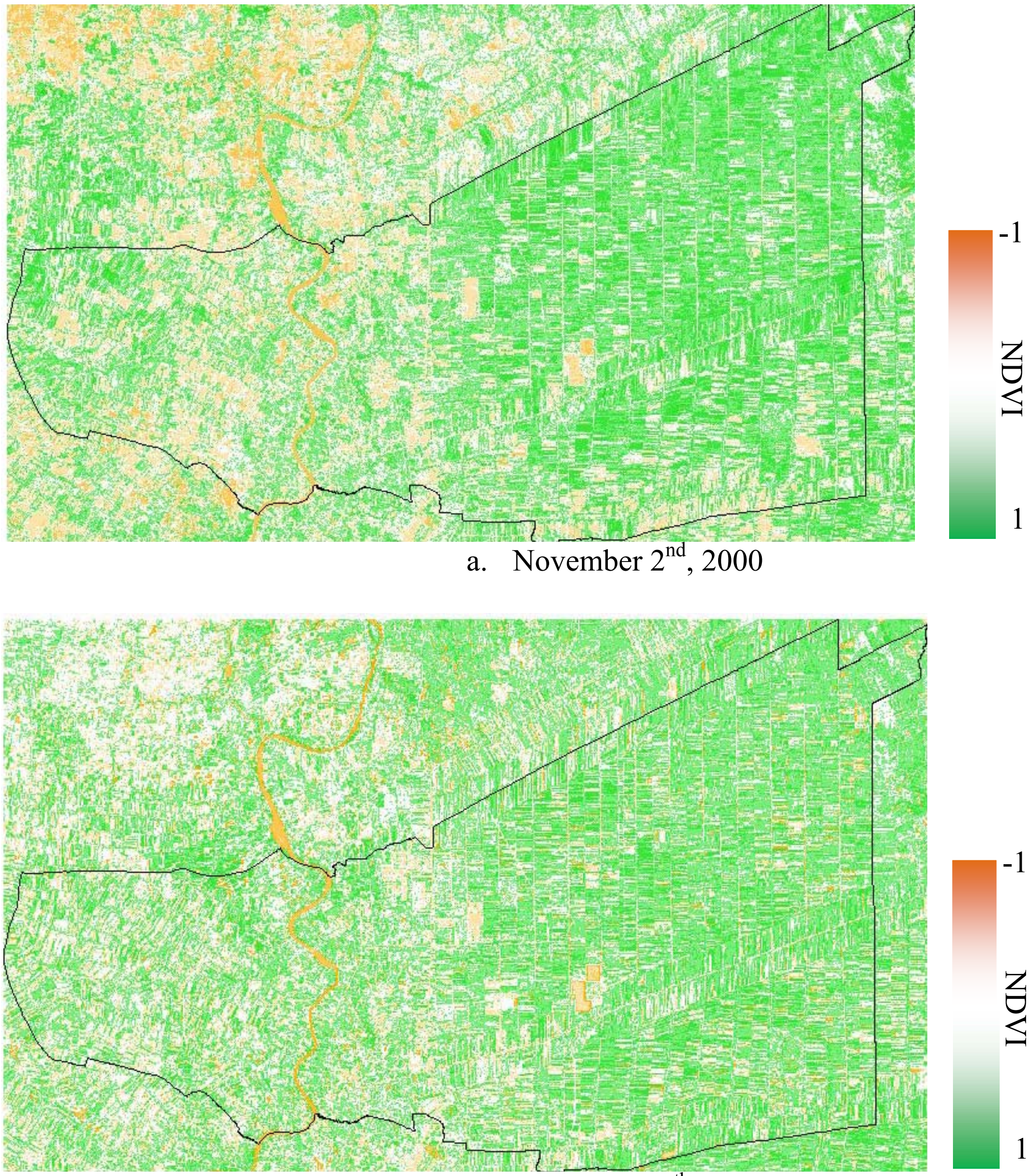
a. November 2nd, 2000



b. December 15th, 2004

Figure 5. Characteristic of Land surface temperature of study area (Pathumtani, Thailand)

Distribution of surface temperature on the land covers indicating build up area demonstrate the highest, follow by temperature, barren, agriculture forest area and water, respectively as depicted in Figure 6. It was indicated that the tendency of temperature was increasing from year 2000 to 2004. The relationship between LST and NDVI demonstrate the nonlinear and strong relationship which was affect by time (years) as depicted in Figure 7. This study also confirmed the usefulness of the methodology that the surface radiant temperature response can be used to determine by both surface soil and vegetation cover. This is due to land surface temperature measurement can be typically represented the radiometric temperatures of vegetation and non-vegetation surface.



a. November 2nd, 2000

b. December 15th, 2004

Figure 6. Spatial distribution of Normalized difference vegetation index (NDVI)

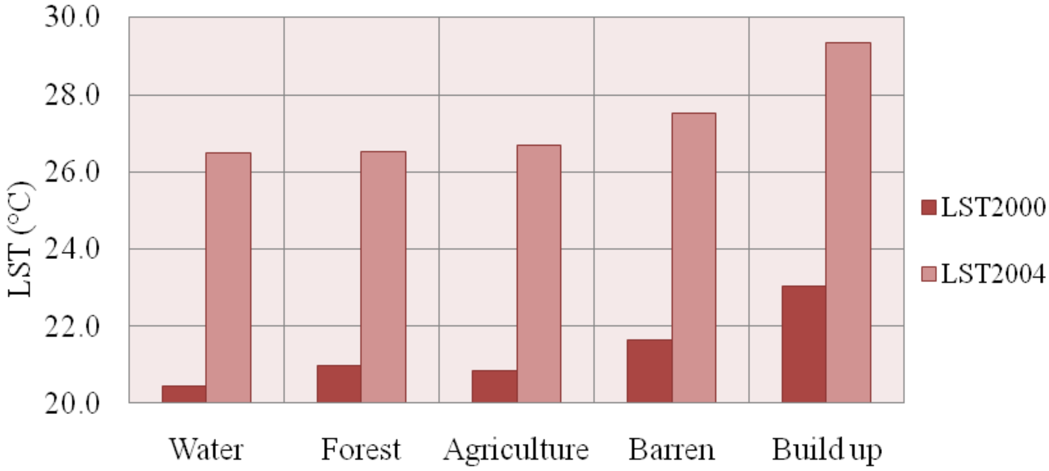
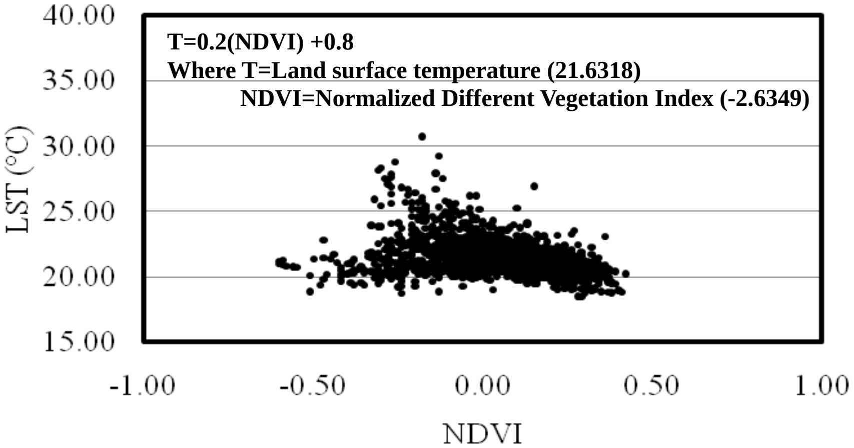
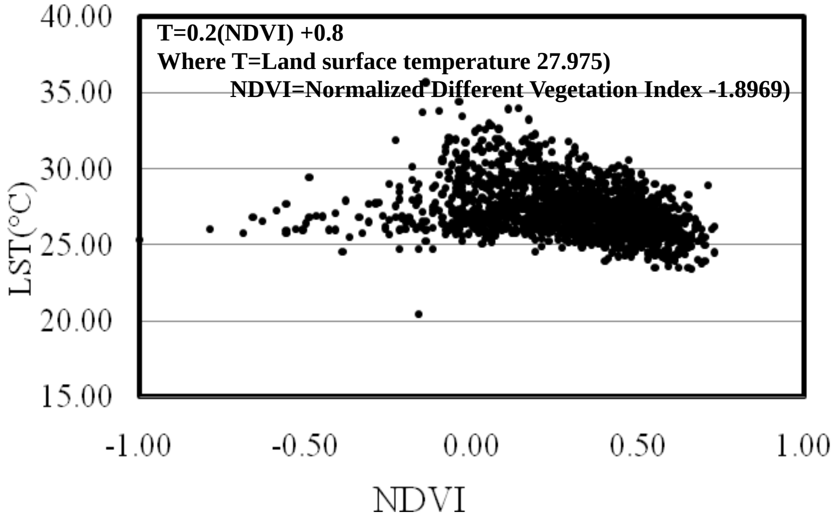


Figure 7. Comparison of Temperature distribute on different land cover type between year 2000 and 2004

For better understanding of the distribution of temperature, a scatter plot can be used and the result of comparison between year 2000 and 2004 is shown in Figure 8. The result of analysis also displayed the reverse relationship between surface temperature and the NDVI. Its' association shows the higher compacted pattern than in 2004. This result can be observed in normalized with different vegetation index. It can be seen that the surface temperature in the later year represented the higher trend of temperature rising. In addition, it can be obviously seen that the increasing in amount of distribution of vegetation also influence on the higher reduction of temperature in urban area. (as depicted in Figure9)



a. Year 2000



b. Year 2004

Figure 8. Relationship between land surface temperature and Normalized different vegetation index

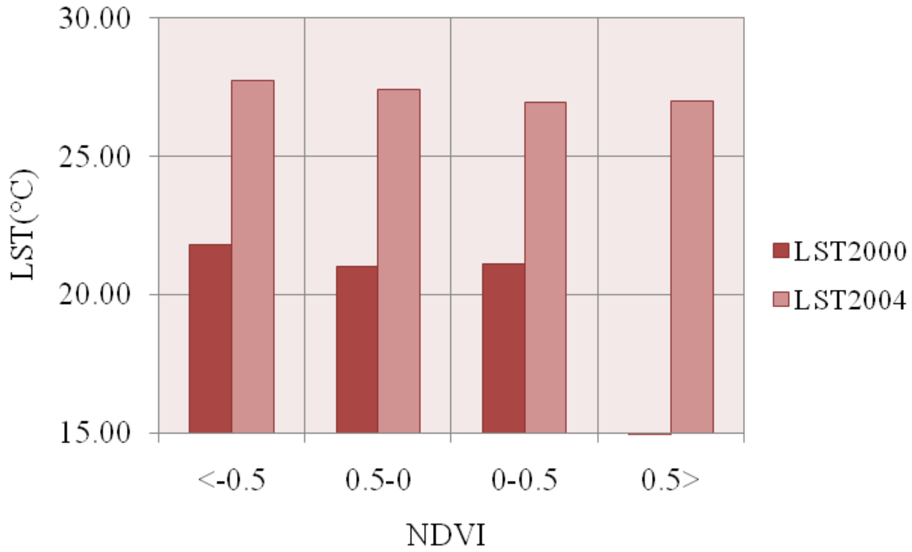
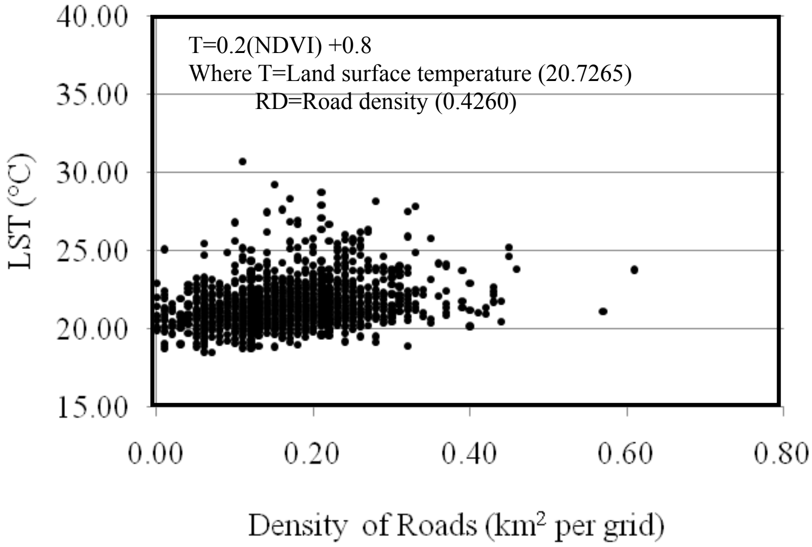


Figure 9. Comparison of Land surface temperatures on Normalized Different Vegetation Index, year 2000 and 2004

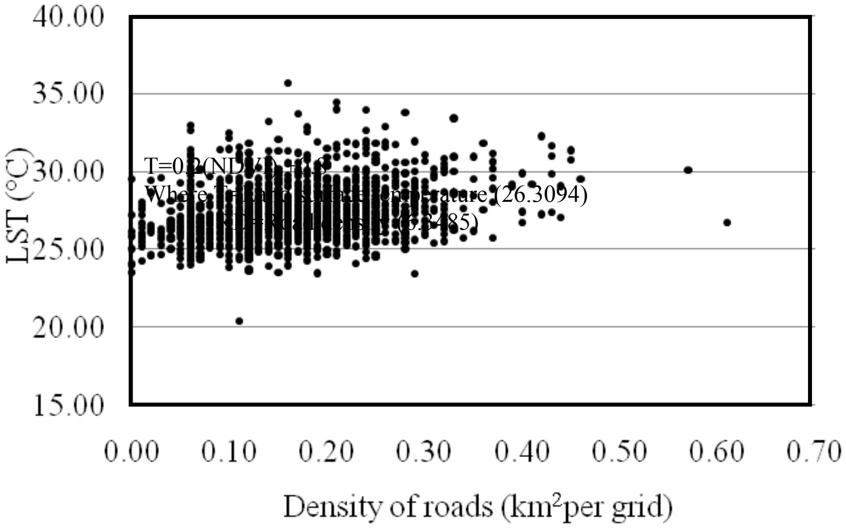
4.3 Density of road and land surface temperature

The distribution of road network in the study area presented the characteristic of urban development that was consistent with the urban morphology by follow the natural alignment of river or canal. Its uniqueness of this development pattern is to allow the historical commuters travel by boat. With the analysis base on the geographical tool, the results demonstrated that the density of the roads was directly related to the increasing of surface temperature. This trend verified the same relationship between NDVI and surface temperature. The density of road was estimated on the average area of grid size of 1 km^2 with the number of land use 1,557 blocks and the classification pattern of 7 densities.

The relationship between LST and density of roads was also demonstrated base on the value of surface radiant temperature which response by both surface soil and density of roads. The surface temperature measurements were typically represented through the radiant temperatures of roads surface. It also can be viewed in term of a scatter-plot of year 2000 which represented the highly compact pattern with lower temperature than in 2004.



a. Year 2000



b. Year 2004

Figure 10. Scatter plot of relationship between density of roads and surface temperature

The distribution of land surface temperature with density of road, compared between 2000 and 2004 is shown in Figure 10. The result showed that the temperature distribution in the study area tends to be increasing when there was more road development. Additionally, the density of road in Figure 11 also indicated the same tendency which evidently confirmed the more road development resulted to the temperature rising in over the region.

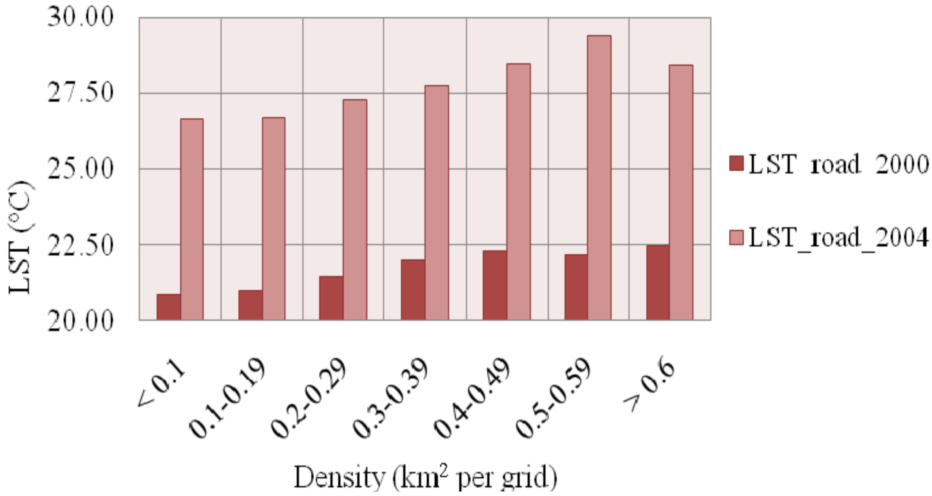


Figure 11. Distribution of land surface temperature on density of road

5. CONCLUSION

In this study, the density of roads at the 1 km^2 has direct relationship with the land surface temperature based on the application of Landsat TM/ETM+ and the geographic information system (GIS). This method could bring the fruitful information on the capability of the predicting model with consistent of temperature rising on the relationship with urban development in term of road network expansion with land cover change. The result indicated that the density of the roads can be represented as a significant indicator of urban heat island. Besides land cover types changes is also a key factor for indication of urban heat. Base on the methodology of this study, it is verified that the relationship between LST and NDVI can be used to support to overtime increasing warmth level. Consequently the NDVI can be also applied to indicate the phenomenon of urban heat island. The finding result of significant factors influence on surface temperature increasing such as vegetation and non-vegetation surface and the variation in surface temperature provides an alternative approach to consider the land cover type than simply take into account of normalized different vegetation index. Additionally, road network is also non-vegetation surface index that can be also applied to estimate temperature increase. Base on the relationship among different land cover type index, e.g., the density of roads, vegetation distribution, the increasing affect of surface temperature can be undoubtedly understood. This information provides constructive information for urban and transportation planner to work in a cooperative way in order to mitigate the effect of urban heat. The implication can be drawn for an integrating of land use design and road network design to reduce the higher temperature while urbanization. Not only it provides means as a tool for sustainable development in this region, it also can be applied for any other cities.

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IMPROVE AND REVIEW TRAFFIC SAFETY OF STUDENTS OF UNIVERSITY ON MAIN ROAD: A CASE STUDY OF NAKHON SI THAMMARAT RAJABHAT UNIVERSITY

Piti CHANTRUTHAI
Lecturer, Ph.D. student
Faculty of Industrial Technology
Nakhon Si Thammarat Rajabhat University
Nakhon Si Thammarat
Thailand 80280
Fax: +66-75-377439
E-mail: pchantruthai@gmail.com

Saravut JARITNGAM
Asst. Professor, Ph.D. student
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: +66-74-212891
E-mail: jaritngam@gmail.com

Opas SOMCHAINUEK
Ph.D. student
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: +66-74-212891
E-mail: drsomchainuek@yahoo.com

Sulkiflee MAMA
Ph.D. student
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Phone/Fax +66 897380315
E-mail: keeyotha@yahoo.com

Suparp BOONRUANG
Assistance Professor
Faculty of Industrial Technology
Nakhon Si Thammarat Rajabhat University
Muang, Nakhon Si Thammarat
Thailand
Fax: +66-75-377439

Pichai TANEERANANON
Professor
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: +66-74-212891
E-mail: pichai.t@psu.ac.th

Abstract: Road traffic accidents are the major cause of fatalities, disabilities and other serious social problems in Thailand. In 2005, 12,871 people died as a result of road accidents and 52,538 were injured (Traffic accidents statistics in 2005, Royal Thai Police). These accidents are the major cause of death of people in the 15-45 age group. Records of the Ministry of Public Health showed that the 3 age groups which suffered the most number of fatalities in 2001 were: the 20-24 age group (14.16%), the 15-19 age group (12.63%) and the 25-29 age group (12.28%). In addition, more than 80% of fatalities involved people riding motorcycles. This paper improves and reviews a previous paper of traffic safety of students of university located on main roads. Rajabhat Nakhon Si Thammarat University (NSTRU) was selected a case study again. The NSTRU has over 10,000 students, and is located on the 4 lane highway number 4016, Ban Payang, Thahew district, Nakhon Si Thammarat (NST) province. In 2005-2006, there occurred 13 road crashes around the NSTRU with the resulting 10 casualties which were mostly students and people living in the area. In 2007-2008, Number of road crashes in front of the NSTRU: 6 cases in 2007 and 9 cases in 2008. There were in total 20 injuries in road crashes, 9 in 2007 and 11 in 2008. There was 1 fatality in 2007. Motorcycles were involved in most of these crashes. Plan to implement road safety countermeasures to reduce deaths and an injury around the University is described.

Key Words: Road Safety, School Road Safety

1. INTRODUCTON

Road traffic accidents are a major cause of fatalities worldwide with more than 1.2 million people killed and over 50 millions injured annually (WHO, 2004). More than half of the fatalities are those in the 15-44 age groups who are either studying or working. Among the 15-19 years old, the leading cause of death is traffic accidents, while for those in the 10-14 years and 20-24 years age group, it is the second leading cause of death (see Table 1).

In 2004, in South East Asia Region, 80,400 road traffic deaths were under 25 years of age, the majority are aged between 15 and 24 years. These may be a reflection of the high usage of motorcycle among this group in this region. Due to their relatively low cost, motorcycles tend to be the first affordable vehicles that can be purchased and used by young drivers (Toroyan T, Peden M. 2007).

2. OBJECTIVES

The objectives of previous study were to investigate the traffic safety of road users on main road around the university. They are summarized as follows:

• To determine the characteristics of accidents on the main road in front of the university, their distribution and frequency

• To investigate the road users behavior in front of the university

• To propose a plan to implement appropriate road safety countermeasures to the university, community and other stakeholders

And the objectives of this study are to evaluate the improvement of any road safety measures and review proposes a plan to implement appropriate road safety countermeasures to the university, community and other stakeholders.

3. METHODOLOGY

The processes conducted in this study are as follows:

• Using Royal Thai Police & Department of highways accident data in 2005 - 2008, statistical analyses were carried out to better understand the relationships of accidents and road users.

• Survey for existing conditions in front of the university: speed, volume of vehicles in peak hours, road physicals and roadside problems

• Compare road accidents severity index between area study with NST province.

• Proposal of remedial measures according to the survey results.

• Evaluate the effectiveness of measures before and after improvement.

Table 1. Ranking of causes of death among young people under 25 around the World, 2002

Rank	Cause of death in each age range						
	< 1	1 to 4	5 to 9	10 to 14	15 to 19	20 to 24	All < 25
1	Perinatal conditions	Lower respiratory inflections	Lower respiratory inflections	Lower respiratory inflections	**Road traffic injuries**	HIV/AIDS	Perinatal conditions
2	Diarrhoeal diseases	Childhood cluster diseases	HIV/AIDS	**Road traffic injuries**	Self-inflicted injuries	**Road traffic injuries**	Lower respiratory inflections
3	Lower respiratory inflections	Diarrhoeal diseases	**Road traffic injuries**	Drowning	Maternal conditions	Self-inflicted injuries	Diarrhoeal diseases

Source: WHO global burden of disease (GBD) mortality database for 2002 (version 5)

Thailand is a member of the Association of Southeast Asian Nations (ASEAN). In 2005, Statistics from Royal Thai Police showed 12,871 people died as a result of road accidents and 52,538 were injured. These accidents are the major cause of death of people in the 15-45 age groups. Records of the Ministry of Public Health showed that the 3 age groups which suffered the most number of fatalities in 2001 were: the 20-24 (14.16%), the 15-19 (12.63%) and the 25-29 age group (12.28%) respectively (see Table 2). Motorcycle was the vehicle involved in road accidents resulted in more than 70% of all road traffic deaths (Toroyan T. et al. 2006).

Table 2. Number of Fatalities classified by age group in 2001

Age group (years)	Number of Fatalities	Percent of Fatalities (%)
< 1-4	208	1.63
5-9	226	1.78
10-14	339	2.66
15-19	**1,607**	**12.63**
20-24	**1,801**	**14.16**
25-29	**1,562**	**12.28**
30-34	1,417	11.14
35-39	1,295	10.18
40-44	1,054	8.28
45-49	898	7.06
50-54	637	5.01
55-59	460	3.62
60-64	444	3.49
65-69	335	2.63
70-74	199	1.56
> 75	231	1.82
Unknown	9	0.07
Total	**12,722**	**100.00**

Source: Ministry of Public Health, 2003.

4. SCOPE OF THE STUDY

Nakhon Si Thammarat Rajabhat University (NSTRU) is the target university in this study. NSTRU is located on the 4 lane highway no. 4016, Ban Payang, Thahew district, Nakhon Si Thammarat (NST) province as shown in Figure 1.

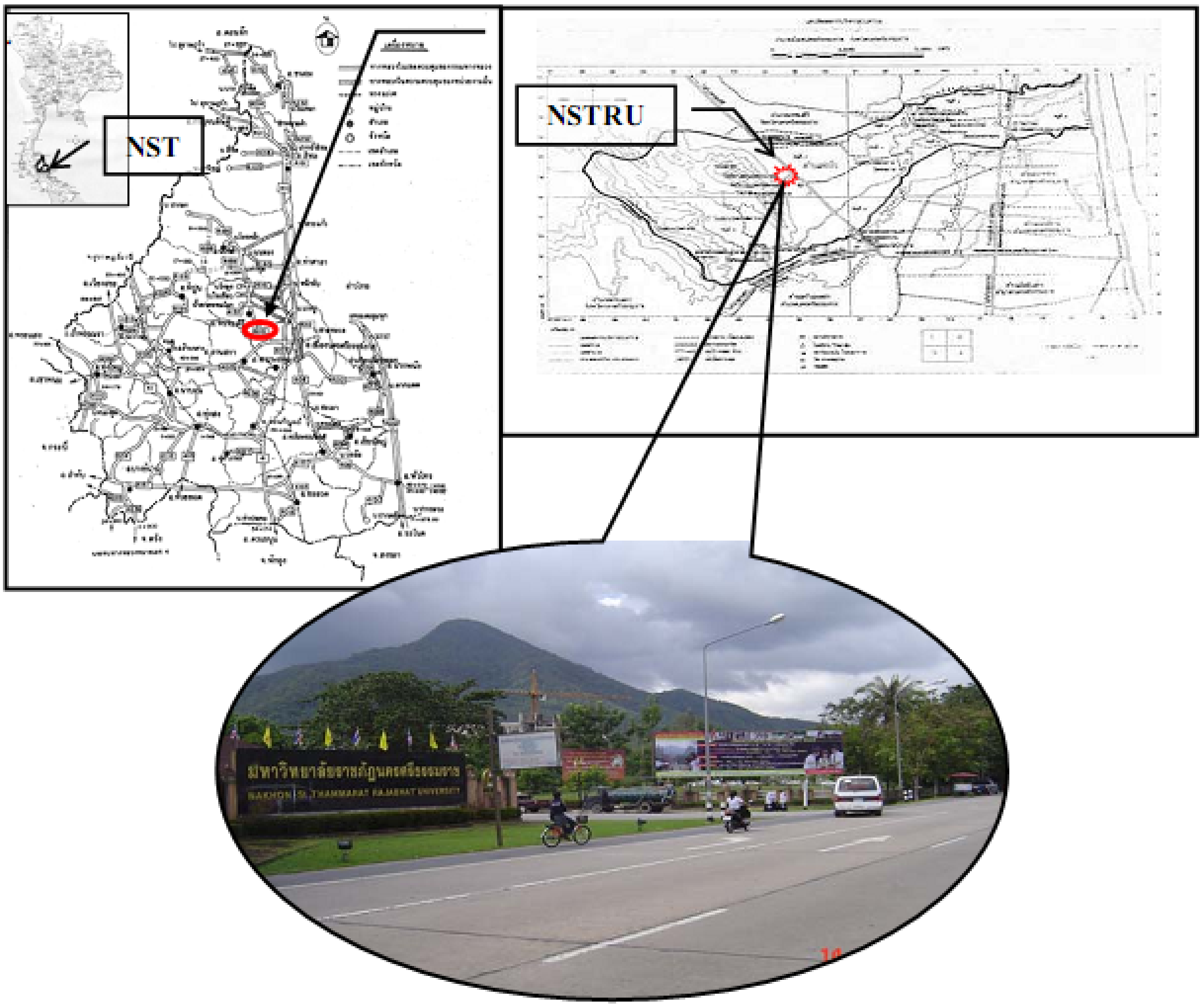

Figure1. Location of NSTRU on the 4 lane Highway number 4016 in Ban Payang, Thahew district, Nakhon Si Thammarat (NST) province.

5. OVERVIEW OF TRAFFIC SAFETY SITUATION OF EDUCATION ESTABLISHMENTS LOCATED ON MAIN ROADS

Thailand Global Road Safety Partnership (TGRSP) started the 3 phase of pilot project “Safer school zones” in 2004. The first pilot phase was to install new pedestrian crossing signs at five school sites in Srisaket municipality. The second phase was implemented in Khoen Kaen municipality, the educational programmes and improvement of school zone safety around the selected schools. The third phase was the study of a pilot project “safer routes to school” in two different towns with the participation from municipalities, local police and provincial offices of the land transport department. The evaluation was completed in 2005; the result showed that the children who completed the road safety education course did not change their behavior when using the road (using and not using the crosswalk in the vicinity of school, pedestrian walkway usage and safe crossing gap). Likewise, the behavior of parents did not seem to have changed (double parking or dropping off or picking up their children at unsafe locations). School zones in regional cities of Thailand have been neglected in terms of safety and without good management, can and have created hazardous conditions for road users and pedestrians (S. Suttayamully 2005).

Sirikul Kullab and et al. studied of process of changing the traffic injury prevention behavior of student and Kaennakorn Witayalai school were selected to the case study in 2001. The behavior modification was started with set up the injury prevention club in school and the members consist of 2 teachers and 18 students. The objectives of this club were to prevent and solve road accidents in area study. The result of study showed the rate of proper behavior of student walking along the roadside, riding behavior abiding by traffic regulation and helmet use among the motorcycle passengers increased statistic significantly to 19.5%, 61.1% and 35.8% respectively. The rate of helmet use increased to 5.3% but it did not increased statistic significantly and the injury rate of student decreased statistic significantly to 0.66% comparing with the records in 1999.

Traffic conditions near school/university can seriously affect the safety of students. The traffic environment around schools is one of the most complexes as encountered by motorists and pedestrian. However, the safety problems can be addressed by solutions based on educations and encouragement, enforcement and engineering.

5.1 Traffic Safety of University Located on Main Road in Thailand

The previous paper study traffic safety of university located on main road in 2005 to 2006 and this paper study in 2007 to 2008. Nakhon Si Thammarat Rajabhat University (NSTRU) is the target University in the study of traffic safety of students. NSTRU is located on the 4 lane highway number 4016, Moo 4 Ban Payang, Thahew district, Nakhon Si Thammarat (NST) province. The NSTRU has over 10,000 students who are studying full-time for bachelor degrees and those doing bachelor degrees, master degrees and PhDs on a part-time basis. NSTRU was selected for the study due to the high frequency of traffic accidents in front of the University. There were total 13 road crashes around the NSTRU which 3 cases occurred around the NSTRU and 10 cases occurred on highway number 4016 in front of the NSTRU. Traffic safety problems in 2005 -2006 can be indentified and summarized as follows:

- Number of road crashes: 5 cases in 2005 and 8 cases in 2006.
- During the 2 year periods, there were in total 15 injuries in road crashes, 4 in 2005 and11 in 2006. There was no fatality in these crashes.
- Seven accidents occurred during the day time and 6 occurred at night. Nine of these cases occurred on weekdays and 4 cases on weekends.
- Motorcycles and pickup trucks are vehicles mostly involved with half of all vehicles were motorcycles and around 46% pick-ups.
- Around 90% of motorcycle riders were not wearing safety helmets and 65% were riding against through traffic.
- Young people under the age of 25 years account for 80% of all injuries.
- Moreover, 50% of traffic accidents occurred in u- turn area in front of the main entrance of NSTRU.

In 2007-2008, Traffic safety problems can be indentified and summarized as follows:

- Numbers of road crashes in NST were total 2007 cases, 307 injuries and 230 fatalities in 2007 and in 2008 there were total 2136 cases, 187 injuries and 207 fatalities.
- Number of road crashes in Moo 4 Ban Payang were total 24 cases, 12 injuries and 1 fatality in 2007 and in 2008 there were total 14 cases, 18

injuries and no fatality

• Number of road crashes in front of the NSTRU: 6 cases in 2007 and 9 cases in 2008. There were in total 20 injuries in road crashes, 9 in 2007 and 11 in 2008. There was 1 fatality in 2007.

• Severity index of injury/100,000 population and fatality/100,000 population in area study is higher than severity index in NST. (except fatality rate in 2008) (Shown in table 3).

• 8 accidents occurred at night.

• Motorcycles volume are the most of all vehicles volume around 71%, next frequently volume are passenger cars (14%) and pickup trucks (11%) respectively. (shown in figure 2)

• Motorcycles are vehicles mostly involved in road crashes with 90% of all vehicles.

• Around 86% of motorcycle riders were not wearing safety helmets and 52% were riding against through traffic.

• Young people under the age of 25 years account for 65% of all injuries.

• Moreover, 90% of traffic accidents occurred in front of the main entrance (Gate no.1) of NSTRU.

Table 3. Compare Severity Index between NST with Moo 4 Ban Payang in 2007 and 2008

Year	Population		Severity index in NST			Severity index in Moo 4		
	NST	Moo 4	Accident	Injury	Fatality	Accident	Injury	Fatality
2007	1,513,163	2590	132.6	20.29	15.20	926.6	263.3	38.6
2008	1,516,504	2590	140.8	12.33	13.65	540.5	695.0	0

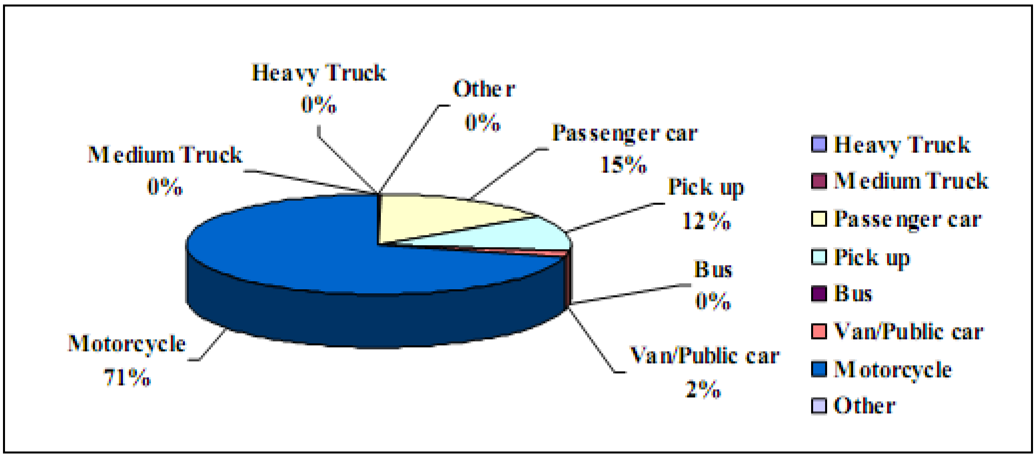

Figure 2. Volume of vehicles in area study

5.2 Finding Solutions in previous research

Traffic safety problems on highway number 4016 in front of the NSTRU can be addressed by measures based on the 3'E principles: education and encouragement, enforcement and engineering. The study results reveal several facts about safety conditions and suggest the appropriate countermeasures.

The guideline of countermeasures intends to reduce injuries to motorcyclists and pedestrians around the NSTRU. Investigation of the physical layout of the highway and traffic environment around the NSTRU can assist in determining appropriate measures to the traffic safety problems. The following provides summary of the results of the investigation and road safety audit.

• The highway number 4016 passing in front of the NSTRU is a 4- lane concrete pavement with raised median and trench with steep slope along the fence in front of NSTRU. There are 3 driveways that connect with the highway. Gate number 1 is the main entrance for vehicles and pedestrians, gate number 2 is for pedestrian use only and a pedestrian bridge located in this area, and gate number 3 is for pedestrian use and occasionally for vehicle use. (shown in figure. 3)

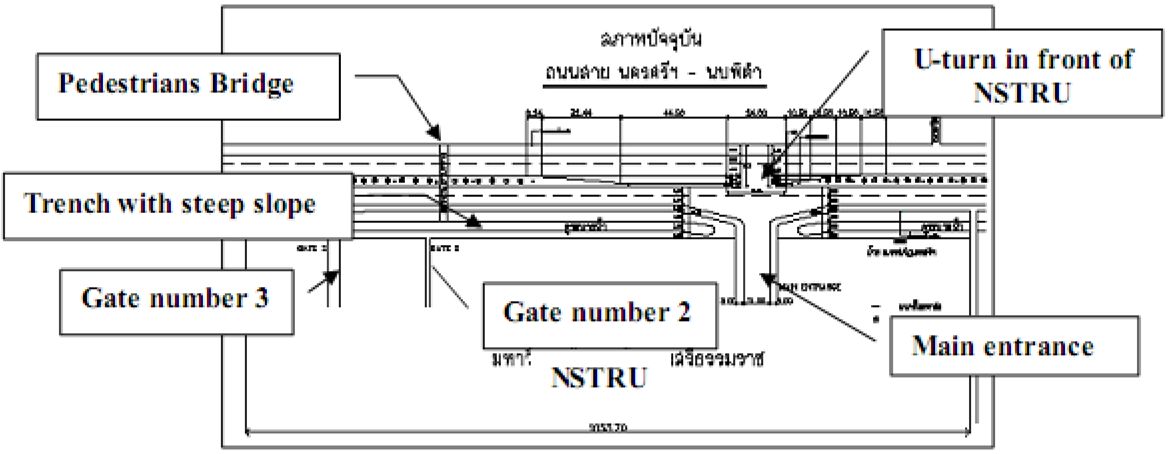

Figure 3. Section of Highway number 4016 in front of NSTRU

• U-turn area in front of the main entrance of NSTRU is often the site of traffic accidents because of the traffic congestion in the morning as well as the evening peak hours, motorcycles riding against through traffic stream and using excessive approach speed to the intersection around main entrance. Figure 4 shows the traffic congestion in the morning peak times at the u-turn in front of the NSTRU. As many motorcycles were waiting to turn to NSTRU, this u-turn has become the site of frequently occurred traffic accidents. Figure 5 shows motorcycle riders most of whom are students of NSTRU, who tend to ride against through traffic stream. This is because the next u-turn is quite a distance from the dormitories to NSTRU or food shops around gate number 3 of NSTRU

.

Figure 4. Traffic congestion in the morning peak hour at the U-turn of highway in front of the NSTRU

• Pedestrians are unsafe as they are forced to walk on the road pavement as the highway shoulder is being occupied by the temporary food shops around gate number 3, the lack of regulation on parking for public transit, motorcycle, passenger car, also contributes to the unsafe situation. (shown in figure 6)

• According to the survey, 85th percentile of the drivers selected to drive at speed 114 km/hr which was significantly above the highway speed limit of 90 km/hr (shown in figure 7). Almost all drivers disobeyed the posted speed limits on highway around community due to lack of traffic regulations, inadequate police enforcement of traffic laws on speeding, and non-presence of physical deterrents such as rumble strips, and road narrowing.

Figure 5. Motorcycle riders tend to ride against through traffic stream: the upper pix shows the main entrance area and the lower the area around gate number 3.

Figure 6. Pedestrians unsafe due to lack of regulation of temporary food shops and parking

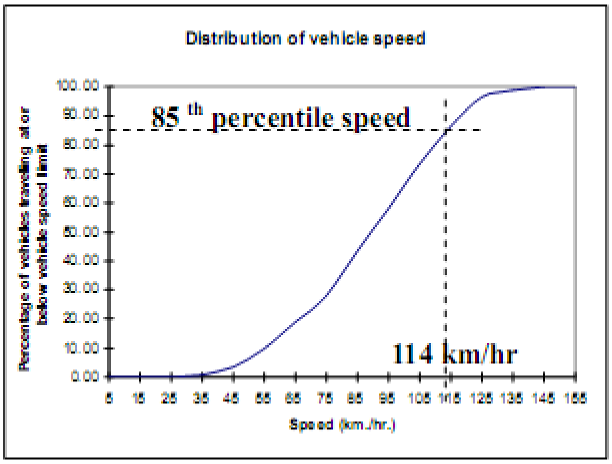

Figure 7. Distribution of vehicle approach speed in front of NSTRU

5.2.1 Guideline for Traffic safety countermeasures

Implementation of traffic safety countermeasures are the responsibility of NSTRU, local government and people in this community. Traffic safety problems can be addressed by 3 E principle measures. A plan is proposed for implementation in the form of countermeasures matrix. The countermeasures have been classified in the matrix as education and encouragement, enforcement and engineering. The lists of proposed countermeasures are shown in Table4.

Table 4. The Proposed Countermeasures Matrix

Road User/ Environment	ISSUES IDENTIFIED (shown in 5.2)	Countermeasures		
		Education/ Encouragement	Enforcement	Engineering
Traffic Environment (included road)	• High crash rate at u-turn in front of NSTRU. • Excessive approach speed in front of NSTRU.	• Education through the university newsletter.	• Traffic police operate at main entrance in the morning and the evening peak hours. • Speed check zone (speed camera, etc.) • Strict police intensive enforcement	• Install traffic island and channelizatio n adjustment. (see in figures 8&9) • Install rumble strips on both sides of highway. (see in figure 8)
Motorcycles	• Illegal riding against traffic. • Not wearing safety helmet.	• Education through the university newsletter.	• Enforcing the law with motorcycle riders for illegal movement. • Increase law enforcement.	• Decrease shoulder by installation of the footpath. (see in figure 8)

Table 4. continued

Road User/ Environment	ISSUES IDENTIFIED	Countermeasures		
		Education/ Encouragement	Enforcement	Engineering
Pedestrians	• risk due to lack of regulation of shops and parking • Pedestrians ignore to use pedestrian bridge.	• Education through the university newsletter. • Education through the local government & university newsletter • Encouragement of safe crossing behavior by providing cover way at gate number 2 in NSTRU connecting to the pedestrian bridge.	• Law enforcement by local government and highway authorities.	• Installation the footpath on both sides along the highway in front of NSTRU and on street bus stop can be indented into adjacent footpath (see in figure 9 &10)

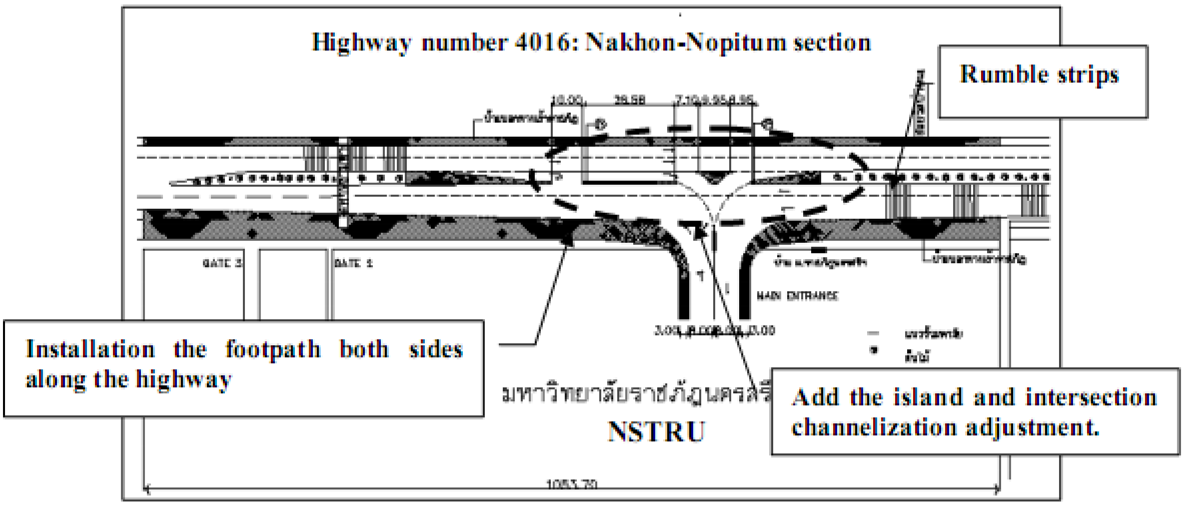

Figure 8. Improvement of u-turn and footpath both sides along the Highway no. 4016

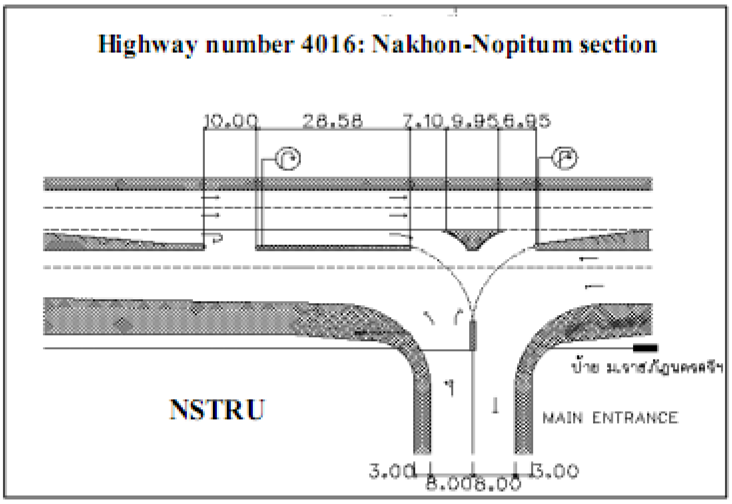

Figure 9. Detail of u-turn adjustment around the Main entrance.

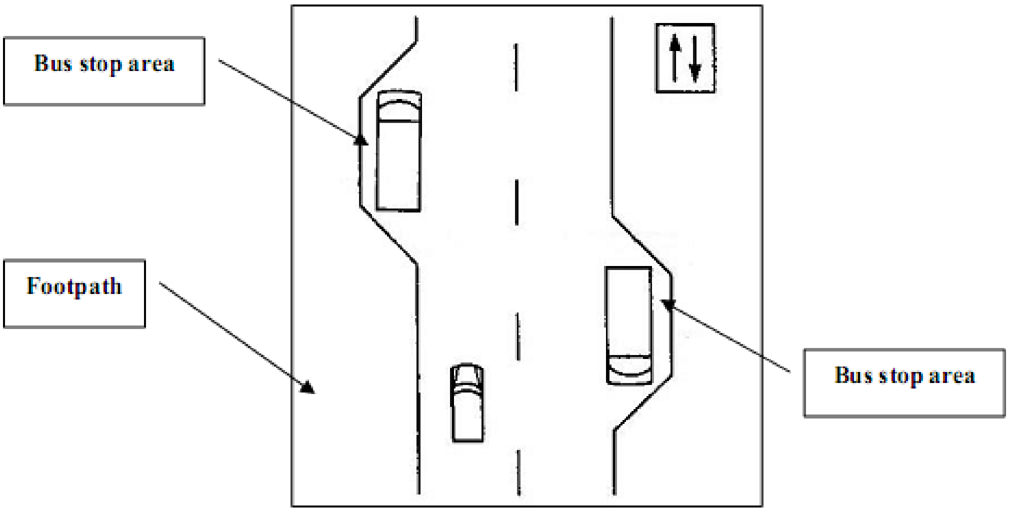

Figure 10. Detail of on street bus stop indented into adjacent footpath.

Figures 8&9 show u turn and intersection channelization adjustment by installing a traffic island and separated u – turn channel and right turning channel into the NSTRU as the number of turning vehicles into NUTRU is more than the number of u-turn vehicles. Installation of footpath is a safe pedestrians' countermeasure as it separates conflict of pedestrians and vehicles. Figure 10 shows on street bus stop area indented into adjacent footpath designated as a safety point at which buses stop to pick up and set down passengers. Bus stop should be installed as far from the intersection as possible.

5.2.2 Fact finding for traffic safety countermeasures

Guideline for Traffic safety countermeasures were presented and accepted in meeting between NSTRU and 14th Bureaus of Highway (NST) in 2007. After meeting, there was not action from 14th Bureaus of Highway (NST) and there was road crash in front of the main gate of NSTRU in the same year and cause of motorcycle rider death in site. President of NSTRU realized to responsibility in solving traffic accidents in front of the NSTRU. One of the measures is adjust the direction in and out of vehicle by use gate no.1 for in direction and gate no.3 for out direction and start up on January 2008. NSTRU and Khao Mahachai subpolice station cooperated in wearing safety helmet campaign and driving/riding safety campaign for students and people around NSTRU. (Shown in figure 11)

Figure 11. Gate no.1 for vehicles drive in and Gate no.3 for vehicles drive out

After implementation during January to November in 2008, the data recorded the road user's behavior was used as a tool to evaluate traffic safety countermeasures. This paper study to 85th percentile approach speed in vehicles (not include motorcycle), wearing safety helmet and motorcycle riding against through traffic steam compare with the previous paper. The evaluation can be summarized as shown in table 5.

Table 5. Evaluation of road user's behavior around NSTRU

Road user's behavior	Before	After	Diff. (%)	Chi-square
				P-value
1. 85^{th} percentile approach speed (km./hr.)	114	93	4.74	< 0.05
2. Rate of not wearing safety helmet (%)	90	86	4.00	> 0.05
3. Rate of riding against through traffic (%)	65	52	13.00	> 0.05

From table 5, the 85^{th} percentile approach speed decreased statistic significantly after implementation to traffic safety countermeasures. On the other hand, rate of not wearing safety helmet and rate of riding against through traffic decreased but it did not decreased statistic significantly.

6. CONCLUSIONS

From the study, it is clear that motorcycles were heavily involved in injuries in traffic accidents. Motorcycle riders are at increased risk of a crash because of the complexity of the traffic situation created by fast moving vehicles, illegal movements and illegal parking. Most of the motorcycle riders and passengers are the students of NSTRU and most of them did not wear safety helmet. In fact, there are more injuries than those recorded by the police. Excessive speeds are one of the key factors contributing to these traffic accidents. The speed control measures are intended to reduce vehicles speed and risk of accidents in this community.

Traffic safety countermeasures are proposed based on police records and investigations carried out at the site. The proposed countermeasures matrix is not a exhaustive list of all measures possible. As number and types of accidents would vary from place to place, Each university community will have to identify site-specific problems, propose and implement measures developed jointly by all stakeholders in the community such as university, local government and people in community.

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DEVELOPMENT OF A METHOD FOR ASSESSING SAFETY ON THAI NATIONAL HIGHWAYS

Opas SOMCHAINUEK
Ph.D. student
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: +66-74-212891
E-mail: drsomchainuek@yahoo.com

Sulkiflee MAMA
Lecturer
Department of Engineering
Faculty of Engineering, Princess of Naradhiwas University, Thailand
Fax: +66-74-212891
E-mail: keeyotha@yahoo.com

Phayada PRAPONGSENA
Statistical Administration Officer
Bureau of Traffic Safety
Department of Highways
Ministry of Transport
Ratchatavi, Bangkok
10400 Thailand
Fax: +66-23-546713
E-mail:phayada_prapongsena@yahoo.com

Pichai TANEERANANON
Professor
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: Fax: +66-74-446514
E-mail: 2007tao@gmail.com

Piti CHANTRUTHAI
Faculty of Industrial Technology
Nakhon Si Thammarat Rajabhat University
Aumpoe Muang Tha Ngew District
Nakhon Si Thammarat Province 80280
Thailand
Phone & Fax: +6675377439
p_chantruthai@hotmail.com

Saravut JARITNGAM
Ph.D. student
Department of Civil Engineering
Prince of Songkla University
Hadyai, Songkla
Thailand
Fax: +66-74-212891
E-mail: jaritngam@gmail.com

Abstract: This paper describes the development of a system to address risk of potential accidents on Thailand national highways under the jurisdiction of DOH. The pilot study develops a system which uses two different protocols for showing the safety level of a highway. It models on the method used by the European Road Assessment Program (EuroRAP), this is so that the risk of having a crash and the level of safety of a highway section in terms of crash consequence can be compared to highway networks in other countries. An initial risk map which shows the risk a driver faces on a certain highway and is derived from the accident history of the highway was developed for highways 414, 407, 408 the three divided 4-lane highways in Songkhla. It shows 4 levels of risk of having a fatality and injury along the various lengths of the highway. As for the star rating map which rates the level of safety offered by a highway section when a crash occurs, the authors have developed an initial criterion to be used for preparing the map which is being prepared for the Songkhla highway network. The system under development uses technology suitable for continual operation, as it enables DOH to update the risk situation and improvement outcomes of the network.

Key Words: Assessment safety, road safety, risk mapping, stars rating

1. INTRODUCTON

Road accident is a major worldwide problem. Already 1.3 million people die annually on the world's roads and the number of seriously injured has been estimated as some 50 million. The growing burden of road crashes is comparable with malaria and tuberculosis and costs a staggering 1-3% of the world's GDP. [1]

Economic growth in Thailand has brought about an expanding network of roads and an increasing number of the driving public. The growing number of vehicles on the roads, in turn, has contributed to significant increases of road crashes annually. Road crashes have been a major cause of death and injury in Thailand. The trend of accident occurrences and number of fatalities between 1991 and 2008 are shown in Figure 1.

As shown in Figure 1, the number of road crashes can be seen to rise from 49,625 cases in 1991 to 102,610 in 1994; dropping to 67,800 in 1999 and surge to 88,689 in 2008, in line with the economic recovery. While the number of fatalities were on an increasing trend starting from 8,589 in year 1991 to peak at 16,727 (1.91 deaths per hour) in 1995. After peaking, the number of fatalities declined to 11,581 (1.34 deaths per hour) in 2008.

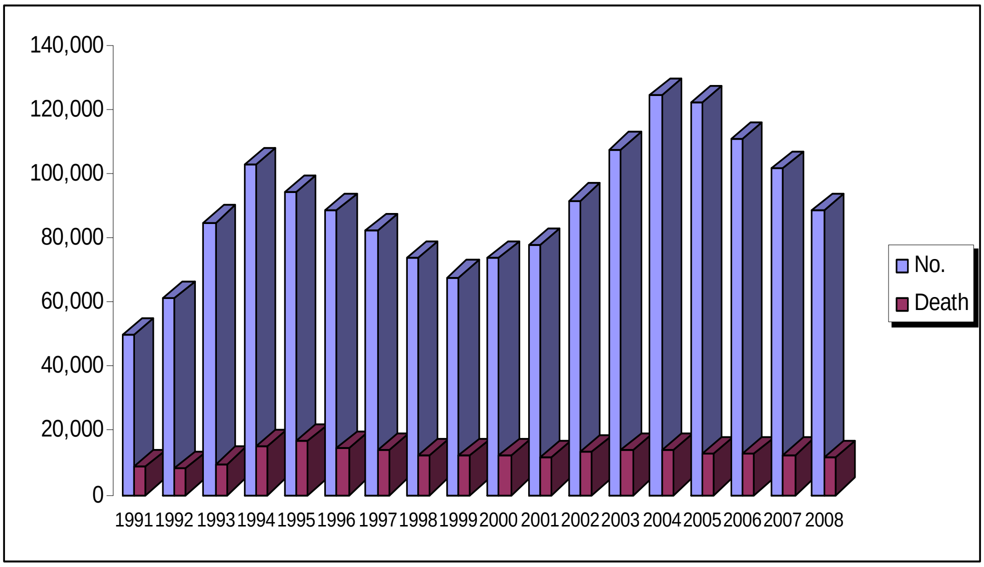

Figure 1. Trend in traffic accident occurrences and fatalities [1]

The national highways accident database of the Department of Highways (DOH) reports the number of accidents on highways in 2008 at 14,336 cases with 1,513 persons killed. This figure constitutes a significant 13% of the road tolls for the whole country [2] Table 1 show the traffic accident on DOH network during the year 2002-2008. For the 7 years period, there were 105,975 cases (15,139 cases per year) with 13,546 deaths (1,935 deaths per year).

Table 1. Traffic accidents statistics on highways under the responsibility of Department of Highways during 2002-2008 [1]

Year	Highways under responsibility of Department of Highways Special intercity highways		
	Accident	Death	Injury
2002	15,066	2,265	13,285
2003	15,171	2,023	12,984
2004	18,547	2,324	18,381
2005	16,287	2,169	15,300
2006	12,913	1,647	11,129
2007	13,655	1,605	11,132
2008	14,336	1,513	11,680
Total	105,975	13,546	93,891

The total distance of Thailand national highways under the responsibility of the Department of Highways is about 51,300 km, within the network; there are more than 730 black spots. Adding to that, the potential for accident risk and its dire consequences is very much present, fortunately, there is opportunity to address the road safety problem on both the network and individual route level. This can be achieved by systematic assessing the safety level of all the highways.

2. CURRENT INTERNATIONAL ASSESSMENT OF SARETY ON ROADS

2.1 European Road Assessment Program (EuroRAP)

EuroRAP is an international not-for-profit organization formed by motoring organizations and highway agencies throughout Europe to work together for improvements to the safety of Europe's roads. It is the sister program to EuroNCAP, a safety program that crash tests cars and assigns them star ratings for safety [3]

The goal of EuroRAP is to provide safety ratings for roads across Europe. This will generate consumer information for the public and give road engineers and planners vital benchmarking information to show them how well, or how badly, their roads are performing compared with others, both in their own and other countries. EuroRAP is also committed to forging a partnership between all agencies with responsibility for road safety.

The primary objectives of EuroRAP are to:

1. Reduce death and serious injury on European roads rapidly through a program of systematic

assessment of risk that identifies major safety shortcomings which can be addressed by practical road improvement measures.

2. Ensure that assessment of risk lies at the heart of strategic decisions on route improvements, crash protection, and standards of route management

EuroRAP is designed with the philosophy that safety improvement programs should move from blackspot treatment (i.e., improvement of identified high crash locations) to route management and eventually to network safety management. European countries have set ambitious safety improvement goals (e.g., 50 percent reduction of fatal and serious injury crashes by 2010). EuroRAP takes the view that the achievement of this goal requires "mass action" to improve safety along extended road sections and that the goal cannot be achieved solely by low-cost improvements at identified spot locations.

This leads to the focus of EuroRAP on safety for extended roadway sections rather than for point locations. Example of outcomes of EuroRAP is shown in Figure 2 which illustrates the risk map of Great Britain.

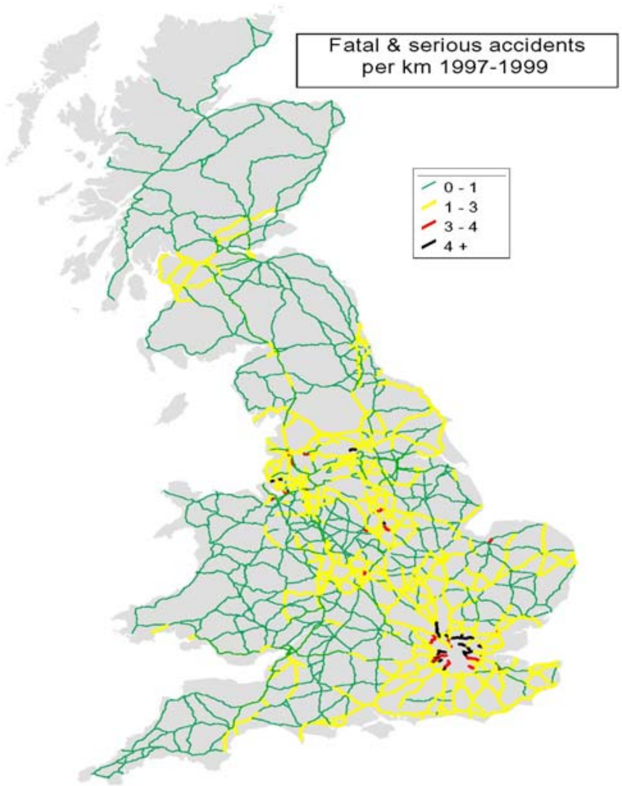

Figure 2. Risk rating of Britain's motorway and major road [4]

2.2 International Road Assessment Program (iRAP)

The International Road Assessment Program (iRAP) was established in 2004 to provide international coordination for all road assessment program efforts. iRAP serves as an umbrella organization to coordinate AusRAP, EuroRAP, and UsRAP.

Road assessment programs are expected to expand to additional countries in the future. Pilot tests for a

Canadian Road Assessment Program (CanRAP) are under discussion. An iRAP project to improve safety in low- to medium-income developing countries is being planned; this project would be conducted on a fast-track schedule and would include pilot studies in Asia, Africa, and Latin America. Currently iRAP is conducting assessment in Malaysia, Costa Rica, Chile and South Africa [5]. An example of star rating map for Malaysia is shown in Figure 3.

3. THAILAND PILOT STUDY OF ASSESSMENT OF HIGHWAY SAFETY

A pilot study to assess highway safety is currently being conducted by the authors in Thailand. It includes the development of a system to addressing risk of potential crashes on Songkhla highway network under the jurisdiction of DOH. The system being developed uses two different protocols for showing the safety level of a highway. This follows the method used by the European Road Assessment Program (EuroRAP), the reason for using similar protocol is so that the risk of having a crash and the level of safety of a highway section in terms of crash consequence can be compared to highway networks in other countries. The risk map shows the risk a driver faces on a certain highway and is derived from the accident history of the highways. The safety offered by a highway section when a crash occurs, can be rated taking into accounts the various features of the highway. The resulting map commonly known as Star Rating map shows the extent to which a highway protects the vehicle's occupants in a crash. The main objectives of the system are 2 folds: first, to reduce death and serious injury on the DOH highways by systematically carry out assessment of risk that enable the identification of major safety problems like roadside hazards, and other safety shortcomings which can be addressed by practical road improvement remedies; second, to promote the assessment of risk as a key part of the DOH roadside safety strategic plan. The system under development uses technology suitable for continual operation, as it enables DOH to update the risk situation and improvement outcomes of the network.

Figure 3. Star rating map for motorcyclists in Malaysia [5]

Table 2. The initial criteria under development in this study adapts.

Rating Scale	Divided Highway
*****	Straight with good pavement surface, skid resistance, good line-marking sealed shoulders, sufficient clear zone area, no connected side roads, safe roadsides, occasional over- passes and no u-turns
****	Minor deficiencies in some of the above features such as minor pavement defects, presence of some well designed connections, roadside or roadsides, few u-turns
***	Major deficiencies in some road features such as poor skid resistance, insufficient clear zones, inadequate roadside protections against collisions with roadside hazards, poorly designed intersections, a few u-turns
**	Many major deficiencies such as poor alignment, extensive potholes and other defects, poor skid resistance presence of continued roadside hazards eg. long line of trees and poor roadside protection, poorly designed connections and many u-turns
*	Winding alignment, inadequate protection against run-of the road crashes, poorly designed connections, u-turns at horizontal or vertical curves

3.1 Pilot Assessment of Safety of Highway Route in Songkhla

Three years of data (2006-2008) were collected for analysis and presentation in line with the practice used in EuroRAP. The data are used to produced highway risk map for Songkhla province. In this study an example risk map is presented for highway number 407, 408 and 414.

Number of road crashes on national highways in Songkhla during 2006 – 2008 amount to 606 cases. There were 130 persons killed and 761 injuries 6 Table 3 and Figure 4 show the location of Songkhla province, the site for the pilot study in assessing safety on Thailand national highway network.

Table 3. Road accidents statistic on Songkhla highways [6]

Year	No. Crashes	No. Fatalities	No. Injuries
2006	180	26	202
2007	211	70	289
2008	215	36	270
Total	606	130	761

Songkhla province is chosen as the site for the pilot study of the assessment of safety on Thailand national highways network because the authors have access to reliable data on road crashes and it has also many divided inter-provincial highways. The study route covers a distance of 19.430 kilometers of Segment no. 04070100 on Route 407 (Songkhla to Hatyai), 32.796 kilometers of Segment no. 04080501 on Route 408 (Sathingphra to Khaodang) and 24.315 kilometers of Segment no. 04140101 on Route 414 (Numkrachai-Route 43), which comes under the supervision of Songkhla district highway authority. The segment was selected for study due to the high frequency of accidents on this stretch of road where 22.3% of all road crashes (135 cases), 17% of all fatalities (22 persons) and 12% of all injuries (92 persons) occurred during 2006 - 2008 (see Table 4). Figures 5, 6, 7 show the risk map in terms of number of fatalities and injuries per km for the Route 407 Segment 04070100, Route 408 Segment 04080501 and Route 414 Segment 04140101. It is seen that along the entire length of the highway, there are 3 levels of risk with the end section with a length of 8 kms starting from km. 18.000 to km. 24.315 presents the highest risk. As for the star rating map, works are on-going and will be reported in the future.

Table 4. Road accidents statistic on Songkhla highways [5]

	No. Crashes	No. Fatalities	No. Injuries
Route 407	66	6	21
Route 408	60	7	70
Route 414	135	22	92

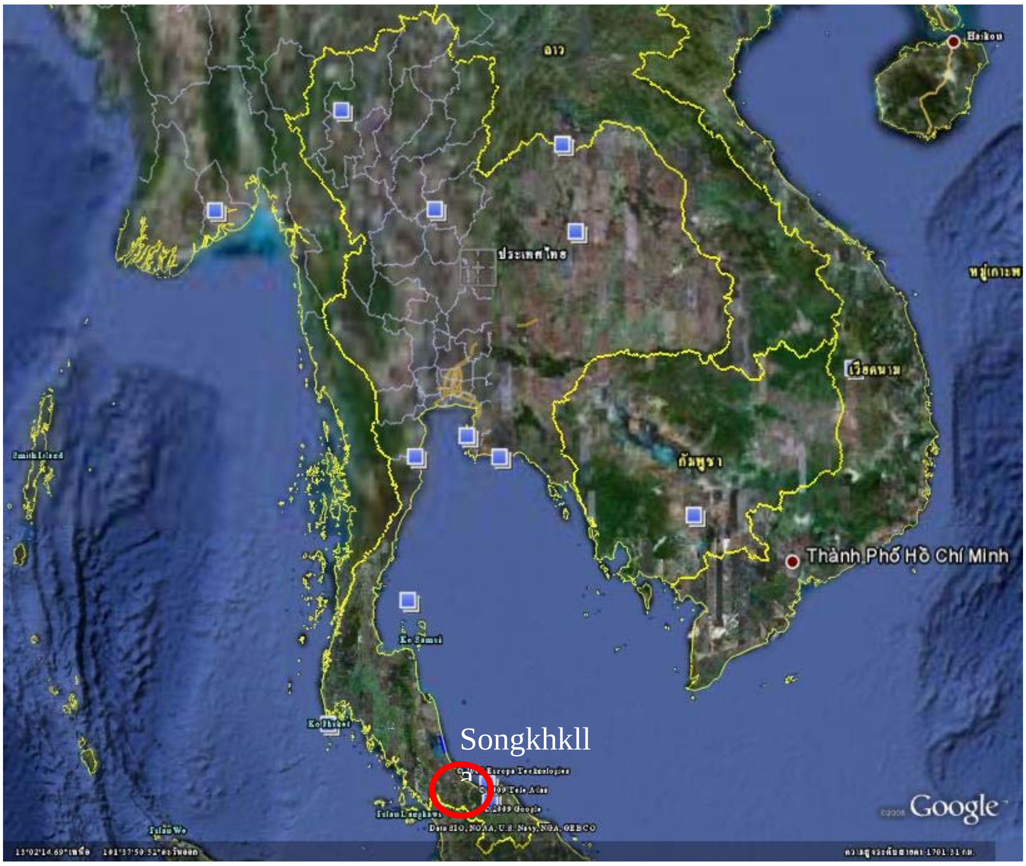

Figure 4. Location of Songkhla provinces the site for a pilot study to assess safety on Thailand national highway network

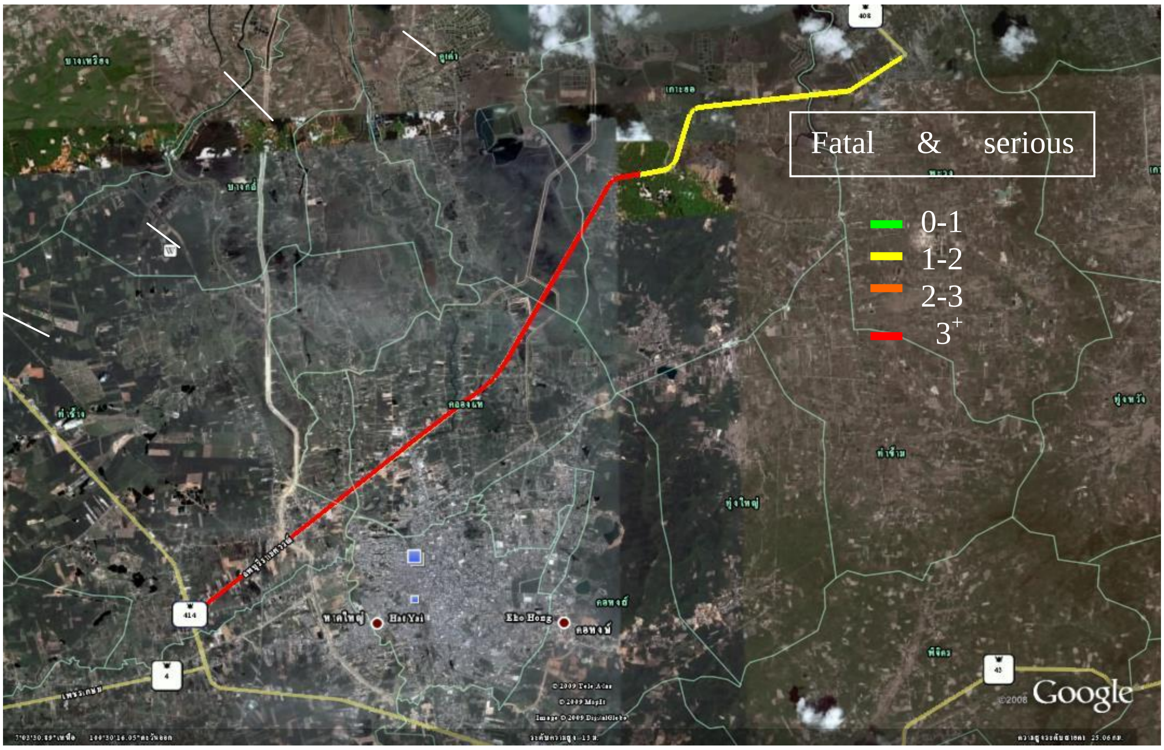

Figure 5. Fatal and serious injuries per km on route 414 segment 04140101

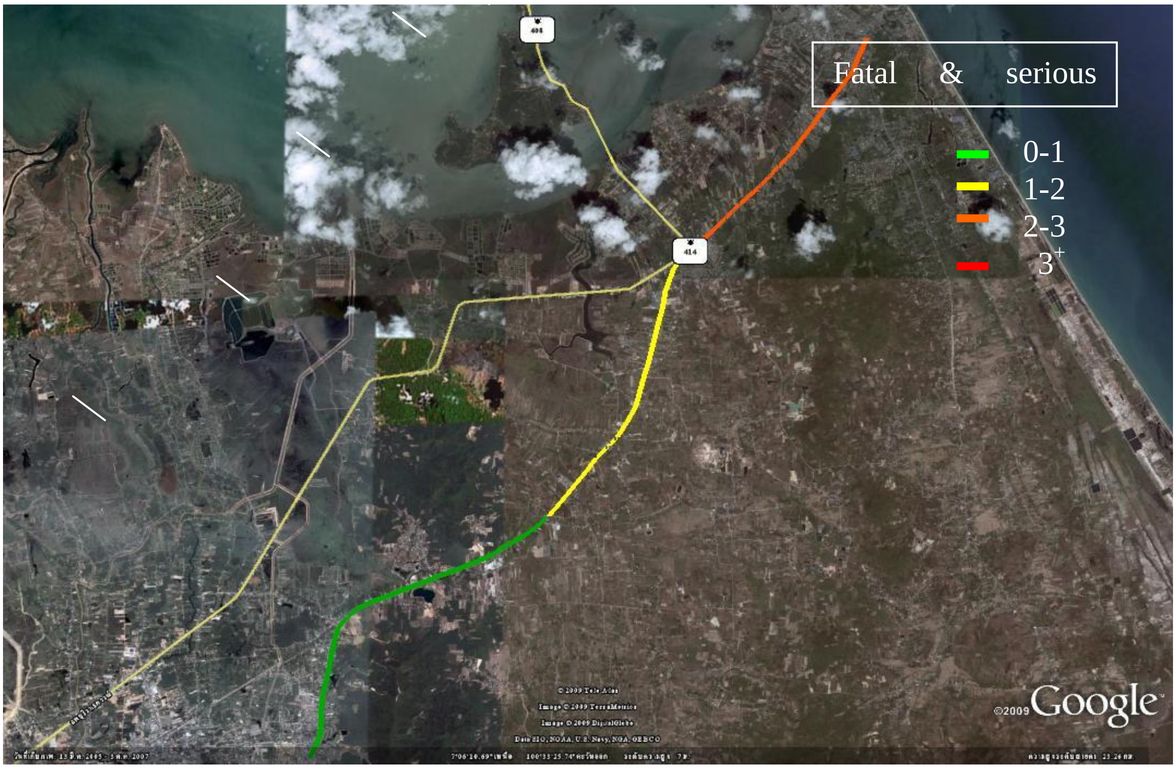

Figure 6. Fatal and serious injuries per km on route 407 segment 04070100

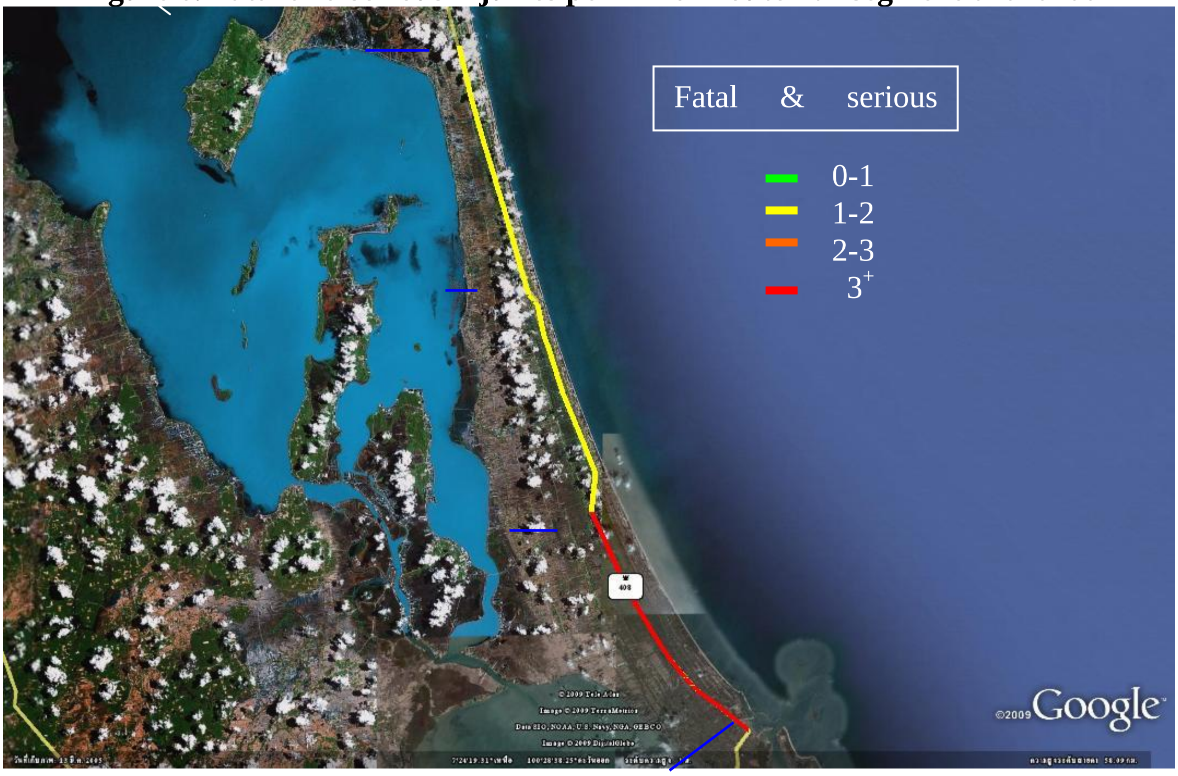

Figure 7. Fatal and serious injuries per km on route 408 segment 04140501

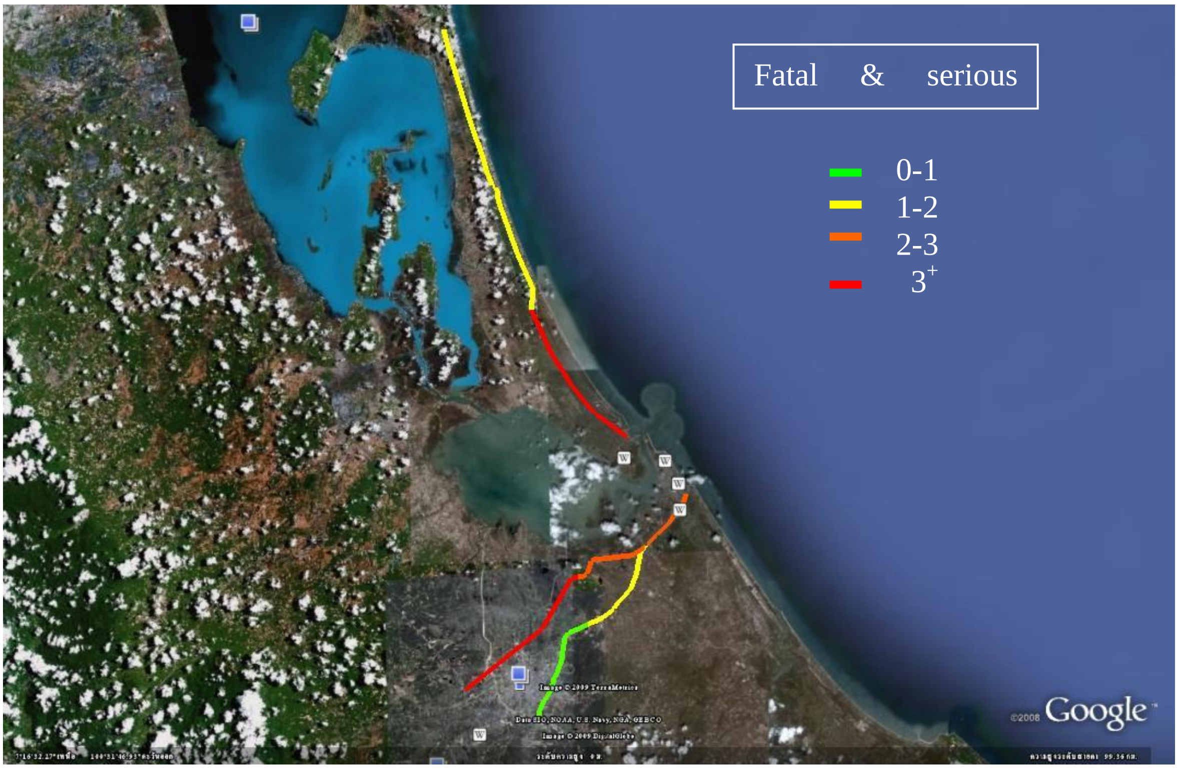

Figure 8. Fatal and serious injuries per km on route 407, 408, and 414

4. CONCLUSIONS

This paper describes the development of a system to address risk of potential accidents on Thailand national highways under the jurisdiction of DOH. The pilot study develops a system which uses two different protocols for showing the safety level of a highway. It models on the method used by the European Road Assessment Program (EuroRAP), this is so that the risk of having a crash and the level of safety of a highway section in terms of crash consequence can be compared to highway networks in other countries. A initial risk map which shows the risk a driver faces on a certain highway and is derived from the accident history of the highway was developed for highways number 414, 407, 408 all divide 4-lane highways in Songkhla. It shows 4 levels of risk of having a fatality and injury along the various lengths of the highway. As for the star rating map which rate the level of safety offered by a highway section when a crash occurs, the authors have developed an initial criteria to be used for preparing the map which is being prepared for the Songkhla highway network. The system under development uses technology suitable for continual operation, as it enables DOH to update the risk situation and improvement outcomes of the network.

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Songkhla highway district authority 2009 Traffic Accident Statistics

EVALUATION OF AIR PASSENGER SERVICE QUALITY IN BANGLADESH

Dr. Md. Mizanur RAHMAN
Associate Professor
Department of Civil Engineering
Bangladesh University of Engineering and Technology, BUET
Dhaka – 1000 Bangladesh
Fax: +88-02-9665639
E-mail: mizanur@ce.buet.ac.bd

Tahmina SULTANA
Assistant Professor
Department of Civil Engineering
The University of Asia Pacific
Dhaka, Bangladesh
Fax: +88-02-8110832
E-mail: sultana-mina@yahoo.com

Md. HADIUZZAMAN
Assistant professor
Department of Civil Engineering
Bangladesh University of Engineering and Technology, BUET
Dhaka – 1000
Bangladesh
Fax: +88-02-9665639
E-mail: hadiuzzaman@ce.buet.ac.bd

Abstract: The air transport is required high professional in work to ensure safety, exactly and fast which are outstanding advantages of traveling passenger by air. Service quality then becomes significantly important factor to achieve a genuine and sustainable competitive advantage and the question for civil aviation industries in Bangladesh, which need to solve imperatively. The passenger service quality of ZIA International Airport was evaluated by questionnaire survey on 232 passengers who used this airport and this information was analyzed by score method. The questionnaire was designed simply and focused mainly on general information of passenger and passenger evaluation through check in facilities, security, staff attitude and other facilities, which are supposed to arrange for passengers. The passenger service quality of Biman Bangladesh Airlines Limited was also evaluated by questionnaire survey on 150 passengers who used Biman Bangladesh airlines was analyzed by score method. This technique helps decision makers and marketing in air transport field to upgrade passenger service quality to attract more passengers traveling by ZIA International Airport and Biman Bangladesh Airlines Limited.

Key Words: Air passenger, Service quality, Score method, Questionnaire survey

1. INTRODUCTON

This research is significant today, but will become even more so in the future in context of Bangladesh. Aviation plays an important role in today's social and economic prospects. An extensive air transport network represents essential infrastructure assets of a country like banking or telecoms network and is a vital component for economic development and growth (IATA, 2006). Air transport provides the only worldwide passenger and cargo transportation network. It connects people and businesses to the global economy. So, the world demand for air transportation has grown at a very rapid pace in the last several decades. It is predicted to keep growing rapidly over the next several decades. Boeing -2000 forecasts suggest that air travel will grow at an average annual rate of 4.8% over the period 2000-2019 (Boeing, 2000). But in case of Bangladesh, aviation industry faces a great challenge. Bangladesh loses over four billion taka (around $57 million) annually. As more than 60 percent passenger-handling capacity of Dhaka's Zia International Airport (ZIA) remains unutilized (CAAB, 2008).

Bangladesh has three international airports including ZIA in capital Dhaka, one in the southeastern port city Chittagong and another in the northeastern city of Sylhet. With its present infrastructure, ZIA is capable of handling around 8.5 million passengers yearly, while 150 planes can take off and land at the airport every day. According to an analysis of last five years, ZIA has handled 3.2 million passengers yearly on an average with 50 flights carrying around 8,500 passengers to different international destinations daily(CAAB, 2008).

The specific objectives of this research are:

• To evaluate the air passenger service quality of ZIA International Airport in Bangladesh and Biman Bangladesh Airlines Limited.

• Make recommendations for improving air passenger service quality in Bangladesh.

It is expected that outcome of this research will be able to evaluate the performance of existing passenger service system of ZIA International Airport and Biman Bangladesh Airlines Limited.

2. AIR TRANSPORT IN BANGLADESH

The transport system of Bangladesh is consists of a network of roads, and the road transport services which ply on them; a railway network with different gauges in the east and west of the country, providing freight and passenger services; three maritime sea ports and an inland waterways system; transshipment centers (road/rail, road/port, road/waterways) offering opportunities for modal transfers for freight traffic; three international airports, a network of domestic airports and international and domestic air services; and urban transport services (buses, taxis, 3-wheeler public transport services, etc) within Bangladesh's cities and towns. A comparison of modal shares may be interesting as an overall indication of the competing modes, but is not fully representative of the actual situation. Though the share of air transport is comparatively small, it is the fastest growing mode in Bangladesh (CAAB, 2008). So, trends in air transport carry greater importance on the transportation system of Bangladesh. Figure 1 provides indications of reported passengers (million-km) and freight (million ton-km) modal shares for 2003, respectively.

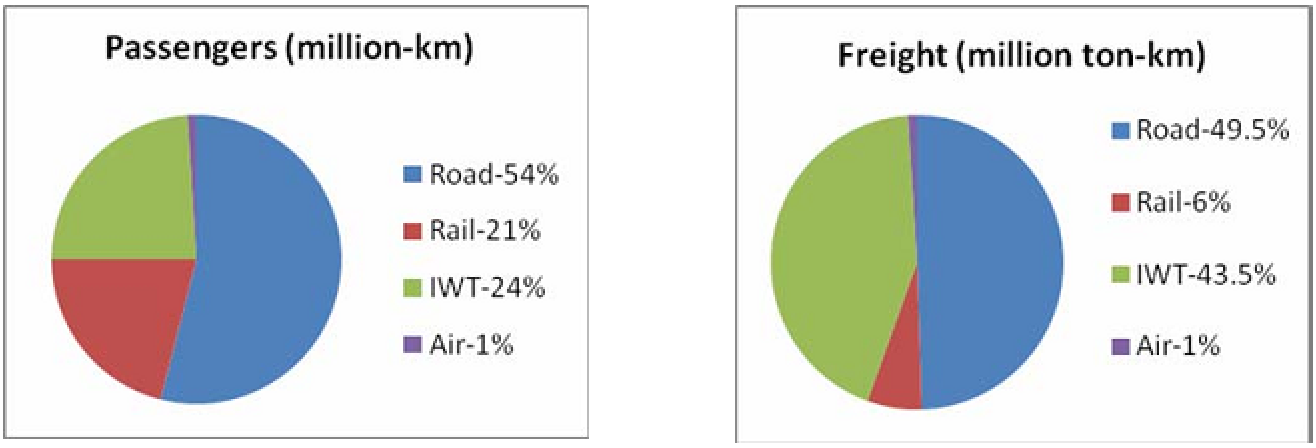

Figure 1. Modal Shares of Passengers and Freight in Bangladesh, 2003

All the airports in Bangladesh are operated under the Civil Aviation Authority of Bangladesh (CAAB), an autonomous body. CAAB is responsible for airports, runways and air traffic control, taxiways, terminal buildings, warehouse, control tower, operation and administrative buildings, air navigation and radio communication system. There are three international and six domestic airports in Bangladesh. Table 1 provides the list of International and Domestic airports in Bangladesh with their locations.

Table 1. Airports in Bangladesh (International and Domestic)

LOCATION	ICAO	IATA	AIRPORT NAME
International airports			
Chittagong	VGEG	CGP	Shah Amanat International Airport
Dhaka	VGZR	DAC	Zia International Airport
Sylhet	VGSY	ZYL	Osmani International Airport
Domestic airports			
Bagerhat			Khan Jahan Ali Airport (under construction)
Barisal	VGBR	BZL	Barisal Airport
Cox's Bazar	VGCB	CXB	Cox's Bazar Airport
Jessore	VGJR	JSR	Jessore Airport
Rajshahi	VGRJ	RJH	Shah Makhdum Airport
Saidpur	VGSD	SPD	Saidpur Airport

3. QUESTIONNAIRE DESIGN AND METHODOLOGY

There are different methods of air passenger service quality analysis: the performance indicator analysis and the questionnaire analysis. In this study questionnaire analysis were used and as such two-questionnaire survey were adopted. Questionnaire Survey is an appropriate method for producing information to describe, compare, and predict attitudes, opinions, values and behavior based on what people say or see and what is contained in records about them and their activities.

The questionnaire were designed simply and focused mainly on general information of passenger and passenger evaluation through cabin staff service (such as staff attitude and friendliness), onboard catering (food, beverage), onboard comfort (cabin seat comfort, in-flight entertainment etc.), airport terminal facilities, and parking facilities. Respondents were classified according to passenger gender, age, nationality, occupation, location, income, travel purpose, seat class, travel frequency of Biman and ZIA. This study applies the qualitative analysis to evaluate the passenger service quality of ZIA and Biman. The qualitative analysis was implied by passenger questionnaire survey analysis. Finally, the survey information were analyzed by score method (there are five score with 1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = very good) to measure the passenger’s service quality (Trinh and Hung, 2007)

Given the much larger population of airports worldwide, it was not practical to survey all airports and therefore a sample was taken for the airport survey. Zia International Airport of Bangladesh is considered as a specimen. Based on a questionnaire survey of 232 passengers of ZIA, the paper tried to find out the present service quality of ZIA. This study applies the qualitative and quantitative analysis to evaluate the passenger service quality of Biman Bangladesh Airlines Limited to obtain the objective. Biman Bangladesh airlines is a national flag carrier. So, the survey on this airline is considered especially. Based on a questionnaire survey of 150 passengers of Biman, the paper tried to find out the present service quality of Biman.

4. PASSENGER SERVICE QUALITY OF ZIA INTERNATIONAL AIRPORT

This study applies the qualitative and quantitative analysis to evaluate the passenger service quality of ZIA International Airport to obtain objective of the paper. Survey time was on three month, 232 questionnaire forms were sent to passenger to different institution like Bangladesh Air force, Civil Aviation, different private and public universities, Bank to take opinion. Survey operated from April to July 2008. Questionnaire underwent rigorous testing during the development stage. Prominent academics and professionals of Civil Aviation and Bangladesh air force were consulted on the design and content of the questionnaire before piloting on airport and airline began. Market segmentation of the respondents according to their nationality at Zia International Airport is presented in Table 2.

The paper finds that almost all passengers traveling by ZIA International Airport are Bangladeshi (95 %) and the age of Bangladeshi passengers concentrate mainly 31-40 age (59%) and under 30 year old (6%) while the age of foreigner passengers are 31-40 (3%). The data suggest that Bangladeshi passengers traveling are more likely to be middle-age (59%). Bangladeshis' income is not so high, Bangladesh, with per-capita gross national income (GNI) of $470 in 2005, could become middle-income country - defined by the International Development Association, it is the reason why passenger traveled most by Economy class (67 %) contrary to foreigner passengers with high income (all their income is larger than 3 million) and using business class (3%). Bangladeshi passengers used air transport largely for conference (37 %). Travel frequency by using ZIA International Airport was 63 % for 1-2 visits per year for Bangladeshi.

This research also relates the response with demographic characteristics of the respondents who participated in the survey of the service quality of ZIA International Airport. In case of Check in facilities in ZIA, based on gender 94.74% male gave their opinion in favor of excellent while 14.75% female said it was good and based on occupation, 36.84% service holder favored for excellent and 39.34 % businessman said good. In case of average check - in - time, 46% engineers had poor experienced whereas 37% businessman gave their opinion in favor of good. For baggage screening, 44% businessman favored in good but 22% student said that service quality was poor. In case of staff attitude, 32% service holder gave their opinion in alignment of good while near about 40% businessman said fair. In case of information display, 26.92% engineer gave their vote on very poor category. In case of internet availability facility, 30% businessman had very poor experienced.

Table 2. Passenger Profile by Nationality at ZIA International Airport

Demographic Classification		Bangladeshi (Number)	Foreigner (Number)	Total (Number)	Bangladeshi (%)	Foreigner (%)	Total (%)
Gender	Male	210	7	217	91	3	94
	Female	10	5	15	4	2	6
	Total	**220**	**12**	**232**	**95**	**5**	**100**
Age	<30	15	1	16	6	0	7
	31-40	136	6	142	59	3	61
	41-50	50	4	54	22	2	23
	>50	19	1	20	8	0	9
	Total	**220**	**12**	**232**	**95**	**5**	**100**
Occupation	Engineer	36	1	37	16	0	16
	Doctor	6	0	6	3	0	3
	Student	24	1	25	10	0	11
	Businessman	75	7	82	32	3	35
	Service holder	48	2	50	21	1	22
	Teacher	25	1	26	11	0	11
	Others	6	0	6	3	0	3
	Total	**220**	**12**	**232**	**95**	**5**	**100**
Income	<12,000 Tk	5	0	5	2	0	2
	12,000-15,000 Tk	10	0	10	4	0	4
	15,000-25,000 Tk	45	0	45	19	0	19
	>25,000 Tk	160	12	172	69	5	74
	Total	**220**	**12**	**232**	**95**	**5**	**100**
Travel frequency	1-2 Visit	145	9	154	63	4	66
	3-5 visit	60	3	63	26	1	27
	6-10 visit	10	0	10	4	0	4
	> 10 visit	5	0	5	2	0	2
	Total	**220**	**12**	**232**	**95**	**5**	**100**
Seat class	VIP	5	0	5	2	0	2
	Economy	155	5	160	67	2	69
	Business	60	7	67	26	3	29
	Total	**220**	**12**	**232**	**95**	**5**	100
Travel Purpose	Conference	85	8	93	37	3	40
	Tourism	25	0	25	11	0	11
	Visiting Relatives	15	1	16	6.47	0.43	7
	Business	60	2	62	25.86	0.86	27
	Study	35	1	36	15.09	0.43	16
	Total	**220**	**12**	**232**	**95**	**5**	**100**

The respondent didn't give opinion in favor of excellent category in case of average check in time, baggage screening, security screening efficiency, staff attitude, baggage delivery times, information display, terminal cleanliness, food and drink prices, internet availability, and information about delay, divert and canceled flight, airport accessibility and exiting the airport facilities. Table 3 provides the passenger evaluation of Zia International airport.

Table 3. Analysis of Passenger Evaluation of Zia International Airport

Arrival and Departures	Excellent %	Good %	Fair %	Poor %	Very Poor %	Total %
Check-in facilities	8	26	60	3	3	100
Average check in time	0	35	39	16	10	100
Baggage screening	0	34	53	8	5	100
Security screening efficiency	3	32	39	24	2	100
Passport control	0	44	37	16	3	100
Staff attitude	0	35	50	10	5	100
Baggage Delivery times	0	24	26	47	3	100
Information Display	0	26	21	42	11	100
Terminal Cleanliness	0	32	37	26	5	100
Baggage trolley availability	12	44	20	19	5	100
Choice of tax-free shopping	0	15	40	35	10	100
Food & drink prices	0	28	39	30	3	100
Internet availability	0	5	5	69	21	100
Telephone/Fax services	0	8	18	58	16	100
Delay, divert (Procedure to inform passenger)	3	8	34	40	15	100
Cancelled flight (Procedure for rerouting)	3	2	26	54	15	100
Cancelled flight (Hotel service)	3	8	21	52	16	100
Parking Facilities	3	47	34	11	5	100
Airport accessibility	0	24	58	15	3	100
Exiting the airport	0	19	60	13	8	100

Service quality is directly proportional with the average value. This study applies the qualitative analysis to evaluate the passenger service quality of ZIA. The qualitative analysis has been implied by passenger questionnaire survey analysis. Finally, the survey information has been analyzed by using score method to measure the evaluation level from passengers. There were five score with 1- very poor, 2 - poor, 3- fair, 4 - good, 5-excellent. For example, in case of check in facilities, average score is 3.33. In case of check in facilities, 8% passenger gave their opinion in favor of excellent, 26% good, 60% fair, 3% poor and 3% very poor. The detail procedure is shown below,

$$\text{Average Score for check in Facilities in ZIA} = \frac{8*5+26*4+60*3+3*2+3*1}{100} = 3.33 \tag{1}$$

The followings are the outcomes of the survey on service quality at ZIA International Airport

• Check in facilities is rated with 60% 'fair' comments with average score is 3.33

• Average check in time is considered with 39% 'fair' comments with average score is 2.99

• Baggage screening is rated with 53% 'fair' comments with average score is 3.16

• Security screening efficiency is rated with 39% 'fair' comments with average score is 3.1

• Passport control is rated with 44% 'good' comments with average score is 3.22

• Staff attitude is rated with 50% ‘fair’ comments with average score is 3.15
• Baggage delivery times is rated with 47% ‘poor’ comments with average score is 2.71
• Information display is rated with 42% ‘poor’ comments with average score is 2.62
• Terminal cleanliness is rated with 37% ‘fair’ comments with average score is 2.96
• Baggage trolley availability is rated with 44% ‘good’ comments with average score is 3.39
• Choice of tax free shopping is rated with 40% ‘fair’ comments with average score is 2.6
• Food and drink prices is rated with 39% ‘fair’ comments with average score is 2.92
• Internet availability is rated with 69% ‘poor’ comments with average score is 1.94
• Telephone/fax services is rated with 58% ‘poor’ comments with average score is 2.18
• Procedure to inform passenger in case of delay, divert and cancelled flight is rated with 40% ‘poor’ comments with average score is 2.44
• Procedure to rerouting passenger in case of delay, divert and cancelled flight is rated with 54% ‘poor’ comments with average score is 2.24
• Hotel service in case of delay, divert and cancelled flight is rated with 52% ‘poor’ comments with average score is 2.3
• Parking facilities is rated with 47% ‘good’ comments with average score is 3.32
• Airport accessibility is rated with 58% ‘fair’ comments with average score is 3.03
• Exiting the airport is rated with 60% ‘fair’ comments with average score is 2.90

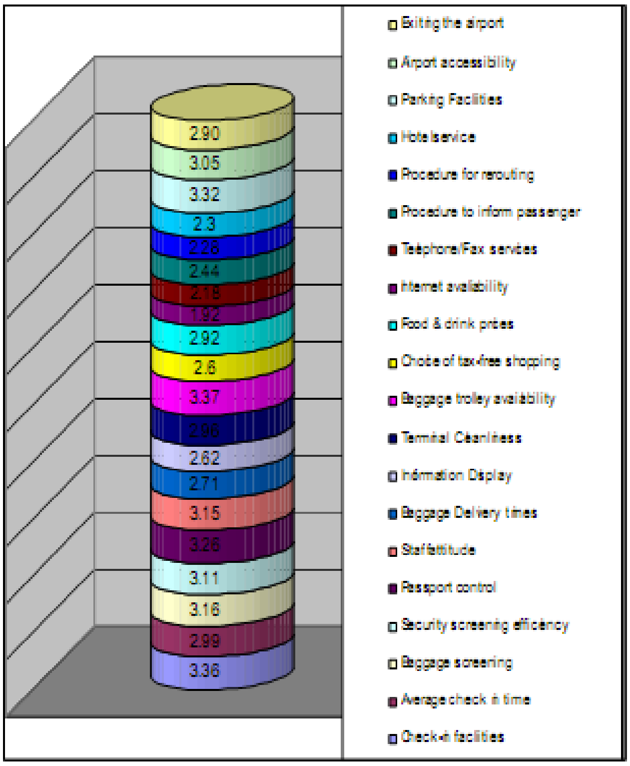

Figure 2. Average Score on Various Service Facilities of ZIA International airport

Figure 2 provides the average score of different service facilities of Zia international airport based on questionnaire survey.

The analysis finds that 39% passengers claimed that the average check-in time per passenger was so long around 5-10 minutes, 35% claim this time is 3-5 minutes. The check-in time per passenger in 10-15 minutes and over 15 minutes occupy not so high compared with other check-in time intervals but this results cannot be accepted in simplify check-in procedure in the world at the international terminal as ZIA International Airport. Table 4 provides the average check in time in Zia international airport in Bangladesh.

Table 4. Average check in time in ZIA International Airport

Average check in time	Excellent %	Good%	Fair%	Poor%	Very Poor%
	0%	35%	39%	16%	10%
	< 3 minutes	3-5 minutes	5-10 minutes	10-15 minutes	> 15 minutes

5. PASSENGER SERVICE QUALITY OF BIMAN BANGLADESH AIRLINES

The questionnaire was designed to collect information from the customer of Biman Bangladesh Airlines Limited on their service. The questionnaire was designed simply and focused mainly on general information of passenger and passenger evaluation through cabin staff service (such as staff attitude & friendliness), onboard catering (food, beverage), and onboard comfort (cabin seat comfort, in-flight entertainment), flight schedule maintain etc.

Respondents were classified according to passenger gender, age, nationality, occupation, location, income, travel purpose, seat class, and travel frequency by Biman Bangladesh Airlines Limited. Market segmentation of the respondents according to their nationality for Biman Bangladesh Airlines is presented in Table 5. The paper finds that almost passengers traveling by Bangladesh Airlines are Bangladeshi (92%) and the age of Bangladeshi passengers concentrate mainly 31-40 age (47%) and under 30 year old (10%) while the age of foreigner passengers are 31-40 (4%). The data suggest that Bangladeshi passengers traveling are more likely to be middle-age (47%). Bangladeshis' income is not so high, Bangladesh, with per-capita gross national income (GNI) of $470 in 2005, could become middle-income country defined by the International Development Association, it is the reason why passenger traveled most by Economy class (73%) contrary to foreigner passengers with high income (all their income is larger than 3 million) and using business class (10%). Bangladeshi passengers used air transport largely for business purpose (37 %). Travel frequency by using Biman Airlines was 57% for 1-2 visits per year for Bangladeshi.

Table 5. Passenger Profile by Nationality for Biman Bangladesh Airlines Limited

Demographic Classification		Bangladeshi (Number)	Foreigner (Number)	Total (Number)	Bangladeshi %	Foreigner %	Total %
Gender	Male	115	7	122	77	5	82
	Female	15	5	20	15	3	18
	Total	138	12	150	92	8	100
Age	<30	15	1	16	10	0.67	11
	31-40	70	6	76	47	4	51
	41-50	38	4	42	25	2.67	28
	>50	15	1	16	10	0.67	11
	Total	138	12	150	92	8	100
Occupatio n	Engineer	15	1	16	10	0.67	11
	Doctor	8	0	8	5	0	5
	Student	14	1	15	10	0.67	11
	Businessman	60	7	67	40	4.67	45
	Service holder	15	2	17	10	1.33	11
	Teacher	10	1	11	7	0.67	8
	Others	15	1	16	10	0	10
	Total	138	12	150	92	8	100
Income	<12,000 Tk	3	0	3	2	0	2
	12,000-15,000 Tk	15	0	15	10	0	10
	15,000-25,000 Tk	30	0	30	20	0	20
	>25,000 Tk	90	12	102	60	8	68
	Total	138	12	150	92	8	100
Travel frequency	1-2 Visit	85	9	94	57	6	63
	3-5 visit	33	3	36	22	2	24
	6-10 visit	5	0	5	3	0	3
	> 10 visit	15	0	15	10	0	10
	Total	138	12	150	92	8	100
Seat class	VIP	13	0	13	9	0	9
	Economy	110	5	115	73	3	76
	Business	15	7	15	10	5	15
	Total	138	12	150	92	8	100
Travel Purpose	Conference	34	8	42	23	5	28
	Tourism	4	0	4	3	0	3
	Visiting Relatives	30	1	31	20	1	21
	Business	55	2	57	37	1	38
	Study	15	1	16	10	1	11
	Total	138	12	150	92	8	100

The followings are the outcomes of the survey on service quality of Biman Bangladesh
Airlines limited

• Comfort in flight is rated with 39% ‘fair’ for seat size and 49% ‘poor’ for useful equipment comments with average score are 2.72 and 1.91 respectively.

• Cleanliness of the cabin is considered with 49% ‘poor’ comments with average score is 1.81

• Cleanliness of toilet is rated with 50% ‘very poor’ comments with average score is 1.61

• News paper service is rated with 49% ‘fair’ comments with average score is 2.71

• Airline magazine is rated with 50% ‘fair’ comments with average score is 2.7

• Pillows, Blankets, towels etc is rated with 49% ‘poor’ comments with average score is 1.71

• Onboard Catering is rated with 39% 'poor' comments with average score is 2.11
• Cabin Staff attitude and friendliness is rated with 39% 'poor' comments with average score is 2.31
• Cabin Staff Language Skills is rated with 59% 'very poor' comments with average score is 1.82
• Cabin Staff presence trough flight is rated with 48% 'poor' comments with average score is 1.94
• Cabin Staff Responding to passenger is rated with 39% 'fair' comments with average score is 2.4
• Entertainment is rated with 63% 'very poor' comments with average score is 1.63
• Flight Schedule Maintain is rated with 70% 'very poor' comments with average score is 1.43

Table 6. Analysis of Passenger Evaluation of Biman Bangladesh Airlines Limited

Onboard Product		Excellent %	Good %	Fair %	Poor %	Very Poor%	Total
Comfort in flight	Seat size	0	21	39	31	9	100
	Useful Equipment	0	0	21	49	30	100
Cleanliness of the cabin		0	0	20	41	39	100
Cleanliness of Toilets		0	0	11	39	50	100
News paper service		0	11	49	40	0	100
Airline Magazine		0	10	50	40	0	100
Pillows , Blankets, towels etc		0	0	11	49	40	100
Onboard Catering		0	10	21	39	30	100
Food		0	20	19	40	21	100
Beverage		0	19	19	50	12	100
Cabin Safety Procedures		0	11	9	20	60	100
Cabin Staff	Staff attitude & friendliness	0	10	31	39	20	100
	Language skills	0	9	23	9	59	100
	Service efficiency	0	0	37	41	22	100
	Presence through flights	0	0	23	48	29	100
	Responding to Passenger requests	0	11	39	29	21	100
	Assisting Parents with children	0	0	9	29	62	100
Entertainment		0	9	8	20	63	100
Airline website	Ease of site navigation	0	0	30	40	30	100
	Schedules, Fares, Booking	0	0	30	40	30	100
	Product & Service info	0	0	39	31	30	100
	Language options	10	10	53	20	17	100
	Seat reservation	0	0	40	29	31	100
Flight Schedule Maintain		0	3	7	20	70	100

The flight information analysis was done as described before by score method to measure of evaluation level from Passengers. There were five score with 1 – very poor, 2 – poor, 3- fair, 4 – good, 5-Excellent.

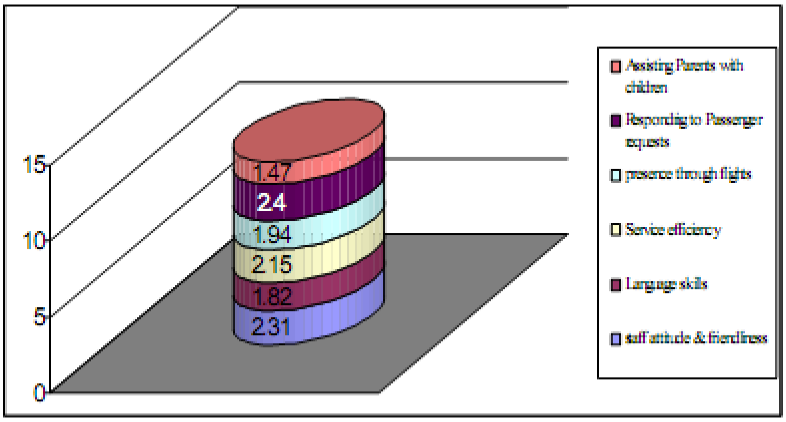

Figure 3. Cabin Staff Service Quality of Biman Bangladesh Airlines

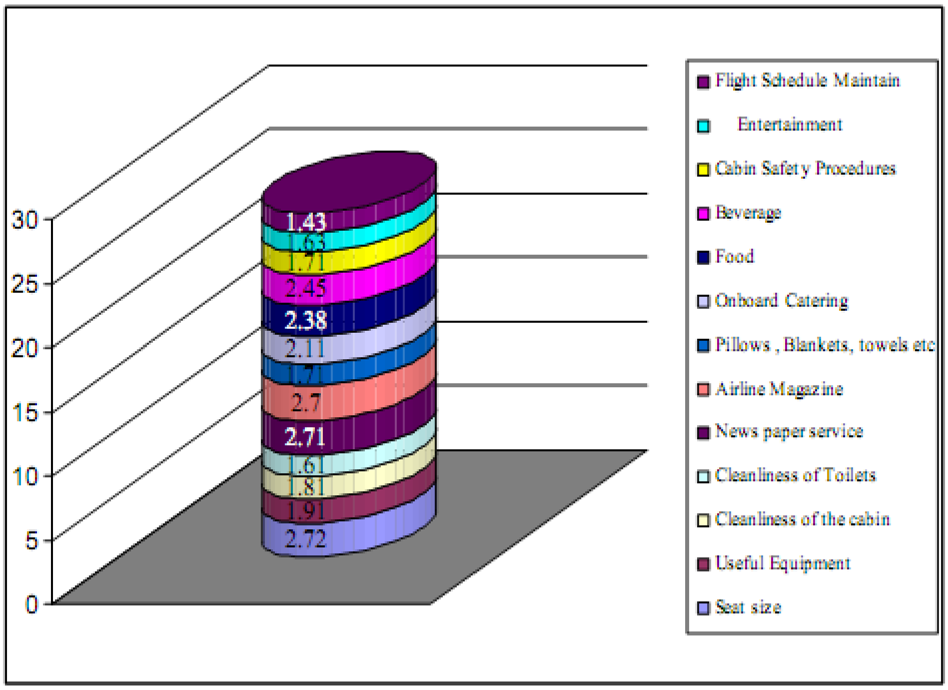

Figure 4. On-Board Service Quality of Biman Bangladesh Airlines

Biman is notable for regular disruptions to its flight schedule including lengthy delays and cancellations from questionnaire survey analysis, the passenger of Biman claimed that airline does not maintain the flight schedule properly. In this survey 70% passengers complained about this issue is very poor. The average score level is lowest in case of to maintain flight schedule only 1.43. A Flight Delay is any change from the promised time and date of departure or arrival. Flight delays are caused by a variety of circumstances including

o Cancellations
o Mechanical Malfunctions
o Acts of God
o Schedule Changes
o Hijackings And Bombings
o Noxious Body Odors
o False Imprisonment
o Wrongful Detention
o Violation of Air Carrier's Access Act
o Wrongful Refusal To Board
o Failure to Confirm or Reconfirm Reservations
o Discrimination

o Airline overbooking
o Wrongful Ejection
o Failure To Assist Disabled Passenger
o Misinformation
o Civil Disorder
o Shortage Of Fuel
o Misplaced Tickets
o Collapsing Ticket Counters
o Altered Tickets

In case of Biman, they have to cancel flight schedules due to technical glitches and shortage of aircraft. Different international airports including Heathrow Airport strongly criticized Bangladesh Biman for its repeated failures to maintain flight schedules and warned of not granting slots if it failed to be punctual. Jeddah, Riyadh, Kuwait, Rome and a number of other international airports also accused Biman of not keeping its flight schedule and warned Biman that they would not grant slots to Biman if its flight did not become more punctual. The authority of busy airport like Heathrow, Dubai has to hold aircraft both in the sky and on the ground for Biman's delay. They could manage it if the delay was once or twice, the fact is the authority of Biman cannot keep any of the flight schedules and that is why those international airports warned them. Delays hamper immigration and checking departments of the concerned airport. Biman needs more aircraft otherwise the situation will not improve.

In-flight entertainment aboard Biman aircraft is rated 1.63. The Douglas DC-10-30s are equipped with a projector in each cabin while the Airbus A310s have monitors that drop down from the ceiling below the luggage racks in the center of the aircraft. While other airlines utilizing modern aircraft are able to provide more personal in-flight experiences via seatback LCD screens, Biman's ageing fleet has maintained the standard equipment available when the planes were manufactured. The average score level is also low in cleanliness of cabin and toilet , cabin safety procedure, supply of pillow, blankets, & towels are 1.81,1.61,1.71 respectively.

In case of cabin staff, average score for language skill, staff attitude & friendliness, assisting parents with children level, Service efficiency, presence through flights, responding to passenger requests are 1.82, 2.31, 1.47, 2.15, 1.94, 2.4 respectively. The analysis of service quality and the average score show more detail in table 6 and figure 4 and 5.

6. RECOMMENDATIONS

6.1 Recommendations for Zia International Airport:

Following are the recommendations for the improvement of the service quality of ZIA International Airport:

a) Based on survey result

• Improved baggage delivery times
• Improved the display of passenger information
• Improved internet availability, telephone and fax services.
• Improved the hotel service in related to delay, divert and cancelled flight

b) Based on the comments of the participants in survey

i) A customer service-oriented organization

• Drawing up of a quality assurance programmer
• Creation of a security division
• Creation of a department for internal appraisal
• Making improved customer service the responsibility of service providers
  • Improved the choice of tax free shopping
  • Improved the quality of food and drinks

ii) Reinforced training and more information

• Increased Training facilities for the staff
• Creation of a new security / training partner

ii) New developments

- Video surveillance
- Detectors for traces of explosives
- Reinforcement of checks at road access points
- New structures to simplify and facilitate passenger movement like electric vehicle
- Implement airport ambassador programme, which is implemented in Hong Kong International Airport.
- Deployment of a system for the reconciliation and traceability of luggage
- Special services for people with reduced mobility
- Special facilities for children
- Special arrangement for visitors
- Facilities should be improved for mother with children

iv) Improvement in management level

- Adopt and implement the new Airport Master Plan
- Work with the Economic Development Administration to obtain grant funds to improve for future development
- Determine initial and monitoring ongoing air service trends on a local, regional, and national basis
- Develop and implement air service development activities to attract a new air carrier or expand existing service
- Maintain a safe environment for aircraft and airport users
- Seek new approaches to revenue growth and funding sources, and revise lease agreements to improve revenues to the airport enterprise fund.

6.2 Recommendations for Biman Bangladesh Airlines Limited

To help Biman move out from its old-fashioned way of management, to accommodate the future opportunities and to avert the current crisis and threats, it is extremely essential for Biman to undertake the following steps set forth as

a) Based on survey results

- Useful equipment should be increased like noise cancellation headphone
- Cabin and toilets should be neat and clean
- Pillow, blanket and towel should be available
- Price and quality of food and beverage should be improved
- Service efficiency of the staff should be improved by proper training
- Airline website should be improved
- Biman should maintain flight schedule properly
- Entertainment facilities like audio, video, magazine and newspaper should be improved

b) Based on the comments of the participants in survey

i)Policy Level

- Biman should have a vision and mission statement.
- To ensure accountability, the Board of Directors needs to be reformed. The Minister for Civil Aviation should not be the Chairman of the Board of Directors. The responsibilities of the members of the Board should be specified.
- Experts on commercial airline and aviation industry must be included as members in the Board of Directors.
- Biman should abide by the current business methodologies as used in world-class airline to make it successful and profitable.
- The Annual Report should be made public. This report must include financial statements.
- Biman should not be exploited in the name of national interest. It should not operate unprofitable flights.
- Biman's existing procurement rules should be appropriately amended so that Biman can take its own business decisions.

ii) Operational Level
Administrative

- Consultants should be hired with regard to finance, store and purchase.

Planning

• Biman should make a phased fleet renewal plan.
• Biman should develop and adopt a coping strategy addressing the market need.

Service level

• Biman must refocus their efforts to improve customer service.
• The Department should take a more active role in airline customer service issues.
• Providing Timely and Adequate Flight Information
• Offer the lowest fare available.
• Notify customers of known delays, cancellations, and diversions.
• Deliver baggage on time.
• Support an increase in the baggage liability limit.
• Provide prompt ticket refunds.
• Properly accommodate disabled and special-needs passengers.
• Meet customers' essential needs during long, on-aircraft delays.
• Disclose travel itinerary, cancellation policies, frequent flyer rules, and aircraft configuration.
• Be more responsive to customer complaints.
• Focusing on the Training for personnel who assist passengers with disabilities and children.

7. CONCLUSIONS

This study evaluated the service quality of passengers in ZIA International Airport and Biman Bangladesh Airlines Limited. Excellent and reliable customer service is one of the greatest aspects for an airport and airlines in today's competitive environment. There are many factors that can help an airport to build its customer base and customer service can be a determining factor in the success of an entire operation.

The analysis of passenger service quality of ZIA International Airport was reviewed by questionnaire survey on 232 passengers who used this airport and the information of the airport was analyzed by score method to measure the evaluation level from passengers. The questionnaire was designed simply and focused mainly on general information of passenger and passenger evaluation through check in facilities, security, staff attitude and other facilities which are supposed to arrange for passengers. Check in facilities at ZIA is considered best with 60% "fair" comments but internet availability is considered poor with only 21% of 'poor' comments. The average score for internet availability is 1.94. The average score level is also low in case of telephone, fax service and service due to delay, divert and cancelled flight. The analysis of passenger service quality of Biman Bangladesh Airlines Limited is also reviewed by questionnaire survey on 150 passengers who used this airport and the information of the airlines is analyzed by score method. Comfort in flight that seat size is considered 21% "good" comments whereas flight schedule maintain 70% "very poor" comments and average score level for maintain flight schedule is only 1.43. The average score level are also low for cleanliness of cabin and toilet, cabin safety procedure, supply of pillow, blankets, and towels, assisting parents with children and entertainment.
This paper presents systematic method to examine the quality of passenger service through the average score method analysis. This technique helps decision makers and marketing in air transport field to upgrade passenger service quality to attract more passengers traveling by ZIA International Airport and Biman Bangladesh Airlines Limited.

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