The Proceedings

2019 First International Conference on Smart Technology & Urban Development (STUD)

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2019 First International Conference on Smart Technology & Urban Development (STUD)

IEEE Part Number: CFP19W71-ART
ISBN: 978-1-7281-6435-9

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The readiness of information technology of Rajamangala University of Technology Phra Nakhon for educational communication to ASEAN

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***Abstract*—The objective of this research was to study the readiness of information technology of Rajamangala University of Technology Phra Nakhon to support educational communication in AEC [1]. This quantitative research used questionnaire to collect data from the sample group, who was 40 professors from Faculty of Business Administration, Rajamangala University of Technology Phra Nakhon.**

Findings illustrated that the readiness of information technology for classroom at Faculty of Business Administration was 93.75%. The opinion of respondents on the readiness of information technology was in good lever, average at 4.06. Regarding the access to internet network of the university, the respondents agreed that it was in good level (4.11) with the use through various channels such as LAN, WiFi, and VPN. Further, the respondents accessed internet via other devices provided by the university such as personal computer, notebook, mobile, and tablet. The respondents stated that they use internet for the purpose of academic, social media, communication with foreigners, and research.

Keywords—*information technology for education communication; readiness of information technology; ASEAN Rajamangala University of Technology Phra Nakhon*

I. Introduction

Nowadays, Thailand entered Asean Economics Community or AEC by the end of 2015, which is the gathering of ten countries in ASEAN: Thailand, Myanmar, Laos, Vietnam, Malaysia, Singapore, Indonesia, Philippines, Cambodia, and Brunei. The slogan is “One Vision One Identity One Community” [1].

Rajamangala University of Technology Phra Nakhon is one of the universities that is awakened and respond to the government policy for entering AEC as the educational center of ASEAN. Thailand has organized the volunteer for rural development for ASEAN project, seminar on knowledge management network “Knowledge Management Integration to AEC”, International Academic Seminar Project “Upgrading ASEAN Quality of Life and Local Wisdom”, Thai Arts and Innovations Training Project to ASEAN Youth, Thai and ASEAN Student Exchange Program such as Singapore and Vietnam.

With this reason, to promote the potential of Rajamangala University of Technology Phra Nakhon to join AEC the preparation of the university for information technology for educational communication to enter AEC is crucial and necessary, particularly internal communication in Rajamangala University of Technology Phra Nakhon and between Rajamangala University of Technology Phra Nakhon and the universities from neighboring countries [2].

II. Research Objectives

- To study and evaluate the satisfaction of personnel of Rajamangala University of Technology Phra Nakhon on basic information technology of the university regarding educational communication.
- To examine and evaluate the readiness of personnel of Rajamangala University of Technology Phra Nakhon on basic information technology of the university regarding educational communication.
- To develop potential of personnel of Rajamangala University of Technology Phra Nakhon to be ready for implementing information technology of Rajamangala University of Technology Phra Nakhon to enter AEC.

III. Concepts

A. Readiness of information technology to support educational communication.

Readiness of information technology to support educational communication is the equipment and internet that is useable at all times.

As technology is important and necessary for education nowadays, both for teaching and searching for more knowledge of professors, personnel, and students of Faculty of Business Administration, Rajamangala University of Technology Phra Nakhon, although the readiness of information technology is efficient, the readiness of personnel to learn how to implement modern information technology is required.

In short, the concept of readiness of information technology to support educational communication refers to the sufficiency of information technology equipment using in education by professors, personnel, and students.

Definition 1: Readiness of information technology refers to the availability of basic information technology for education such as computer, projector, and visualizer[3].

B. Measuring and evaluating the readiness of information technology to support educational communication.

Measuring and evaluating the readiness of information technology to support educational communication is to measure the readiness of information technology equipment using in education such as the adequate quantity of equipment to the classroom number.

Development and implementation of information technology to teaching and learning have direct and indirect effects. Direct effect is that it offers quality teaching and

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learning while indirect effect falls on professors, personnel, and students in searching more knowledge outside classroom.

IV. CONCEPTUAL FRAMEWORK

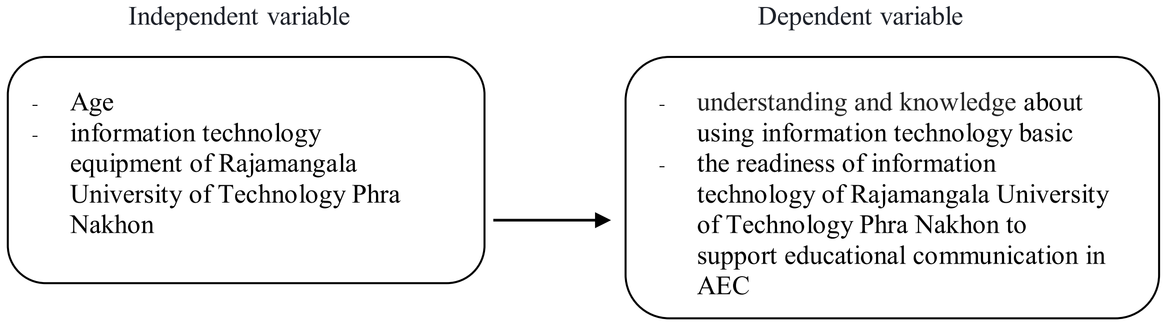

Fig. 1. Conceptual Framework

Definition 2: Information technology equipment of Rajamangala University of Technology Phra Nakhon refers to the equipment relating to technology and education which Rajamangala University of Technology Phra Nakhon applies in teaching and learning such as projector, visualizer, and computer [4-5].

Definition 3: Basic information technology refers to the equipment relating to technology and education which Rajamangala University of Technology Phra Nakhon applies in teaching and learning such as projector, visualizer, computer, LAN and WiFi internet.

V. RESEARCH METHODOLOGY

This was the quantitative research applying survey research and qualitative research. The sample group was 40 professors from Faculty of Business Administration.

A. Research tool.

Questionnaire was created based on the research objective and research framework and divided in to five parts:

Part 1 Personal information of respondent.
Part 2 Behavior of using information technology of the university.
Part 3 Readiness of information technology of the university.
Part 4 Actual condition and expectation (Demand).
Part 5 Additional opinion
Survey form about the readiness of information technology system.

B. Creating the *questionnaire*.

Regarding the questionnaire, the researcher followed the following step to obtain the quality questionnaire.

- Study relevant documents, text books, articles, and researches.
- Study, compile, and synthesize the information obtained from Step 1.
- Create the questionnaire to evaluate the satisfaction of the personnel of Rajamangala University of Technology Phra Nakhon.
- Propose the questionnaire to the expert to validate content validity by finding Index of Item –Objective Congruence: IOC) .There were three levels for scoring:

+1: Confident that the questions were validated.
0: Non-confident that the questions were validated.
-1: Confident that the questions were not validated.
Represent the value in the formula.

$$IOC = \sum R/N$$

IOC represented IOC
$\sum R$ represented total score of the expert's opinion.
N represented number of expert.
Score from 0.5-1 was applicable to the questionnaire
Score lower than 0.5 required the revision.

VI. DATA ANALYSIS

The researcher analyzed the statistical data using computer program as the following details.

- Personal information of the respondent was analyzed using Frequency and Percentage.
- Behavior of using information technology of the university was analyzed using Frequency and Percentage.
- The use of information technology of the university was analyzed using Frequency and Percentage.
- Actual condition and expectation on information technology were analyzed by Mean.

VII. RESEARCH RESULTS

The study and evaluation of satisfaction of the personnel of Rajamangala University of Technology Phra Nakhon on basic information technology of the university relating academic communication:

A. Personal information of the personnel of Faculty of Business Administration.

From 40 respondents, 15 were male and 25 were female, accounting for 37.5% and 62.5% respectively, aged between 26-55 years old. However, most of respondents aged between 36-45 years old and 36 of them graduated with Master's degree.

B. Behavior of using information technology of the university.

Regarding behavior of using information technology of the university, the respondents used the computer provided by faculty, however, some used personal computer, tablet, Ipad, and smart phone. During 12.00-13.00 and 13.00-16.00 were the period that the internet was accessed the most, accounted for 65.0% and 80.0% respectively.

85% of the respondents used information technology regularly, followed by several times per week. Most of them used information technology for the purpose of pursuing knowledge, searching online information, and sending E-mail, accounted for 90, 60, and 65.0% respectively.

C. The use of information technology system of the university.

For the use of internet account, 60% used the account regularly, followed by 40% who used it sometimes. Some stated that the internet lost the connection quite often and Wifi did not accessible of all area. This was in line with the internet service network that was used at 65%, followed by 35%.

The respondents accessed Facebook and Youtube for exploring new knowledge regularly; 50% used it frequently while another 50% used it sometimes. In regard to teaching implementing e-learning with foreigners, 55% used it frequently and 30% used it sometimes.

In regard to the overall service of information technology to support the communication in AEC, the respondents were satisfied with the permission to use other equipment to access internet system of the university, and 70% accessed the internet regularly. The use for other purposes such as for study and research, long-distance conference via LAN and Wifi was at 70% whereas some accessed internet network of the university via VPN, accounted for 65%.

D. Actual condition and expectation of the respondents on information technology.

The respondents had knowledge and skills in using information technology at 4.4 and had the expectation on E-service system to support the communication in AEC, at the average, at 4.11 as show in Table I. However, from the actual condition, the respondents scored it at the average, at 3.56 as show in Table I. In regard to the infrastructure of information technology service to support communication in AEC, the respondents had the average expectation at 3.97 as show in Table II, however, from the actual condition, they scored it at the average at 3.42 as show in Table II.

TABLE I. THE EXPECTATION ON E-SERVICE SYSTEM TO SUPPORT THE COMMUNICATION IN AEC.

Detail	**the expectation**	**The actual condition**
1. Computer user account system	4	3.85
2. e-mail system for professor	4.35	3.55
3. Internet service system	4.1	3.75
4. IT problems report system	4	3.45
5. the use of social media such as Facebook, You Tube to learn new global knowledge	4.15	3.5
6. teaching and learning via online learning resource such as using e-learning with foreigner	4.05	3.2
7. access of online media such as Facebook Live, You Tube Live in new communication pattern	4.15	3.65
Average	4.11	3.56

TABLE II. THE INFRASTRUCTURE OF INFORMATION TECHNOLOGY SERVICE TO SUPPORT COMMUNICATION IN AEC

Detail	**the expectation**	**The actual condition**
1. permission to connect personal device to the university's internet network such as Smart phone, Ipad	4	3.75
2. the access of internet in the university	4.1	3.7
3. international network roaming management for education (eduroam)	4	3.25
4. IP Telephony	3.75	3
5. LAN	4	3.55
6. Wifi	4	3.45
7. connection system from the outside to the university's internal system (VPN)	3.95	3.3
Average	3.97	3.42

Definition 4: VPN [6] stands for Virtual Private Network which connects with the outside network to enable the safer data transfer and facilitate the connection with server and equipment in the same network.

E. Knowledge and skills in using information technology of the respondents.

The respondents aged 31-40 years old had the average knowledge and understanding in using information technology in good level, 4.61, followed by 41-45, and 46-50 years old respectively.

In regard to reporting IT problems, there were 45% who were regular users, followed by 35%. It implied that problems of using IT obstructed the respondent. As a result, there was the use of IT expert service.

F. Readiness of physical information technology in classroom.

The researcher surveyed 64 classrooms at Faculty of Business Administration and found that each classroom had projector, visualizer, switching device, computer, sound audio, and internet. From 64 classrooms, 60 classrooms were fully equipped with the mentioned equipment, accounted for 93.75%.

VIII. DICUSSION

The research result finds that the respondents aged 31-40 years old had the average knowledge and understanding in using information technology in good level, 4.61. Readiness of physical information technology in 64 classrooms at Faculty of Business Administration, 60 classrooms were fully equipped with the mentioned equipment, accounted for 93.75%. The respondents had knowledge and skills in using information technology at 4.4 and had the expectation on E-service system to support the communication in AEC, at the average, at 4.11. However, from the actual condition, the respondents scored it at the average, at 3.56. In regard to the infrastructure of information technology service to support communication in AEC, the respondents had the average expectation at 3.97, however, from the actual condition, they scored it at the average at 3.42.

IX. CONCLUSION

Findings from the research on the readiness of information technology of Rajamangala University of Technology Phra Nakhon to support educational communication in AEC showed that there was the use of various system of information technology for researching and communication through LAN and WiFi. There were some problems of connecting internet as it frequently disconnect. In regard to equipment in classroom, there was the readiness in all aspect, however, there was some technical problems during teaching and learning. The users would report to IT staff to resolve problem.

The researcher gives the suggestion on the solution of the stability of internet, both for LAN and WiFi. Further, the instructor should have self-development constantly in terms of information technology training and basic solution. Training on new information technology implementation should be organized for the personnel of Faculty of Business Administration in order to enhance knowledge and understanding of using basic information technology.

ACKNOWLEDGMENT

The research was supported by the annual government statement of expenditure of Thailand (2017) (Thailand Budget Fund)

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Utilizing User Generated Contents to describe Tourism Areas of Interest

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***Abstract*—The use of available place databases (like GeoNames and traditional maps) to obtain descriptive keywords of a user-defined place is not possible because such data sources mainly maintain location definitions of the well-known places only. Traditional sources may not be updated dynamically and may not ensure diverse information. Additionally, they do not give any information on the popularity, e.g., which is more popular among the places indexed by the same keyword. A bottom-up approach, based on real user attention, can address these problems. We propose a method to describe tourism area of interest (TAOI) by aggregating user generated social media text. We match the co-occurrence of important keywords in a particular location and select such words to describe TAOIs. We applied the proposed method to data on micro blogging service Twitter and photo sharing service Flickr and confirmed that our method made it possible to extract TAOI description. The recommended bottom-up approach enables the extraction of valuable information that is not possible by using traditional top-down approaches.**

***Index Terms*—Tourism Area of Interest, Twitter, Flickr, TFIDF, User Generated Contents**

I. Introduction

Information is the most the valuable asset in the current world. Access to up-to-date information bout a place is always advantageous in any domain be it politics, disaster or tourism. Place databases like GeoNames [1] can describe well known places to some extents but they may not fulfill the quest for other places of interest which are newly formed or which contains user defined geographic extent. It is always good to refer dynamic and diverse data sources while describing such places. The unprecedented growth of user generated contents (UGC) , e.g. tweets, Flickr photos, leverage the use of such publicly available data to devise many novel applications [2]–[5]. Many of them are related to some kind of places of interest where people usually visit like landmark, park, mall, touristic spot, etc. Utilizing such UGCs to semantically describe such places by discovering relevant keywords is an interesting topic for research. Such works not only provide a summarized aspects of a place for general public but also help in understanding representative views useful for a particular scenario like tourism, social events, etc.

This study focuses on tourism domain, and aims to generate such description for assisting travelers to understand a particular tourism area of interest (TAOI). The focus is not only to reveal important keywords but also to provide clues about the reason of popularity, and assist the travelers in selecting and rejecting places while planning travel itinerary.

A. Problem Scenario

It is important for the travelers to have a representative view of their travel destination. This study explores two different scenarios discussed below:

1) *How can a traveler decide if a TAOI is worth visiting?* Travelers may check traditional sources like maps to identify tourist places and visit the areas. However, such maps may not provide diverse information. Most importantly it may be biased based on the knowledge of the publisher. The spots in the tourist maps may not provide a clear idea of the popularity of the different tourist spots. For example, Tourist map of Pokhara show places like "Sarangkot" as tourist spots but other details may not be available. It is essential to know popular keywords which can identify the important aspects of those TAOI. Moreover, some emerging TAOIs may have custom geographic extent and hence enough information may not be available via traditional data sources.
2) *How to plan itinerary?* While in Pokhara if the tourist want to have a good view of "Mount Annapurna" where can he go? For example, the mountain can be seen from "Lakeside" but it may be better from "Sarangkot". This can be known by following the experienced advice of majority of the viewers. For example, mountains can be seen from "Lakeside" but it may be better from "Sarangkot". However, if the tourist want to save time and budget then he can avoid traveling to Sarangkot and get the view from "Lakeside" while observing "Phewa Lake".

The proposed approach aims to solve such problems by identifying important TAOI keywords which have gained attention from majority of the visitors.

B. Solution Approach

The main goal of this study is to find a set of semantically meaningful keywords that can uniquely characterize the TAOIs. We start with tweet clusters which are are identified as TAOI. Next, descriptions of the Flickr photos and the Twitter messages posted in the vicinity of the obtained TAOIs are

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used to extract descriptions. Our hypothesis is based on the assumption that important keywords that describe a place can be derived from the UGCs posted by majority of the people in the vicinity of the place. We exploit Natural Language Processing algorithms like Term Frequency and Inverse Document Frequency (TFIDF) to discover relevant keywords for each TAOI. Our method is based on bottom-up approach unlike traditional GIS databases created with top-down approach. The approach is diverse and dynamic as it enables bottom-up approach where the general public contribute in the content generation. This is because social media sites like Twitter and Flickr are consistently reachable across the world and anyone can provide their opinion and experience in such media unlike traditional print media which may be biased based on the publishers opinion. The contributions of this work are as follows:

1) Identifying representative keywords:
   We attempt to automatically extract the TAOI descriptions based on dynamic and diverse sources. Additionally, unlike traditional sources our approach gives more weight to the keywords with more user attention.
2) Determining unique and related aspects:
   This study helps in identifying the unique and similar aspects of a particular TAOI in relation with other TAOIs. This helps in itinerary planning for the traveler, so that they do not miss/repeat desired features.

II. Related Works

The motivation of this work is to ultimately describe TAOIs, by analyzing UGCs from that have been contributed spontaneously by Twitter and Flickr users. Many studies have been conducted in the past to extract the semantics of a place using various information sources. Jiang et al. [6] in their work "Travel recommendation via author topic model based collaborative filtering" utilized social media text for extracting user preferences regarding a tourism region. They proposed an Author Topic Collaborative Filtering (ATCF) method to facilitate comprehensive POIs recommendation for social media users. The topics about user preference (e.g., cultural, cityscape, or landmark) were extracted from the textual description of photos by author topic model. Daniele et. al. [7] published their work "The Shortest Path to Happiness: Recommending Beautiful, Quiet, and Happy Routes in the City" by utilizing social media text for extracting different aspects of travel route. They worked for automatically suggesting routes that are not only short but also emotionally pleasant. To quantify the extent to which urban locations are pleasant, crowd-sourced data were used. For instance, they compared two street scenes in London base on user votes to quantify which street looks more beautiful, quiet, and happy. Bui et.al. [8] proposed an approach to generate description for POIs by using geo-tagged data from Flickr. To generate description for a POI, they proposed a tag clustering method to discover topics to describe characteristic of the POI. Majid et. al. [9] proposed a way to give semantic meanings to locations by using textual tags annotated to flickr photos in combination with the information provided by Google Places. Along with the name and type of POI obtained from Google service, they also applied text processing techniques to determine a matching textual name of the place. descriptions and category for tourist locations. Korakakis et. al. [10] completed a study on "exploiting social media information toward a context-aware recommendation system". They utilized the user generated text from Flickr to extract areas-of-interest within a given city along with their underlying semantics. Representative textual tags were identified for each place (i.e. cluster derived from geo-tagged Flickr image locations) using the co-occurrence relation between the photos and textual tags.

As discussed above, different methods have been in use to describe (or name) a place of interest based on unstructured and semi-structured data from crowdsourcing. Our proposed work ensure the use of more diverse data and also synthesizes more useful end information. Majid and his team [9] proposed a scheme to estimate a representative name of an tourist attraction mainly based on the name of any POI located at the central of the area. If no POI is found, then geotagged Flickr photos in the region were examined and any photo tag with highest TFIDF score was nominated as the name of the spot. However, the name chosen in this way may not always be representative. Bui et. al. [8] employed tag clustering method to describe POI form web photos but they do not focus neither on custom regions like TAOIs nor their relationships. Moreover, most studies [8]–[10] used text from a single data source only, i.e. Flickr. The main focus of Flickr is publishing images rather than textual expressions and several images lack descriptions. Hence, we tried to integrate data source with a focus on text data like Twitter. This not only ensure more representative user opinion but also availed more data essential for applying different statistical and machine learning algorithms. Besides this work, reveals the uniqueness and relatedness of different TAOIs in a given geographic region.

III. Methodology

Figure 1 shows the general methodology followed in this study. Free streaming tweets are collected as described in our previous work [11], raw tweets were collected and stored using Twitter's Streaming API. Also, we have illustrated that the tweet data collected as such can provide useful insights [18], [19]. Similarly, Flickr data were collected using their respective API. Next, the raw data were pre-processed so as to obtain clean geo-tagged data within the target region. Then, important tourism areas were identified and finally, representative keywords for each TAOIs were estimated.

A TAOI t can be defined as $t = (location, keywords)$. Geo-tagged Twitter and Flickr data signify that the user was present at certain point on the earth surface. However, a TAOI is much larger than a point. It is essential to approximate the geographic boundary of a TAOI wisely. A simple way to delineate the extents of a TAOI is by referring to point of interests (POIs) and areas of interests (AOIs) from mapping services like OpenStreetMap (https://www.openstreetmap.org/). However, a more natural boundary of TAOIs can be obtained by identifying regions related activities as discussed in our previous study [13]. Hence, we identified the locations and extents of the TAOIs by applying DBSCAN clustering algorithm to the geo-tagged tweets. The main focus of the current work is on determining representative keywords for each TAOIs. The relevant keywords (e.g. name, category and other aspects) are identified by integrating user attention as well as semantic analysis of the social media texts. Semantic annotation of TAOIs are done by finding their representative term based on collective social knowledge mined from popular geo-tagged social media data.

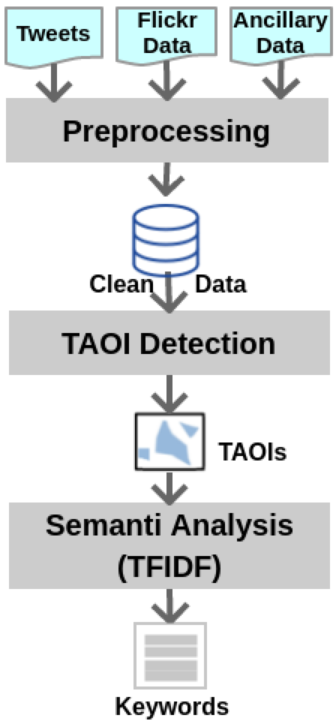

Fig. 1. Overall Method to estimate Keywords

A. Data collection and pre-processing

The increased use of social media sites like Twitter and Flickr have availed an unprecedented volume of publicly available data. Social media sites can be accessed worldwide and anyone can publish their opinions anytime. This research is carried out by using geo-tagged data over a well-known tourism destinations in Kaski district of Nepal, i.e., Pokhara City. Kaski district lies at the centroid point of Nepal and lies within the bounding box from (83.70 longitude, 28.08 latitude) to (84.28 longitude, 28.61 latitude). This district has an area of 2017 square kilometers and its population was estimated to be 492,098 based on the 2011 Census. The Ministry of Federal Affairs and General Administration have listed Pokhara as the only urban municipality in the entire Kaski district (http://mofaga.gov.np/) . Also, Pokhara is considered as the tourism capital of Nepal. This study focused on exploring and examining the social media activities in Kaski district.

We chose Twitter and Flickr for this study as they have a simple and well-defined public interface for extracting data. Twitter is one of the most popular social networking sites as well as a micro-blogging site. Twitter provides a platform for online users to share a text message up to 280 characters which is popularly known as a tweet. The popularity of Twitter in the research and academic community is attributed to various characteristics such as message size, metadata, availability and accessibility [14]. During the recent years, huge amount of geo-tagged Flickr data have been analysed which have catered a range of meaningful research outcomes in various domains like information retrieval, travel and tourism, tag recommendation, human activity tracking and so on [17]. Though the main focus of Flickr is sharing photos, users normally share a short descriptions as well. It is noticeable that a majority of cameras used by Flickr users are smartphones and consumer or entry level SLR cameras. All the data and related metadata (e.g. photo, description, geo-tag) can be easily obtained using the Flickr API. Hence, Twitter and Flickr geo-tagged are found to be accessible and act as a good source for spatio-temporal investigation.

Data collection was performed via respective APIs published by Flickr and Twitter. Table I provides a summary of tweets and Flickr data collected for this study. Such data are often "polluted" with other non-relevant elements such as ASCII art, numbers, URLs, etc. Data pre-processing is an essential activity done to eliminate such noisy elements. Retweets, user mentions, emotions, html tags, links, stop words, special symbols, URLs, punctuation, etc. were cleared so that dataset could be standardized. Word lemmatization and word lowercasing were performed so as to minimize sparsity. At the end of the pre-processing step, we retain only English language nouns with word length greater than two.

TABLE I
SUMMARY STATISTICS SOCIAL MEDIA DATA COLLECTED FOR KASKI DISTRICT

	Twitter	**Flickr**
Period	March 2017 - June 2019	Feb 2004 - June 2019
Geo-tagged Data	9587	15105
Points within TAOIs	5241	4029

B. Term Frequency and Inverse Document Frequency

In a collection of social media text, words with the high weight provide more representative information about a TAOI. This weight is a statistical measure used to evaluate the importance of a word that appear in a tweet or Flickr description in relation to the entire corpus. Term Frequency and Inverse Document Frequency is a technique that measures such importance of a word in a given document. Although this method is based on the frequency approach, it is different from other popular methods like bag-of-words approach because TFIDF not only considers the occurrence of a word in a single document (or tweet and Flickr text) but also considers its occurrence in the entire corpus. TFIDF takes care of merely common words in all the documents by assigning them lower weights and assigning more weights to words which are scarce in the entire document corpus but appear only in few documents. The normalized TFIDF scheme is used for keyword weighting scheme.

$$TF = \frac{w_d}{w_T}$$

where w_d is the number of times noun word w appears in a document d. w_T is the number of nouns in the document d. The notion of TF assigns more weight to the nouns which have gained more attention from the social media users. Only nouns were selected because they have been successful in providing aspects level information in various previous studies [15], [16].

$$TDF = log(\frac{N}{df_w})$$

where, N is the number of documents and df_w is the number of documents a word w has appeared in.

$$TFIDF = TF * IDF$$

In order to acquire good results with TFIDF, a huge corpus is necessary. The top k-nouns which have the highest TFIDF scores are considered as the representative keywords for the TAOIs. Hence, we are capable of identifying a set of keywords which are semantically related to each TAOI. By employing this technique we are able to accumulate a varied set of keywords that can relate and also distinguish a TAOI with other.

IV. Results and Discussion

The proposed technique is applied to describe a touristic region using geo-tagged social media data. This section illustrates the results obtained by applying the proposed method in Kaski district of Nepal. The locations and extents of each TAOIs in Kaski districts were obtained using DBSCAN clustering algorithm as described in our previous study [13]. Next, we chose some popular touristic areas in the region for further exploration. For example, Lakeside (i.e. TAOI_1) is one of them. It has the most concentration of tourism activities in the surrounding areas of Phewa Lake and hence it was developed as the centre of the entire region [18]. A total of 2085 geo-tagged tweets and 2797 geo-tagged Flickr images were collected within the extent of this TAOI. Other details of the selected TAOIs are listed in Table II.

A. Top ten keywords

Figure 2 shows the top ten keywords selected by the proposed method. The keyword in red color are unique to each TAOI only. It is notable that "nepal" and "pokhara" occur in all the TAOIs. This is reasonable because all the TAOIs are located in Pokhara, Nepal. The word "lakeside" is present only in TAOI_1 but not in other TAOIs and this is valid because it is the real name of TAOI_1. Similarly, the most important tourism feature of TAOI_1, i.e. "Phewa Lake", is represented by keywords like "phewa" and "lake". The direct view of Mount Annapurna as well as its reflection in the lake water can be seen clearly from TAOI_1 and hence the keyword "annapurna" is significant. The keywords "beautiful" and "view" signifies that the expressions of the visitors while observing these places. As evident from Table II, this TAOI has the most photo shared in the entire region, and hence the keyword "photo" justifies its appearance in the top ten list. Also, the word "trekking" is relevant because TAOI_1 has many trekking agencies and almost all travellers stay in this place before and after trekking in regions like "Annapurna Base Camp". Similarly, the keywords selected for other TAOIs are also relevant because they express either the location name (e.g. Sarangkot, Davis Fall), views (e.g sunrise point, annapurna, mountain, himalaya), landmarks (Buddha and Mahadev temple, Gupteshwor cave, etc) or other facilities like cafe.

Figure 3 shows the common keywords among the selected

TAOI_1	TAOI_10	TAOI_19	TAOI_27
pokhara	pokhara	nepal	**falls**
lakeside	nepal	pokhara	**davis**
nepal	photo	**sarangkot**	**cave**
lake	annapurna	view	pokhara
photo	travel	**sunrise**	**mahadev**
phewa	lake	**invisible**	nepal
annapurna	himalaya	annapurna	**gupteshwor**
trekking	mountain	**point**	photo
beautiful	**buddha**	himalaya	**water**
view	**cafe**	mountain	travel

Fig. 2. Top ten keywords (Keyword in red color are unique to each TAOI)

TABLE II
SUMMARY OF SELECTED TAOIS

Place (TAOI)	Tweet	Flickr	Description
Lakeside (TAOI_1)	2085	2797	- An intense concentration of tourism in the surrounding areas of Phewa Lake [18]. - Top attraction in Pokhara [19]. - Other aspects (hotel, restaurant, cafe, travel Agent; convenience stores, ATMs, etc)
World Peace Pagoda (TAOI_10)	88	63	- Panoramic views [18]. - Top attraction in Pokhara [19]. - Other aspects (Buddha Stupa, cafe, restaurant, trekking route, etc)
Sarangkot (TAOI_19)	56	241	- Panoramic views [18]. - Top attraction in Pokhara [19]. - Other aspects (sunrise view, cafe, restaurants, trekking route, etc)
Davis Fall & Gupteshwor Cave (TAOI_27)	79	141	- Amazing waterfalls, near the Fewa Lake and Lakeside area [18]. - Top attraction in Pokhara [19]. - Other aspects (Mahadev Temple, cave, restaurants, shops, etc)

	TAOI_1	TAOI_10	TAOI_19	TAOI_27
TAOI_1	10	5	3	3
TAOI_10	5	10	5	4
TAOI_19	3	5	10	2
TAOI_27	3	4	2	10

Fig. 3. Relatedness of TAOIs based on common keywords

”TAOIs” from the top ten keywords. As depicted in 2 TAOI_1 shares five common words with TAOI_10 (i.e. pokhara, nepal, lake, photo, annapurna). Similarly, TAOI_1 share three common words with TAOI_19 and TAOI_27. This information regarding the common keywords among the TAOIs is very helpful. For example, Mount Annapurna can be observed from TAOI_1, TAOI_10 and TAOI_19. If a tourist wish to see the mountain, he can just visit any one of the TAOIs. This information will be helpful in optimizing their travel plan.

B. Comparison with selected keywords

Figure 4 shows a comparison among the selected TAOIs against a list of important keywords related to the selected TAOIs. The list of keywords was compiled by the local tourism experts. The TFIDF values of the keywords reciprocates their importance in the respective TAOIs. Important observations are listed below:

- All these TAOIs are situated in Pokhara city. Hence, the word ”pokhara” have high TFIDF in all the TAOIs.
- TAOI_1 is called ’Lakeside’. It is famous for ‘phewa lake’ so TFIDF scores of ”lake”, ”lakeside”, ”phewa” are better than that of ‘mountain’ ,‘view’ or ‘annapurna’.
- TAOI_19 is Sarangkot. It is mainly known for “sunrise view” and mountain view like Mount Annapurna range. The word scores represents this information well.
- TAOI_10 is World Peace Pagoda and have Lord Buddha Stupa as the main feature. A distant view of the Stupa is observable from TAOI_1. The value of the words ”stupa” imply accordingly in the respective TAOIs.
- TAOI_10 have the Lord Buddha “Stupa” and also offers the view of mountains and lake. And hence are the respective TFIDF scores.
- For all the visitors TAOI_1 is the choice for hotel and restaurants.
- TAOI_19 offers nice ‘sunrise view’ and ‘annapurna mountain view’ than other TAOIs so the TFIDF in TAOI_19 is better than that of other TAOIs.
- Paragliding is a favorite activity among the tourists in Pokhara. It starts from Sarangkot (i.e. TAOI_19) and ends at Lakeside (i.e. TAOI_1).
- TAOI_19 is known for waterfall (i.e. Davis Fall). Gupteshwor Cave located in the vicinity of the waterfall is another popular destination.

Upreti et.al. stated that Lakeside have been developed and emerged as the tourism center of Pokhara [18]. Accordingly, it is noticeable in this comparison that, the TFIDF score of the keywords related with other TAOIs have also established their relation with TAOI_1. This is justifiable, for e.g., many people who visit any of these TAOIs (like waterfall in TAOI_27 or sunrise in TAOI_19), consider staying and dining in hotels and restaurant in TAOI_1.

Keyword	TAOI_1	TAOI_10	TAOI_19	TAOI_27
pokhara	0.090542	0.110646	0.105445	0.066937
lakeside	0.059656	NaN	NaN	NaN
lake	0.027778	0.027231	NaN	NaN
phewa	0.017845	0.016249	NaN	NaN
annapurna	0.015008	0.034887	0.057692	NaN
view	0.008534	0.016524	0.074450	0.008263
hotel	0.008077	NaN	NaN	NaN
paragliding	0.006279	NaN	0.038685	NaN
mountain	0.003901	0.025504	0.046797	NaN
sunrise	0.002764	NaN	0.060801	NaN
sarangkot	0.002106	NaN	0.101858	NaN
stupa	0.001888	0.019537	NaN	NaN
cave	0.001038	NaN	NaN	0.069346
restaurants	0.000748	NaN	NaN	NaN
waterfall	0.000368	NaN	NaN	0.019959

Fig. 4. Comparison of TFIDF values of important Keywords in different TAOIs (NaN means no data presence)

C. Comparison with frequent nouns from TA

In this section, Mann-Whitney U test is used to examine the similarity between the selected keywords and another independent list of keywords from another data source. This test is widely used to compare the similarity between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

Popular travel website, TripAdvisor.com, is a largest online network of travel consumers and provides user-generated content from the travelers. By analyzing online user reviews on TripAdvisor, frequent nouns were collected by employing word count analysis in each TAOIs. The Skip-Gram version of the word2vec algorithm [20] was applied to obtain word frequency from TripAdvisor reviews. The frequency score is normalized based on the total word count. The normalized score of each word obtained by examining the TripAdvisor reviews is assigned to the top 10 keywords obtained in Section IV-A. Next, this top 10 keyword list is compared against the top 10 noun list from TripAdvisor using Mann-Whitney U test. For statistical significance at a significance level of 0.05, the accepted range of Z and U values are [-1.9600 :

TABLE III
COMPARISON OF TOP 10 KEYWORDS AGAINST FREQUENT WORDS FROM TRIPADVISOR REVIEWS FOR TAOI_1

Tweet/Flickr		TripAdvisor	
pokhara	0.019	*lake*	0.203
lakeside	0.005	*boat*	0.055
nepal	0.000	*phewa*	0.049
lake	0.203	*beautiful*	0.047
photo	0.000	*temple*	0.036
phewa	0.049	*place*	0.036
annapurna	0.005	*views*	0.025
beautiful	0.047	*pokhara*	0.019
trekking	0.000	*middle*	0.019
views	0.025	*enjoy*	0.016
Z = -1.542280			
U = 29			

1.9600] and [23.0000 : 77.0000] respectively. As illustrated in Table III, it is observed that TAOI_1 passed the significance level. Similarly, TAOI_19 (i.e. Z=0.629764, U=59) and TAOI_27 (i.e. Z=1.699582, U=73) scored significant values whereas TAOI_10 (i.e. Z=3.711940, U=94.5) could not obtain the significance level. The ccarcity of social media data for TAOI_10 (refer Table II) in comparison with other TAOIs may be the reason for the poor U scores. It is essential to have sufficient amount of text data to ensure the generation of relevant keywords. If the input corpus is small and there is the presence of irrelevant noisy text then this may lead to the generation of more insignificant results.

V. CONCLUSION

The proposed method could generate description for TAOIs by using Tweet and Flickr text. The process of describing TAOI suffers badly in scarcity of sufficient input data. The inherent characteristics of social sharing sites like Flickr and Twitter encourage their users to summarize their views in fewer text. Hence, we proposed to integrate the text data from multiple sources to generate better TAOI description by applying TFIDF based scoring scheme. We examined the effectiveness of our method by examining the extracted keywords against TAOI specific words for four popular TAOIs in Pokhara City. Also, we compared the keywords generated from the proposed method with the list of frequent nouns collected from another independent data source, TripAdvisor using standard Mann-Whitney test. The result indicates that our method has shown its advantage in deriving representative words which relate to the tourism aspects of the place. The proposed approach may not work well in places with less social media reach. Additional improvements will be done in the future by including data from other sources and comparing the results with that of Geonames and traditional maps. Further, refinements are thought to be made in selecting keywords based on their freshness e.g. assigning more weight for recent keywords than older ones.

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Improvement of TD-TR Algorithm for Simplifying GPS Trajectory Data

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***Abstract*—Over the past decades, massive amounts of GPS trajectories have been obtained with the development of low-cost GPS enabled devices, capturing users' spatial and temporal information. The massive increase in trajectory data generates high storage and data processing burdens. Several of trajectory simplification algorithms have been proposed to overcome these difficulties. A key requirement in trajectories simplification is to minimize information loss while preserving the quality of the information. To further reduce the compression time, an improved algorithm for top-down time-ratio (TD-TR) called top-down time-ratio Reduce (TD-TR Reduce) is proposed. The algorithms were evaluated using several parameters, such as compression times and errors arising from trajectory data simplifications in the *Geolife* trajectory data set. The results of the simulation show that TD-TR Reduce can achieve an attractive trade-off between the compression rate and the simplification error with up to 33% lower compression time.**

***Index Terms*—GPS, Trajectory Data, Trajectories Simplification**

I. Introduction

Over the past decade, the number of GPS-enabled devices has increased significantly [1]. Due to the increasing number of GPS-enabled devices, such as mobile phones or in-car navigation systems, the volume of spatial and temporal information recording the footprint of a moving device has increased dramatically. The massive amounts of trajectory data could easily exceed the existing available data storage, which leads to three major challenges: storing, transmitting and visualizing the data. For example, a calculation due to Meratnia and de By [2] shows that without any data compression, storing a trajectory data of 400 objects per day at an interval of 10 seconds requires a storage capacity of 100 Mb.

While dealing with these massive amounts of trajectory data, an effective compression mechanism is one of the most key components of the storage layer. Many trajectory compression types have been introduced in the past. This can be divided into various methods of categorization, lossless compression and lossy compression or online compression and offline compression. The advantage of online compression is that it supports real-time applications, which can compress trajectory data while picking up new trajectory points. Only after all points are obtained from the input trajectory, offline algorithms soon begin to compress. However, offline compression usually has smaller errors compare to online compression. Lossless compression enables the original data to be reconstructed without loss of information, while Lossy compression is not possible. The main advantage of lossy compression is that it can significantly reduce the trajectory size while maintaining reasonable error tolerances.

This paper introduces an offline lossy trajectory simplification algorithm, by efficiently utilizing the feature extraction points and skip threshold, which results in a shorter compression time against the current state of the art compression algorithms.

The rest of this paper is arranged according to the following: Section II summarizes related work. Section III presents the metrics for evaluating the simplification algorithm. Section IV explains the feature point extraction procedure. Section V presents the proposed trajectory algorithm in detail. Section VI discusses our evaluation results. Section VII describes our conclusion and future work.

II. Related Work

Several algorithms have been proposed to simplify trajectory data, different algorithms use different approaches to find a similar trajectory with fewer points. As for trajectory simplification, the current state of the art algorithm had been studied by zhang et al. [3] for both online and offline compression mode, providing a comprehensive evaluation of 25 trajectory simplification algorithms on 5 different data sets.

For offline compression mode, The well-known trajectory The Douglas-Peuker (DP) algorithm [4], compresses trajectory data by recursively divides the trajectory to decide which points should be retained according to user-defined perpendicular Euclidean distance (PED) threshold. Top-down time-ratio (TD-TR) [5] is an extension of the Douglas-Peucker, which uses Spatial Euclidean distance (SED) instead of PED. MRPA algorithm [6] is proposed to compress trajectories in O(N) computational time, where a new error metric called an integral square synchronous Euclidean distance (ISSD) was introduced.

For online compression mode, the Spatial QUalIty Simplification Heuristic Algorithm (SQUISH) [7] used a priority

978-1-7281-6435-9/19/$31.00 ©2019 IEEE

queue data structure. It compresses each trajectory by removing points from the priority queue that has the lowest priority until the desired compression ratio is achieved. Later, Spatial QUalIty Simplification Heuristic-Extended (SQUISH-E) was developed to ensure that the SED error is within a user-specific bound.

III. Metrics

This section describes the metrics for evaluating the simplification algorithm. In this study, the original trajectory T of length n is represented as a temporally ordered sequence of points $\{P_1, ..., P_n\}$, where each point $P_n(x_n, y_n, t_n)$ contains longitude x, latitude y and timestamp t

After the simplification, the simplified trajectory can be express as $T' = \{P_{s_1}, ..., P_{s_m}\}$ and $P_{s_n}(x_{s_n}, y_{s_n}, t_{s_n})$ where $m \leq n$ and $1 = s_1 < ... < s_m = n$

This section provides a comprehensive survey of both error metrics (Chapter III-A) and performance metrics (Section III-B) and a detailed discussion of these metrics (Section III-C).

A. Error Metrics

1) *Synchronized Euclidean Distance* (SED): The distance between the actual points P_k and its synchronized point $P'_k(x'_k, y'_k, t'_k)$ created by two points P_s and P_e at identical time stamps (see Figure 1) and can be calculated as follows:

$$SED(P_k) = \sqrt{(x_k - x'_k)^2 + (y_k - y'_k)^2}$$

$where$

$$x'_k = x_s + \frac{x_e - x_s}{t_e - t_s}(t_k - t_s)$$

$$y'_k = y_s + \frac{y_e - y_s}{t_e - t_s}(t_k - t_s)$$

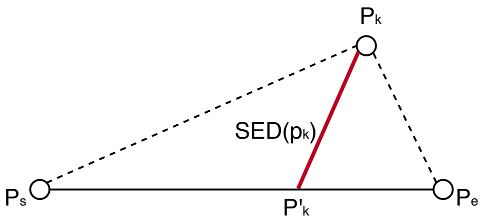

Fig. 1. Synchronized Euclidean Distance (SED)

2) *Trajectory Distance Reduction Ratio* (TDRR): Trajectory distance reduction ratio is the accumulated travel distance ratio of the simplified trajectory T' versus its original trajectory T and can be calculated as follows:

$$TDRR(T, T') = 1 - \frac{TDD(T)}{TDD(T')}$$

$where$

$$TDD(T_i) = \sum_{i=1}^{|T|-1} DISTANCE(P_i, P_{i+1})$$

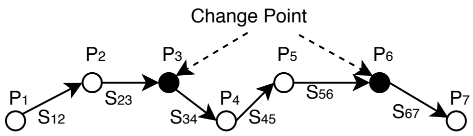

Fig. 2. Two speed change points

B. Performance Metrics

1) *Compression Ratio* (CR): Compression ratio is defined as the size of the simplified trajectory T' versus its original trajectory T and can be calculated as follows:

$$CR(T, T') = 1 - \frac{|T|}{|T'|}$$

2) *Compression Time*: Compression time is the amount of time taken for a trajectory to be simplified.

C. Discussion

The trajectory-simplifying algorithm's efficiency is defined as the combination of error metrics and performance metrics. For the further improvement of error metrics, In order to measure the average time-synchronized euclidean distance between the original trajectory T and its simplified trajectory T', we introduce Average Synchronized Euclidean distances (ASED). The ideal simplified trajectory should be highly compressed with minimum compression time, TDRR and ASED. (see Figure 3)

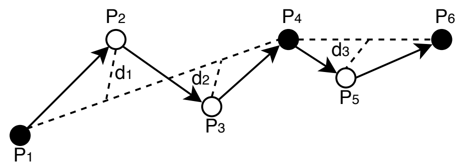

Fig. 3. Example of calculating ASED. Given Trajectory $T = \{P_1, P_2, P_3, P_4, P_5, P_6\}$ and simplified trajectory $T' = \{P_1, P_4, P_6\}$ ASED is calculated as $(d_1 + d_2 + d_3)/2$

IV. Feature Point Extraction

Some GPS tracking point is redundant in some applications. To retain only the important part where some events occur (e.g. travel mode transition), we proposed a feature point extraction model with a focus reducing the trajectory data based on several of the movement characteristics given as follows.

1) *Movement Speed*: In the transition mode, node movement speeds typically change significantly [8], this includes walking, cycling, driving vehicles or taking the train. As shown in Figure 4, The feature node is the place where the node changes transportation mode from driving to walking.
2) *Heading*: The heading changes accordingly to the current modes of transport. For example, when the mode of transport is walking rather than another mode of transport, the heading will change very often.

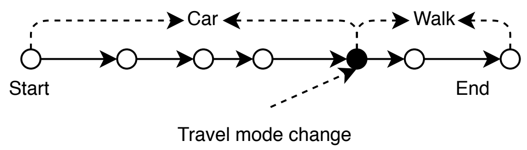

Fig. 4. Transition of transportation mode

In order to obtain the above-mentioned node points, we propose a process for the extraction of the feature points. To detect a feature point caused by switching between transportation modes. First, we specify the difference of movement speed as $\triangle_{i+1} = |SP_{i+1} - SP_i|$, in which SP_i is an average speed in the line segment $\overline{P_{i,i+1}}$. When $\triangle_{i+1}$ exceeds a certain threshold, P_{i+1} is kept as a feature point. Because speed changes are usually caused by switches between travel modes (see Figure 4). We propose the usage of the standard deviation of movement speeds as the speed threshold since the standard deviation can indicate changes in velocity. The speed threshold SP_{th} is expressed as

$$SP_{th} = \sqrt{\frac{\sum_{i=1}^{n-1}(SP_i - \overline{SP})^2}{n-1}}$$

$where$

$$\overline{SP} = \sum_{i=1}^{n-1} \frac{SP_i}{n-1}$$

To detect a feature point caused by a significant change in the node heading. δ_{i+1} was defined as the heading different between θ_i and θ_{i+1} and can be calculated as follows:

$$\delta_{i+1} = \begin{cases} 360 - |\theta_{i+1} - \theta_i|, & if\ |\theta_{i+1} - \theta_i| > 180 \\ |\theta_{i+1} - \theta_i|, & \text{otherwise} \end{cases}$$

where θ_i represents the current heading on the line segment $\overline{P_{i,i+1}}$, that can be calculated using The haversine formula. If δ_{i+1} exceeds a certain threshold δ_{th}, P_{i+1} is kept as a feature point.

When the node travels in a straight line at a constant speed (e.g. highway, tollway), the entire point will be ignored from the two feature point extraction method mentioned above. In order to prevent the above scenario from occurring, we introduce the skipping threshold $skip_{th}$. When the number of points that are ignored from the feature point extraction method above reaches the skipping threshold, the point is kept as a feature point.

V. TD-TR Reduce algorithm

In order to reduce the compression time of the current TD-TR algorithm (see Figure 5), we propose a TD-TR Reduce algorithm to simplify the trajectory by performing a traditional TD-TR algorithm on a set of extracted feature points. The following procedure is provided in algorithm 1 below:

1) Add the first from T to the feature point array $T_{feature}$ (line 3)
2) Calculate the standard deviation of speed in T and set it as the speed threshold SP_{th} (line 4)
3) Starting from $i = 1$, iteratively add point p_{i+1} to the feature point array $T_{feature}$ and set $skip$ parameter back to zero if the movement speed different $\triangle_{i+1}$ is greater than or equal to speed threshold SP_{th} or the heading different δ_{i+1} is greater than or equal to heading threshold δ_{th} (lines 5-7)
4) If the n point was not added to the feature point array $T_{feature}$, increase $skip$ value by one (line 10)
5) If the the $skip$ value reaches the certain skip threshold $skip_{th}$, add point p_{i+1} to the feature point array $T_{feature}$ and set $skip$ parameter back to zero (lines 12-15)
6) Add the last points in T to the feature point array $T_{feature}$ (line 18)
7) Perform TD-TR algorithm on feature points array $T_{feature}$ and stored it as a simplified trajectory T'. (line 19)
8) Finally, the simplified trajectory T' is returned. (line 20)

Algorithm 1 TD-TR Reduce algorithm

Input: T = $\{p_1,...,p_n\}$, heading threshold δ_{th}, error threshold ε, skip threshold $skip_{th}$
Output: Simplified Trajectory T'

1: $T_{feature} = []$
2: $skip = 0$, $i = 1$
3: $T_{feature} = T_{feature}$ **APPEND** p_1
4: $SP_{th} \leftarrow$ SD of speed in T
5: **while** $i < n - 1$ **do**
6:   **if** $|\triangle_{i+1}| \geq SP_{th}$ **or** $\delta_{i+1} \geq \delta_{th}$ **then**
7:     $T_{feature} = T_{feature}$ **APPEND** p_{i+1}
8:     $skip = 0$
9:   **else**
10:     $skip = skip + 1$
11:   **end if**
12:   **if** $skip == skip_{th}$ **then**
13:     $T_{feature} = T_{feature}$ **APPEND** p_{i+1}
14:     $skip = 0$
15:   **end if**
16:   $i = i + 1$
17: **end while**
18: $T_{feature} = T_{feature}$ **APPEND** p_n
19: $T' = TDTR(T_{feature}, \varepsilon)$
20: **return** T'

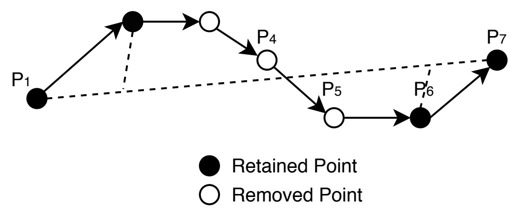

Fig. 5. TD-TR Algorithm

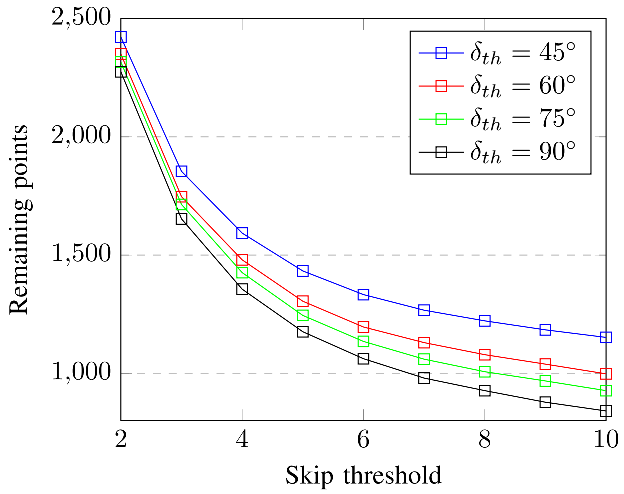

Fig. 6. Trajectory one

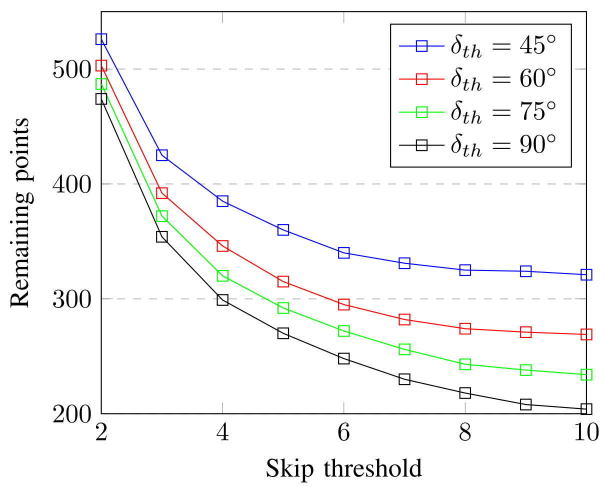

Fig. 7. Trajectory three

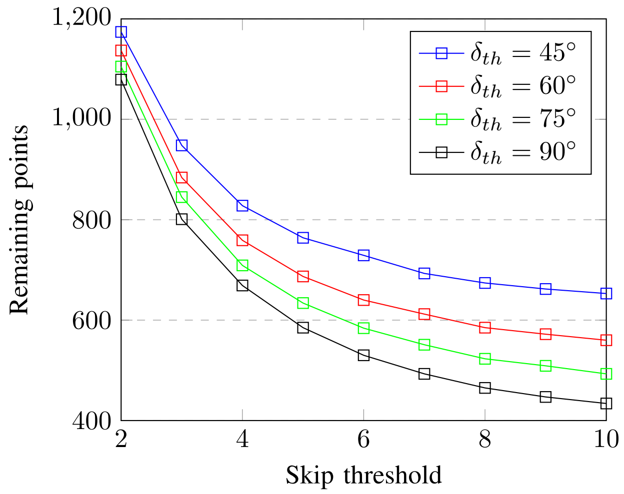

Fig. 8. Trajectory two

VI. Evaluations

This section introduces a dataset and then our proposed algorithms are evaluated on the basis of three aspects: compression ratio, compression time and error metrics. Finally, we discuss the results and summarize the performance of the proposed algorithms. Three algorithms (DP, TD-TR, TD-TR Reduce) were written in Python, while MRPA was written in Matlab. The experiment is conducted on Windows 10 with 4 CPU cores (Intel i7-7700K with 4.20GHz) and 32 GB RAM.

A. *Dataset*

The Geolife dataset was collected by 182 participants in the (Microsoft Research Asia) Geolife project [9] for five years (from April 2007 to August 2012). Different transport modes, including biking, walking and traveling, are included in the data set. Most of the data collection has taken place in China, Beijing. More than 90% of trajectories are collected in a dense format, e.g. every 1 to 5 seconds or every 5 to 10 meters per point. The data set was cleaned to remove trajectories with high noise such as large jumps in time and space.

B. *Experiment Settings*

For this simulation, three trajectories are chosen to observe the effect of $skip_{th}$ and δ_{th} on the number of remaining points. Figures 6-8 show the number of stop points under different heading threshold and skip threshold. The details of each trajectory are shown in Table 1. From Figures 6-8, the curve decreases dramatically when $skip_{th}$ increases from 2 to 3 and from 3 to 4. The curve starts to changes slowly when $skip_{th} \geq 5$, so we set $skip_{th} = 5$. On the other hand, the number of remaining points decreases significantly when δ_{th} change from 45° to 60° and starts to change constantly when $\delta_{th} \geq 60°$, so we set δ_{th} to 60°.

TABLE I
TRAJECTORY DETAILS

Trajectory ID	# of Points	Start	Stop
1	4,164	2009-02-20 04:01:36	2009-02-20 14:51:36
2	1,937	2008-10-28 23:51:59	2008-10-29 11:25:00
3	838	2009-02-24 12:16:55	2009-02-24 13:35:55

C. *Comparison of Trajectory Simplification Algorithm*

Our proposed TD-TR Reduce algorithm was compared against three other algorithms DP, TD-TR, MRPA) in terms of compression ratio, compression time and simplification error. To simulate the result, 25 trajectories are selected from the *Geolife* dataset and the trajectory details are shown in Figure 9. Figures 10-13 display the simulation results.

As shown in Figure 10, on compression time, DP outperforms other algorithms, while the compression time of MRPA is significantly longer than other algorithms. The reason could be that MRPA error metric (LSSD) requires higher computation cost. Furthermore, TD-TR Reduce achieve shorter compression time than both of TD-TR and MRPA. This is because the feature point extraction technique was adopted, which reduces the computational time significantly.

In Figure 11, with regard to the compression ratio, the plots of DP and MRPA are close to each other, while the plot of TD-TR and TD-TR Reduce are slightly lower. Meanwhile, TD-TR Reduce outperforms the traditional TD-TR algorithm.

Figures 12, illustrates that both TD-TR and TD-TR Reduce achieve much lower trajectory distance reduction ratio, while DP obtains the highest trajectory distance reduction ratio among all algorithms.

In Figures 13, the ASED error of DP is generally higher than other algorithms and the curves of TD-TR Reduce are slightly higher than Traditional TD-TR. Particularly, TD-TR always achieves the lowest ASED error.

Therefore, TD-TR Reduce makes a favorable trade-off between the compression ratio, the trajectory distance reduction ratio and the ASED error while having up to 33% lower compression time on large trajectory compares to the traditional TD-TR algorithm.

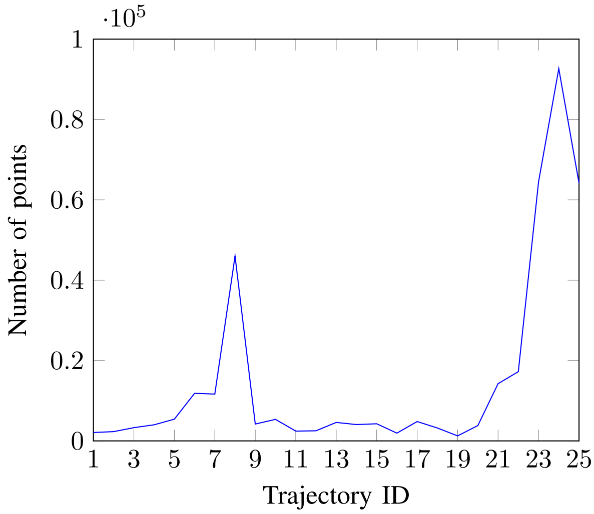

Fig. 9. Trajectory details

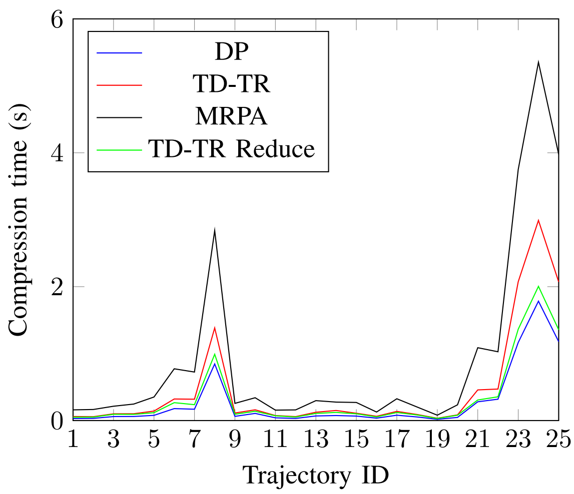

Fig. 10. Compression time

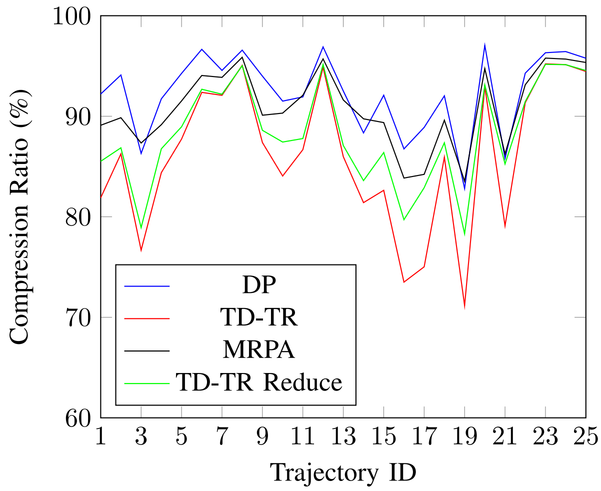

Fig. 11. Compression ratio

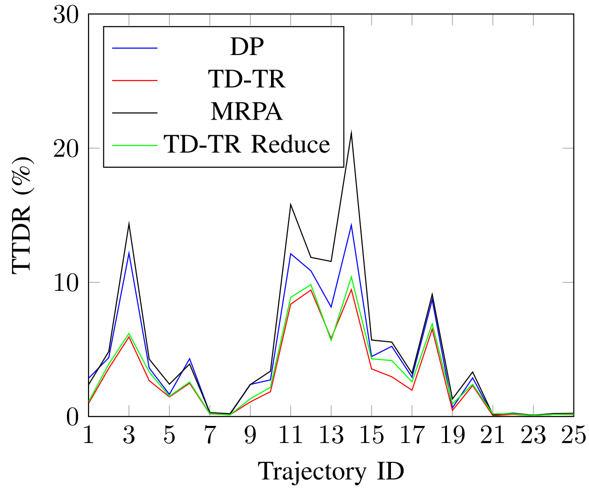

Fig. 12. Trajectory distance reduction ratio (TDDR)

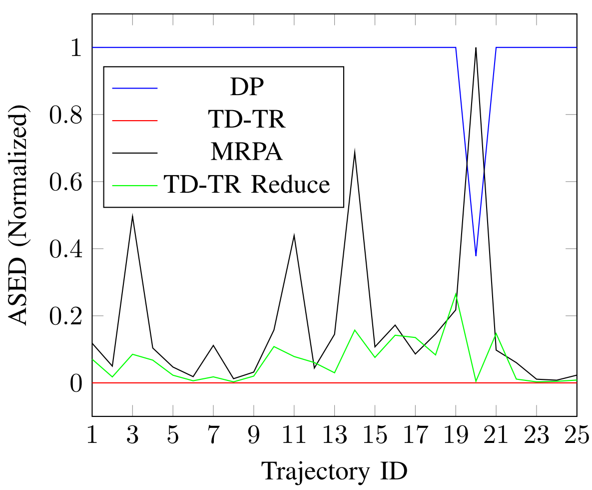

Fig. 13. Average SED error (ASED)

VII. Conclusion and Future Work

In this paper, we presented a new Trajectory Simplification Algorithm called TD-TR Reduce, which proposes a new method of data reduction based on the extraction of a feature point. Only the important points will be retained by using this data reduction method. The algorithm then performs the traditional TD-TR algorithm on the extracted feature point set. The experiments show that a favorable trade-off between the simplification rate, the distance reduction ratio and the ASED error with up to 33% lower compression time can be achieved through the proposed algorithm. Future studies should identify appropriate dynamic parameters for the heading threshold and skip threshold as well as investigate the effectiveness of TD-TR Reduce on different datasets.

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Effect of Public Transport Network on Urban Core and the Future Perspective in Bangkok, Thailand

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***Abstract*— City center is an essential components of urban structure that rules urban activities including economy, transport, and social interactions. In Bangkok, Thailand, the railway network is expanding** and the expansion **is expected to affect the city center locations. In this study we attempt to capture the effect of public transport network on the accumulation of three types of urban core facilities based on the spatial statistical approach, and estimate the future perspective of locations of those facilities. As a result we found that expected number of facilities in current urban core in Bangkok decreases and the number of facilities at stations on planned railways increases under certain conditions. The results can be utilized to estimate the future travel pattern and residential locations.**

Keywords—urban core, railway network, network centrality, point of interest, location probability

I. INTRODUCTION

Locations of center of city is one of the essential components of urban structure that rules urban activities including economy, transport, and social interactions. City centers are significant place of those activities where people, information, and traffic are concentrated, and most of world large cities are facing severe congestion problems. Bangkok in Thailand is one of those cities facing the worst level of traffic congestion and high rise of land rent at city center. In Bangkok the urban core functions like financial service and hotels for business conventions are highly concentrate at the city center that causes massive traffic flow into the area for commuting, business trips, as well as private activities including shopping and tourism. Since the opening the first urban railway BTS in 1999 and consequent provision of the other railways, the worst road congestions had been avoided by modal shift from road transport to railways. However those improvement stimulates the further agglomerations of the urban core functions and construction of those facilities in the spheres of train station which causes further traffic flow into the existing urban cores and congestions on both roads and trains.

Thai government endorsed the Mass Rapid Transit Master Plan (MMAP) in Bangkok Metropolitan Region in 2010 that designates 8 routes 556km by 2029. Currently 124km are in service and 169km are under construction [1]. As experienced in the other countries, provision or extension of railway line is expected to induce the urban development along the line and increase the access to the connecting stations to the other railways. When this accessibility improvement is enough high to attract demand for the railway users, it will induce the location of urban functions. The accumulation of these functions will form the sub-center. Therefore the future construction of planned railway network may trigger the emergence of new urban cores that would possibly disperse the concentrated activities on the existing urban core and may contribute to alleviate the congestion at current city center.

Our purpose in this study is to 1) capture the effect of public transport network on the accumulation of urban function in the city center and 2) estimate future perspective of urban cores induced by construction of planned railway network based on the captured mechanism. To represent the effect of public transport network, first we employ network centrality indices in graph theory. Using the indices we quantify the centrality of each station for current and planned railway network. Second we quantify the spatial accumulation of urban function based on the Point of Interest data for urban services. Third we analyze the effect of network centrality of the stations on locations of urban services considering the decay of centrality effect on the location by distance. Finally we estimate the future perspective of urban core locations under the planned railway network in MMAP.

II. LITERATURE REVIEW

A. Urban core formation

In reality urban cores in large cities are formed in the complex system of urban activities composed by the stakeholders and agents including firms, household, government and their behavior of location choice, travel, trade and interaction each other. Studies in new economic geography [2-4] have tried to investigate the conditions of emergence of the polycentric urban systems, however those researches do not warrant to represent the observed polycentric agglomeration forms in geographical space[5].

B. Captureing urban core

Capturing the urban centers itself is still a research topic to be challenged. The definition of city center does not get consensus yet and various ways to detect the city center including using remote sensing of night time light [6], 3D city models [7], human activity pattern [8] and spatial statistics of employment [9]. These researches represent the urban centers recognized experimentally, that implies there are substantial correlation between those observed indices even though the

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availability of data usage and spatial resolution are quite different each other.

C. *Application of network theory in transportation*

Network theory is applied to public transport network to examine its robustness [10], vulnerabilities [11] and reliability [12]. These studies checks the features of the public transport network under the malfunction of some nodes and links. Other studies analyzed relationship between network indices and its size [13], features of evolution of subway network structure [14], as well as the complexity of the subway network [15,16]. These studies are trying to capture generalized network features and only considering the network itself and no consideration for surrounding urban component like land use, population or locations of urban facilities.

Jayasinghe et al. [17] tries to explain the trip attraction by centrality indices of road network taking the case of Colombo. Their regression analysis resulted that the R-square of trip attraction estimation for calibration data is about 0.78-0.79 and for validation data is about 0.76-0.79. It is quite good representability of the trip attraction only using the simple network indices and it would suggest of that some network centrality indices can be applicable for the analysis of urban activities and projection of future urban core locations.

D. *Scope of this study*

Our interest is projection of future perspective of emerging urban cores with railway network expansion. New economic geography models have economic fundamentals for the analysis however further elaborations are needed for the application in the fine resolution of urban space.

In this study we take similar approach with Jayasinghe et al. to estimate the impact of railway network expansion on the location of urban functions that consist urban cores.

III. METHOD AND DATA

To estimate the locations of urban functions, we take following step for the analysis in this study; first we estimate the network centrality indices using current railway network data and estimate the indices for each station; second point of interest (POI) data are counted on the geographical grid system; third estimate stochastic location model parameters using these two dataset considering distance decay between station and the land grid; and finally applying planned railway network to the stochastic location model we estimate the expected number of urban function locations under current and planned railway network and its change. This analytical steps are summarized in Fig. 1. Details of method and data are described in the following subsections.

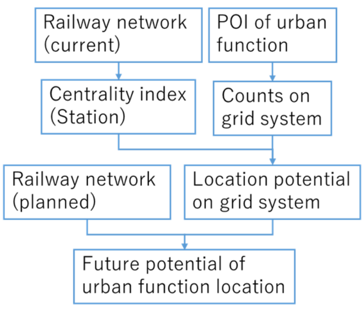

Fig. 1. Analytical flow

A. *Method*

We use "closeness" and "betweenness" as centrality indices to represent the centrality of stations on the railway network. These indices are calculated by following equations.

Closeness
$$C_C(i)=\left(\sum_{j=1}^{n} d_{ij}\right)^{-1} \tag{1}$$

Betweenness
$$C_B(i)=\left(\sum_{i\neq j\neq k}^{n} g_{jk}(i)/g_{jk}\right) \tag{2}$$

Where n is number of stations, d_{ij} is network distance of shortest path between station i and j, g_{jk} is number of shortest path between station j and k, and $g_{jk}(i)$ is number of shortest paths going through station i.

Here the centrality represents a kind of accessibility to the other stations on the network, therefore location surrounding the station with higher centrality is expected to have higher value to locate for urban functions. We assume the location value of land decays according to the distance from the station and the total location value of land j is expressed by following equation.

$$q_j = C(i)\exp(\theta \cdot d_{ij}) \tag{3}$$

Where d_{ij} is distance between station i and land j, i is the nearest station from location j (i=argmin($d_{ij}\leq d_{i'j}$ | $\forall i'$)), q_j is land value, $C(i)$ is centrality index, and θ (<0) is distance decay parameter.

Here we assume that land slot is represented by grid system and each grid has same area. Number of facilities in a grid j is assumed to be random variable from exponential distribution.

$$p_j(n)=\lambda_j\exp(-\lambda_j \cdot n_j) \tag{4}$$

Where n_j is number of facilities locate in the land grid j. Mean of this distribution is $1/\lambda_j$, and we assume that as higher the land value q_j, higher the expected number of facilities. Therefore $\partial\lambda_j/\partial q_j<0$. We assume following relation between λ_j and q_j.

$$1/\lambda_j = \alpha_1 q_j^{\alpha_2} \tag{5}$$

Where α_1 and α_2 are parameters ($\alpha_1>0$, $\alpha_2>0$).

If d_{ij} and n_j is given, parameters θ, α_1, α_2 can be estimated by maximize following log-likelihood function.

$$LL=\log\lambda_j(\theta,\alpha_1,\alpha_2)-\lambda_j(\theta,\alpha_1,\alpha_2)\cdot n_j \tag{6}$$

B. *Target region and data*

In this study we focus on the impact of railway to the urban function location taking the case of Bangkok, so we set the analytical boundary to the rectangular region where the whole current and planned urban railway network is contained. In detail, first we set a geographical boundary based on the existing and planned stations, and the analytical boundary is set by expanding 5km to north-south and east-west directions. Fig. 2 shows the target region and current and planned railway network. Current railway has 104 stations and additional 175 stations are planned.

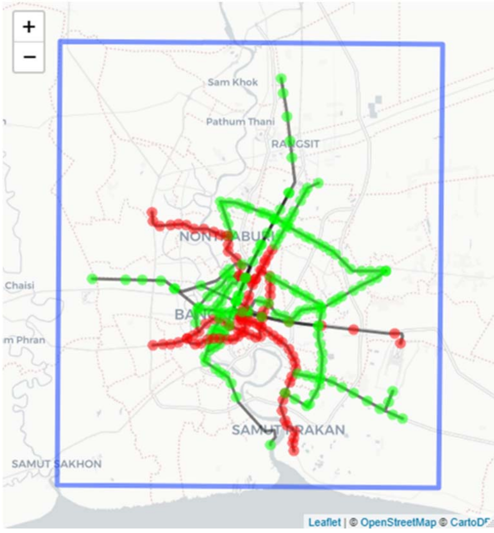

Fig. 2. Target area. (*blue box: analytical boundary, red dot: stations in operation, green dot: stations in plan*)

Number of urban core facilities are obtained from POI data in MapFan DB by Increment P Corporation. As type of urban core facilities, we use location data of hotels, banks and office buildings. Fig.3 shows the heat map of locations of those facilities on the 100m×100m spatial resolution and band width 1000m . Its color scales are different by type of facilities. They have similar tendency to agglomerate at city center but in detail their peak locations and dispersion patterns are different.

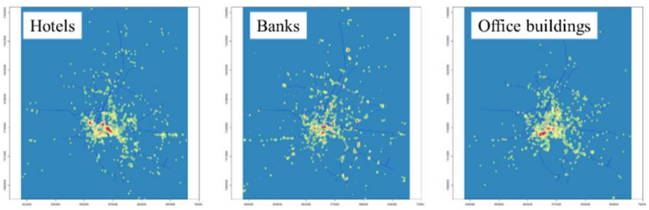

Fig. 3. Heat map of urban core facilities. (*left: hotels, middle: banks, right: office buildings*)

IV. RESULTS

A. Network centrality of stations

Using equation (1) and (2) closeness and betweenness centralities are calculated. These equations are the original definitions of network centrality, however those indices depend on scale of network. When number of nodes increase the closeness will decrease and betweenness will increase. To compare the current and planned network, we adjust future network by multiplying the ratio of number of stations of current and planned networks. Denoting n_0 and n_1 as number stations of current and planned network respectively, we multiply n_1/n_0 to closeness and n_0/n_1 to betweenness for planned network.

Fig.4 shows the centrality indices for current and planned network. These two indices have different evaluation of stations in detail but in overall central area stations tend to have higher index value in current network. In planned network, stations in current urban core continues to have high centralities while some of the planned stations outside current urban core also have quite high centralities especially at the crossing points of different rail lines.

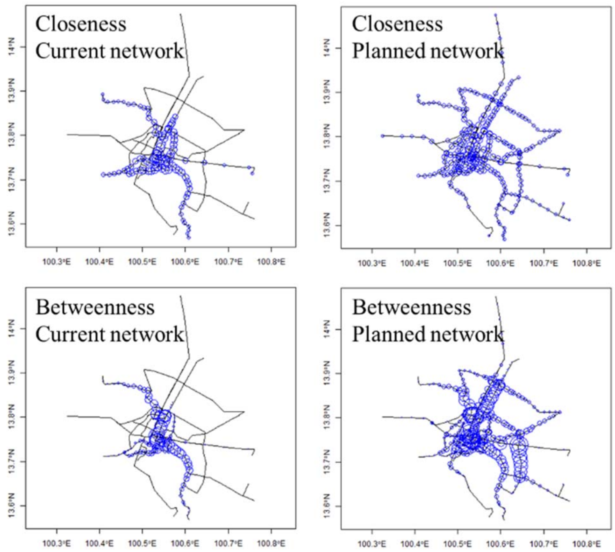

Fig. 4. Network centralities for current and planned networks. (*top: closeness, bottom: Betweenness, left: current network, right: planned network*)

B. Location model parameter estimation

Using the current network centralities, we estimate the location model parameters for three types of urban core facilities based on equation (6). Table 1 shows the estimated parameters, their t-value and likelihood ratio test statistics. Parameters for office location model using betweenness were not able to estimated correctly because the final hessian matrix was not positive define. For the other models the parameters signs are consistent with methods, t-values and likelihood ratio test statistics are enough high to find the model and parameters significant. This means null hypotheses of parameters and models are rejected and the stations have effect on the location of those urban facilities.

TABLE I. ESTIMATED PARAEMTERS FOR LOCATION MODEL

		Closeness			Betweenness	
		Hotel	Bank	Office	Hotel	Bank
Parameters	θ	-0.274	-0.116	-0.443	-3.236	-2.457
	α1	1585	10024	3606	0.021	0.027
	α2	0.979	1.112	1.001	0.085	0.052
t-value	θ	-126.6	-183.6	-234.4	-43.1	-6.8
	α1	14.0	42.9	29.3	131.7	127.0
	α2	157.5	532.8	328.4	48.4	7.9
Likelihood ratio test statistics[a]		202 $\times 10^3$	94 $\times 10^3$	306 $\times 10^3$	195 $\times 10^3$	62 $\times 10^3$

[a] $\chi_2^2(0.99)=9.21$

C. Expected number of urban core facilities and impact of railway construction

As shown in equation (4) we assume exponential distribution for the number of urban core facilities, and the expected number of facility is given by $1/\lambda_j$. Using equation (5), we estimate the expected number of facilities for all land grid under the estimated parameters in both cases of current and planned network. In addition to the adjustment of closeness and betweenness explained in IV.A., we adjust the expected number of facilities under planned network so that the sum of the expected number equals to the total number of facilities under current network, because our analysis does not fully consider the total demand for facility locations but we focus on the spatial distribution of facility locations. Perhaps public transport network extension may induce economic activities and it may increase total number of facilities in the target region, but in this study we focus on the effect on locational distribution of facilities. Therefore, the expected number of facilities estimated by equation (5) for planned network is adjusted as follows so that the sum of the expected number is equal to sum of the expected number under the current network.

$$\tilde{n}_{pj}^{k} = \frac{\sum_{j} \bar{n}_{cj}^{k}}{\sum_{j} \bar{n}_{pj}^{k}} \bar{n}_{pj}^{k} \tag{7}$$

Where $\tilde{n}_{pj}^{k}$ is the adjusted expected number of type k facilities for planned network at location j, $\bar{n}_{cj}^{k}$ and $\bar{n}_{pj}^{k}$ are the estimated expected number of facilities by equation (5) ($=1/\lambda_j$).

Fig.5 shows the expected number of facilities for current network, planned network, and their difference using closeness and betweenness network centrality. Here, the estimation of office building is only given for closeness centrality because the betweenness model parameter is not estimated properly.

Looking at the current network with closeness index comparing among facility type, bank is most dispersed, office building is most concentrated, and hotel is middle of the other two facilities. This reflects the difference of distance decay parameter θ. Office building has the highest absolute value of θ that means the expected number of the facility decreases more steeply as distance to the station increases compare to the other two type of facilities. While bank has the lowest absolute value of θ, therefore its location is more dispersed from station. The figure of planned network is darker than that in current network because we adjusted the estimated number of facilities at each land grid using equation (7) so that the total number of expected number of facilities equals to that of current network. In the planned network of course the number of stations increase and facilities are expected to locate around the new stations, therefore the number of facilities around the existing station declines if we assume the total number of facilities is constant. Difference of expected number of facilities between planned network and current network indicates the change of spatial dispersion of urban core facilities according to the railway expansion. The number of facilities decreases around existing stations or current city centers and it increases around the new stations.

Taking the case of betweenness, the figure indicates some areas are marked out with black, which means expected number of facilities are zero. Betweenness indicates the number of shortest path go through the target station among the other stations, so some stations like terminals have zero value of the index. Therefore if the betweeness of nearest station is zero, expected number of facilities are also zero at land grid. This feature of betweenness leads the clear edge of location area and the patchwork shape in difference between planned and current networks.

For all the facility types and two indices, the locations of urban core facilities are estimated to shift from existing railway stations to new stations on extended lines under the condition of constant total number of facilities. Even though the total number of facilities increase the location pattern is expected to disperse in planned network compare with current network, therefore the railway expansion will reduce the pressure of concentration of urban core functions at current city center and possibly contribute to create sub-centers of urban functions. It may alleviate the severe congestion in traffic and land use at current center and may shift the development and transportation pattern relatively dispersed that would contribute to avoid the congestion time loss and longtime commuting/travel.

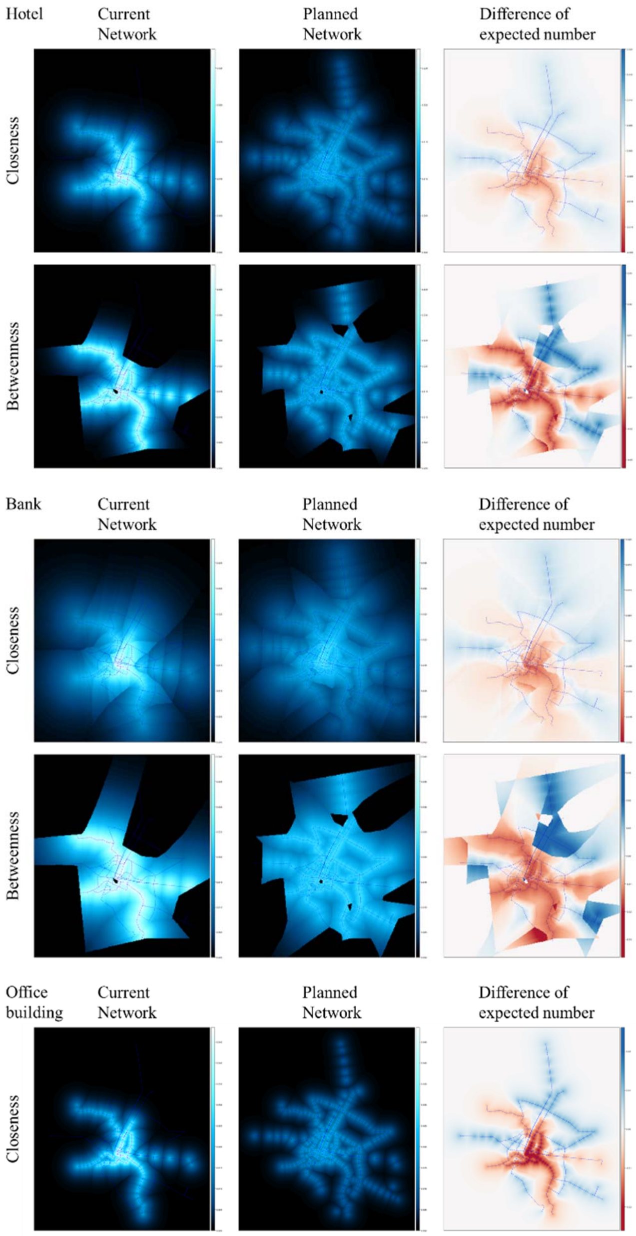

Fig. 5. Expected number of facilities. *(left: current network, middle: planned network, right:difference of expected number betrween planned and current network: top: closeness, bottom: betweenness. In the figure of difference, blue indcates expected number of facilities is larger in planned network than that in current network, red indicates smaller number of expected number of facilities in planned network than current network.)*

V. CONCLUSION

In this study, we captured the effect of railway network on the accumulation of urban functions using network centrality indices and spatial decay function, and estimate the spatial shift of urban core functions under the MMAP railway network based on the stochastic location model of urban facilities. As a result we found that the concentration of urban function at the current urban core along the existing railways can be reduced by extension of planned network of railway in MMAP and urban functions in the current city center would relocate along new railway lines under the condition of total number of facilities constant. This spatial shift is expected to contribute to alleviate traffic congestion, long time commuting and the other travel, and shortage of land supply at the city center. According to the OTP study, traffic demand from east side of Bangkok is estimated to far exceeds the public transport service supply. To manage the problems caused by the transport demand-supply gap, we may need to consider the development policy of urban cores to control the trip attraction in addition to the public transport capacity upgrading.

Our results are based on the spatial statistical analysis of relationship between railway network centrality and urban facility location. We only consider the effect of centrality of nearest station, but facility location may be affected by plural stations. Furthermore, centrality indices represents a limited and indirect aspect of transportation function of the railway network system. More direct accessibility indices on the railway network using generalized cost are also alternative to represent the importance of a station. We estimated the expected number of urban facilities based on simple statistics considering the effect of station. Autocorrelation of locations or agglomeration effect of facilities would make the estimation more accurate and variate. Moreover location choice model for those facilities based on profit maximization behavior of agents may provide a theoretical fundamental for the estimation of locations even though it is quite difficult to prepare data of the factors of firm's behavior including production function, land and floor rent, or agglomeration effect.

This study needs further elaborations, but our results can be utilized to generate scenarios of future travel demand pattern under the railway expansion. Urban cores are major destinations of commuting and the other activities, and they will affect residential location and travel behavior. Probably reduction of number of facilities in existing urban center would reduce the traffic concentration and disperse the trip destinations to the sub-centers. That would change the travel time and residential costs, as well as total congestion, energy consumption and CO2 emissions. Results of this study can be an essential input for those wide range of urban transportation and housing studies.

ACKNOWLEDGMENT

This work was supported by Science and Technology Research Partnership for Sustainable Development (SATREPS), Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA).

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Microsimulation for Mixed Traffic Flow at Intersection Area in Bangkok

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***Abstract*—Application of a microsimulation model that reproduces the vehicle behavior is effective in analyzing the phenomenon of traffic jams and examining countermeasures. However, the theories and parameters in such a simulation are based mainly on the assumption of homogeneous traffic in developed countries and cannot be applied to traffic with mixed vehicles and driving capacities in megacities in Southeast Asia, nor for analysis of measures. In this study, a microsimulation model under mixed traffic was created in the area around the Asok intersection located in the center of Bangkok, where traffic congestion is particularly severe among ASEAN countries. The model was developed, firstly, with traffic volume, geometric structure, and signal control. To improve the accuracy, road structure, and operation, the driving behavior parameters obtained by video observation and travel speed by direction compiled from the probe data were applied. With the developed model, a sensitivity analysis was carried out for various traffic jam measures as driving behavior, signal control, and road structure improvement. The analytical results explained that (1) future demand increases create further congestion and (2) combining measures produces a synergistic effect rather than implementing individual measures. Therefore, implementing various measures in combination rather than in one drastic measure could potentially improve traffic congestion in the Bangkok's city center.**

Keywords—Mixed traffic flow, Microsimulation, VISSIM, Traffic congestion, Sensitivity analysis

I. Introduction

Traffic congestion is a very critical issue in Asian megacities, including ASEAN countries [1]. Congestion not only deprives citizens of their time but also the various social issues such as loss in economic growth opportunities [2] [3], increased traffic accidents [4], and health concerns due to air pollution [5] [6]. Although highway and public transportation networks are being developed in various countries [1], urbanization is predicted to continue to progress in the future [7]. Different factors increase congestion and accidents, such as increased car ownership due to income improvement, lack of public transportation network [8], signal control [9] [10], and various modes of traffic as motorcycles and Tuk-tuk [11]. However, the underlying mechanism for which factors influence what remains unclear. To examine this structure, a microsimulation of the behavior of each vehicle could be effective. However, many existing microsimulations are only intended for traffic flows composed of a single mode, whereas the traffic situation in Asian megacities cannot be accurately reproduced [11, 12].

In this study, a microsimulation model under mixed traffic is developed in the area around the Asok intersection in the center of Bangkok where traffic congestion is particularly severe, from the viewpoint of the ASEAN countries. The model is first developed with traffic volume, geometric structure, and signal control, followed by application of detailed road structure and operation, driving behavior parameters obtained by video observation, and travel speeds by direction compiled from probe data. The developed model is then used to investigate the impact of increasing the demand and to analyze the sensitivity of various measures like driving behavior, signal control, and road structure improvements.

II. Previous Studies of Microsimulation on Mixed Traffic

On one hand, there are many existing studies on the application of microsimulation in Asia, especially when it comes to mixed traffic. For instance, several studies have employed local parameter calibration and model building, with the inclusion of motorcycles [12] [13] [14] [15], to improve the accuracy of individual vehicle behavior under mixed traffic. In these studies however, the generated model was not used for policy analysis, and sensitivity and congestion mechanism analyses were not coducted.

On the other hand, there are many studies on parameter calibration and policy analysis that are applicable to real road networks. For example, Ref. [16] examined the changes in traffic capacity due to changes in the number of lanes, with the highways in Bangkok as the main targets. In applied studies targeting intersections, Ref. [17] conducted a sensitivity analysis of the continuous flow intersection, along [18] [19] with an analysis focusing on signal control and delay time. Indeed, in these studies, microsimulation was conducted to evaluate the impact of each measure and road/intersection structure. However, because there are many intersections connecting to the city center of Asian megacities, and operations such as parkings, U-turns, and crossings take place in unexpected places, such a complex traffic phenomenon could not be simply explained by signal control. Moreover, a detailed analysis of this phenomenon, with inclusion of driving behavior, is hardly performed.

Meanwhile, the World Business Council for Sustainable Development has been able to reduce traffic congestion by optimizing signal control, controlling parking on the road, and moving bus stops near intersections [20]. As serious traffic jams in megacities are caused by the accumulation of complex factors, complex measures should be enforced to solve these problems.

The microsimulation model developed in this study addresses signalized intersections where complicated conditions of signal cycle, vehicle behavior, and stopped vehicles are entangled, by utilization of microsimulation methods that have been subjected to various theoretical

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studies. After traffic conditions have been expressed as precisely as possible using different data and surveys, the congestion mechanism was explained with a sensitivity analysis having multiple measures such as road structure, signal cycle, and driving behavior.

III. The Microsimulation Model

A. *Simulation Model*

The microsimulation software used VISSIM [21] model, which applies a psychophysical model-based vehicle following theory that integrates the physical characteristics of traffic with psychological human factors [22]. Moreover, this follow-up model composed of four driving modes for the driver of free driving (no response), approach (with response), next driving mode (unconscious response), and braking (deceleration) [23].

These four modes and the transitions between these modes control the longitudinal movement of the vehicle (car following) in the simulated traffic flow. Several patterns are given to this control method, where, in this study, "Wiedemann 74" suitable for urban traffic was adopted. In the "Wiedemann 74" model, vehicle responses, such as acceleration, deceleration, braking, and stopping, are determined by changes in the distance and speed difference between the two vehicles.

A model of lateral movement (lane change) regulated according to a rule-based algorithm is also important. For example, aggression is an important characteristic of drivers and has a significant impact on lane change decisions [24]. This model has two types, lane-based and non-lane-based. This study adopted the non-lane-based behavior model that does not complete the lane change at once according to the actual situation in the field.

To model the lane change behavior for VISSIM, important parameters such as maximum deceleration, minimum inter-vehicle distance, and reduction of safety distance are necessary. The appropriate parameters reflecting actual traffic conditions were calibrated by a procedure that will be discussed later.

B. *Model Development Process*

Figure 1 illustrates the process for building the simulation model. First, the model was developed with default parameters based on the traffic volume, road network, and signal cycle observed in the field. Next, the model was calibrated based on local detail information, which includes travel speed in each direction obtained from probe data, vehicle behavior obtained from video observation results, and actual vehicle operation obtained from field surveys (i.e., street parkings, irregular U-turns, motorcycle taxis platforms). After a certain accuracy was validated with a confirmation test based on traffic volume and travel speed, the congestion mechanism was analyzed by sensitivity analysis of the demand and measures.

IV. Case Study

A. *Target Area*

The target area was the Asok intersection in the center of Bangkok, which features an advancing economic growth relative to ASEAN standards (Fig. 2). Having the eighth worst traffic congestion and the second highest accident mortality rate worldwide, Bangkok is considered one of the risks hindering Thailand's future economic growth. Nevertheless,

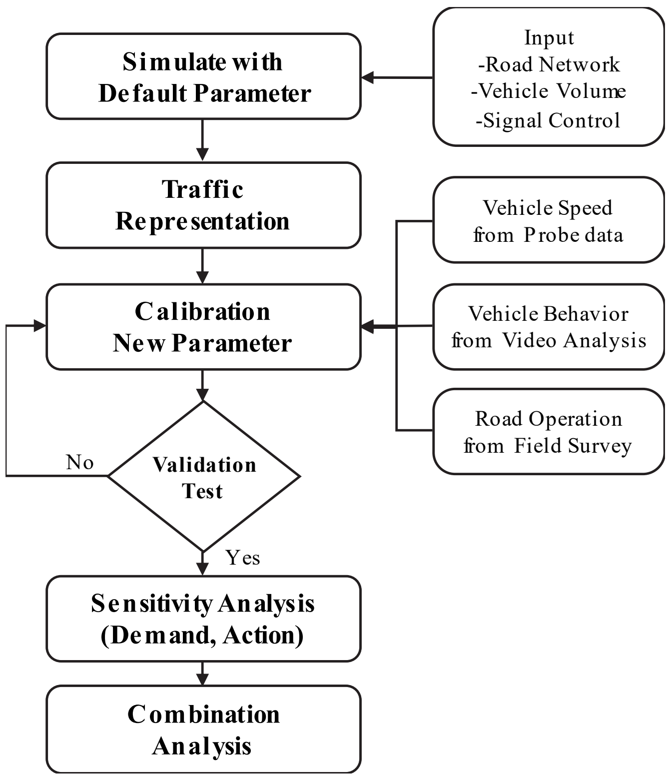

Fig. 1. Process flow in building a simulation model

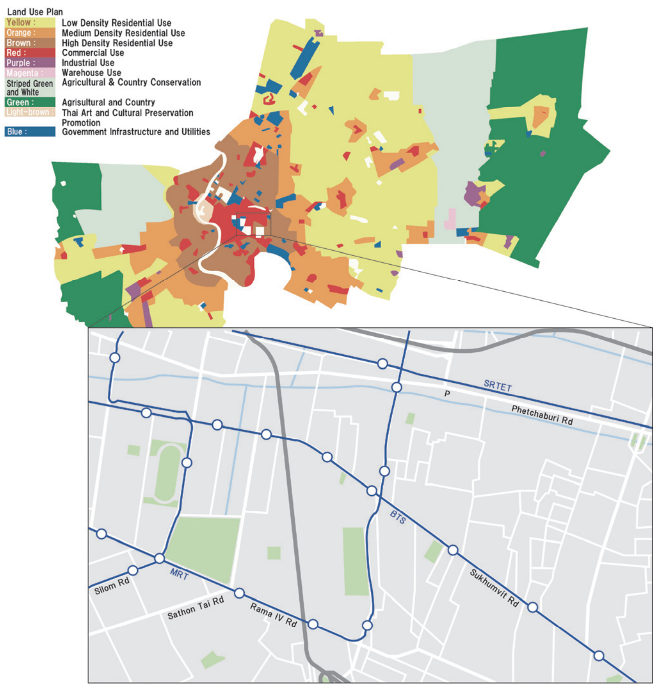

Fig. 2. The target area

development of public transport such as BTS and MRT also increases the momentum of urban development in the city center. More particularly, the target area was near the BTS Asok station in the center of Bangkok, at the intersection of Sukhumvit Road and Ratchadaphisek Road. Due to the road structure where countless sois are connected to the main road, cars tend to concentrate on the main road, which creates large-scale traffic congestion daily during morning and evening peaks. To confirm the mutual influence with not only the intersection but also the surrounding roads, the target range was set to approximately 1.0 km from the intersection. Since this study aims at modeling of the occurrence of complicated traffic jams, the target period was set at 17:00, which is most likely to cause traffic jams in the target area.

B. Data

1) Traffic volume and signal control: Traffic volume and signal cycle data were obtained through a video observation survey, performed between 17:00 and 17:30 on August 1, 2018. Videos were recorded in four directions from the pedestrian deck above the intersection, and traffic volume and signal cycle data at the intersection were counted. Because the signal at the target intersection was manually controlled, the signal cycle was determined using the average value of each cycle noted during the survey.

2) Travel speed: Travel speed data were compiled using historical probe data [25], which show the location information of each vehicle, as published by ITIC. Such data were a record of location information every minute of the vehicle. The travel speed by direction of the intersection was formulated using the vehicular data for August 2018.

3) Field survey: A field survey of the target area was performed from March 4 to 5, 2019 to investigate actual road operation conditions other than road geometry and vehicle behavior, such as parking and stopping. The field survey included (1) signal control methods and signal cycles other than Asok intersection, (2) locations where U-turns were possible and traffic volumes, (3) locations of frequent stops and stops such as taxis and frequency, and (4) vehicle inflow from each soi. The vehicle behavior obtained from the field survey was once recorded on the floor plan, and a video was recorded with a video camera so that the movement of the vehicle could be tracked.

C. Model Calibration

Table 1 shows the results of setting the default model and calibration model behavior parameters. Apparently, the calibration model had lower parameters related to the inter-vehicle distance. More appropriately, each vehicle in the model tended to reduce the inter-vehicle distance due to congestion, where safety judgment was small as well.

In terms of the observed traffic volume and travel speed by direction (Table 2), the traffic volume can be roughly reproduced in the default model, but with a travel time that was less than half of the observed value. In contrast, both

TABLE I. BEHAVIOR PARAMETERS OF EACH MODEL

	Average standstill distance	Additive part of safety distance	Multiplicative part of safety distance	Minimum inter-vehicle distance	Collision avoidance time	Safety distance factor	Maximum deceleration
Default	2.0 m	2.0 m	3.0 m	0.5 m	11s	0.6	-3 m/s2
calibrated	1.0 m	2.0 m	2.0 m	0.3 m	11s	0.5	-3 m/s2

TABLE II. RESULTS OF THE MODEL CALIBRATION

Direction		Observed		Default model				Calibrated model			
		Volume (vehicle/6 min)	Time (min)	Volume (vehicle/6 min)	Rate	Time (min)	Rate	Volume (vehicle/6 min)	Rate	Time (min)	Rate
N-W	right	650	18	640	98	7	39	740	114	18	102
N-S	straight	1,520	12	1,960	129	7	57	1,800	118	12	96
N-E	left	460	15	530	115	7	43	520	113	17	112
E-N	right	570	23	520	91	13	56	570	100	22	96
E-W	straight	1,040	20	980	94	12	63	1,180	113	20	102
E-S	left	1,130	15	1,090	96	11	74	1,100	97	12	79
S-E	right	1,020	18	1,090	107	8	42	1,270	125	20	110
S-N	straight	1,290	18	1,120	87	11	63	1,380	107	22	120
S-W	left	990	15	1,450	146	9	60	1,250	126	14	94
W-S	right	920	12	940	102	11	96	740	80	11	90
W-E	straight	940	15	1,010	107	11	76	860	91	17	118
W-N	left	300	19	270	90	11	59	400	133	21	110

*Coloring items with an error within 20%

TABLE III. IMPACT OF TRAFFIC DEMAND INCREASE

Direction		Volume(vehicle/6min) Current	+10%	+20%	+30%	Time(min) Current	+10%	+20%	+30%
N - W	right	180	194	190	194	12	13	13	13
N - S	streight	52	49	54	54	17	20	21	19
N - E	left	57	67	73	69	22	21	24	24
E - N	right	118	134	129	128	20	18	21	24
E - W	streight	110	85	94	106	12	12	16	16
E - S	left	127	116	134	120	20	24	23	25
S - E	right	138	162	149	156	22	23	26	28
S - N	streight	125	139	154	119	14	17	20	22
S - W	left	74	55	66	64	11	12	12	12
W - S	right	86	62	80	75	17	20	18	18
W - E	streight	40	59	69	37	21	23	25	18
W - N	left	74	73	75	75	18	20	20	21
total		1,181	1,195	1,267	1,197	19,620	21,907	25,346	24,233

※Coloring items with a change of 20% or more compared to the current situation

TABLE IV. MEASURE LIST BY SENSITIVITY ANALYSIS

No	Category	Measure	Abstract
01	Signal Control	Optimization of Asok	Optimize signal control with intersection demand rate
02		Shortening the signal cycle	Reduce signal cycle (from 360s to 120s)
03		Coordinated control	Coordinated control of signals close to Asok intersection
04	Road operation	Stop regulation	Restrict taxi and motorcycle stops near intersections
05		U-turn regulation	Restrict U-turns near intersections
06	Traffic demand	10% reduction	Reduce traffic demand by 10%
07		20% reduction	Reduce traffic demand by 20%
08		30% reduction	Reduce traffic demand by 30%
09	Change of vehicle	Miniaturization of automobiles	Replacing 50% of passenger cars with small passenger vehicles

TABLE V. SENSITIVITY ANALYSIS RESULTS FOR INDIVIDUAL MEASURES

	Case	00	01	02	03	04	05	06	07	08	09
Volume (vehicle/6 min)	N	307	231	352	336	338	307	290	280	255	378
	E	299	256	337	333	303	313	297	318	277	362
	S	390	427	390	411	400	276	418	422	378	458
	W	218	268	321	225	214	234	213	247	255	324
	Total	1,214	1,182	1,400	1,305	1,255	1,130	1,218	1,267	1,165	1,522
Time (min)	N	16	19	15	14	12	17	13	12	11	11
	E	18	19	19	16	21	18	14	13	12	13
	S	19	15	17	19	18	19	17	14	11	13
	W	16	17	15	14	13	16	14	13	12	13
	Average	17	17	16	16	16	18	15	13	11	13

traffic volume and travel time were highly reproducible in the calibration model. This finding confirms that traffic congestion at complex intersections cannot be expressed only by signal cycle, geometric structure, and excess demand, but that it is important to reflect the actual vehicle behavior and actual road operation.

V. SENSITIVITY ANALYSIS

A. Impact of Traffic Demand Increase

With the calibrated model, sensitivity analysis was carried out based on the traffic volume flowing into the Asok intersection (Table 3). After analysis of the case where traffic demand increased by 10%, 20%, and 30% from the present, the traffic capacity as a whole did not change much. However,

TABLE VI. RESULTS OF THE COMBINATION ANALYSIS

Case	Volume (vehicle/6 min)				Time (min)			
	00	+02+03	+04+05	+06+09	00	+02+03	+04+05	+06+09
N	307	340	366	361	16	13	10	7
E	299	318	278	361	18	17	21	16
S	390	435	339	397	19	14	12	8
W	218	295	325	321	16	12	7	6
Total	1,214	1,388	1,308	1,440	17	14	12	9

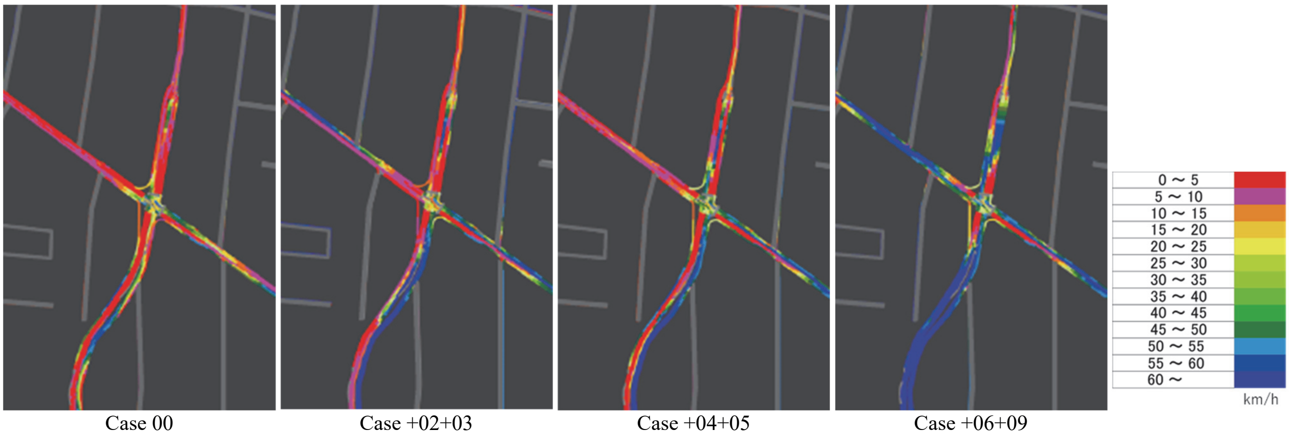

Fig. 3. Heat map of travel speed

the travel time increased significantly, mainly in the inflow from the east and south, and if the traffic demand increased by more than 20%, then the travel time increased by more than 20% as well.

B. *Sensitivity Analysis*

Table 4 outlines an overview of the measures analyzed, while Table 5 shows the results of individual sensitivity analysis. For signal control, optimization of the Asok intersection bore little effect. Nevertheless, shortening the cycle length and surrounding signal control increased the traffic capacity by 5%–10%, resulting in a time reduction effect of approximately 5%. Road improvement operation demonstrated an effect of stopping control, but the suppression of U-turn was not so effective. The effect of reducing traffic demand had a linear effect on travel time reduction. The impact of miniaturization of the vehicle was also considerable, as it increased the traffic volume by 20% and reduced the travel time by more than 20%.

Table 6 shows the results of effective combination analysis. Here, shortening the signal cycle and cooperative control could reduce travel time by 18% and increase traffic capacity by 14%. Further, with improvement in road structure, a greater effect was obtained than when each measure was implemented solely; a travel speed reduction effect of 29% was obtained. When traffic demand was reduced by 10%, along with reduced vehicle size, traffic capacity increased by 20%, with travel time expected to shorten by 47%.

Figure 3 shows the current speed and travel speed distribution when each measure was incorporated. By improving the efficiency of signal control, the linkage of traffic congestion on the south and west sides was eliminated, whereas the clogging on the north and west sides was eliminated by prohibiting stopping and making U-turns. As demand reduction and vehicle miniaturization progressed, traffic congestion would be limited to the vicinity of the intersections, which confirms that traffic congestion will be greatly reduced.

VI. DISCUSSION

Firstly, even if traffic demand increased from its current level, the traffic capacity would not change, but only the required time would increase. Apparently, traffic demand has already been saturated at this intersection and any increase cannot be processed further. In the future, the development of condominiums and other urban infrastructures will continue in Bangkok, accompanied by a rise in further traffic demand; thus, there is the urgent need to shift to modes other than automobiles.

Regarding the sensitivity analysis of individual measures, the required time reduction effect was approximately 12% at the maximum (Case 06), except for extreme cases as in Cases 07–09. Various measures have been reviewed including advancement of the signal control, but this result confirms that congestion is caused by many factors, which suggests the difficulty to expect a significant effect with a single measure.

On the contrary, combining measures made it possible to reduce travel speed by 18% only by shortening the signal cycle and cooperative control. However, when such measures were combined with operational improvements such as stopping, a 29% reduction effect could be achieved. Rather than focusing on a single measure, it is essential to combine various measures, with focus on the events occurring at each location.

Moreover, reduction of traffic demand and miniaturization of vehicles could be attained by implementing wide-area measures, such as the development of public transportation networks and inflow of large vehicles into the city center. These drastic measures are indispensable to achieve significant traffic smoothness in the future, but it is desirable to perform such efforts step by step.

VII. CONCLUTION

In this study, a detailed microsimulation model was developed based on probe data and field surveys focusing on mixed traffic, at intersections in the center of Bangkok. A sensitivity analysis was performed for the model, and the cause of congestion at the target intersection was explained, along with the direction of measures. The microsimulation was based on various inputs such as road geometry, operational status, driving behavior, and signal control; thus, various information collection and trials were performed to express the phenomenon concretely. However, note that with a high-accuracy model, it is possible to verify the effectiveness of measures across various viewpoints and to analyze the combinations. Studies focusing on this aspect are rare. As its novelty, this research improves the accuracy from various viewpoints and realizes sensitivity and combination analyses of various measures based on such accuracy.

On the other hand, the model implemented in this study is only one intersection in Bangkok, which is limited time zone. If the time zone and season change, the traffic situation will also change. Traffic conditions can also change significantly due to sudden events such as accidents. By analyzing under various circumstances, it is possible to know the sensitivity of the countermeasure effect in more detail. It is also important to apply many of these models in megacities in Bangkok and other ASEAN countries. In the future, it will be necessary to compare case studies in various districts and cities, and to analyze the trends and desirable measures for each country and city, or common items. Many studies on driving behavior in ASEAN countries have been published. Moreover, information important for model calibration such as probe data and CCTV has been diversified. Lately, it has become easier to build a model with high accuracy, and this fact can be used as an effective tool to analyze traffic congestion in a certain area.

ACKNOWLEDGMENT

This research was supported by JST-JICA, SATREPS, and JPMJSA1704, “The Project of Smart Transport Strategy for Thailand 4.0.”

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Transportation Mobility Factor Extraction Using Image Recognition Techniques

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Abstract—**For an urban development, the Quality of Life (QOL) of people in the city is a vital issue that should be considered. There are many researches in QOL topics that use questionnaire survey approach. These studies yield very useful information for city development planning. As the Artificial Intelligence technologies are developed very fast recently, they are applied to solve many transportation problems. In this paper, we propose a method that automatically extract mobility indicators using two image recognition techniques: Semantic Segmentation and Object Recognition. Because the mobility is an important factor in QOL evaluation, our work can be used to enhance a performance and reduce a data gathering cost of the QOL evaluation.**

Keywords—Quality of Life (QOL), Transportation Mobility, Image Recognition, Semantic Segmentation, Object Detection

I. INTRODUCTION

In many countries, big cities are developing very fast. This leads to increasing in the number of population and many consequences to be considered, including the quality of life (QOL) of people in the cities.

Several research topics of QOL have been conducted. The main issues are what are important factors influencing QOL and how to evaluate QOL using the related factors. In many studies, transportation is an important factor that directly impacts QOL. Schneider [1] studied people behaviors in Minnesota, USA and reported that transportation was important because it connected people to their destinations. Doi et al. [2] proposed a QOL evaluation method based on accessibility and social interaction. Nakamura et al. [3] evaluated megacities development by combining a land-use transportation model with QOL index using Bangkok as a case study. Nakamura et al. [4] analyzed difference of QOL in station areas by comparing Nagoya to Bangkok and suggested the importance of developing efficient transportation systems. Gu et al. [5] investigated a methodology to evaluate QOL of people in Nanging and considered a convenience in transportation network accessing as an evaluating factor. These studies in QOL not only provide us urban people's insights, but also give useful information for urban development. However, the data gathering process was costly and time-consuming. Moreover, the gathering information could be changed over time.

In recent years, the image recognition technology has been developed rapidly. It has been used for solving problems in various practical fields including transportation. Chowdhury et al. [6] proposed a model for traffic management by counting the number of vehicles on the road. Hua and Anastasiu [7] designed a tracking algorithm for a smart traffic network running in a real-time environment. Putri et al. [8] estimated traffic density using a video processing model. Kim et al. [9] proposed a framework for vehicle tracking using the Faster R-CNN algorithm. Osman et al. [10] designed an intelligent traffic management system for road junctions using image processing. Chen and Huang [11] modeled a moving vehicle tracking system based on traffic surveillance systems. Ali et al. [12] proposed an intelligent and autonomous traffic management system for reducing traffic congestion problems. Munajat et al. [13] designed a road condition detection algorithm using RGB histogram filtering. Dinh et al. [14] constructed a traffic jam warning system based on coarse data in Vietnam. Trivedi et al. [15] designed a vehicle counting module for smart traffic management in a small city. Delavarian and Maarouzi [16] proposed a multi-object tracking system for intersection using multilayer image sequences. Mithun et al. [17] developed a video-based intelligent traffic management system that can track objects and also their flow directions. These systems overcome the traditional traffic management system because they work more efficient, while human operation cost is lower. In addition, we can collect data log and analyze people behavior in order to plan traffic management policy in the future.

In this paper, we apply two types of image processing techniques to extract useful information from a video dataset. The first one is *Semantic Segmentation* to recognize areas of observed objects. The second one is *Object Recognition* which

978-1-7281-6435-9/19/$31.00 ©2019 IEEE

can detect and count the number of observed objects. The acquired information can be used to figure transportation mobility, which is a vital factor affecting QOL of people. Using an automated algorithm for data gathering process will reduce survey costs. Moreover, we can gather new up-to-date data as much as we need to evaluate QOL in the future.

This paper is organized as follows. Section II discusses overview of QOL and transportation mobility. Section III reviews image recognition techniques that are used in this paper. Section IV proposes our method. Section V provides experimental details and results. Section VI discusses about possible future works. Section VII summarizes our research.

II. Transportation and Quality of Life

A. Accessibility and Quality of Life

In context of QOL evaluation, accessibility is employed in many papers. In [2], the authors concluded that accessibility were directly and indirectly related to five QOL elements: safety and security, economic opportunity, service and cultural opportunity, spatial amenity and environmental benignity. Accessibility was mentioned again in [4] as one of four elements that were included in the questionnaire: accessibility, amenity, safety and cost. The research also found that peoples in both Bangkok and Nagoya valued accessibility as the most important factor for them. Using facility data points from BaiduMap and road/subway networks from OpenStreetMap, QOL index was calculated based on distribution of accessible values in education service, shopping services and medical care service [5]. According to these papers, we can see that accessibility is a vital issue for QOL evaluation.

B. Accessibility vs Mobility

As shown in the previous section, accessibility is a vital factor in QOL evaluating process. Mobility is another factor affecting QOL. Both accessibility and mobility are related to travelling quality. Accessibility means the quality in travelling. It focuses on travel time, travel cost, and travel options. On the other hand, mobility is the ability and level of ease of moving goods and services. It focuses on traffic congestion, obstacles, and the number of lanes. Hence, accessibility and mobility are the same thing in different point of view.

In our research, as we will apply image recognition techniques, we will measure our experimental results in the view of mobility. To illustrate more, we will detect and count the number of observed objects from one destination to another; but we will not measure travel time or cost consumed in travelling between two destinations.

III. Image Recognition

Among researches in Artificial Intelligence, Image Recognition is growing very fast, especially after emerging of the Convolutional neural networks (CNNs), a Deep Learning for Image Recognition, have become the dominant machine learning approach for semantic segmentation and object detection.

In this paper, two computer vision types are used: (i) semantic segmentation (ii) object detection. The difference between these two types is that semantic segmentation classifies each pixel into a set of categories; whereas object detection localizes and classifies an object using a bounding box.

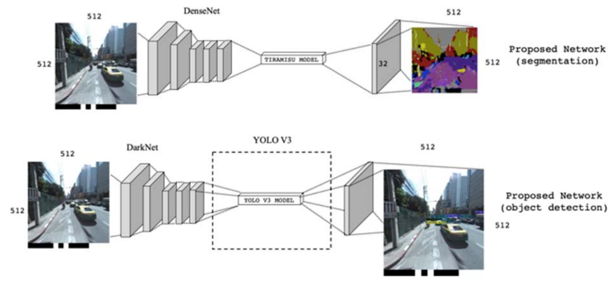


Fig. 1. An overview of our deep learning architectures

A. Semantic Segmentation

Semantic segmentation classifies all the pixels of an image into meaningful classes of objects and helps determine the relations between objects, as well as the context of objects in the image.

DenseNet [18] is originally used for image classification. Several advantages of DenseNet are: (i) it is more efficient in the parameter usage (ii) it performs deep supervision thanks to short paths to all feature maps in the deep learning architecture, and (iii) all layers can easily access their preceding layers making it easy to reuse the information from previously computed feature maps.

In this paper, we present Fully Convolutional DenseNet for semantic segmentation. Because of the segmentation task, Fully Convolutional DenseNet (also known as The One Hundred Layers Tiramisu, in short as Tiramisu) [19] has up-sampling layers on the contrary to the DenseNet. Tiramisu uses a downsampling-upsampling style encoder-decoder network. Each stage between the pooling layers uses dense blocks. Also, it concatenates skip connections from the encoder to the decoder.

We use these modern semantic segmentation frameworks that combine low-level and high-level features from pre-trained Tiramisu models on the Camvid [20, 21] corpus to predict our images.

B. Object Detection

Object detection is one of a computer vision technique that c. The objects can be generally identified from either images or video feeds. Object detection has been applied widely in object or people tracking, robotic maneuverability, autonomous driving, intelligent motion detection, tracking systems and so on. There are many modern deep learning architectures for object detection and one of the best deep networks is YOLO (You Only Look Once) [22].

YOLO views image detection as a regression problem, which makes its pipeline quite simple, and it is extremely fast because of this simple pipeline. It is a state-of-the-art, real-time object detection system on Pascal VOC challenge [23].

It can process a streaming video in real-time with a latency of fewer than 25 seconds. During the training process, YOLO sees the entire image and is, therefore, able to include the context in object detection. In YOLO, each bounding box is predicted by features from the entire image. Each bounding box receives 5 predictions; x, y, w, h, and *confidence*. (x, y) represents the center of the bounding box relative to the bounds of the grid cell. w and h are the predicted width and height of the whole image, and *confidence* is the probability of the event (or probability of input to fall in different classes). Commonly, object detection models also generate a confidence score for each detection. The convolutional layers of the network are responsible for extracting the features, while the fully connected layers predict the coordinates and output probabilities.

In this work, we select YOLOv3 [24] from University of Washington for object detection. It is extremely fast and accurate than all the previous YOLO versions. Moreover, it uses a few tricks to increase amount of training data and improve model accuracy, including multi-scale predictions and a better backbone classifier.

IV. Proposed Method

In this paper, we propose a new approach to evaluate transportation mobility using image recognition techniques. The benefits of a new method are not only high scalability to span evaluating areas, but also cost effective.

We start our task with selecting a video recording method. In order to coverage a wide area range, we choose a video record from a camera attached to a moving vehicle. Compared to a fixed position camera (such as a surveillance camera or CCTV), our method can collect data with more coverage areas. Moreover, as the vehicle are movable, we can freely determine the areas of interest.

After collecting the video dataset, we apply two image recognition techniques, semantic segmentation and object recognition, to extract information from the video records. The summary of observed classes and acquired outputs are shown in Table 1.

TABLE I. Applied Image Techniques and Output Details

Technique	***Observed Classes***	***Recognized Output***
Semantic Segmentation	1. Car 2. Bike 3. Person 4. Road 5. Tree 6. Other	Percentage of observed areas (in pixels)
Object Recognition	1. Car 2. Truck 3. Bike 4. Person	Numbers of observed objects

The idea of using the semantic segmentation is to evaluate positive and negative areas of the images. The positive image area are our desirable factors: (i) road and (ii) tree. On the other hand, the negative areas are undesirable factors or obstacles: (i) car, (ii) bike and (iii) people. The more positive areas affect the more transportation mobility. To indicate satisfaction and unsatisfaction by each factor, percentage of area is conducted. We calculate percentages of pixels using the equation (1).

$$percentage\ of\ pixels = \frac{pixels\ of\ the\ interested\ area}{total\ pixels\ of\ the\ image} \quad (1)$$

For the desirable factors, the more percentages of pixels that the system yields, the more satisfaction is obtained. In contrast, for the undesirable factors, the more percentages of pixels the system provides, the less satisfaction that we acquire. For the object recognition, the idea is to evaluate undesirable factors by detecting the numbers of obstacles in each class: (i) car, (ii) track, (iii) bike and (iv) people. Therefore, the greater numbers of obstacles in each class are detected, the less satisfaction it means.

In the next step, we interpret the recognition results into mobility evaluation. There are many ways to interpret the acquired results. Firstly, we can use them to compare mobility between different areas in a city; Bangkok is used as a studying case in this paper. Next, we can collect sets of recognition results from various periods of times and areas in order to compare general mobility of different cities. Finally, we can combine them to enhance a performance of the traditional QOL evaluation or reduce data survey cost. However, more researches are required.

We can apply Artificial Intelligence or Machine Learning techniques to predict QOL evaluation from the recognition results. However, it requires a lot of survey data in traditional methods and more research is also required, and hence, we left the topic as a future work.

V. Experiments

A. Dataset

The original videos used in this experiment were recorded in Sukhumvit District, Bangkok. They were taken by Iwane Laboratory [25] using the Image based Mobile Mapping System (IMS3/IMS5+).

For our experiment, we categorize the scenes into three types: large-road, medium-road and small-road scenes. The large-road scene contains a road with 6 lanes, while the medium-road and small-road scene contains 4 lanes and 2 lanes or none, respectively. We capture the video records by 2 images per second, acquiring images from each scene as shown in Table 2.

TABLE II. Selected Scenes

Road Size	***Scene***	***video length***	***no. of images***
Large	1 2 3	188 seconds 188 seconds 188 seconds	375 375 375
Medium	4 5	188 seconds 188 seconds	375 375
Small	6 7	188 seconds 122 seconds	375 244

B. Implementation and Computer Configuration

We implemented our methods on Tensorflow [26]. All of the semantic segmentation experiments were conducted on a server with an Intel® Xeon® Silver 4110 CPU @ 2.10GHz (8 Cores, 16 Threads per socket; 2 Sockets), 128 GB of memory (RAM), with GPU: Nvidia Tesla V100 32GB x 2, while all of the object detection experiments were conducted on a server with an Intel® Xeon® Processor E5-2660 v3 (25M Cache, 2.60 GHz), 32 GB of memory (RAM), an Nvidia GeForce

GTX 1070 (8 GB), an Nvidia GeForce GTX 1080 (8 GB), and an Nvidia GeForce GTX 1080 Ti (11 GB).

C. Hyperparameter Confuguration

For a semantic segmentation on CamVid [20, 21], we first remove the last three pooling layers and the last dense layer since it helps to reduce the number of parameters and computation in the deep learning network without decreasing performance. Then, we set the dilation rates of the convolution layers as 3 and 5, respectively. We also make experiments using YOLOv3 with ResNet that consists of a 3×3 convolutional layer with 64 channels, followed by 3 stages with 2 basic blocks in each stage and ends up with a global average pooling and a 10-way fully connected layer, as the backbone.

Specifically, we adopt Nesterov momentum optimizer [27] with momentum = 0.9, initial learning rate = 0.05, rate decay = 0.94 every 2 epochs, and weight decay 4e-5. Batch normalization [28] is used before each weight layer in our implementation to ease the training and make it is comparable to concatenate feature maps from different layers. To avoid overfitting, data augmentations are used as data preprocessing, including random flipping vertically, random flipping horizontally, and a random crop of 512×512 image patches.

D. Experiments and Results

We feed the dataset images into our image recognition system to extract mobility components. The examples of the large-road, medium-road and small-road scenes are shown in figures 2-7, respectively[1].

The object detection system yields excellent performance, while the semantic segmentation system gives satisfy performance. For the object detection system via the pretrain YOLOv3 network, unsurprisingly, all the classes can be detected very well. The semantic segmentation system performs very well when the image texture is clearly separated in each section, such as the images of large road. But its performance tends to decrease for medium and small road because the image dataset contains a lot of unclear edges between each section.

The summary of recognition results is shown in Table 3. In general, the trends of semantic segmentation and object detection results from the same class and scene are in the same direction. For the large road, the images contain a lot of areas and numbers of cars and roads, but few in areas of bikes and person. For the medium road, the object detection can work well. However, as there are a lot of unclear edges of shadow or dark sections, the semantic segmentation outputs higher tree areas and lower road areas than the actual. In the scene 5, the number of cars seems to be high compared to its area. This is because the system detects a lot of cars from opposite direction of the road and count into the system (as shown in fig. 2). For the small road, as they contain a lot of unidentified objects, the segmentation system recognizes some of them as bikes and person, and hence their percentage of areas seems to be too high. However, thanks to the object detection system that performs well, the actual road situation can be implied.

We can also analyze some mobility situation from the experimental results. For the large road, the main objects are cars, as the percentages of cars and roads are relatively high compared to bikes and persons. On the other hand, bikes and persons are main objects for the medium or small road. Among the scenes in the large road, scene 2 is the highest in mobility because it contains the lowest percentage of cars and contains the highest percentage of the road. For the same reason, the highest mobility scenes for the medium and small roads are scenes 4 and 7, respectively.

VI. CONCLUSIONS

The Quality of Life (QOL) is an important issue in city development. The traditional researches require questionnaire surveys that consume a lot of resources in data gathering. As the Artificial Intelligence technologies are developed rapidly, they are applied to solve many problems, including the transportation problems. In this paper, we propose an image recognition method for extracting mobility factors from videos or images. The new method consists of two techniques, semantic segmentation and object recognition. The first one recognizes percentage of positive and negative components on the observed videos or images, while the second one detects the number of obstacles. As the mobility is a significant component of QOL, our extracted factors could be added to QOL evaluation process in order to augment data or cut down the cost of data collecting.

We perform experiments and gain satisfy results in factor extraction. The acquired results can be used to indicate the actual mobility situation of the observed road and can be used in transportation planning or city development. In the view of QOL, our system yields a set of measured number that can be used as a primary information for evaluating QOL of people. However, to figure out the exact QOL value from images, further researches are required.

VII. FUTURE WORKS

There are many possible tasks for the further works. First, although we obtain a lot of information about transportation mobility from our system, how to include them into traditional QOL evaluation are still a topic needed to be considered. Second, it is possible to predict QOL index from images using Machine Learning techniques. To achieve this task, data gathering using questionnaire survey is required. Third, in technical views, there are some objects that require more research for better classify, for example, trash bin, electric pole, footpath. Finally, in this paper, we conduct a research only in driving mode for the vehicles. Therefore, a transportation mobility in walking mode for the pedestrian can be conducted as another study.

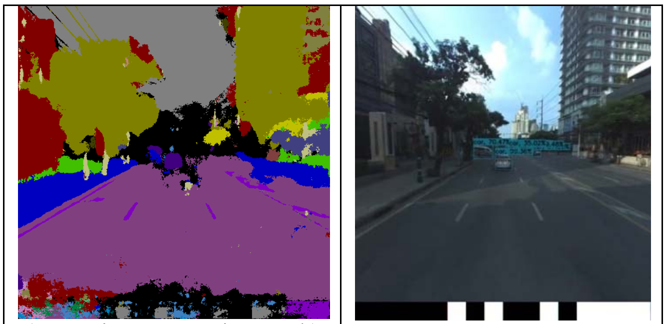
ACKNOWLEDGMENT

This research is supported by SATREPS Project of JST and JICA: "Smart Transport Strategy for Thailand 4.0 Realizing better quality of life and low-carbon society", by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (C)(17K00252) and by Chubu University Grant.

[1] To see the full recognition results, please visit www.youtube.com/watch?v=W6WXxBVTKvY

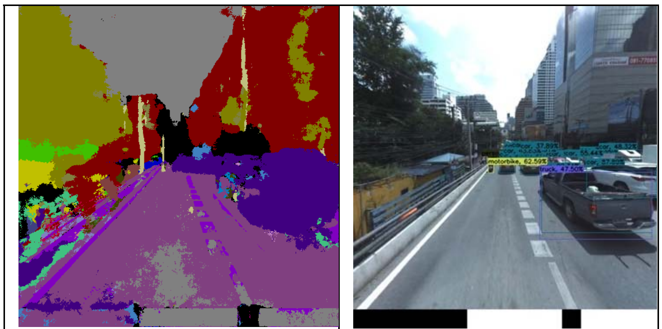
(semantic segmentation result) (object detection result)

Fig. 2 – A recognition result example from the 1st scene



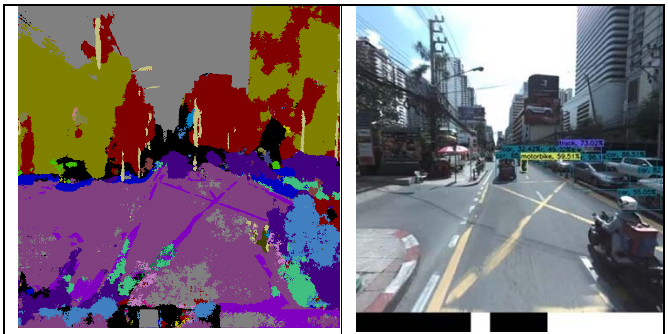
(semantic segmentation result) (object detection result)

Fig. 3 – A recognition result example from the 2rd scene



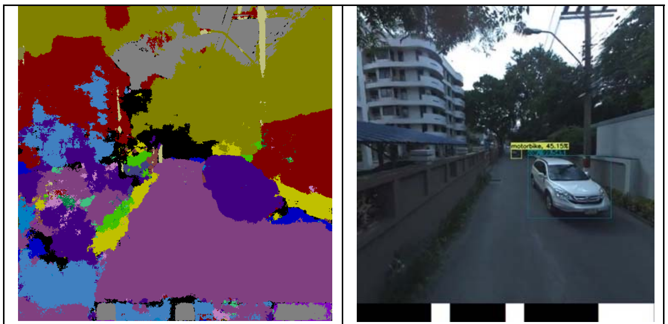
(semantic segmentation result) (object detection result)

Fig. 4 – A recognition result example from the 4th scene



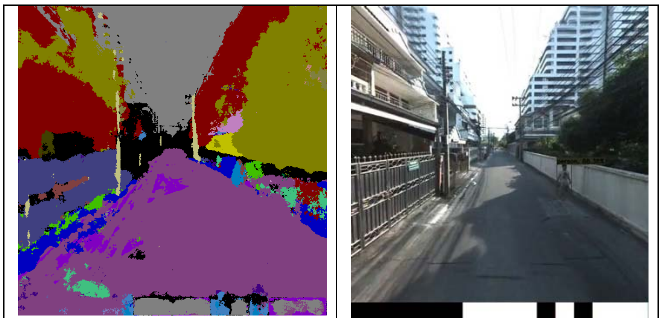
(semantic segmentation result) (object detection result)

Fig. 5 – A recognition result example from the 5th scene



(semantic segmentation result) (object detection result)

Fig. 6 – A recognition result example from the 6th scene



(semantic segmentation result) (object detection result)

Fig. 7 – A recognition result example from the 7th scene

Void	Building	Wall	Tree	VegetationMisc	Fence
Sidewalk	ParkingBlock	Column_Pole	TrafficCone	Bridge	SignSymbol
Misc_Text	TrafficLight	Sky	Tunnel	Archway	Road
RoadShoulder	LaneMkgsDriv	LaneMkgsNonDriv	Animal	Pedestrian	Child
CartLuggagePram	Bicyclist	MotorcycleScooter	Car	SUVPickupTruck	Truck_Bus
Train	OtherMoving				

TABLE III. IMAGE RECOGNITION RESULTS FROM ALL SCENES

Scene	**Road size**	**Semantic Segmentation (avg. percentage of pixels)**						**Object Detection (avg. no. of objects)**			
		Car	Bike	Person	Road	Tree	Other	Car	Truck	Bike	Person
1	Large	21.23	11.54	5.25	16.44	9.54	35.99	6.57	0.33	2.63	2.16
2	Large	18.77	9.26	8.34	22.34	7.32	33.97	6.38	0.25	0.86	0.81
3	Large	25.68	12.54	2.45	14.77	3.65	40.92	7.08	0.30	0.31	0.43
4	Medium	7.43	16.53	15.44	9.55	22.56	28.49	1.00	0.77	1.00	2.24
5	Medium	11.35	14.43	17.54	7.77	26.45	22.46	7.86	0.65	1.65	2.32
6	Small	17.54	21.77	19.45	11.56	0.23	29.43	0.78	0.04	0.09	0.40
7	Small	14.55	25.44	17.56	13.49	0.44	28.53	1.12	0.07	0.22	2.24

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Development of micro population data for each building: Case study in Tokyo and Bangkok

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***Abstract*— This study developed the micro population data (MPD) across Tokyo and Bangkok which can monitor the estimated number of residents pre building using detailed building maps and population census in subdistrict units. In addition, the reliability of MPD was verified by comparing it with population census with higher resolution than subdistrict unit in Tokyo. As a result, it has become possible to develop MPDs that are strongly correlated with the population census of various aggregation units and have small errors.**

***Keywords*— census, population, micro geodata, disaggregation, building**

I. Introduction

In recent years, rapid population growth and urbanization are progressing, and various infrastructure developments in cities have not caught up with them in developing countries around the world. In order to realize sustainable development and management of cities, it is necessary to design and implement appropriate city planning and traffic planning. Indispensable information for designing them is the physical extent of the city, i.e. spatial distribution of buildings and population. Examples of information that can be used to grasp these information are maps and various census. However, especially in developing countries, maps and census for grasping them are not continuously maintained, or even if they are continuously maintained, the spatial resolutions of them that is available to the public are often not fine. Therefore, it can be said that the quality is not enough to be used for the design and implementation of detailed city and transportation planning. For these reasons, the development of demographics with as high a spatial resolution as possible is desired.

In order to overcome this problem, it is necessary to realize for development of a method to grasp the spatial distribution of high-resolution population. By accomplish it, the world's first micro geodata that can pinpoint the spatial distribution of residents in each building will be realized that can support urban and traffic planning in every city in the world. As a result, it is expected that it will be possible to design and implement city planning and traffic planning in cities around the world smarter, especially in cities in developing countries that will need more appropriate and continuous urban planning and traffic planning than ever before.

Therefore, this study examined the development of a method for estimating the number of residents per building in Tokyo and Bangkok using detailed digital maps that shows the spatial distribution of buildings and relatively low-resolution population census in subdistrict units. In addition, using this method, we tried to develop micro population data across Tokyo and Bangkok. Moreover, the reliability of this method is verified by comparing it with population census with higher resolution than subdistrict in Tokyo where more detailed population census than subdistrict are developed.

II. Related works

It is possible to grasp the population distribution in Japan not only in urban areas but throughout Japan by not only subdistrict ("Oaza" in Japan) unit, but also city block ("Chome" in Japan) and grid cell (1km, 500m and 250m square) units by using existing statistics: national population census provided by Statistics Bureau, Ministry of Internal Affairs and Communications. In addition, there are also studies that estimate the population of each building by integrating existing statistics and digital maps [1], and there are some applied studies using the estimated population of building units (see [2] , [3], and [4]). However, these methods have been rarely applied outside of Japan.

On the other hand, estimated population by 1km square grid by Gridded Population of the World developed by Columbia University, Center for International Earth Science Information Network (CIESIN) [5], and estimated population by 100m square grid by World Pop developed by University of Southampton [6] are known as examples of trying to grasp the detailed population distribution of developing countries outside of Japan. These can be used to monitor the estimated population and GDP in grid units. However, the building unit estimation proposed in this study has not been achieved.

In addition, in the use of a model for urban land use and traffic analyses represented by SILO (Simple Integrated Land-Use Orchestrator), and MATSim, high resolution population data is important input data (see [7] and [8]).

III. Outline of this study

This study tried to develop the "Micro Population Data (MPD)" in Tokyo and Bangkok. It is the micro geodata which estimated the population distribution of each building.

A. Study Flow

Fig.1 shows the flow of this study. This study first developed MPD by disaggregating Japanese population census aggregated in subdistrict units for the entire Tokyo prefecture using five methods described in Chapter 3 ((1) in Fig. 1). In the case of Tokyo, more detailed population census than subdistrict units are available. On the other hand, in the case of Bangkok, only subdistrict population census are available. Therefore, considering that the method developed in Tokyo is also applied to Bangkok, MPD in Tokyo was also developed using subdistrict unit census. Next, because higher-resolution population census are available than subdistrict in Tokyo, the reliability of each five method is verified by comparing five types of MPD with high-resolution census (city block unit and 1km, 500m and 250m square grids) ((2) in Fig. 1). Finally, the best method is applied to the entire Bangkok area to produce MPD of Bangkok ((3) in Fig. 1).

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B. Target Areas

Target areas are Tokyo prefecture (Hereinafter referred to as “Tokyo”) and special administrative area of Bangkok (Hereinafter referred to as “Bangkok”). Fig.2 shows target areas and subdistricts of population census in Tokyo and Bangkok. Tokyo includes three zones: the special wards of Tokyo: the most urbanized area, suburban areas: it mainly formed by residential areas, and Tama area: it has rural and mountainous areas. On the other hand, Bangkok has the Chao Phraya River running from north to south in the center, and the urban function is different on the east and west side of the river. West side district, where the capital function was once located, is now a local residential area where many middle class residents live. In contrast, the current city center is located in the east side district, and luxury residential areas are distributed around the city center. In addition, both districts are still growing rapidly with suburban residential areas sprawling towards the outskirt.

C. Building Data and Population Census

In this study, we used population census of Tokyo and Bangkok to grasp the spatial distribution of households and population. Latest population census of Tokyo is in 2015. In addition, we can use higher-resolution population census than subdistrict (“Oaza” in Japanese) units: city blocks (“Chome” in Japanese) and grids (1 km, 500 m, and 250 m square) shown as Fig. 1. On the other hand, latest population census of Bangkok is in 2018. The aggregation unit of available census is subdistrict (“Tambon” in Thai).

In addition, in order to disaggregate population census and to allocate households and residents for each building, position information of the building that is the allocation destination is required. Therefore, this study used building polygon data of Tokyo and Bangkok (Fig. 3). In Tokyo, we used the digital residential map in 2015 developed by Zenrin Co. Ltd. This data contains approximately 100 million building polygons across Japan. There were about 3.06 million buildings in Tokyo. On the other hand, in Bangkok, we used the Map Fan DB data in 2018 developed by Increment P Corporation. This data contains polygon data of about 5.89 million buildings, mainly in urban areas throughout Thailand. There are about 2.16 million buildings in Bangkok. Moreover, each building data has attributes shown in Table I. Both Tokyo and Bangkok building data can grasp not only location and shape (area), but also number of floors or height (volume) and use of all buildings.

IV. DEVELOPMENT OF MICRO POPULATION DATA IN TOKYO

In this chapter, we introduce development methods of the MPD of Tokyo. The population census for both Tokyo and Bangkok store the number of households and the number of residents for each subdistrict. Therefore, we first allocated the household to which the residents are allocated to the building data. Subsequently, we allocated residents to allocated households.

Fortunately, we were able to use high-performance building data that can monitor the area, volume, and usage of all buildings in both Tokyo and Bangkok in this study. However, in many cities in developing countries, high-performance building data such as those in this study are not always available. Therefore, we examined the development method of MPD according to the performance of the available building data. In this study, MPD was developed in Tokyo by the following five methods.

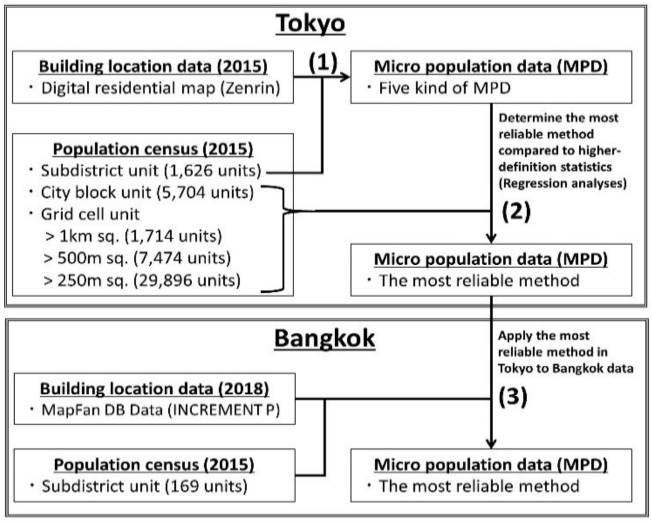

Fig. 1. Study flow in this paper

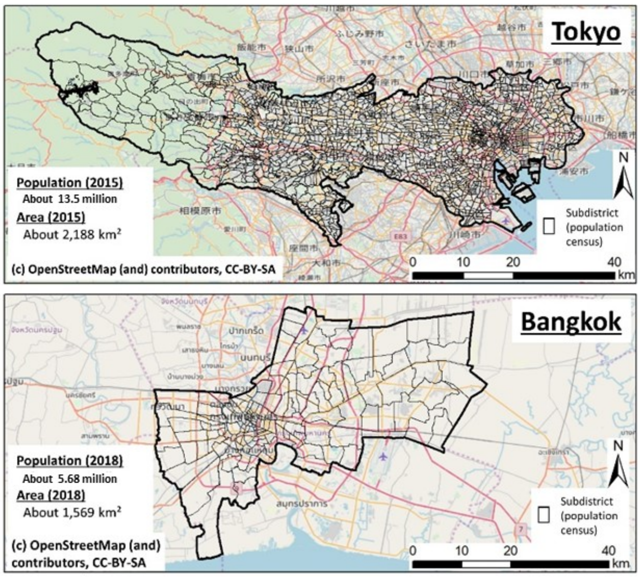

Fig. 2. Target areas

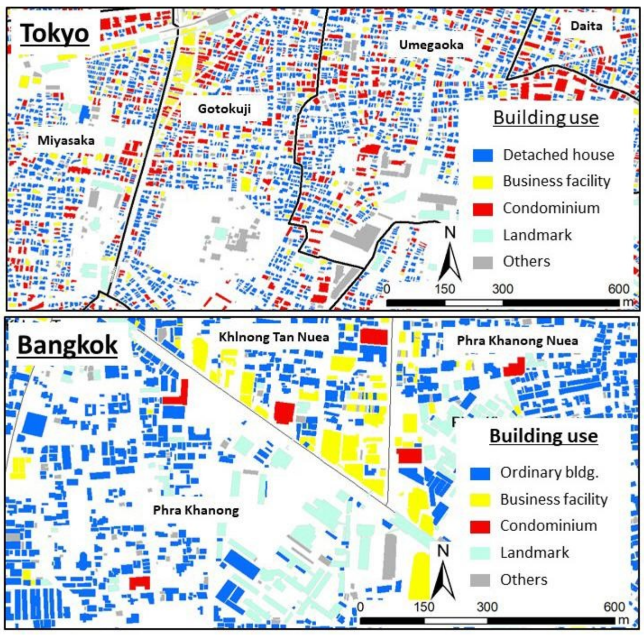

Fig. 3. Building polygon data in Tokyo and Bangkok

TABLE I. ATTRIBUTES OF BUILDING POLYGON DATA

	Tokyo	*Bangkok*
Data source	Digital residential map	Map Fan DB data
Data provider	Zenrin Co. Ltd	Increment P Corp.
Location and area	Available (polygon)	Available (polygon)
Number of floor	Available	---
Building height	---	Available
Building volume	Estimable (area * floor)	Estimable (area * height)
Building use	Available ➢ Detached house ➢ Business facility[b] ➢ Condominium ➢ Landmark[a] ➢ Others	Available ➢ Ordinary bldg. ➢ Business facility[b] ➢ Condominium ➢ Landmark[a] ➢ Others

[a] Government and public buildings, transportation facilities, hospitals, schools, religious buildings, and highly public buildings etc.

[b] Company office, industrial facilities, hotels, commercial facilities, banks etc.

A. Method 1: In case that only building location is cleared

This is the condition with the least available building information. For example, if only satellite images or land use maps with relatively low resolution are available, you may know only the location of buildings. In this case, the number of households $h1_{ij}$ allocated to the building j in subdistrict i was determined by Equation 1.

$$h1_{ij} = H_i / b_i \tag{1}$$

where, H_i is the total number of household in subdistrict i, and b_i is the total number of building in subdistrict i.

Then, $AR1_i$ which is the number of residents allocated to each household in subdistrict i was determined by Equation 2.

$$AR1_i = R_i / H_i \tag{2}$$

where, R_i is the total number of residents in subdistrict i.

Finally, the number of residents $r1_{ij}$ allocated to the building j was determined by Equation 3.

$$r1_{ij} = h1_{ij}AR1_j = (H_i / b_i)(R_i / H_i) = R_i / b_i \tag{3}$$

$r1_{ij}$ is equal to the value obtained by dividing the total number of residents by the number of buildings in subdistrict i.

B. Method 2: In case that building area is cleared

For example, when satellite images and maps with better resolution than the method 1 are available, we can monitor not only the location but also the shape of building. As a result, we can estimate the building area. In this case, it can be used as a control factor when allocating households. In the method 2, the larger the building area, the more households are allocated. The number of households $h2_{ij}$ allocated to building j in subdistrict i was determined by Equation 4.

$$h2_{ij} = H_{ij}(s_{ij} / \ \Sigma[k=1,m]s_{im}) \tag{4}$$

where, s_{ij} is the area of building j, and m is the number of buildings in subdistrict i.

Then, the number of residents $r2_{ij}$ allocated to the building j was determined by Equation 5.

$$r2_{ij} = h2_{ij}AR1_i \tag{5}$$

C. Method 3: In case that building height or number of floors are also cleared

If the conditions are better than the method 2, the shape of the building can be understood three-dimensionally. In other words, we can monitor the number of floors or height of the building and can estimate the building volume. In this case, not only the building area but also the building volume can be a control factor. In the method 3, the larger the building volume, the more households are allocated. The number of household $h3_{ij}$ allocated to building j in subdistrict i was determined by equations 6 and 7.

$$v_{ij} = s_{ij}f_{ij} \tag{6}$$

$$h3_{ij} = H_i\ (v_{ij} / \ \Sigma[k=1,m]v_{im}) \tag{7}$$

where, f_{ij} is the number of floor or height of building j, and v_{ij} is the volume of building j.

In addition, since the building volume is known, the area hs_{ij} of each household can be estimated by Equation 8, and the number of residents $r3_{ij}$ allocated to each household was determined by Equation 9.

$$hs_{ij} = v_{ij} / h3_{ij} \tag{8}$$

$$r3_{ij} = R_i\ (hs_{ij} / \ \Sigma[k=1,m]hs_{im}) \tag{9}$$

D. Method 4: In case that building use are also cleared

If the conditions are even better than Method 3, we can also understand the building use. Basically, the population in the population census is not resident at Public buildings such as government buildings or schools, business facilities such as enterprise offices and factories, and commercial facilities, etc. Therefore, in the case of Tokyo, the method 3 was executed after narrowing down the destination of distribution to the building which building use in Table I is the “Detached house” or the “Condominium”. In the case of a subdistrict where residents exist even though there are no detached houses and condominium buildings, all the buildings were exceptionally assigned as distribution destinations. If the method is applied to data in Bangkok, the distribution destination should be narrowed down to buildings where the building use is the “Ordinary building” and the “Condominium”.

E. Method 5: Give method 4 realistic fluctuation

In this method, building data conditions are the same as the method 4. This method is an improved method that gives realistic fluctuations to the method 4 allocation method for the number of households and residents. In the method 4, in the case of a building like the condominium where multiple households are distributed, the number of residents of the households in the same building is the same. However, in reality, it is unlikely that this situation will happen. Therefore, in this method, at least one household was allocated to all the buildings that are candidates for household allocation in the method 3. If there are unallocated surplus households, the selection probability rwh_{ij} was given to the building j in subdistrict i by Equation 10.

$$rwh_{ij} = v_{ij} / \ \Sigma[k=1,m]v_{im} \tag{10}$$

Then, the roulette selection was performed using rwh_{ij} of all buildings, and one household was allocated to each selected household. This process was continued until the number of unallocated households becomes zero.

Similarly, at least one resident is allocated to the household created by the above method. If there are unallocated surplus residents, the selection probability rwr_{ij} is given to the households distributed in the building j in subdistrict i by Equation 11.

$$rwr_{ij} = hs_{ij} \,/\, \Sigma[k{=}1,m]hs_{im} \tag{11}$$

As in the case of households, the number of residents is determined by the roulette selection.

The genetic algorithm (GA) is widely known as a method of trying to obtain realistic results by generating fluctuation by the roulette selection [9]. In GA, samples are randomly extracted by the roulette selection, and the evaluation of the samples after extraction is repeated to generate data with a high evaluation, in other words, close to the solution to be obtained. In this study, only one roulette selection was performed. However, in the future we would like to examine a method that is expected to create more reliable MPD by using GA or any other suitable methods.

F. Visualization of five types of MPD

Fig.4 shows the MPD in Tokyo created by method 1 to method 5. As the conditions for building information improve and the development method of MPD becomes more sophisticated, the spatial distribution of households changes from a uniform distribution to a biased distribution. In addition, we also found that the distribution of the number of residents in each household changes from a uniform distribution to distribution with variation, similar to the spatial distribution of households. In particular, the distribution of households has changed significantly by improving the method from the method 3 to the method 4. It means that building use has a great influence on the control of household spatial distribution. In addition, the distribution of residents in each household clearly changed from the method 2 to the method 3 and from the method 4 to the method 5. This result shows that the area of each household has a significant impact on the decision of the number of residents, and the spatial variation of residents can be increased by giving realistic fluctuations to the allocation method.

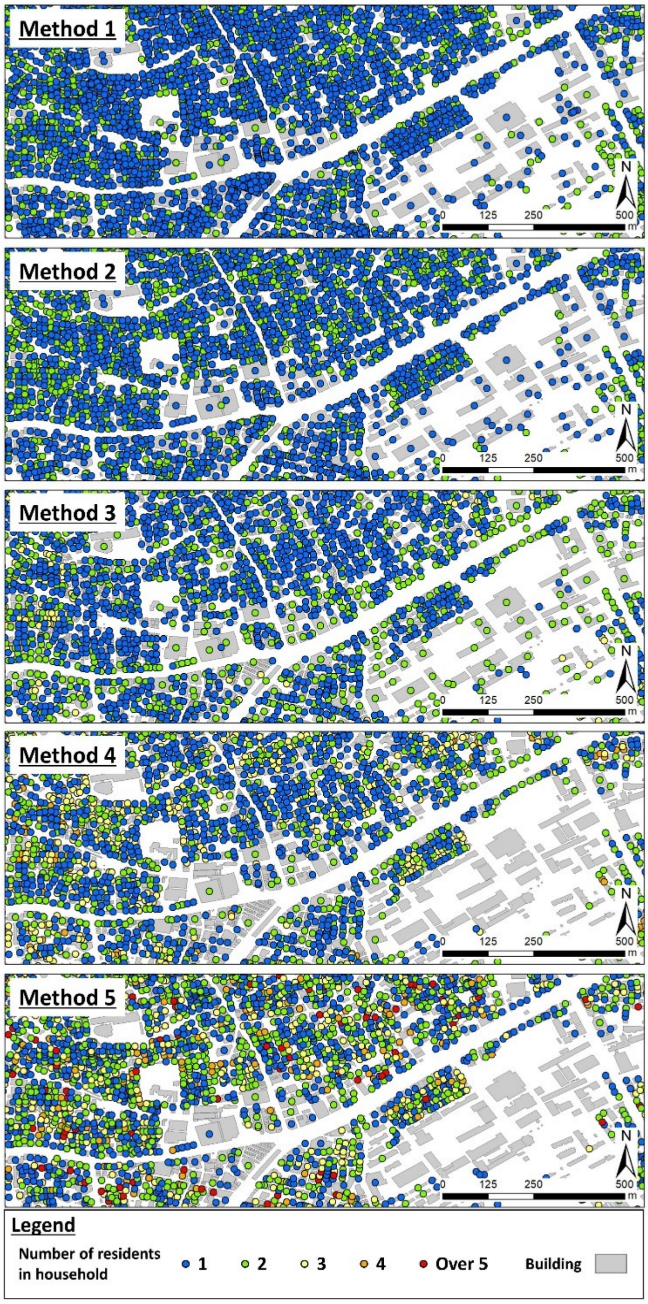

Fig. 4. MPD in part of Tokyo created by five types of method

V. Reliability verification of MPD in Tokyo

This chapter will clarify the reliability of the five types of MPD developed in Tokyo. In Tokyo, it is possible to use population census with higher spatial resolution as well as subdistrict unit: city block units and grid units. Therefore, reliability of five types of MPD was verified by comparing the estimated number of resident obtained from five types of MPD by aggregating in city block unit and 1km, 500 m, and 250 m square grids with true residential populations obtained from the national census by correlation analysis.

Table II to Table V show the comparison of five types of MPD and population census. In the case of a 1km square grid: the number of aggregation unit is small (Table III), there is no significant difference in the results of either method. On the other hand, when the number of aggregation unit is large such as Table IV and Table V, the method 2 has better results for both R and AR2 than the method 3, and the method 4 recovered the same level as the method 2. This is considered to be caused by the fact that many households are allocated to large-scale office buildings or government buildings etc. because households were allocated by building volume without considering building use. In addition, the result of method 5 was the best result for both R and AR2. RMSE of the method 5 also gave the best results. Moreover, MAEs of the method 4 and the method 5 were significantly better than other methods. This result indicates that households and residents can be allocated with less error by considering the building use like the method 4 and the method 5.

VI. Development of MPD in Bangkok

The results in Chapter 5 shows that the most reliable method for developing MPD is the method 5. Therefore, assuming that the characteristics of the spatial distribution of households and residents in Bangkok are similar to those in Tokyo, we developed MPD throughout Bangkok. Table VI shows the specifications of MPD developed by the method 5 in Tokyo and Bangkok. Since the characteristics of Tokyo are

TABLE II. COMPARISON OF FIVE TYPES OF MPD AND POPULATION CENSUS (CITY BLOCK UNIT: 5,704 BLOCKS)

Method[c]	*R*[d]	*R2*[e]	*AR2*[f]	*RMSE*	*MAE*
1	0.8650	0.7483	0.7482	931.21	-3.42
2	0.9039	0.8171	0.8170	768.57	-3.36
3	0.8777	0.7704	0.7703	932.89	-3.21
4	0.9041	0.8191	0.8190	754.34	-2.69
5	0.9399	0.8835	0.8835	618.99	-2.42

c. All results were statistically significant at the1% probability level.

d. "R" means correlation coefficients (Table III, IV, and V are same).

e. "R2" means coefficient of determination (Table III, IV, and V are same).

f. "AR2" means adjusted coefficient of determination (Table III, IV, and V are same).

g.

TABLE III. COMPARISON OF FIVE TYPES OF MPD AND POPULATION CENSUS (1KM SQUARE UNIT: 1,292 GRIDS)

Method[g]	*R*	*R2*	*AR2*	*RMSE*	*MAE*
1	0.9753	0.9512	0.9511	1786.58	32.16
2	0.9866	0.9733	0.9733	1324.33	57.56
3	0.9745	0.9496	0.9496	1821.62	34.96
4	0.9884	0.9773	0.9772	1214.21	9.15
5	0.9893	0.9787	0.9787	1173.51	5.85

h. All results were statistically significant at the1% probability level.

TABLE IV. COMPARISON OF FIVE TYPES OF MPD AND POPULATION CENSUS (500 M SQUARE UNIT: 4,904 GRIDS)

Method[h]	*R*	*R2*	*AR2*	*RMSE*	*MAE*
1	0.9064	0.8215	0.8214	909.69	10.69
2	0.9425	0.8882	0.8882	706.07	21.48
3	0.9089	0.8262	0.8261	915.00	19.04
4	0.9454	0.8884	0.8884	682.13	1.65
5	0.9692	0.9299	0.9299	596.18	-1.40

i. All results were statistically significant at the1% probability level.

TABLE V. COMPARISON OF FIVE TYPES OF MPD AND POPULATION CENSUS (250 M SQUARE UNIT: 17,312 GRIDS)

Method[i]	*R*	*R2*	*AR2*	*RMSE*	*MAE*
1	0.7628	0.5819	0.5818	382.37	6.65
2	0.8393	0.7044	0.7044	305.55	17.84
3	0.7802	0.6087	0.6087	408.99	16.74
4	0.8476	0.7221	0.7221	299.99	-3.85
5	0.9038	0.8011	0.8011	236.65	-2.65

j. All results were statistically significant at the1% probability level.

TABLE VI. SPECIFICATION OF MPD IN TOKYO AND BANGKOK

Specification		*Tokyo*	*Bangkok*
Number of household	Single person	2,882,539	1,431,484
	Two persons	2,079,013	798,925
	Three persons	1,007,967	376,416
	Four persons	425,828	164,753
	Five persons	174,363	71,355
	Over six persons	126,124	69,357
	Total	6,695,834	2,912,290
Number of resident		13,500,874	5,699,578
Average number of household members		2.0163	1.9571
Median of household members		2.000	2.000

Fig. 5. MPD in Bangkok's city center, luxury residential area, and middle-income residential area

also reflected in the Bangkok MPD, it shows that the ratio of the number of households by number of resident and the average and median of household members are similar.

Fig. 5 shows the MPD in whole area, city center, luxury residential area, and local residential area of Bangkok. The map of the entire Bangkok shows that in Bangkok, as we moved from the city center to the suburbs, it turned out that the number of households with larger households tends to increase. In particular, it was found that the number of single-person households was significantly higher in the city center than in other areas. Most of the households distributed around the Asok station in the city center were singles, and there were many buildings where no households are located. This is because there are many buildings in the city center that are not allocated households, such as government buildings and commercial facilities. Next, we compared the distribution of households and residents in Thong Lo: luxury residential area and Thonburi: local residential area. Overall, household of Thonburi was more densely distributed than that of Thong Lo. In addition, although there were differences depending on the subdistrict, there was a tendency for Thonburi to have larger household members than Thong Lo. The characteristic seen in the city center: around Asok station and the differences due to the wealth of the residential areas: between Thong Lo and Thonburi are common phenomena in many previous studies (see [10] and [11]). It is an interesting result that these characteristics were clearly seen even when the population distribution in Bangkok was observed with MPD.

A. *Future tasks of MPD in Bangkok*

At the time we wrote this paper, reliability of MPD in Bangkok could not verified because more detailed population census than subdistrict units were not available. However, we are now preparing to obtain higher-resolution population census in some part of Bangkok. In addition, a census called the "Housing and Land Survey" is maintained in Japan. It is possible to know the number of households by resident and the number of households by residential area from this census. By using them as a control factor when allocating household and residents, it is possible to develop a more reliable MPD [1]. If similar census is available in Bangkok, the reliability of Bangkok's MPD may be greatly improved. Therefore, we would like to investigate the census data in Bangkok.

VII. CONCLUSION

In this study, we developed the MPD that can estimate the number of resident for each building using the detailed digital map and population census aggregated by the subdistrict unit for the entire Tokyo and Bangkok. Through this study, prototyping of the MPD across Tokyo and Bangkok was accomplished. In addition, by comparing the higher-resolution population census than subdistrict unit with the MPD in Tokyo by correlation analysis, the reliability of the development method of five types of MPD was verified. As a result, it was found that building use is an important control factor when allocating households and residents.

This study has many problems and future prospects. First, as mentioned in Chapter VI, it is necessary to verify the reliability of the MPD in Bangkok. To achieve it, it will be necessary to obtain more detailed population census than subdistrict unit in Bangkok. In addition, this study estimated only the distribution of households and the number of residents in each household. However, we would like to examine the estimation method of residents' age and gender in the future. It may be possible not only in Tokyo but also in Bangkok because population census in both Tokyo and Bangkok include populations by age and gender, and Tokyo has been prototyped in Akiyama et al. (2013) [1]. Since the existing method [1] uses census on detailed household types, it is necessary to investigate whether the same level of statistics on households is available in Bangkok. Moreover, the method of this study allocates households and residents to buildings with population census as correct values. However, in developing countries in particular, there seems to be a considerable number of populations that are not counted in the population census: the "informal sector". Therefore, it will be necessary to develop MPDs for countries and regions where census are accurately maintained, and to build models that can estimate the number of households and residents in areas with incomplete census by using them.

Through this study, we were able to clarify the problems of MPD development in developing countries such as Bangkok. Although many problems remain, we believe that the development of MPD in a city of developing country: Bangkok will contribute to the realization of smarter urban and transportation planning in developing countries. In the future, we will try to develop MPDs not only in Bangkok but also in other cities in Thailand, as well as in cities around the world, and to sophisticate the development method of MPD.

ACKNOWLEDGMENT

This study was supported by the project of "Smart Transport Strategy for Thailand 4.0 -Realizing better quality of life and low-carbon society-" granted by SATREPS (JST). In addition, the authors were given digital residential map from joint research with the Center for Spatial Information Science (CSIS), the University of Tokyo (research ID: 122). We would like to thank them for their valuable contributions.

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A Stated Preference Experiment of Residential Location Choice in Mandalay

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***Abstract*—Mandalay, as a major commercial and industrial hub of Myanmar, is now facing great challenges due to a substantial increase in automobile, traffic volume, air pollution, and urban sprawl. The rapid urban growth can be seen by the high-density housing development in many parts of the city. However, the current development of high-density housing that is going on in the city center may not best match with people's preference, on the contrary it will even make the problem more severe resulting in traffic congestion and accelerating the urban sprawl. This paper presents a Stated-Preference (SP) experiment of housing location choice in Mandalay. A multinomial logit model is developed based on the SP survey data. Although the discrete choice model has a long history of application in the economic, transportation, marketing and geography fields, it is not well developed in location analysis. The results reveal that people are considering factors not only house size, house price, but also locational convenience in terms of commuting time, and neighborhood quality. It is also found that different socio-economic groups, i.e., ethnicity, exhibit different location preferences.**

Keywords—Residential Location Choice, Stated Preference Experiment, Logit Model, Mandalay.

I. INTRODUCTION

A considerable number of urbanizing cities around the world, including Mandalay which is the second largest city of the Union of Myanmar and is located in the middle part of Myanmar, besides being a religious and cultural center, a major commercial and industrial hub, are facing great challenges because of their growth has been marked by a substantial increase in auto-dependency, traffic congestion, air pollution, and urban sprawl. One strategy often suggested to reduce these negative effects is the integration of land-use and public transportation through intense residential development. The work of urban planners, urban designers, architects, and policy makers centers on improving the built environment and increasing the quality of people's lives. However, their work entails making decisions that are not always in tandem with people's preferences (e.g., increasing housing density, proposing a mix of land uses in residential neighborhoods, introducing public transportation close to where people live and work) [2]. Moreover, the city has been unabatedly urbanizing over the past few years. This urban growth, however, has been characterized by a low-density sprawling pattern and also has tried many approaches to face this problem. On the other hand, high-density housing should not be developed without insight into how people will respond to such developments and, more importantly is which are the factors influencing on that development.

II. LITERATURE REVIEW

A. Urban Development in Mandalay

Mandalay has long history of urbanization process. It was established by King Mindon in 1857. After the independence from British or after 1948, Mandalay continued to be the cultural capital of Upper Myanmar. During this period the population increased rapidly but the urban area of Mandalay was not remarkable changed. From 1962-1988, urban expansion started the Mandalay-Yangon highway, Mandalay-Amarapura road. Urban facilities were launched with hospitals, banks, schools and other enterprises. During this period, the Mandalay urban area developed with houses in vacant places and the population became 417,938 according to 1973 census. The population reached to 532,948 in 1983. After 1988, the government started to launch the market-oriented economy as put into practice trade opportunity which attention to encourage international trade investment. It was followed the new economic policies which pulled many people reside to urban areas [11]. According to this economic policy, Mandalay City Development Committee was constituted to set up systematic urban management and development and urban areas were expanded and absorbed the surrounding suburban areas. Under the control of Mandalay City Development Committee, the six townships are separated into three areas: Central Business District (CBD), Old-town and New-town. The current situation of that three areas are shown in Fig. 1.

B. Population

The population of Mandalay was approximately 636,000, growing to its estimated 1.2 million (86%) in twenty-one years. Based on 2013 population by the Department of Immigration, there are an estimated 240,000 households in Mandalay City with an average household size of 5.25 persons per household. Mandalay District with a population of 1.7 million occupies 28% of Mandalay Region in terms of population size [10]. About 76.4% of the district population are urban residents as shown in TABLE I. In addition, as being a religious cultural center, a major commercial and

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industrial hub, people are living-together in Mandalay such as original Burmese people, seven majority ethnic groups and Chinese people who migrated to the city.

TABLE I. POPULATION OF MANDALAY DISTRICT

Region/ District/ Township	Population (thousand)			Urban Population
	Total	Urban	Rural	
Mandalay Region	6,166	2,143	4,022	34.80%
Mandalay District	1,727	1,319	407	76.40%
Aungmyaytharzan	266	266		100%
Chanayetharzan	197	197		100%
Maharaungmye	241	241		100%
Chanmyatharzi	284	284		100%
Pyigyidagun	238	238		100%
Amarapura	238	81	157	34%
Patheingyi	264	13	251	4.90%

Source: JICA Study Team: Nippon Koei Co. (2016).


(a) CBD area


(b) CBD area


(c) Old-town


(d) Old-town


(e) New-town


(f) New-town

Fig. 1. Six Districts in Mandalay.

C. Transportation

Transport in Mandalay is dominated by motorcycles. It is estimated that two-wheelers account for 92% of trips, excluding walking as shown in TABLE II. Urban bus services play a minor role. The Mandalay region has 30% of the country's motorcycle registrations with 688,652 registered motorcycles in 2014 in the city alone (1,182,691 across the region). This equates to 2.12 motorcycles per household (0.16 for cars and 0.92 for bicycles), and a motorcycle ownership rate of about 400 per 1,000 population. The motorcycle ownership rate might appear high, but international comparisons indicate that it could still grow by 50% before saturation point is reached. [9] stated that considering the city population is likely to double by 2030, the number of motorcycles may triple. Moreover, the road pattern is essentially a grid structure with wide single lane roads (about 10 meters) with occasional sidewalks and the road network is also largely uncongested during peak hours at major intersections [4].

TABLE II. VEHICLE FLEET AND MODE SHARE

Vehicle	Number	Transport Modal Share (%)
Motor-cycle	688,000	70.2
Bicycle	300,000	21.6
Car	54,000	5.6
Bus	450[a]	2.6

[a] refers to daily operations.

Source: Asian Development Bank (2016).

III. RESIDENTIAL LOCATION CHOICE MODEL

A. Factors Influencing on Residential Location Choice

The generalization of preference research results across multiple segments of the population whether based on ethnicity, income, or other socio-demographic variables is a common practice. It helps researchers aggregate research results in a meaningful way to understand a phenomenon and communicate these results with policymakers. People have different preferences, and these preferences are shaped by many factors, including one's stage in life, aspirations, and lifestyle. From this standpoint, a stream of residential preference research has focused on several clustering methodologies, often referred to as psychographics [5], to describe lifestyle as a determinant of housing-type and locational choices.

In Canada, the city of Edmonton has conducted a stated preference survey to consider trade-offs involving a wide range of elements of urban form and transportation, including mobility, air quality, traffic noise, treatment of neighborhood streets, development densities and funding sources such as taxes [8]. Besides socio-demographics, recent studies [16] have shown that 'subjective' (or soft) factors, such as attitudes and environmental awareness, greatly influence on residential location decisions [17]. Although price or affordability is one of the most important factors in determining residential locations, this factor is mostly absent in the previous studies using stated-preference questionnaires [12]. However, understanding the preference of resident in choosing the house location and what really make people to locate in a certain location is needed. [19] found that out of the attributes of household and transportation factors considered, price and brand have greatest impacts on residential attractiveness for the typical household. Therefore, to indicate the influences of different attributes for specific groups households were established by estimating standard logit modes for those households using the observations obtained in the survey. The resulting parameters estimates for the logit model indicate the influences of the attributes.

B. Logit Model

The discrete choice modelling paradigm, and in particular the logit model, have been topics of intense and active research for many years, mainly for applications in the field of transportation choice analysis. Mathematical model, the logit model represents that the behavior of individuals trading off among the attributes of alternatives when selecting one alternative out of a set of available discrete alternatives [14]. The form for the choice situation has considered as below,

$$P_{i*} = \frac{exp(U_{i*})}{\sum_i exp(U_i)} \tag{1}$$

where

i	index representing new home location alternatives
i^*	a particular new home location
P_{i*}	probability that new home location alternatives $i*$ is selected
U_i	utility value associated with new home location alternative i, expressed in (implied) hypothetical units called "utils"

The utility function that describes utility values to the new location alternatives, linear form is as below,

$$U_i = \varphi_1 X_{1i} + \varphi_2 X_{2i} + \ldots\ldots\ldots\ldots\ldots + \varphi_n X_{ni} + \ldots\ldots\ldots, \tag{2}$$

where,

N	index representing attributes,
X_{ni}	value of attribute n for alternative i,
φ_n	utility function parameter associated with attribute n.

C. Parameters Estimation

The mathematical form of the logit model is relatively simple and convenient to work with when using empirical data to estimate the values for the parameters, φ_n, in the utility function. Consequently, this formulation is a very attractive one for modelling choice behavior and it continues to enjoy widespread use [14]. When values for the utility function parameters have been estimated, the relative influences of factors can be determined using ratios among the resulting coefficient values [18].

The significant of differences among estimates can be considered using standard t-statistics and t-ratios, with the t-ratio being the t-statistic for the estimate's difference from 0. When t-statistic or t-ratio has a value greater than 1.96 in absolute magnitude, this indicates that there is a less than 5% chance that the associated difference is due to random effects only [3], and the difference is said to be significant. The overall model goodness-of-fit can be considered using goodness-of-fit index as follows [6],

$$\rho^2(0) = 1\text{-}\frac{L(*)-k}{L(0)} \tag{3}$$

where,

K	number of coefficients in estimated model,
$L(0)$	log-likelihood for model with zeros for all coefficients
$L(*)$	log-likelihood for model with estimated coefficients

This ρ^2 (0) index is analogous to the R^2 statistic for linear regression in that it ranges from 0 to 1, with larger values indicating a better fit. It also takes into account the number of parameters used in the model, favoring more parsimonious model specifications [6].

The NLOGIT software package (NLOGIT, 2007) [15] was used to estimate the parameters in this paper. NLOGIT is an extension of another very large, integrated econometrics package, LIMDEP, that is used world-wide by analysts of models for regression, discrete choice, sample selection, count data, models for panel data, etc. NLOGIT includes all of the capabilities of LIMDEP plus package of estimators for models of multinomial logit (MNL), multinomial probit (MNP), nested logit, mixed logit and several others. By using NLOGIT software, the model goodness of fit can consider with the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). AIC and BIC are both penalized-likelihood criteria. AIC is an estimator of out-of-sample prediction error and thereby relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Thus, AIC provides a means for model selection and the preferred model is the one with the minimum AIC value [1]. Then the AIC value of the model is used as $AIC = 2k - 2\ln(L^{\wedge})$ where, k the number of estimated parameters in the model and $L^{\wedge}$ the maximum value of the likelihood function for the model. Moreover, BIC is also a criterion for model selection among a finite set of models; the model with the lowest BIC is preferred. It is based, in part, on the likelihood function and it is closely related to the Akaike information criterion (AIC). The BIC is formally defined as $BIC = \ln(n)k - 2\ln(L^{\wedge})$ where, $L^{\wedge}$ the maximized value of the likelihood function of the model, n the number of observations and k the number of parameters estimated by the model.

IV. STATED PREFERENCE EXPERIMENT

A. Questionnaire Survey Design

The questionnaire was divided into three parts: (I) Socio-economic characteristics, (II) attitudes and behaviors of considering house location and (III) SP survey for a choice set of housing alternatives. The flow and process of questionnaire survey and SP experiment is as shown in Fig. 2. In Part I, the respondents were asked to provide the following socioeconomic information such as nature of household tenure (own or rent), current house price or rental fees per month, age, gender, employment status, education level, household income, personal income, household location, workplace/school location, commuting time (to work or study), usual mode of transport, number of household member, children younger than 11 years of age, length (years) having lived in the current house, total number of vehicles occupied by household, present dwelling type and size, plan to move or relocate within 1 year.

In Part II, the attitudes of house location choice considered by respondents were described in terms of the following, the township location of the house, the price of the house, the size of the house, having good prospect future value of the location, living in green environment, having local shops within walking distance, living near to the relatives and friends, low crime rate within neighborhood, less traffic congestion on nearby street, living closer to the main road, closer to work place/school and having parking space.

The main data-set used in this paper for the analysis is Part III and based on the Stated Preferences experiment. SP surveys are a widely used method for identifying preferences in cases where revealed preferences (RP) data are unavailable or inadequate to identify preferences [13]. In order to reveal preferences for the characteristics of the residential location choice, the SP experiment presented respondents with choice scenarios and a hypothetical situation where they were asked to choose one among three alternative residential situations. The first option was the respondent's actual area of residence and the attribute values corresponded to real observed values. The second and the third house situation were represented by two hypothetical alternatives with attribute levels pivoted around the values of the current residence situation. This setting permitted respondents to recognize a familiar choice situation, thus making the choice experiment more realistic and reliable. The three residential choice situations were described by a number of different characteristics. The experiment included variables indicating that the township location, size, price, travel time to work/school and neighborhood environment. TABLE III presents the summary details of the experiment. In each option, attribute contained the current residential location of respondents and two additional levels expressed as positive and negative percentage deviations. Besides, the example of considering better neighborhood and bigger or smaller house size are presented in Fig. 3. Based on the fractional factorial orthogonal design, the experiment contained 6 choice tasks by randomly made. The values of attributes describing the alternatives neighborhoods varied across every choice task. The SP choice experiment was conducted by using Computer-assisted personal interviewing (CAPI), is an interviewing technique in which the respondent or interviewer uses an electronic device such as tablet during the field survey.

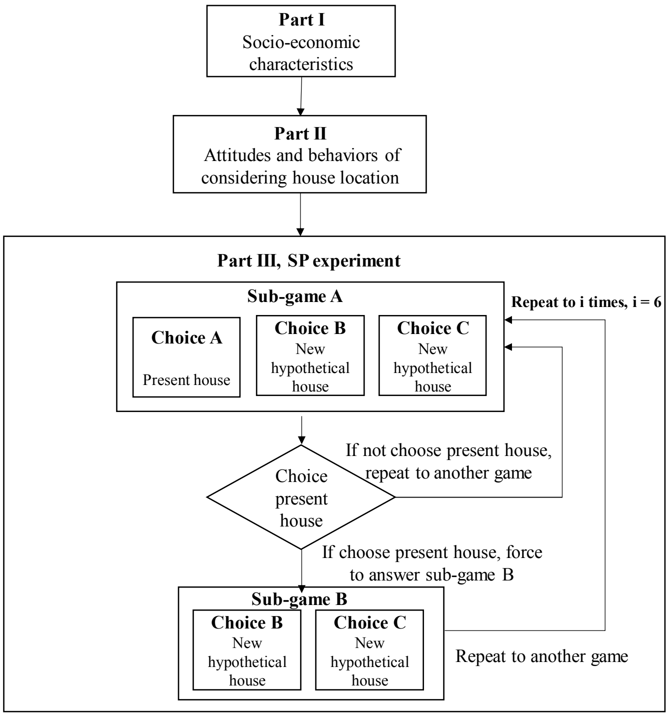


Fig. 2. Steps of the Stated-Preference Choice Experiment.

TABLE III. SUMMARY OF THE EXPERIMENT

Attributes	Levels
Location	New location, Current residence location, New location
Size	-50%, Current house size, +50%
Price	-20%, Current house price, +20%
Neighborhood environment	-10%, Current environment, +10%
Travel time to work/school	-50%, Current travel time, +50%
Experimental design approach	Fractional factorial orthogonal design
Alternatives	Current residence (A) and two hypothetical alternatives (B, C)

Fig. 3. Example of neighborhood and house size.

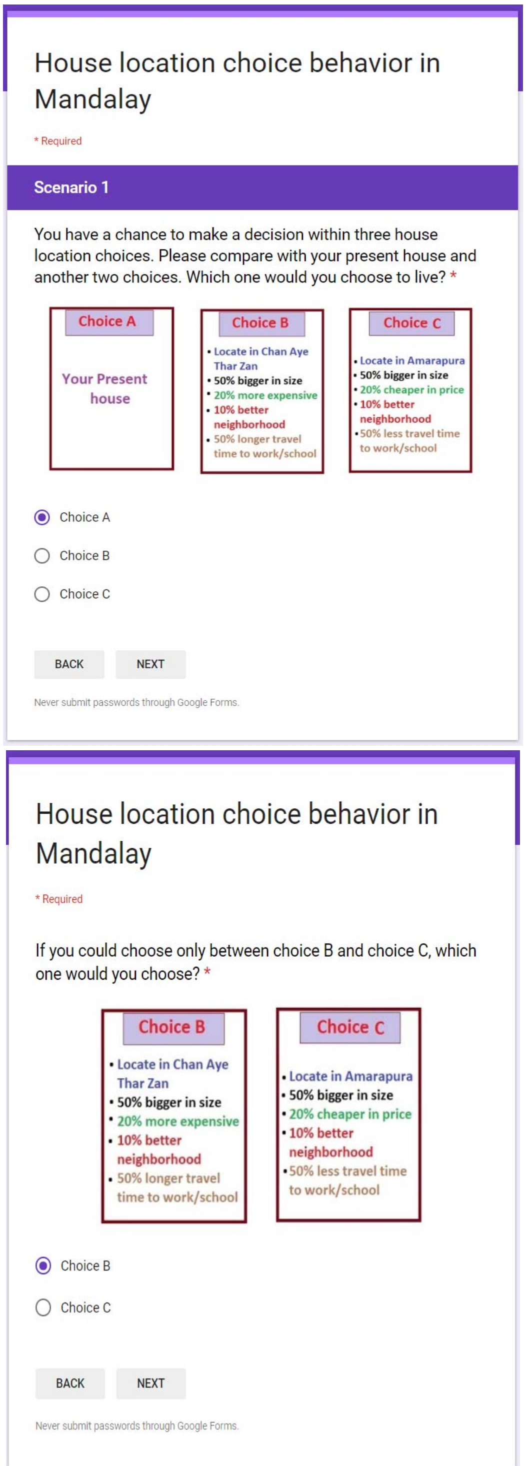


Fig. 4. Example of Google Form.

We employed Google Forms that is free. Each respondent was assigned to choose among 3 alternatives. If the respondents selected the choice of present house, they would be asked to evaluate the rest two unchosen alternatives again and make a choice as shown in Fig. 4.

B. Data Collection

The questionnaire survey was carried out by computer-assisted face-to-face interview, the respondents were randomly chosen at Government offices, Schools, Universities and Private companies/offices by self-administered questionnaire survey. These places were located in three areas (CBD area, old town, new town) of Mandalay city as mentioned above. Survey was carried out during 24th August 2019 to 28th August 2019 and shown in Fig. 4. 122 respondents were interviewed since some respondents did not want to interview survey.

Fig. 5. Computer-assisted face-to-face interview survey.

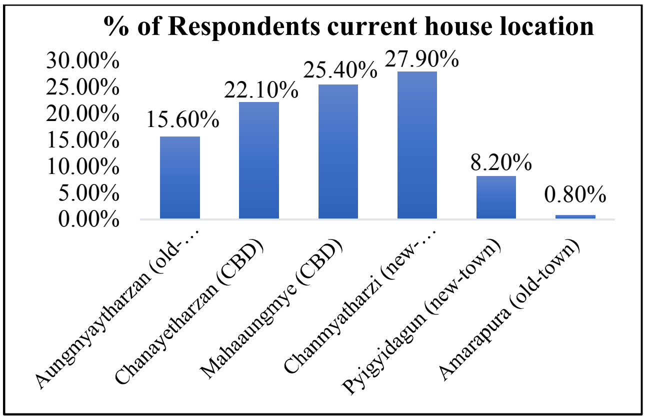
C. Characteristics of the Respondents

The general information of the respondents is described using descriptive statistics in TABLE IV. The sample was mixed in terms of gender 48 male (39.3 percent), 70 female (57.4 percent) and 4 others (3,3 percent). More than 80 percent of respondents hold bachelor degree, while 6.6 percent is master degree or more. In addition, 17.2 percent have diploma/college level education and 5.7 percent report high school.

In terms of ethnicity, 72.1 percent represent the original Burmese and 14.8 percent of Chinese people. For house type and house status, 83.6 percent live in Single house type and 69.7 percent own houses which is indicated that they have highly preferred in their own house and do not have any plan to move a new location.

D. Respondents residence and work/school location

The 34 persons (27.9 percent) live in new-town area and 31 persons (25.4 percent), 27 persons (22.1 percent) live in CBD. The 49 persons (40.2 percent) do their daily activities in CBD area. The percentage of their current house location and work/school location is as shown in Fig. 6. According to Fig. 7, 33 percent of the respondents own more than 3 private vehicles and mostly use Motorcycle (61 percent). That means people prefer to use private vehicle and they did not care about the public transportation and travel time because of less traffic congestion.



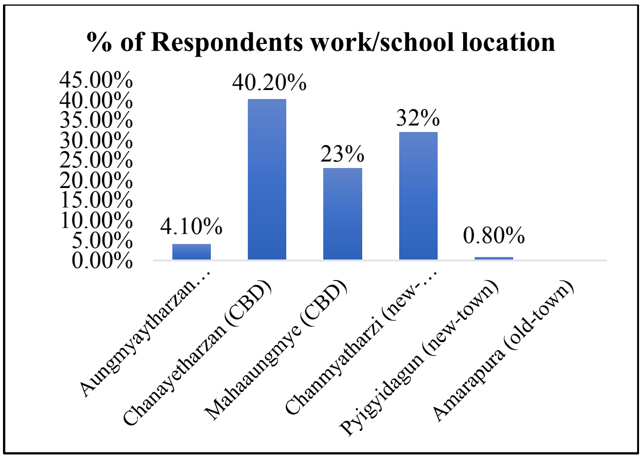
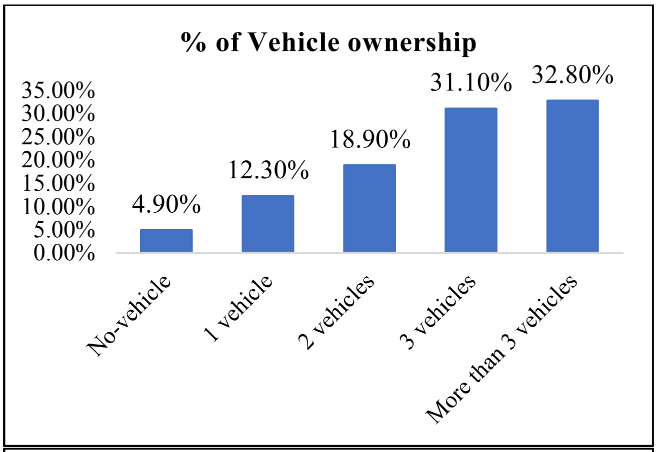


Fig. 6. House and work/school location of respondent.

E. Vehicle ownership and daily usage of respondents



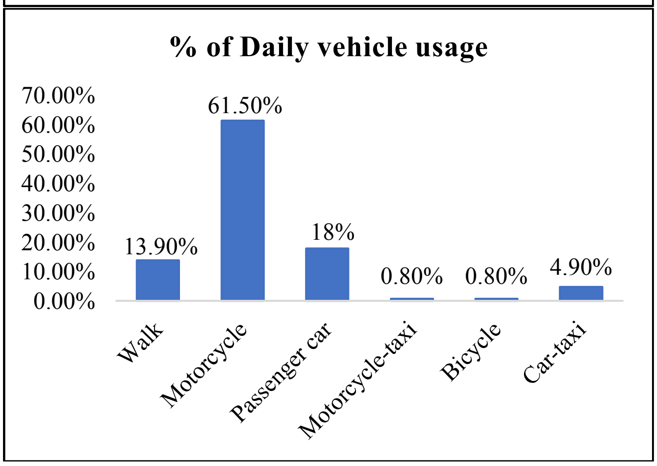


Fig. 7. Vehicle ownership and daily usage.

TABLE IV. DESCRIPTIVE STATISTICS OF THE RESPONDENTS

	Frequency	Percentage
Gender		
Male	48	39.30%
Female	70	57.40%
Others	4	3.30%
Education		
High school	7	5.70%
Diploma/College	21	17.20%
Bachelor	86	70.50%
Higher than Bachelor	8	6.60%
Ethnicity		
Burmese	88	72.10%
Kachin	3	2.50%
Kayin	3	2.50%
Mon	1	0.80%
Rakhine	1	0.80%
Shan	8	6.60%
Chinese	18	14.80%
House-type		
Single-house	102	83.60%
Condominium/Apartment	16	13.10%
Shop-house	4	3.30%
House-status		
Rent	16	13.10%
Own	85	69.70%
Government residence	21	17.20%

V. EVALUATIONS OF RESIDENTIAL LOCATION CHOICE

A. Housing Choice Status

The models were estimated for the entire sample and for various different subsample from the survey. The results for some of the estimations are shown in TABLE V, in which the results of the house status own data in three alternatives and the data part of forced to choose among only two hypothetical new location choices.

1) House location choice sub-game A

In the model estimation from the TABLE V, it is found that some of the attributes are statistically significant, i.e., the township location (CBD area), price, travel time and neighborhood environment. In the sub-sample of making choice decision between current house location and two new hypothetical situations, it is found that the respondents were likely not to live in CBD areas means that people also considered other factors and they do not care about the travel time. That is because they had their own vehicles like as motorcycle to access to every desired destination easily. In addition, the size of the house was not significant in residential location decision making.

2) House location choice sub-game B

The sub-sample of making force to choose the respondents only between two new home situations, they were likely to live in CBD areas and did not consider the size and the price. This is probably because of the travel time that they would not want to travel longer indicated by negative sign of Travel Time variable. Not only they likely to stay in CBD areas and also better-neighborhood environment is statistically significant.

TABLE V. ESTIMATION RESULT BY TWO SUB- GAMES

		Sub-game A		Sub-game B	
		b	t-value	b	t-value
Dummy of CBD area		-0.424	-2.229*	1.755	4.822*
Size		0.000	-1.091	0.000	-0.857
Price		0.001	2.306*	-0.558	-0.028
Travel Time		0.056	4.315*	-0.049	-2.808*
Dummy of better-neighborhood		-1.480	-11.891*	1.919	2.373*
Number of observations		510		238	
Goodness of fit	AIC	1.623		1.250	
	BIC	1.681		1.323	
	ρ^2	0.017		0.035	

* refers to 0.05 errors (95% statistically significant).

B. Ethnic Group

To examine how the ethnic groups of the people influences on residential location decisions, the results of estimations are shown in TABLE VI. The results of Burmese people group are compared with the Chinese or other ethnic groups.

TABLE VI. ESTIMATION RESULTS BY ETHNIC GROUP

		Burmese		Chinese or others	
		b	t-value	b	t-value
Dummy of CBD area		-1.379	-3.709*	2.074	3.371*
Size		-0.001	-1.501	0.469	0.057
Price		-0.001	-2.111*	0.000	0.759
Travel Time		0.001	0.097	-0.045	-1.459
Dummy of better-neighborhood		-0.114	-0.134	3.061	1.946*
Number of observations		158		82	
Goodness of fit	AIC	1.309		1.195	
	BIC	1.405		1.341	
	ρ^2	0.051		0.114	

*refers to 0.05 errors (95% statistically significant).

According to TABLE VI, the Burmese ethnic group does not consider the size of the house and travel time when making choice decision. And they do not likely to live in CBD areas that is they concern about the price of the house. Also, the better-neighborhood environment is not significant for this group of determining the house location decision. The estimation results for sub-sample of Chinese and other ethnic groups, location variable is statistically significant in making choice decision. The better the environment in the area, the more likely these ethnic groups to live. In addition, the price of the house is not a decision-making factor for these Chinese ethnic group.

VI. CONCLUSION

This study has examined the factors that have influence on residential preference, i.e., attractiveness of attributes with respect to various groups of people in Mandalay. The results support the existence of factors which differ in their housing choice preference. For those people who prefer their present house than the two new hypothetical houses, they apparently do not desire to live in the CBD and spend more time for travelling to work or school. This finding clearly reveals that the district location and travel time are not the main factors for people in Mandalay when choosing house. This phenomenon is due to the less congested traffic situation in Mandalay even in the peak hour. Therefore, travelling from outskirt to the CBD to work or school is not a big deal but can compromise with better neighborhood in the outer area of the city. This was examined by asking people to choose only the two new hypothetical houses. The results reconfirm that better neighborhood is preferable. The latter part of the paper has examined the preference of specific groups of the sample based on the socio-economic characteristics, i.e., ethnicity. It is found that the Burmese-race respondents mainly consider location although CBD is not preferred, neither pay attention to travel time. In contrast, Chinese-race respondents exhibit strong preference to locate in the CBD where the commercial opportunity are there while preferring a larger house locating in better neighborhood but still trade-off with travel time. The effect of other socio-economic characteristic is left for the future study.

ACKNOWLEDGMENT

This study is financially supported by Kasetsart University Scholarships for ASEAN for Commemoration of the 60th Birthday Anniversary of Professor Dr. Her Royal Highness Princess Chulabhorn Mahidol.

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Comparison of life patterns from mobile data in Bangladesh

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***Abstract*—Digital economy is growing worldwide with spreading internet and mobile devices. The possibilities are discussed to apply these accumulated data of mobile devices for monitoring purposes, because more detailed data could be collected on activities or status of individuals more efficiently and frequently. Existing studies show some specific features or behavior or mobility patterns can be detected with mobile phone data. However, classifications or clustering of people behavior patterns are not attempted, though such classification may be useful in understanding "human landscape" and help design better sampling for field surveys to collect more detailed data for in-depth analysis and to correct biases due to biased mobile phone holdings and usage. We analyzed human behavior in Bangladesh using "Call Detail Records" of mobile devices for classifying people life patters and understanding the patterns in relation with income index and proximity to cities etc. For this purpose, we calculated features on estimated dwelling areas and subscriber's trajectory. Through comparing the description of "life behavior" patterns from CDR to physical environment and official census, we found that the differences on the distribution of "life behavior" patterns on area and the efficiency varied from the duration of the data.**

Keywords—mobile big data, Call Detail Records, human behavior, urban development, life pattern

I. INTRODUCTION

Recently through growing digital economy with internet and mobile device, the various kind of data on human activity of mobile device are accumulated. The possibilities are discussed to apply these accumulated data on mobile devices to the monitoring purposes, because more detailed data could be collected on activities or status of individuals more efficiently and frequently. Many project are starting to use these data for public goods. OPAL platform project develop and standardize a platform with open algorithms of privacy-preservation for private data, especially mobile big data. They expects that it will accelerate applications of mobile big data of private sectors for public goods. On the other hands, mobile big data can be biased due to a bias of mobile phone holdings. And there are some periods that data on users can't be collected through the device. And it is reported some subscriber have multiple mobile devices.

To discuss application mobile big data for public goods, it is verified how much human activities are expressed with mobile big data.

In this paper, we focused on Call Detail Records (hereinafter, this is called "CDR") obtained from mobile phone. This is a basic record on call and data transaction collected by Mobile Network operator for calculating their charge. These records have Cell tower ID, phone number of caller and callee, IMEI, IMSI, the amount of data transaction and top-up information, which is the amount of charge and the date.

II. THE PREVIOUS WORKS

There are many research to analyze or model human activities using CDR. Ref.[1] focused on the routine of human activities. Ref.[1] categorized human behavior on the specified period to use "eigen-behavior" from behavior space dissolved with per hour and location attribution label such as home, work, elsewhere, no signal and off. The subjects were students ,who are of business school, master course and fresh man of MIT. The authors compared reconstruction accuracy by the groups. They showed six "eigen-behavior" composed of more than 90% of subject's behaviors and the regularity of behavior is diverse on each group. They found the resemblance of behavior space in subscribers who are belonging to close social networks. Ref. [2] calculated individual history trajectory at the prefecture level from the frequency and the distribution of call in hour using CDR on Ivory Coast and show human mobility, especially focusing on commuting crossing borders of different areas.

Ref. [3] researched a relevance to subscriber's mobility pattern and socio-economic status in France. they estimated a home location and calculated a mobility volume using radius of gyration and a mobility entropy using entropy of the number of visitation. The mobile entropy are computed based on subscribers estimated to be residents in the area divided into 10 km grid cells. Some researches show the relationship actual events and people behavior with the CDR data.

Ref. [4] found a change of employment status caused by closing a plant can be shown in a change from CDR using autoregressive models. It is shown the number of call including incoming and outgoing, contacts and visit were declined before and after losing their own job And they reported the autoregression model reduced estimation error by 5% to 20% compared to other estimation model that do not use autoregression model on estimation in province level.

Thus, some researchers found the changes of socio-economic status of subscriber are reflected on their mobile big data. Ref. [5] found a negative correlation between the frequency of call and poverty index from CDR on Ecuador. In regression model, the frequency of calls show high contribution rate of school year for male and female, poverty index, on the contrary, less contribution rate of health care

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coverage. This result illustrates difference in the frequency of calls link to a social life.

III. Objective

Our research aims to examine how clearly "life behavior" patterns can be found in CDR data and how human behavior patterns are associated with socio economic and geographic variables of each regions, like income index and proximity to cities.

IV. Research

A. Call Detail Records(CDR)

CDR is one of basic records on call and data transaction collected by Mobile Network Operators for calculating their charge. These records have Cell tower ID, phone number of caller and callee , IMEI, IMSI, the amount of data transaction and top-up information(the amount of charge and the date).

CDR includes information on messaging (SMS), call and data communications, covering all transactions, or connections to calculate your mobile phone payment. It is characterized by broad coverage of subscriber's activities.

Further, the position is recorded as those of cell towers in CDR, when a subscriber uses data transaction or call services. The accuracy of position has been greatly effected by the coverage of cell tower. In the urban areas which has dense cell towers, the error is within several hundred meters. In the rural area with low density of cell tower, the error is within several kilometers to dozens of kilometers. The position data are sparse and measurement is conducted at irregular timing. We need to estimate subscriber's trajectory or position from point to point during no acquisition of CDR.

B. Data

We use CDR collected from 2016/05/01 to 2016/05/31 in Bangladesh. The number of subscribers is 46,627,314.

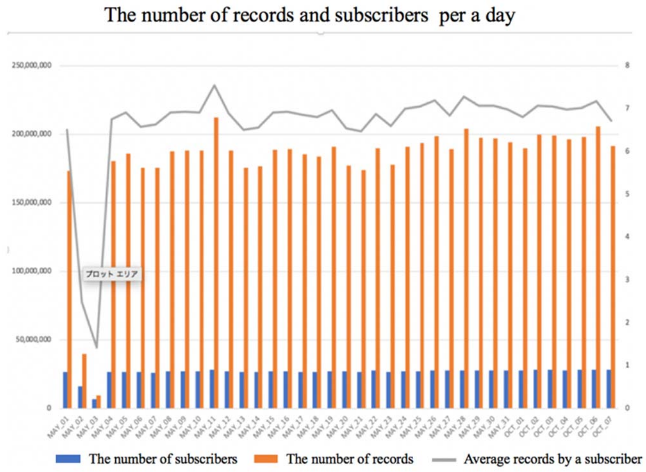


Fig. 1. Basic Statistics of CDR data

A subscriber made, on average, more than around 6 calls per a day and the number of total calls is more than 200,000,000 times every day except 03 May. And a subscribers has the average 17.4 days to be recorded their own CDR. There are 2,270,439 subscribers have calls every day over May. In this paper, we focused these subscribers with every day records for extracting daily life pattern.

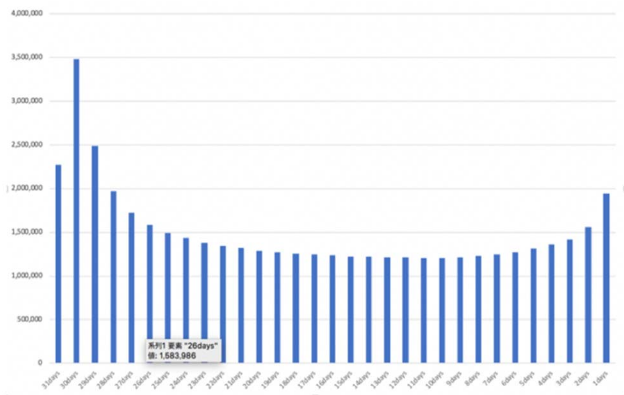


Fig. 2. The number of subscribers per the duration length of data

C. Method

We set a subscriber group with a full month records. The size of this group is 2,270,439 subscribers. The features of individuals are calculated using the number of calls, radius of gyration (RoG) by business days (Sunday to Thursday) and non-business days(Friday and Saturday). The distribution on the frequency of calls is used for clustering life pattern of a week. The radius of gyration is used as indicator on area of mobility. We examined how the characteristics on human life pattern and mobility will be explained.

- We aggregated the number of calls per one hour by each day of week to create a week records.
- These records are separated into business day group and non-business day group.
- We determined the optimal number of clusters by the elbow method. And k-means algorithm is used for clustering.

To extract features on mobility, 160 subscribers was sampled from the group with full records and we calculated their radius of gyration in accordance with [6].

- Radius of gyration (RoG) is defined as root mean square of distance between each point and centroid of all points. This indicator used to evaluate mobility area of subscribers.
- RoG is calculated for business day and non-business day respectively in a month.

V. Results

A. Clustering

We determined the optimal number of clusters is five classes for business day and six classes for non-business day by elbow method in [7].

Fig.3 and Fig.4 show the relationship of selection of optimal number of clusters and the sum of squared errors from elbow method for KMeans clustering. The optimal k is five on business days from Fig.3 and is six on non-business days from Fig.4.

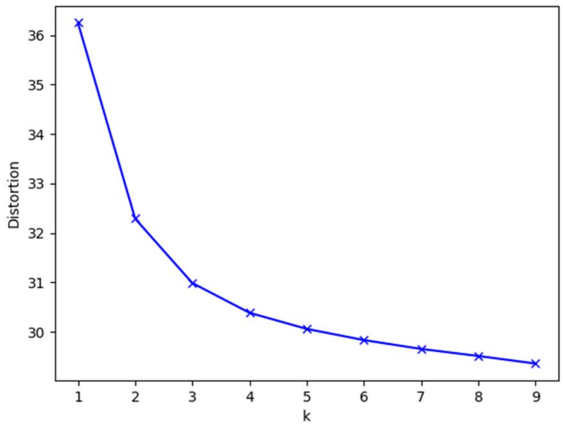


Fig. 3. The Elbow method showing the optimal K value on business days. Shown are Distortion score verus the value of k for clustering CDR in business days. Distortion score in y axis means the sum of squared errors. The sum of squared errors declines toward 0 as the value of k is increasing. The value of k in x axis are chosen in case that the rate of decreasing distortion score. The rate of decreasing distortion score is same after the value of k get five.

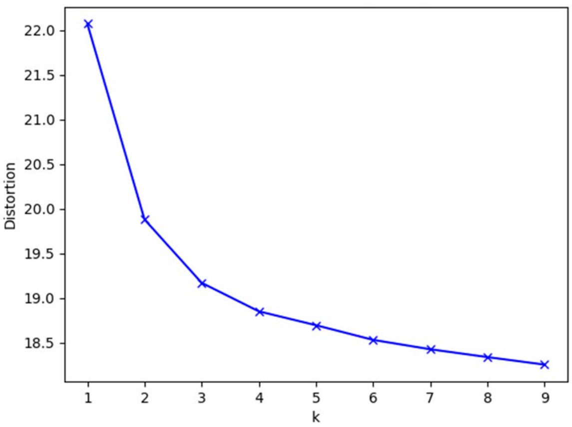
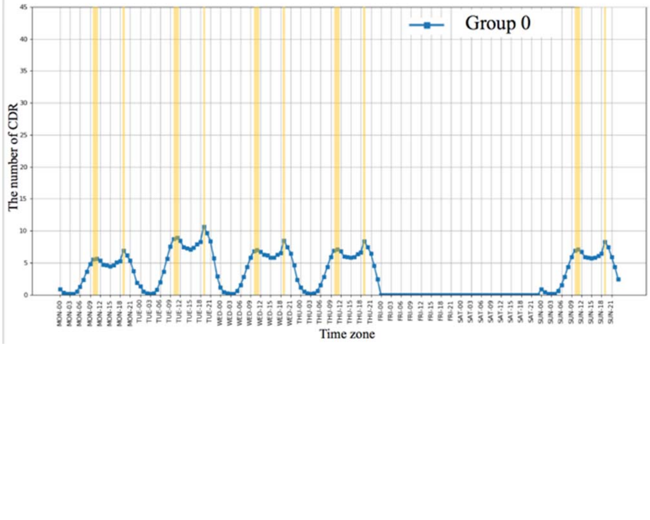
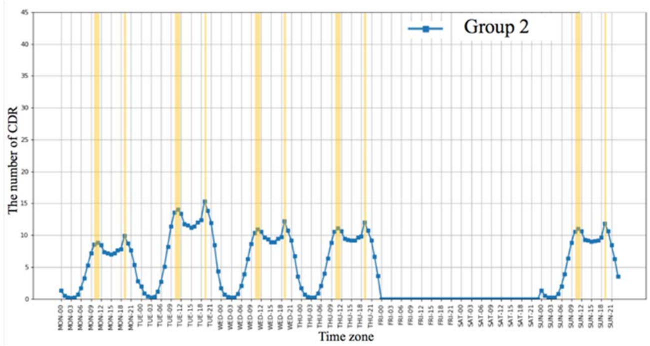
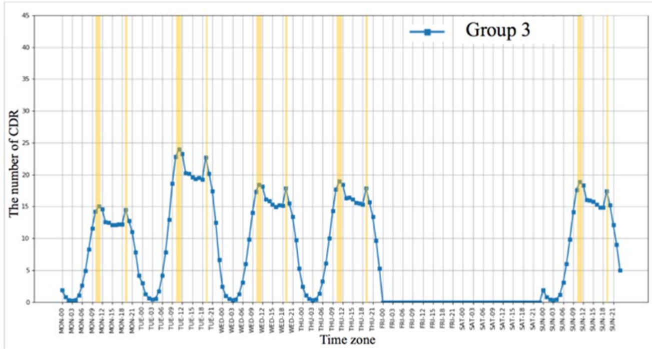


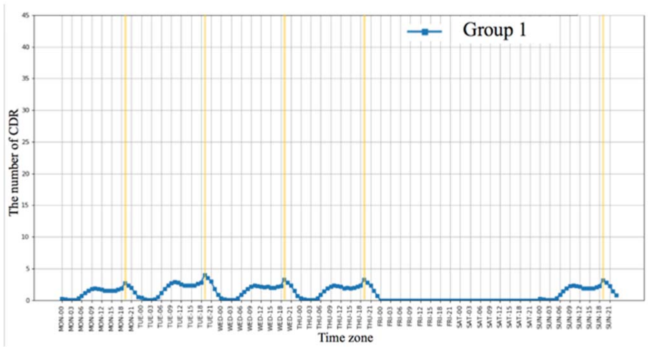
Fig. 4. The Elbow method showing the optimal K value on non-business days. The rate of decreasing distortion score is same after the value of k get six.

The result of clustering is the below. These five figures are on business day.









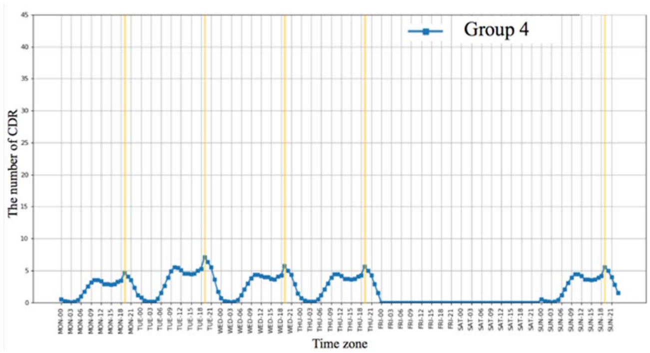
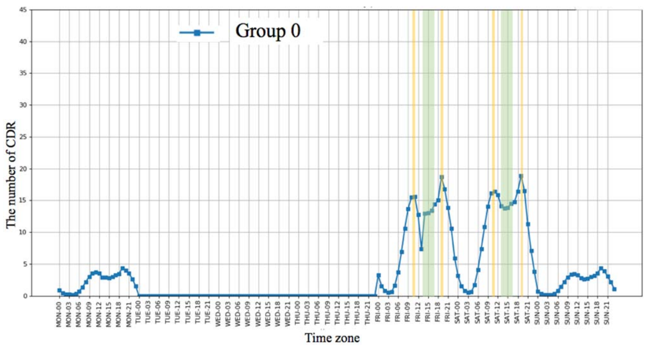
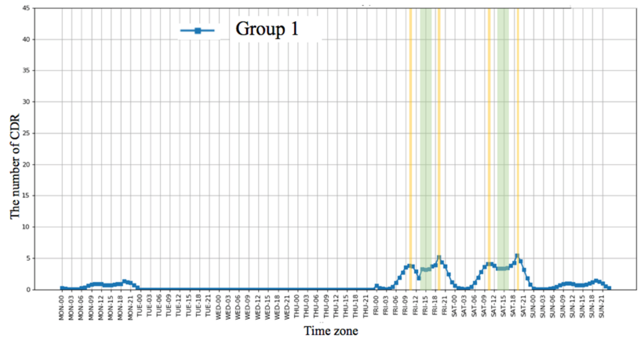


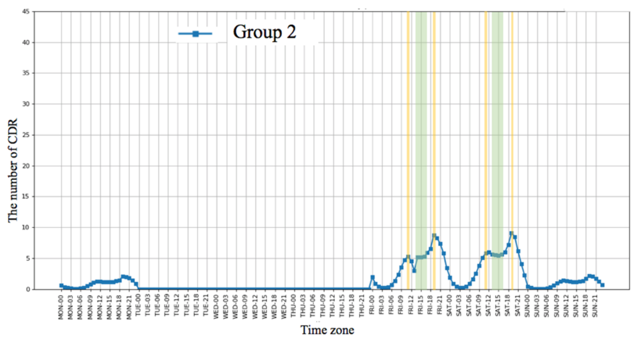
Fig. 5. Distribution of the number of CDR by hours in business days which are from Monday to Sunday except Friday and Saturday in respectively clustering groups. The orange band in time zone shows peaks in each line.

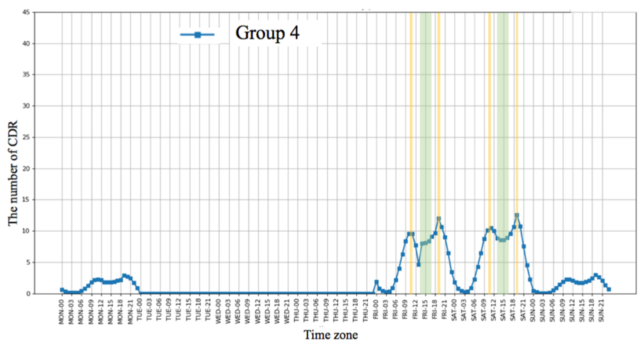
These groups are categorized into two groups from their shape. One group has two sharp peaks in morning and evening which are in 10 a.m. or 11 a.m. and 7 p.m. shown in clustering group 0 ,2 and 3. The other group has one peak in 7 p.m. despite there is no sharp peak in morning, which clustering group 1 and 4. The result shows that subscribers have trend to make a call or data use during 10 and 11 a.m. and 7 p.m. which time are thought to commute or move.

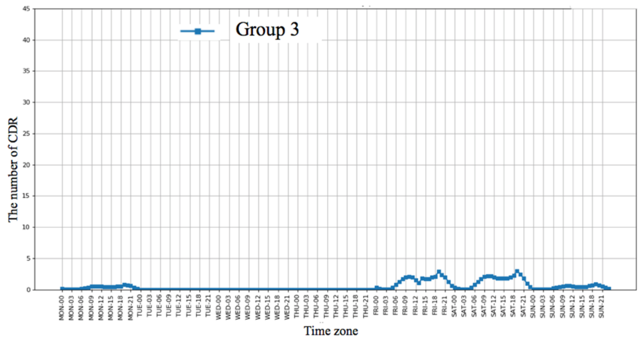
The below six figures are on non-business day. In Bangladesh, Friday and Saturday are weekend. The timing of peak is same as the result of clustering on business day. These groups include two groups. One group, which is called here as clustering groups 0, 1, 2 and 4 have two peaks in during 9 a.m. to 10 a.m. and at 7.pm.A more sharp peak is at 7 p.m. before the sharpness is decreasing in noon. And the other groups show rise and fall but two peaks are relatively flat or with the same height. Both result of clustering is shown regular pattern in each day which the number of CDR increase significantly or gradually from 6 a.m. and go down in noon and increase again around 7 p.m. and become less from 0 a.m. to 6 a.m.











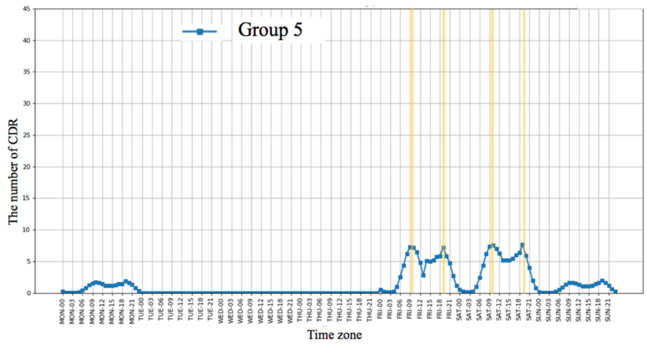


Fig. 6. Distribution of the number of CDR by hours in non-business days which are from Friday to Saturday and national holidays in respectively clustering groups. The orange band means peaks and green band mans decreasing.

B. *Evaluation on Geographic mobility area*

We calculated RoG of sampled 13,550 subscribers from all and evaluated geographic range of their mobility area as average RoG based on Upazilas (administrative zone of Bangladesh). The centroid of all points of each subscriber are estimated as main location and they are aggregated in the Upazila that includes their main location.

We visualized the distribution of each average RoG on weekdays and weekends on Bangladesh map and compared their RoG on weekdays and weekends with distance from major cities and road and income level.

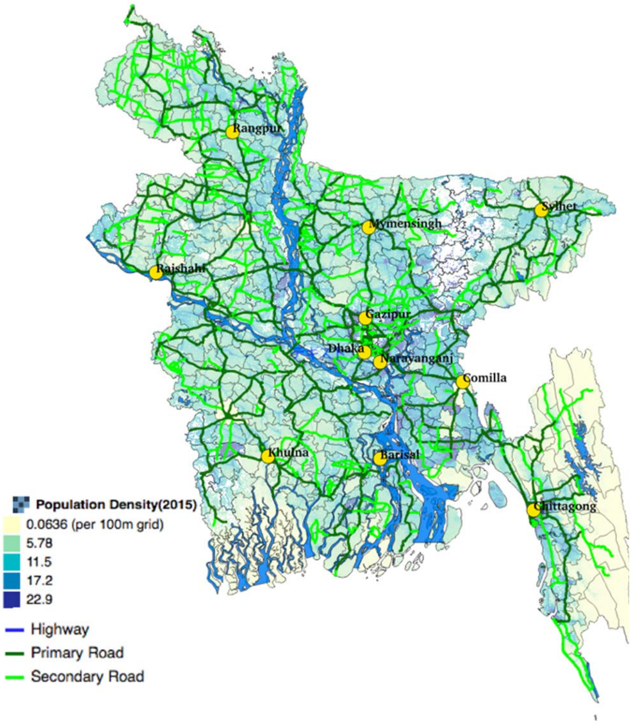


Fig. 7. Bangladesh Population Density Map by Upazila, administrative level 3 with main river, city and road. Major cities are shown with yellow point in map. Population density are shown using the above color band.

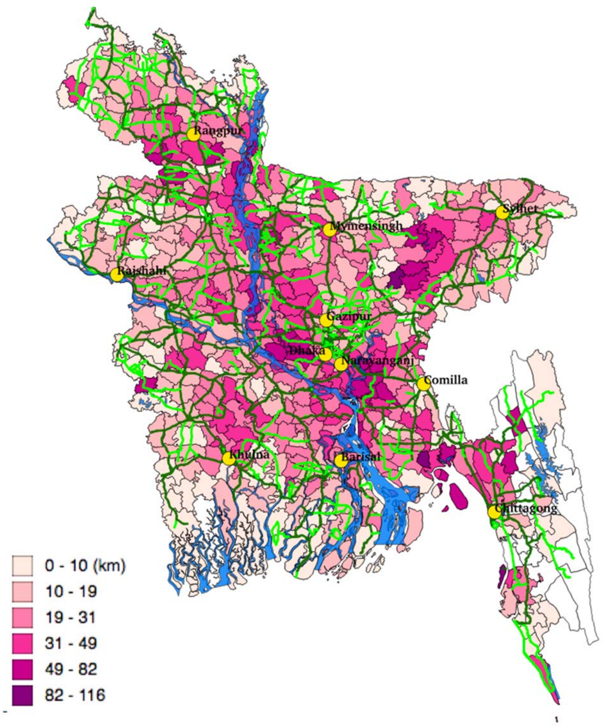


Fig. 8. Distribution of average RoG on weekdays by Upazila. Subscribers in Upazila with more deepend red move further on weekdays.

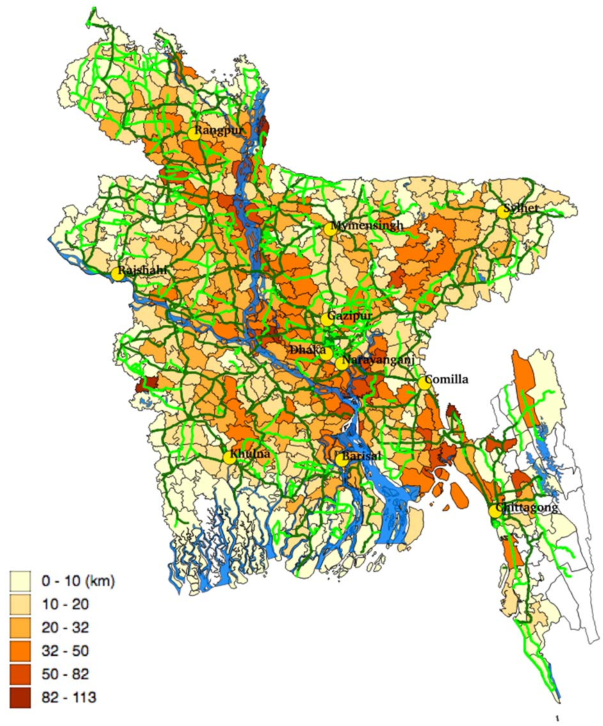


Fig. 9. Distribution of average RoG on weekend by Upazila. Subscribers in Upazila with more deepend orange move further on weekdays.

Fig.8 and Fig.9 show that mobility area could be wide on Upazila districts on the main river flows from north to south because river transportation such as ferry are popular for daily move and logistics.

We aggregated individual's average RoG on weekdays and compared the difference in their distribution to examine how much RoG are influenced by distance from major cities and roads, and how much mobility area are related with income index.

Firstly, we created buffer polygon from each major city per every 10km and aggregated individual's average RoG of weekdays on each buffer polygon.

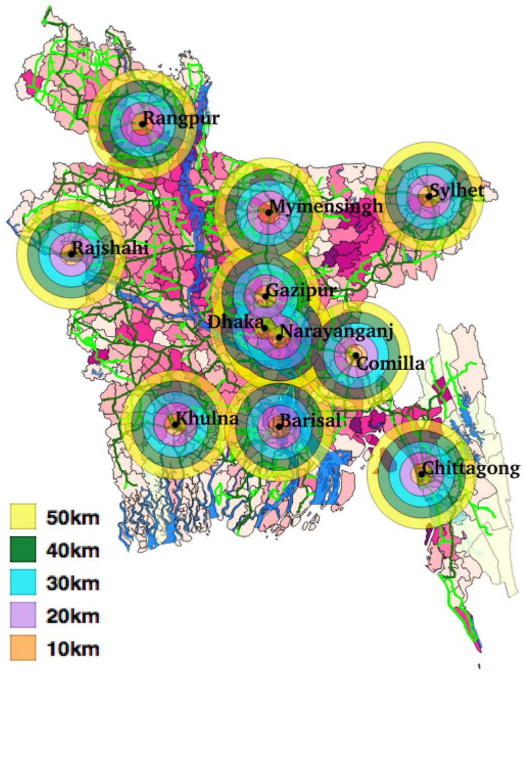


Fig. 10. Buffer area of aggregation. This map show buffer area from the central of major cities. In analysis , the average of mobility area within those buffer area by 10 km are calculated in Fig.11.

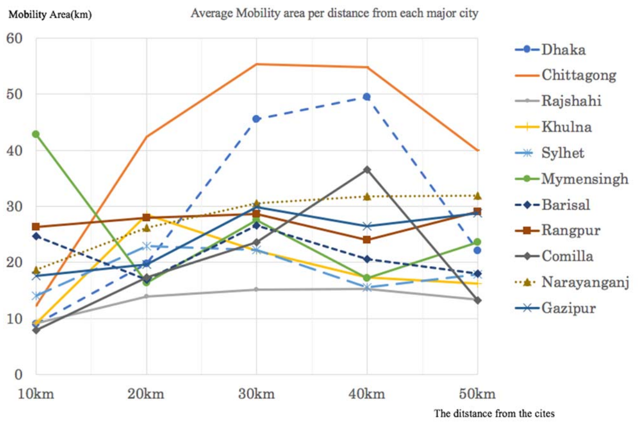


Fig. 11. Distribution of average RoG per each major city by buffer areas per 10 km in each major cities. X axis show the distance form the central of city and Y axis are the value of mobility area.

TABLE I.

Income Index			
Regions	***2015***	***2016***	***2017***
Dhaka	0.648	0.657	0.664
Chittagong	0.585	0.593	0.601
Gazipur,Narayanganj, Narsingdi	0.579	0.587	0.595
Barisal, Jhalokati, Pirojpur	0.552	0.56	0.568
Brahmanbaria,Chandpur, Comilla	0.549	0.557	0.564
Maulvibazar, Sylhet	0.535	0.543	0.55
Faridpur, Manikganj, Rajbari	0.505	0.513	0.52
Bagerhat, Khulna, Satkhira	0.492	0.499	0.506
Kurigram,Lalmonirhat, Rangpur	0.486	0.494	0.501
Kishoreganj,Mymensingh, Netrakona	0.475	0.483	0.49

Fig. 10 shows that the mobility area on the central part of the cities are narrow and the mobility area are expand moving away from the city. But the mobility area shrinks over the certain distance. The trend is clearly shown in Dhaka, Chittagong and Comilla. These cities have higher income index than other cities in past ten years. The opposite trend or flat shape are shown in cities with lower income index such as Mymensingh.

These different trends on mobility area could be created from people flow or activities influenced by city economic zone. The developed city zone could attract people from remote areas, while people in rural areas could be engaged in local economic activities and they tend to move less frequently. And Fig.8 and Fig.9 suggested that disaster especially floods in Bangladesh have impact on human mobility area on the ruined regions. Netrakona, Sunamganj,Kishoreganj and Narsingdi districts, which are the area colored in red in Fig.12, are frequently inundated during floods. People in these regions forced to migrate to other area. It could be possibly that the mobility area on these regions are rather wide because of migration by disaster.

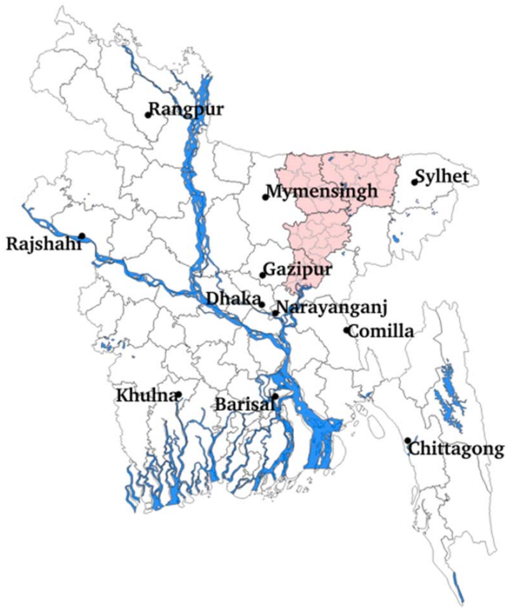


Fig. 12. The regions that are subject to frequent/seasonal inundation . The area colored in red frequently suffer from nundation.

VI. CONCLUSION

We identified several clusters in distribution of hourly activities through CDR data analysis. And we found that mobility range (RoG) of people extracted from CDR is associated with the distance from major city, their economic index and physical environment such as river.

These results suggested people in different regions have different life patterns, especially mobility patterns. And the association with rivers and proximity to cities suggested that natural and socio economic conditions of each areas affects people lives. By using longer-term CDR data, we could extract different and longer-term migration patterns such as seasonal migration to cities for job seeking, migration to avoid floods during rainy seasons.

On the other hands, we must consider the bias on mobile data caused by ownership and usage of mobile phone such as multi-sim phone or multi handsets and the difference on distribution of cell tower between rural and urban area.

In future works, we evaluate the impact by these bias on the estimation using mobile data and establish method on linkage features from mobile phone and status of real world.

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Functional and Contextual Classification Concept for Road Network in Thailand: Preliminary Study

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***Abstract*— Roadway classification is a fundamental step in planning and design of road network for the movement of people and goods. It helps classify the roads according to the road hierarchy and determine the proper design (physical characteristics and environmental context) of the roads, as well as the responsibilities of the relevant agencies. However, each country has different road classification systems. Most of traditional systems mainly focus on the road functions, while disregard environmental and neighboring circumstances. In Thailand, such system results in the overdesign or underdesign of a facility and inappropriate use of roads by all road users. This study presents the concept of road classification system based on both road functions and context setting, and adopt it to the road network in Thailand. The preliminary result showed the disparity of road classes among road function and context settings.**

Keywords*— Road classification, Functional classification, Contextual classification, Road network, Road planning

I. Introduction

The road is the main and worldwide transportation network that can link the settlements together. Each road has its own characteristics. Specifically, it is designed for certain purposes, provides its own function and service, and is managed by certain authority. Road classification plays a significant role at the early stage of road development process.

Road classification is an approach that systematizes the roads according to the road hierarchy [1]. It helps develop sustainable transportation by determining the proper design including physical characteristics and road environment, and also deciding the relevant authorities for responsibilities.

In Thailand, roads are divided into five categories according to the 2006 Highway Act including motorways (special highways with full control of access), national highways, rural roads, local roads, and concession roads. Further, roads in Thailand are approximately 701,847 kilometers, which are equivalent to the road density of 1.37 km per square meter. They are associated with many authorities including Department of Highways, Department of Rural Roads, Expressway Authority of Thailand, Department of Local Administration, and Bangkok Metropolitan Administrations. The majority of roads are local and municipal roads under Department of Local Administration as shown in Fig. I. [2]

Under this administrative classification, road network in Thailand are presented by their functionality similar to other developed countries. The roads are assessed by their mobility and accessibility. However, they are sometimes not fitting with surrounding environment and roadside activities. This can be seen by different conditions; for example, when the high-speed major roads passing through towns or small cities, or when the roads being restricted by neighboring residence.

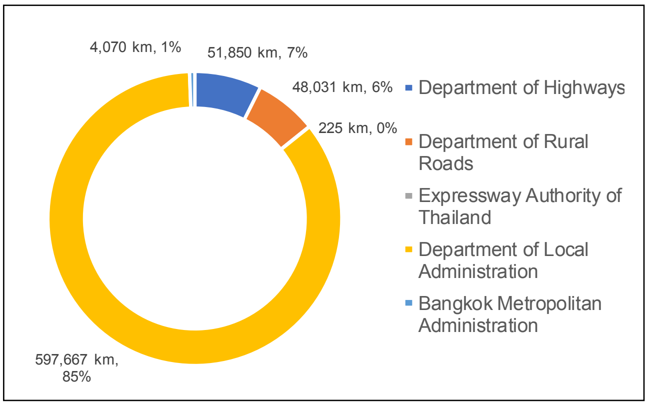

Fig. 1. Percent of road length for Thailand road network by road authorities

This paper aims to present the concept of functional and contextual road classification system, and to apply it to categorize the segments of road network in Thailand under this classification system.

II. Previous Reseaches

The purpose of road transportation system has been changed into a working context that can be more accessible. For instance, local roads that directly connect to arterial roads, result in many alleyways, which cause traffic safety problems and negative impacts to transportation systems. To enhance safety and accountability of the long-term road transportation system, a road classification should be clearly defined and implemented for all road network at an early stage.

The functional classification of the road is to define the role and function of the roads in a road network in order to appropriately serve travel demand. If the functional classification is properly done in a planning stage, then the road design will be in a hierarchical manner in many circumstances including its speed, capacity, and relationship to existing and future land use development [3].

The functional classification has been paid more attention in many countries to enable the roads to be effective and safe [4]. For instance, European countries have developed the concept of sustainable road safety systems through the Decade of Action for Road Safety. To implement this concept, each country in Europe takes the functional classification into account in road design and road safety improvement. [5, 6] A number of parameters are used in the road functional classification in Europe [7].

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- Traffic speed—design speed or speed limit
- Trip length—long-distance traffic or local traffic
- Designation status—linking neighborhoods or cities
- Strategic role—connecting different network levels with different urban scales
- Accessibility—primarily for circulation or access
- Administration—by national or local authority
- Network role—forming strategic or local network
- Access control—access controlled or uncontrolled
- Traffic volume—vehicle flows
- Transport mode—presence of vehicles, public transit, pedestrians
- Other urban users—provision for frontage users
- Environment—sensitivity of environment
- Built frontage—presence of frontage
- Road width—width of road

Each country has a classification set sometimes referred to as a road hierarchy, which organizes a set of road type. Understanding the road classification system around the world helps gain an insight into the differences in the road classification, compare the advantages and disadvantages of each system, create better road standards, proper designs, and sustainable road development. Furthermore, the collection of road classification systems around the world presents the similarities of road systems in the neighborhood countries, which may lead to the development of link road networks, business relations, and international communication.

Table I indicates the road classification systems being defined in various countries in Asia, Africa, Australia, Europe, and North America.

TABLE I. ROAD CLASSIFICATION TYPES BY COUNTRY.

Country	Functional Classification	Contextual Classification
Asia		
Cambodia [10]	✓	
Indonesia [11]	✓	
Japan [12]	✓	
Malaysia (Federal) [13]	✓	
Malaysia (Other states) [13]	✓	
Myanmar [14]	✓	
Thailand [15]	✓	
Africa		
Kenya [16]	✓	
Nigeria [17]	✓	
South Africa [9]	✓	✓
Australia		
Australia (Western Australia) [18]	✓	
Australia (Victoria) [18]	✓	
Australia (New South Wales) [8]	✓	
Australia (Queensland) [8]	✓	
Australia (Other states) [8]	✓	✓
New Zealand [8]	✓	
Europe		
Belgium (Brussels) [7]	✓	
Belgium (Other Cities) [7]	✓	
Denmark (Copenhagen) [7]	✓	
Denmark (Other Cities) [7]	✓	
Germany [7]	✓	
Greece [7]	✓	
Hungary [7]	✓	
Portugal [7]	✓	
Spain [7]	✓	✓
North American		
Canada [8]	✓	✓
USA [4]	✓	

Based on the review, it shows that most countries focus on classifying the roads based on their functionalities. A few classification systems consider urban and rural settings, such as UK, Canada, Australia (some states), and South Africa. Moreover, the context settings are roughly classified into urban and rural environments.

III. PROPOSED FUNCTIONAL AND CONTEXTUAL CLASSIFICATION CONCEPT

The concept of road classification since 1984, AASHTO "Green Book" (A Policy on the Geometric Design of Highways and Streets) has considered the functionality of roads with two criteria: accessibility and mobility. Roads are then divided into 4 categories: freeways, arterials, collectors and local roads.

Later, road classification has taken into consideration the development of urban and rural, and the roads are sub-divided into "major" and "minor" roads. However, this road classification system is still inconsistent and not appropriate with road design on the context setting, so the urban and rural areas may not be sufficient for the functional classification of roads in each road type.

A. Functional Classification

Functional classification is a classification of roads by considering the function of the roadway within its network and the connectivity that the roadway provides among various centers of activity. Network function is defined based on the regional and local importance of the roadway to vehicle movement. Connectivity identifies the types of activity centers and locales that are connected with the particular roadway. The four components of most functionally classified systems are principal arterials, minor arterials, collectors, and local roads.

1) Arterials Arterials are roads that focuses to travel long distances at high speed without interruption and safety. The road needs to control the traffic flow area

a) Principal Arterials Principal arterials serve a large percentage of travel between cities and activity centers, which are typically roadways with high traffic volumes and are the frequent route for intercity buses and trucks. Principal Arterials can provide a high degree of mobility and carry a high percentage of travel for long-distance trips including those that go directly through or bypass activity centers.

b) Minor Arterials Minor arterials provide service for moderate length trips, serve geographic areas that are smaller than the principal arterial roadways, and have higher connectivity to the Principal Arterials. In urban settings, they interconnect and supplement the Principal Arterial system, connect communities, and may carry many bus routes. In rural settings, they are typically designed to provide higher travel speeds with minimum interference to the trough movement.

2) Collector Roads Collector roads provide the connection from local roads to the arterial systems. Collectors may be subdivided into major and minor collectors in both the urban and rural areas. A major part of the rural highway system consists of two-lane collector highways. The rural collector routes generally serve travel of primarily intra-county rather than statewide importance and constitute those routes on which predominant travel distances are shorter than on arterial routes. An urban collector is a public facility that includes the entire area within the right of way. The urban collector also serves pedestrian and bicycle traffic and often accommodates public utility facilities within the right of way

3) Local Roads Local roads account for the largest percentage of roadways in terms of mileage and are typically designed to discourage through traffic. A local road primarily serves as access to a farm, residence, business, or other abutting property. Local roads are typically classified by default; once all other roads have been classified as arterials or collectors, the remainder are local roads.

B. Contextual Classification

Contextual classification is a classification of roads by considering various contexts, including density, land use, and building setback in designing or specifying road types.

Five distinct contexts have been determined to not only represent unique land-use environments, but also identify distinctions that require wholly different geometric design practices in terms of desired operating speeds, mobility/accessibility, demands, and user groups. AASHTO Green Book (2018) presented 5 context categories: rural, rural town, suburban, urban and urban core [1, 21] The context categories are in Table 2.

TABLE II. CONTEXT CATEGORIES AND PRIMARY FACTORS.

Category	Density	Land Use	Setback
Rural	Lowest (few houses or other structures)	Agricultural, natural resource preservation and outdoor recreation uses with some isolated residential and commercial	Usually large setbacks
Rural Town	Low to medium (single family houses and other single purpose structures)	Primarily commercial uses along a main street (some adjacent single family residential)	On-street parking and sidewalks with predominantly small setbacks
Suburban	Low to medium (single and multi-family structures and multi-story commercial)	Mixed residential neighborhood and commercial clusters (includes town centers, commercial corridors, big box commercial and light industrial)	Varied setbacks and mostly off-street parking
Urban	High (multi-story, low rise structures with designated off-street parking)	Mixed residential and commercial uses, with some intuitional and industrial and prominent destinations	On-street parking and setbacks with mixed setbacks
Urban Core	Highest (multi-story and high-rise structures)	Mixed commercial, residential and institutional uses within and among predominately high-rise structures	Small setbacks with sidewalks and pedestrian plazas

The functional classification and contextual classification system of roadways can be presented in a matrix form for designing roads that depend on speed, mobility, access, and user safety/needs as shown in Fig 2.

Context Setting / Roadway Type	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterials					
Minor Arterials					
Collectors					
Local Roads					

Fig. 2. Functional and contextual classification matrix

IV. EXAMPLES OF ROADWAY FUNCTIONAL AND CONTEXTUAL CLASSIFICATIONS

Using the concept of functional and contextual classifications based on their definitions in Section III, the schematic framework of this study is proposed in Fig. 3. The steps of analysis include reviewing the roadway classification systems, defining the measures used to classify roadway types and context settings, developing a classification matrix, collecting relevant data, and performing the classification of segments of road network in Thailand.

In the study, a number of road classification system implemented in both developed and developing countries will be comprehensively reviewed to distinguish the advantages and disadvantages of each classification system. Then, the lists of criteria for roadway functional and contextual classification that properly applied for a road network in Thailand will be determined. The potential criteria used for roadway functional classification are:

- Access control. Access control is the type of control of access and the number of access points along the roadway. Arterials should have limited access points (or full control of access), while local roads should have a number of access points along the road.
- Level of Service. The levels of service are assessed by the efficiency of the road. Roads with high mobility generally have less delay throughout the travel.
- Speed Limit. Speed limits are posted on roads, that relate to the classifications of road. For example, arterial roads have a higher posted speed limit, while local roads have low speed limit.
- Annual Average Daily Traffic (AADT) and Vehicle-Kilometer of Travels (VKT): Each type of road serves different trip characteristics and has different traffic volumes. Arterials serve long-distance trips, and account for greater than half of the daily vehicle kilometers of travel. Collectors account for the next largest percentage of travel. Local roads typically serve low density, dispersed developments with relatively low traffic volume.
- Number of Travel Lanes: Roads are designed and constructed according to their function and forecasted travel demand. Arterial roads will be designed with multiple travel lanes to provide high capacity, while local roads need fewer number of travel lanes to provide low capacity.

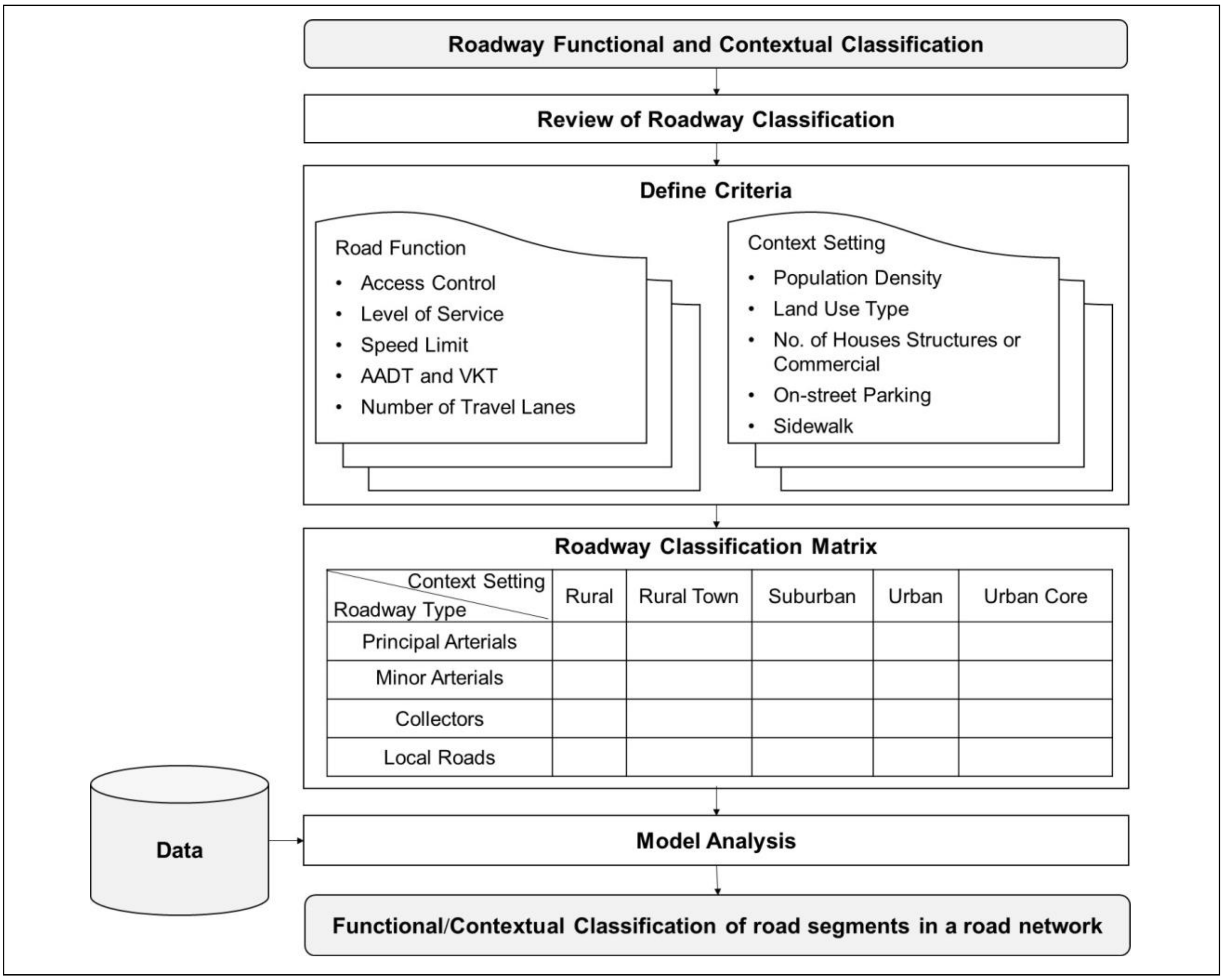

Fig. 3. Proposed model framework

The potential criteria used for roadway contextual classification are:

- Population Density: Population density is one of the most frequently used parameters to identify urban and rural areas. For example, urban areas are the areas with high population density (greater than 5,000 population per sq.km.), while rural areas are those with low density.
- Land Use Type: The land use along the roads can help indicate the context setting of roads. It presents the type of population settlement ana activities along the roads. Rural areas are those agriculture, natural resource, and some isolated residential areas. Urban areas are those commercial, residential, and institutional uses with low-rise or high-rise structures.
- No. of Houses Structures or Commercial: The density of house structures or commercial indicates the amount and types of activities along the roads. It can be another representative of the area type.
- On-street Parking: On-street parking implies the area type and roadside activities along the roadways. The number of on-street parking on urban roads is higher than that on rural roads.
- Sidewalk: Sidewalks typically represent the presence of pedestrians or non-motorized road users and area type along the roadways.

All data associated with road segments in a road network will be collected. These data include road attributes, traffic data, and spatial data related to land use and neighboring environment along the roadways. The model analysis will be performed through spatial analysis and traffic analysis to identify the class of the road segments in a road network.

Table III shows the preliminary results of this study. It presents the examples of road segment under different functional and contextual classes. Although there is no detailed analysis, this table helps visualize the distinction among road classes.

TABLE III. EXAMPLES OF ROAD SECTIONS BY FUNCTIONAL AND CONTEXTUAL CLASSIFICATION

Roadway Type	Context Setting				
	Rural	**Rural Town**	**Suburban**	**Urban**	**Urban Core**
Principal Arterials					
Minor Arterials					
Collectors					
Local					

The examples of road segments in each class are discussed as follows.

A. *Example 1: Rural Minor Arterial*

Fig. 4 shows the example of a minor arterial roadway within rural environment. This type of road has many travel lanes with high speed limit, has few access points with controlled access, e.g. signal- or stop-controlled intersections, and serves high traffic volume. The land use types along this roadway are agriculture and isolated residential area. The density of population and house structures and commercial is relatively low. Moreover, neither on-street parking nor sidewalk is available.

Fig. 4. Example of rural minor arterials

B. *Example II: Rural-Town Collector*

Fig. 5 shows the example of a collector roadway within rural-town environment. This type of road has a few travel lanes with low-to-medium speed limit due to a higher number of access points. The land use types along this roadway are different from typical rural roadway. They can be commercial or single-family residence area. The population density is medium and the density of house structure and commercial is low-to-medium. The on-street parking is possible, but sidewalk is somewhat limited.

Fig. 5. Example of rural-town collector

C. *Example II: Urban Collector*

Fig. 6 shows the example of a collector roadway within urban environment. Similar to a rural-town collector in Example II, this type of road has a few travel lanes with low-to-medium speed limit. The land use types along this roadway are commercial and residence area with multi-story buildings. The density of population and commercial is relatively high. The on-street parking and sidewalk is present.

Fig. 6. Example of urban collector

Table IV compares the elements among three road segment examples with respect to road functionality and context setting.

TABLE IV. EXAMPLES OF ELEMENTS FOR ROADWAY CLASSIFICATION

Element	Examples of Roadway Class		
	Rural Minor Arterials	**Rural Town Collectors**	**Urban Collectors**
Road Functionality			
Access control	Few / Controlled	Medium / Uncontrolled or Controlled	Medium / Uncontrolled or Controlled
Level of service	High	Medium	Low-Medium
Speed limit	High	Low-Medium	Low-Medium
AADT and VKT	High	Medium	Medium-High
Number of lanes	More	Medium	Medium
Context Setting			
Population density	Low	Low	High
Land use type	Agriculture/ Isolated residence	Commercial/ Single family	Multi-story, low-rise building
House/commercial	Lowest	Low-Medium	High
On-street parking	None	Yes	Yes
Sidewalk	None	Sidewalk with small setbacks	Yes

V. CONCLUSIONS AND RECOMMENDATION

This study presents the concept of road classification system that integrates the functional and contextual elements to classify the segments of road network. Functional classification determines the hierarchy status and the road services within the network, whereas context classification provides guidance regarding the design of roads that are suitable for the characteristics of the surrounding environment. By definition, this study presents the examples of road sections associated with each class. It shows that the expanded functional and contextual classification system is plausible to apply to road network in Thailand. Further, the preliminary result can help planners, engineers and designers recognize the needs to consider the context settings in road classification.

Further studies should be conducted to systemically and systematically classify the road network. The entire road network (as a system) should be classified with single classification system. The systematic framework should be deliberately proposed for functional and contextual classification. In addition, clear definition, logical criteria, and justifiable methodology are required.

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the technical and financial support from Department of Civil Engineering, Faculty of Engineering, Chiang Mai University, and the Excellence Center in Infrastructure Technology and Transportation Engineering (ExCITE) of Chiang Mai University.

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Urban Growth Modeling using Historical Landsat Satellite Data Archive on Google Earth Engine

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***Abstract*—This paper presents a pilot of data analysis for urban growth modeling using historical Landsat satellite data archive on Google Earth Engine and SLEUTH cellular automata model. The systems were organized for non-expert so that it could be useful for other applications. The developed system was applied to urban growth modeling for the cities of Hue, Ha Giang, and Vinh Yen in Viet Nam. Although the results indicated that further tuning will be needed in applying SLEUTH for urban growth modeling, the system was well established enabling users to efficiently polish the quality of the modeling results.**

Keywords—Landsat, Google Earth Engine, SLEUTH, land cover mapping, urban growth model, cellular automata

I. Introduction

Urban information and observation are in a key role in tackling global issues, such as the Sustainable Development Goals and the Sendai Framework for Disaster Reduction [1]. Satellite remote sensing provides valuable resources of urban information in broad areas, especially around less documented areas. The past studies demonstrated the usefulness of satellite-based urban information for disaster risk management. Besides, some research groups developed automated methods of human settlement mapping from satellite data with spatial resolutions of 10-30 meters, which is essential to observe urban objects in the city scale. The automated methods shed a light to scale-wide applications of satellite-based urban information on a global scale.

Disaster risk management is the field that satellite-based urban information and observation potentially contribute owing to the importance of international assistance and supporting frameworks. Several good practices of satellite-based disaster risk reduction have been piloted by international development agencies. Although the pilot projects proceeded successful outcomes in the project sites, the capacity required for the pilots is remained as a critical issue, especially with human capacity development that requires limited resources of international experts. Therefore, even excellent results of the pilot projects could not reach outcomes with sustainable benefits for local stakeholders.

Data preparation and processing are often heavy loads for beginners' exercises although those are not substantial procedures for the disaster risk assessment. We regard that these could be automated by script programming that even beginners can configure the processes for the interest of areas and time. In this paper, we present a preliminary development of the program integrating several software and systems used for urban growth monitoring and modeling using Google Earth Engine (GEE) and SLEUTH, an urban growth model.

II. Methods and Results

A. Application of Google Earth Engine for automated land cover mapping

The land cover maps were produced using the archives of Landsat data provided on the GEE. The GEE is a platform of earth observation data, such as earth observation satellite data, scientific data, and socio-economic data, with a seamlessly connected cloud-based processing system. By use of the GEE, significantly fewer efforts are required for handling and managing earth observation satellite data set. Without the GEE, data users have to download large-size data set, i.e., 1 GB for Landsat 8 data and 200-300 MB for Landsat 5/7 data, and process a large amount of data, i.e., 6000 × 6000 pixels for Landsat data set, which requires high-spec computers to complete in a possible time.

Besides the integrated platform of data archive and processing, the GEE provides programmable interfaces for accessing data and commonly-used processing algorithms. The GEE primarily works with JavaScript through the Code Editor while it gives Python API and command-line tools to access the data and functions. Because of better quickness and beginner-friendliness, we developed the land cover mapping processes using the Code Editor so that the developed methods are re-usable to the other parties.

B. Land cover classes

We defined the land covers with four classes: waterbody, vegetation, bare land, and built-up area. We defined the classes with the simplest classes because of a potential extension of this land cover mapping system for the other regions. Although the LULUCF (Land Use, Land Use Change, and Forestry) classification scheme established by the IPCC, which comprises six classes— forest land, cropland, grassland, wetlands, settlements, and the other lands, is a useful scheme, we had to apply the four-class scheme due to the limitation of Landsat data in visual interpretations.

In the following process, the classes were associated with pixel value: waterbody – 1; vegetation – 2; bare land – 3; built-up area – 4.

C. Landsat data selection

The selection of satellite data requires an experienced background of remote sensing, which manages data quality regarding cloud contamination, observation seasons, and target extents. Automation of satellite data selection has been established by research and development of cloud pixel detection and metadata management.

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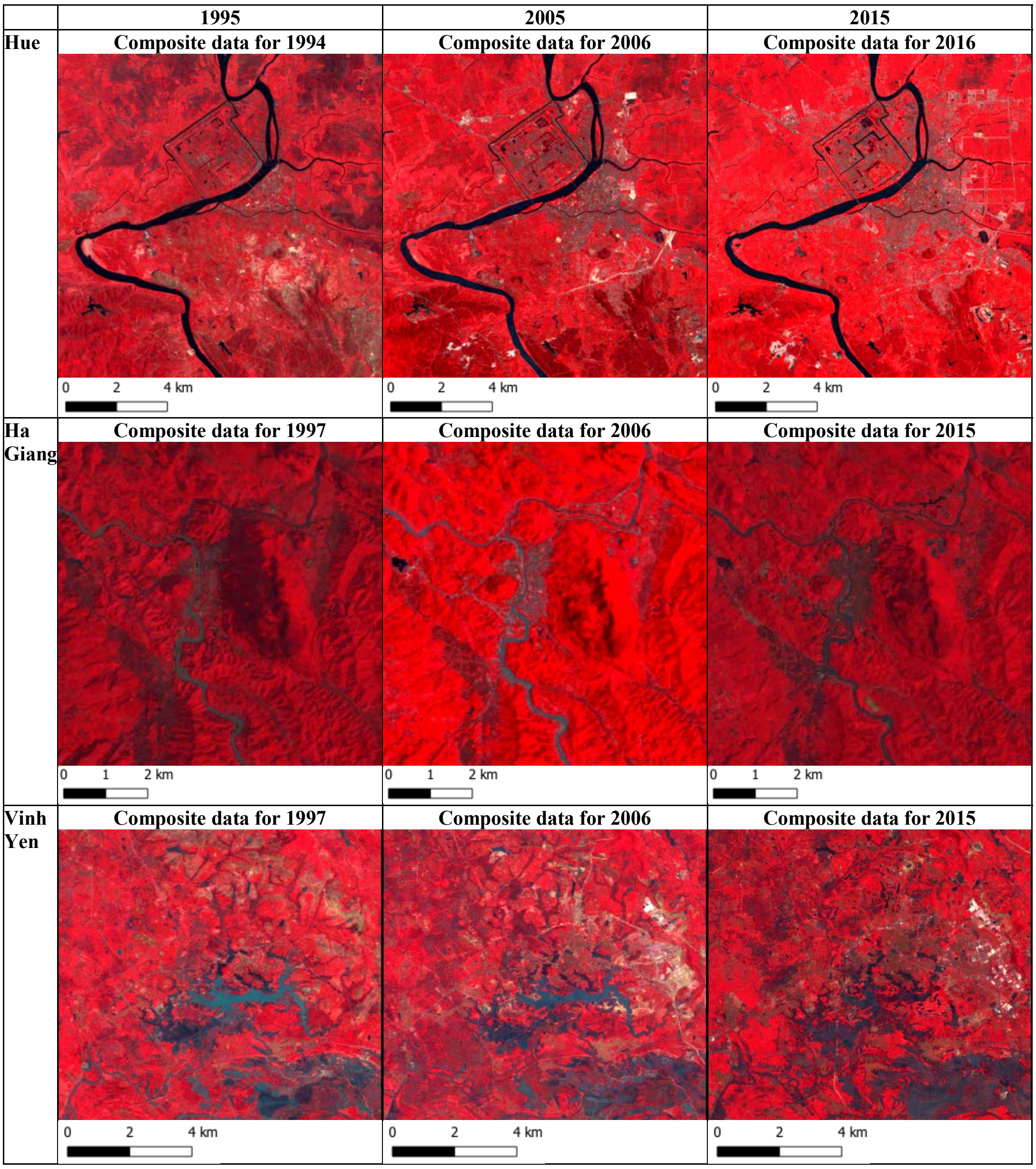

Fig. 1. False color composite of Landsat data used for land cover mapping. Red represents vegetation, dark-red represents barren areas, light-gray represents built-up areas, and dark-blue represents waterbody.

ee.Algorithms.Landsat.simpleComposite is a useful function of the GEE to acquire cloud-free Landsat satellite data. The function accepts parameters of target years and cloud contamination, which are applied to select candidate satellite data from the archive. The function returns Landsat satellite data with median values among the candidate satellite data by pixel. We applied this function to automate the selection of satellite data for land cover mapping.

In the function, filter periods of observation dates were set to ± one year of target years. For example, a period between 1 January 2004 to 31 December 2006 was set for land cover mapping for 2005. Through a recurring program, land cover mapping was automatically processed every year between 1995 and 2015. Fig. 1 presents the Landsat data used for land cover mapping.

D. Training data collection

Land cover mapping requires training data set because of the supervised classification algorithms. The training data was a semi-automated manual visual interpretation of Landsat images. The Semi-automated Classification Plugin (SCP), a QGIS plugin for satellite-based land cover mapping, was used for training data collection. The SCP helps training data

TABLE I. LANDSAT DATA USED FOR TRAINING DATA PREPARATION

City	Path	Row	Satellite	Observation date (Year-Month-Day)
Hue	125	49	Landsat 8	2015-06-01
	125	49	Landsat 5	2005-05-20
	125	49	Landsat 5	1995-05-25
Ha Giang	128	44	Landsat 8	2014-10-09
	127	44	Landsat 5	2004-12-09
	127	44	Landsat 5	1995-11-15
Vinh Yen	127	45	Landsat 8	2015-07-01
	127	45	Landsat 5	2005-10-09
	127	45	Landsat 5	1996-09-30
	127	45	Landsat 5	1995-10-30

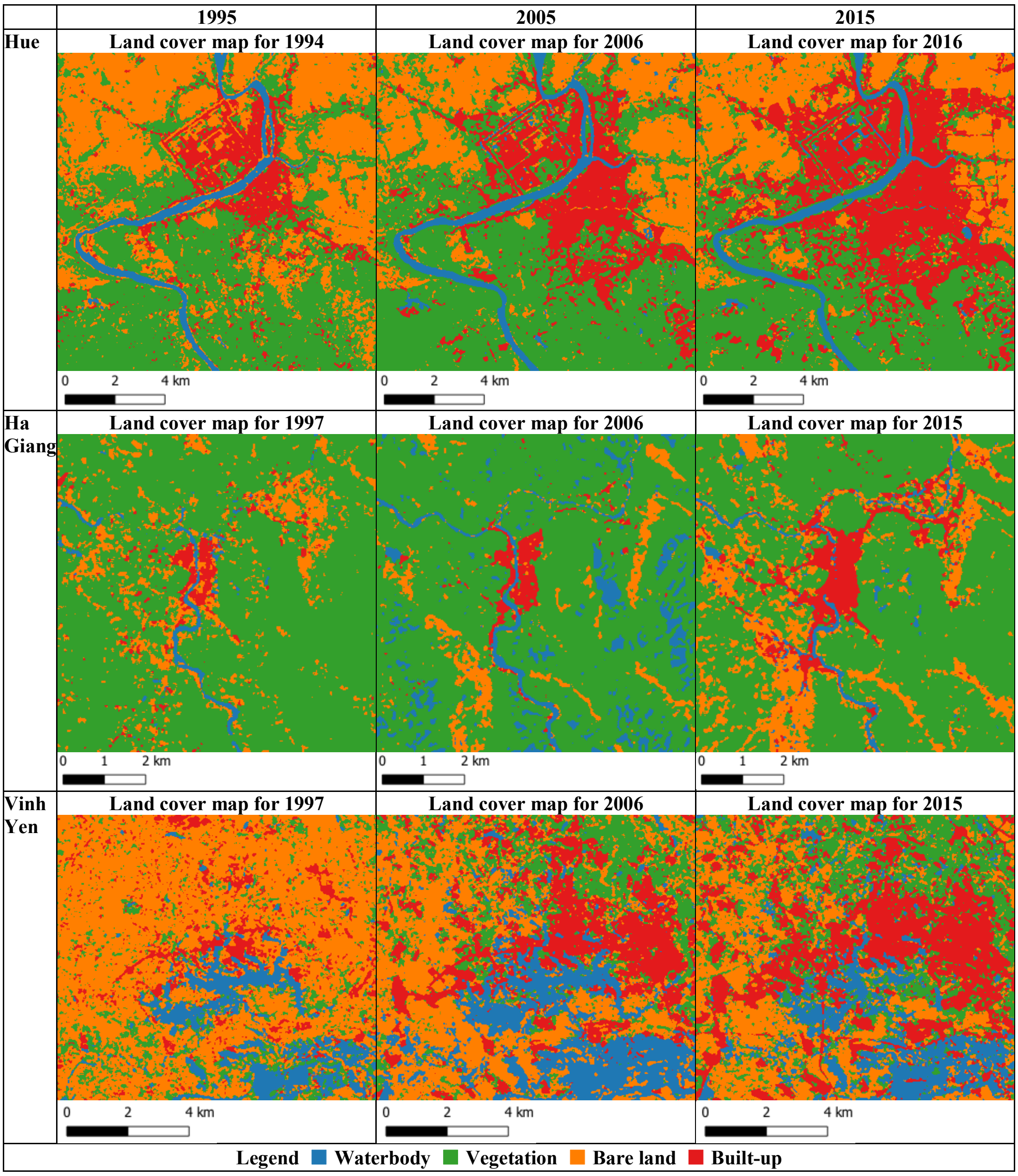

Fig. 2. Results of land cover mapping. Blue pixels represent waterbody, green pixels represent vegetation, orange pixcesl represent bare lands, and red pixels represent built-up areas.

collection by a region growing algorithm, which gathers pixels with similar values into a cluster. The function improves the efficiency of training data collection by the automated recognition of land cover clusters.

We primarily used some training data set that were prepared for areas around Bangkok, Thailand. Also, we prepared training data for Hue, Ha Giang, and Vinh Yen using Landsat data (TABLE I).

E. Classification algorithms and post-processing

We applied a random forest algorithm available on the GEE. Input features of the classification were surface reflectance of band 1-5, 7 (RGB, VNIR, and SWIR) and image entropy of the Band 4 as an image texture. Training data was chosen from the data set prepared in 2.1.4. The algorithm chose 512 data points that were closest to the target extent for each class.

Because the training data was strongly biased due to the collection method, classification methods based on statistical assumptions, such as maximum likelihood classification, are not suitable to the training data set. Besides, such biased data sets often cause overfitting problems, in which only training data is fitting to a model while predictions of the model are outlying from true values. N-fold cross-validation is a method to avoid overfitting problems though it is hard to implement on GEE.

TABLE II. KAPPA COEFFICIENTS OF THE LAND COVER MAPPING RESULTS

	1995	2005	2015
Hue	0.912	0.926	0.967
Ha Giang	0.820	0.866	0.952
Vinh Yen	0.820	0.864	0.893

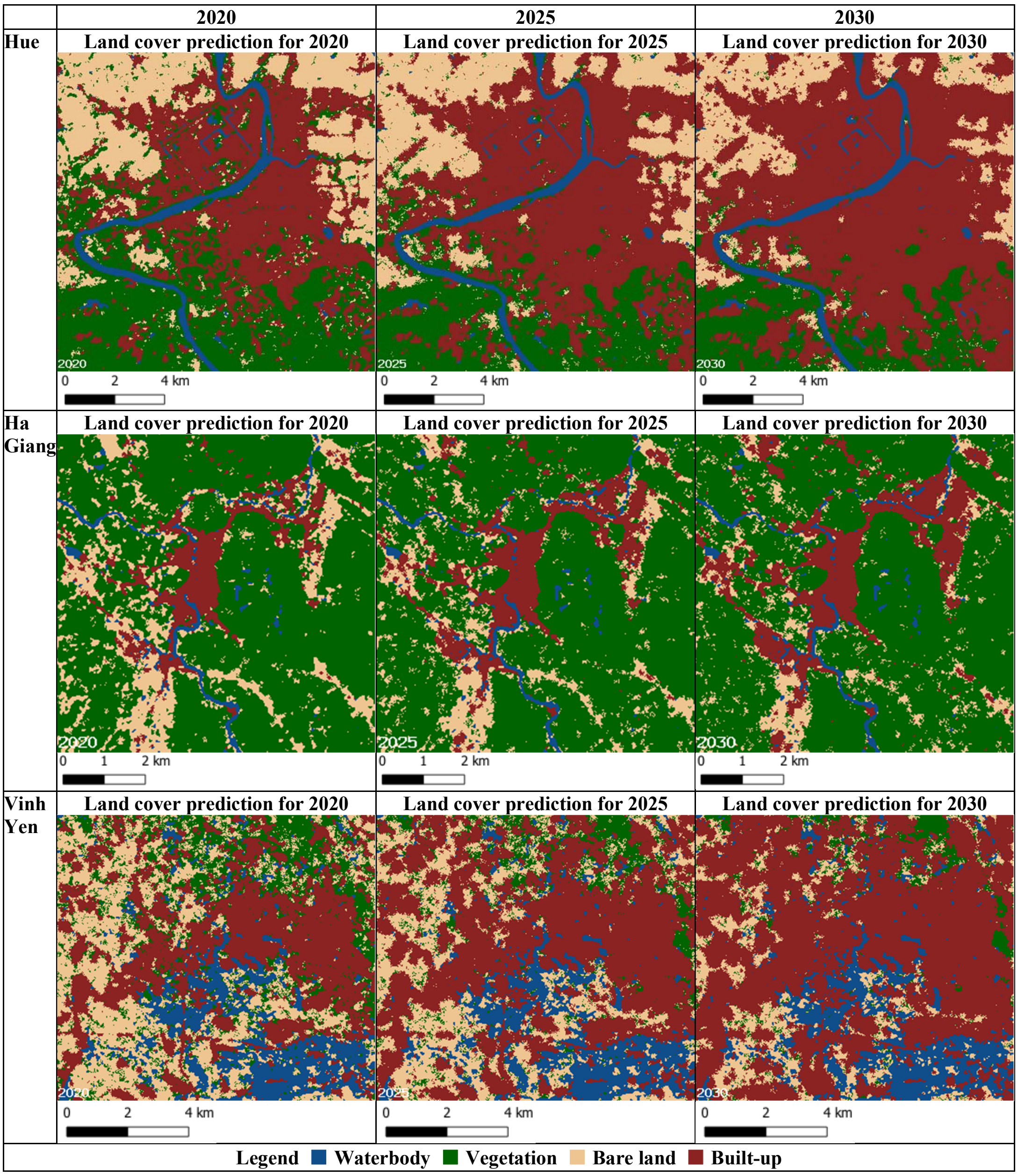

Fig. 3. Results of urban sprawl predictions. Blue pixels represent waterbody, green pixels represent vegetation, light-brown pixels represent bare lands, and red pixels represent built-up areas.

We have chosen random forest (RF) for this preliminary development from the functions of GEE. RF is a machine-learning algorithm to reduce the impact of overfitting. The first advantage of RF is robustness to the non-statistical distribution of training data sets. The second advantage is robustness to overfitting owing to its iterative algorithm, in which a classifier is determined by comparing models constructed with randomly chosen input features. In general, machine-learning classifications require much computation resources than statistical classification methods. However, the GEE solves the problem of resources by the cloud-based high-performance computing systems.

We applied a mode filter to the classification result for sieving minor pixels. The filter was set with a window of the 1.5-pixel radius; therefore, single pixels solely classified to a class are reclassified to a class of neighboring clusters. This process improves data quality as it reduces minor unnecessary information and data size.

Fig. 2 shows the results of land cover mapping from the Landsat data chosen as TABLE I. Accuracy assessment was performed using kappa coefficiency calculated from the confusion matrix (TABLE II). All of the kappa coefficiencies were beyond 0.8, indicating good for practical uses.

F. *Urban sprawl modeling and future prediction*

The land cover mapping indicated urban sprawls in the 20 years between 1995 and 2015. We modeled the land cover change caused by urban sprawl in a probability-based method, called cellular automata (CA). The CA model land cover changes by observed changes of neighboring pixels. Wagner applied Monte-Carlo simulation in the probability calculation, which has been implemented in several software packages [2].

We applied SLEUTH to model the urban growths in the three cities because of the developer-friendly command-line interface on UNIX and Linux [3]. The SLEUTH has the advantage of using several geographic conditions of urban sprawl, such as road networks and terrain, not only neighboring pixels. Besides, it has user-configurable parameters to represent an acceleration of rapid urbanization.

The parameters of SLEUTH were set as below. In addition to the Landsat-based land cover maps, SRTM-based digital terrain model (DEM) and OpenStreetMap's road network data was applied to the SLEUTH model. The parameters are a typical set of urban growth, in which growths beyond a threshold further accelerates the growth rate as below.

CRITICAL_LOW=0.97
CRITICAL_HIGH=1.05
BOOM=1.5
BUST=0.09
ROAD_GRAV_SENSITIVITY=0.1
SLOPE_SENSITIVITY=0.1

A growth rate beyond CRITICAL_HIGH accelerates the growth at a rate fo BOOM. A growth rate below GRIRICAL_LOW suppresses the growth at a rate of BUST. ROAD_GRAV_SENSITIVITY and SLOPE_SENSITIVITY are weights of sensitivity for road network nad terrain slope ranging 0.0-1.0.

Fig 3. shows the results of urban sprawl prediction with the provided parameters. The result of Hue indicated the sprawls are likely along with the roads. For Ha Giang, the urban sprawl was constrained the surrounding mountainous areas. For Vinh Yen, the urban areas are widely spread out because the region is in quite a flat terrain.

Performance assessment of the prediction could be assessed by comparison of actual land cover maps and predicted land cover maps. However, we have not yet implemented the module to retrieve indicators of agreement between those.

III. Conclusions

This paper presented a pilot application of Landsat archive in Google Earth Engine to urban growth modeling using the SLEUTH cellular-automata model. The developed system was applied to urban growth modeling for the cities of Hue, Ha Giang, and Vinh Yen in Viet Nam. Although the results indicated that further tuning will be needed in applying SLEUTH for urban growth modeling, the system was well established enabling users to polish the quality of the modeling results. Also, we will implement a function of performance assessment of prediction by comparison of actual land cover maps and predicted land cover maps.

Acknowledgment

This study was supported under an agreement with Asian Development Bank (ADB) on a joint work program for TA-8913 REG: Promoting Urban Climate Change Resilience in Selected Asian Cities Developing Integrated Urban Development Plans in Selected DMC Cities Incorporating Urban Climate Change Resilience Principles (Subproject 1).

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Thrombus Localization in Middle Cerebral Artery of Patient with Acute Ischemic Stroke on ncCT Image

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***Abstract*—A common cause of an Acute Ischemic Stroke (AIS) is a thrombus in the middle cerebral artery (MCA). Localizing the thrombus on a set of non-contrast computerized tomography (ncCT) image for some composite type is not easy. This work presents an algorithm for localizing thrombus in MCA region on ncCT using an image processing method. Given an ncCT image *P*, brain region is extracted by considering a homogeneous intensity area using *k*-mean cluster. A set of candidate regions is obtained by considering size and average intensity of each connected region. Also, location of the MCA is located to filter the candidate regions that are in the interested region. Experiment is perform on a number of images of the different composite of thrombus. The result shows that the proposed image-processing-based thrombus localization algorithm is able to automatically locate the thrombus on ncCT of both red blood cell-rich and fibrin-rich composite.**

Keywords*—*acute ischemic stroke, image processing,

I. INTRODUCTION

The Acute Ischemic Stroke (AIS) is a neurovascular disease that is major cause of death in the world[3]. A common cause of AIS is a clot in a blood vessel, also called Thrombus. Treatment are varied from alteplase to help thrombolysis and an intervention for fibrin-rich composite. Since the time that the patient receive the treatment as early as possible increase the chance of recovery.

To locate thrombus, non-contrast CT (ncCT) and CTA images are currently used. The CTA images are better than ncCT in locating thrombus, but it requires a specialized doctor to prescribe an injection. For this reason, locating thrombus on ncCT would help shortening the time for deciding whether to perform an intervention to allow blood flow.

Machine-learning techniques was applied to classify the composite of thrombus for predicting the outcome of alteplase treatment [7]. Given a ncCT and a CTA images, a thrombus was segmented manually by an expert. The result shows that utilizing 12 features from both types of images can predict the outcome of the alteplase. One limitation of this method is manually localization of the clot by an expert. MCA dot sign are automatically detected in ncCT[6]. Using 3D Region growing to detect the lentiform nuclei region. Because the MCA dot sign are only occurred inside it. The support vector machine (SVM) was used to find the MCA dot sign region inside lentiform nuclei region.

In this work, we proposed an algorithm that localize thrombus in middle cerebral artery (MCA) from the ncCT image. A region-based image segmentation and interested region localization are applied. The detail of the proposed method can be found in Section 3. The experimental results are reported in Section 4.

II. PREVIOUS WORK

A. Salient Regions Segmentation on CT Image

Takahashi N [7] proposed an automated detection method for the MCA dot sign of acute stroke in unenhanced CT. 3D region growing are used on the left and right lentiform nuclei with seeds given by Statistical Parametric Mapping 8 (SPM8) program. Because the MCA dot sign did not appear outside the lentiform nucleus. The candidate regions are selected if it was inside of lentiform nucleus region. Then, a support vector machine (SVM) is applied with four feature; maximum and an average pixel value within a region, the number of pixels within a region and the number of connections of the region. The localization results are compared with the manually located boundary by the neuroradiologists. This method gave 0.975 accuracy.

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Jonas J. Schöttler [2] proposed an automatic thrombus segmentation on CT image using a cascaded convolutional neural network (CNN). Two CNN networks were applied for candidates segmentation and classifying thrombus region. The candidate regions also contain the information i.e., location, shape, density, and volume of each region. Then, the regions are classified whether or not it is a thrombus by using the second CNN network. This method gave 0.99 accuracy on prediction of the existence of the thrombus and its location. However, the authors mentioned that it could be worthwhile to evaluate simpler and more efficient approaches without using the CNN network for segmentation.

B. Intervention Outcome Prediction

W. Qiu.[7] proposed a method for predicting the recanalization with intravenous alteplase using radiomics-based features. A thrombus is manually segmented by neuroradiologists. The linear discriminative and receiver operating characteristic were used for feature selection. The multivariable SVM is used to predict the outcome of the recanalization with intravenous alteplase. The best accuracy is 0.85 ± 0.03 on selected 12 features from the combination group of NCCT, CTA, and radiomics.

C. Image Segmentation

The k-mean clustering method is a widely used for separating interested region from its background. J. Macqueen.[4] describe the k-mean method to be a process for partitioning an N-dimensional population into k sets. The method find the k amount of center in the data that represent each data group.

The Otsu's threshold method is a segmentation method that propose by N. Otsu [5]. The separate the front-ground from the back-ground using a threshold values that calculate from intensity of the image. This method can sperate really well when the front-ground and back-ground have a high different in intensity value.

Canny is an edge detection method proposed by Canny. J.[1]. Edges in an image are found using; Gaussian filter for noise reduction, find intensity gradients and Apply non-maximum suppression to select only the maximal intensity gradients value. Then double threshold weak edge to reduce false detection.

III. Propose Method

We propose an automatic thrombus localization using the region growing method combine with MCA position filter.

First, we find the brain region using region growing method which have seeds provided from k-mean method. After we have the brain region, we use the region growing method to segment the candidate region. Different intensity from each candidate region is use as filter to select a high intensity region as candidate regions. MCA position were located to filter only candidate regions that are inside or near the MCA position as the candidate regions. An overview of the proposed is shown in Fig. 1.

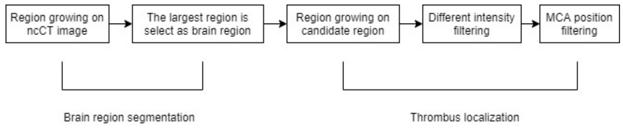


Fig. 1. Overview diagram of proposed method

A. Dataset Preparation

In this work, a set of ncCT images of Data set that use in this paper obtained from Siriraj Hospital. For each patient, a ncCT image that contain thrombus were provided with the boundary of the thrombus provided by a radiologist as a ground truth. See Fig. 2, for illustration.

Fig. 2. Example of CT image and the boundary of the thrombus

B. Image Preprocessing

The CT images contains unnecessary data such as background, bone area, and unrelated organ. A pre-processing step is applied to retrieve only brain region for analysis. In this work, k-mean cluster and region growing method are applied. A set of initial seeds is found by using center of k cluster. For each seed, a monogenous region is found by a region growing.

To retrieve only brain region, $k = 4$ is used for k-mean clustering and the seeds, which are from the middle intensity levels, are applied for the region growing. Let $\{c_1, c_2, c_3, c_4\}$ be the k cluster center value which $c_1 < c_2 < c_3 < c_4$. Let I_{min}, I_{max} be intensity range from minimum and maximum respectively, where $i_{min} = c_1 + ((c_2 - c_1) \div 2)$ and $i_{max} = c_3 + ((c_4 - c_3) \div 2)$. The region growing can be described as follows.

Let $S = \{s_1, \ldots, s_k\}$ be a set of the initial seeds .For each seed $s_t \in S$. The pixels around 8 windows, P_s be a set of pixels that surround s_t, and (i, j) is the position of the seed as in Fig. 3.b .Surrounding pixels $p \in P_s$ are selected if their intensity are within the predefined range. The range is the intensity level from i_{min} to i_{max}. The selected pixel p will be added to the seed set S if $p \notin S$. The next seed that is not already inside the region is selected to expand the region. The process is stop when all of the seeds are inside the region and there is no new seed to be added.

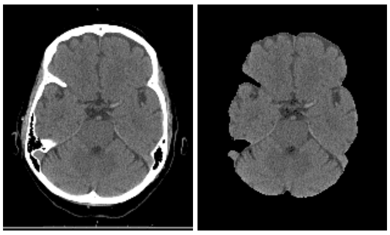
a.

4	5	1
4	5	4
3	3	4

b.

p_{s1}(i-1,j-1)	p_{s2}(i-1,j)	p_{s3}(i,j+1)
p_{s4}(i,j-1)	s_t(i,j)	p_{s5}(i,j+1)
p_{s6}(i+1,j-1)	p_{s7}(i+1,j)	p_{s8}(i+1,j+1)

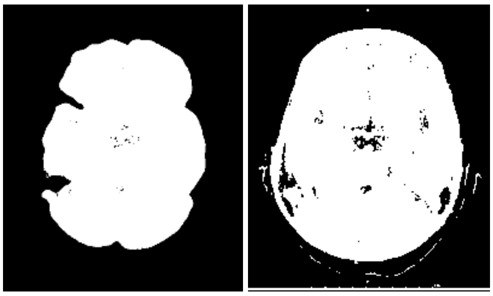
Fig. 3. a. The example of the region growing, when I_{min} is 4 and I_{max} is 5. b. The position matrix of the P_s and the s_t.



a. b.

Fig. 4. a. The original image. b. The segmented image of brain region.

An example of the connected region is shown in Fig. 4aThe output of the segmented brain tissue is shown in Fig. 4d. It can be seen that only the brain tissue is segmented. A comparison of the segmented region using the proposed method and the Otsu's threshold[5] are shown in Fig. 5. It can be seen that the mask region of Otsu's method includes the unnecessary parts which are bones and ears, while our proposed method focuses on the brain tissue.



a. b.

Fig. 5. The mask for k-mean (a) compare to the mask for otsu-threshole(b).

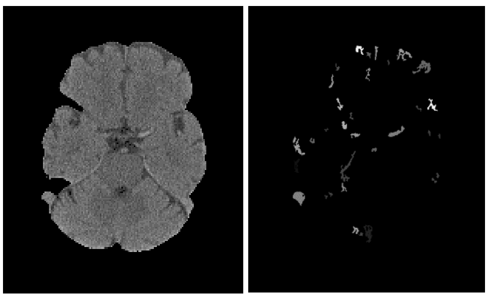
C. Thrombus Localization

Given a brain tissue as shown in Fig. 3d, the thrombus in an interest region is localized using k-mean and region growing method.

A set of candidate regions is found by using region growing and k-mean cluster. Let $C_L \in \{c_1, c_2, \dots, c_k\}$ be the centers value which $c_1 < c_2 < \cdots < c_k$ obtained from k-mean clustering.

The pixels, which are in c_k cluster, are used as a set of initial seeds. The range for including the surrounding pixels is the maximum intensity of the pixels in c_k to the minimum in c_{k-1}.

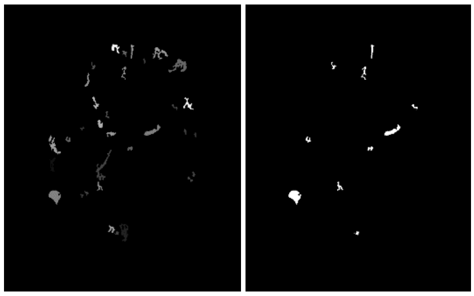
Some regions are too big or too small to be the thrombus. Therefore, the candidate regions are exclude if it is larger than 0.05 percent of the brain area or smaller than 0.5 percent of the brain area.



a. b.

Fig. 6. a. The brain region.b. The candidate region after region growing

The candidate regions are further filtered to remove the ones that are common. The differences of intensity distribution of each region to other regions is used. The candidate is selected when the differences to the other region is more than the average different among them.

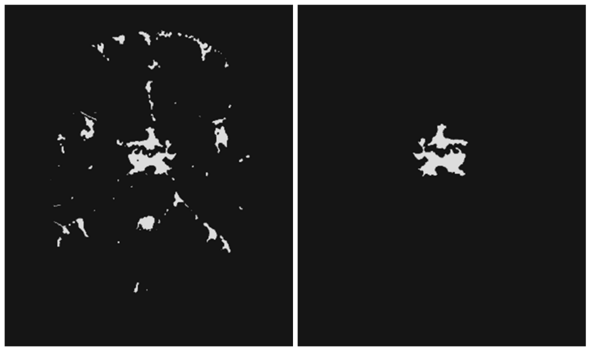


a. b.

Fig. 7. a. The cadidate regions.b. The cadidate regions after apiled the distance filter.

To ensure that the thrombus is in MCA, the interest position from MCA to sylvian fissure is automatically defined.

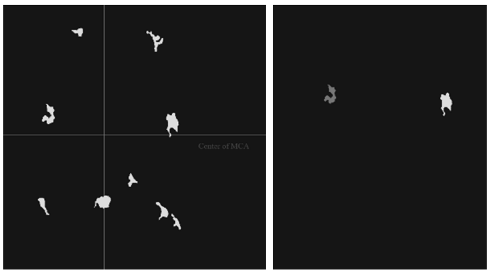
The dark area in the brain region is defined using the center value of k-mean with the least intensity value, and find each region that have connected region. Then the circle of willis is the region in the center of the brain region. We will call this the willis center point.



a. b.

Fig. 8. a. The dark region in brain image b. The dark region that are used to find center of willis

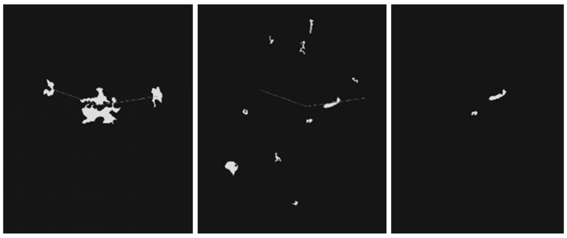
The two sylvian fissure positions are on the left the right. Using the position of willis center point, the left sylvian region is the largest region that have positioned above on the left of willis center point. The right sylvian region is the largest region that have positioned above on the right of willis center point. We called this as left and right sylvian center.



a. b.

Fig. 9. a. The dark region with cross line on willis center point b. The left and right sylvian region

After obtaining willis center point and both sylvian center, two lines are drawn from willis center point to both sylvian center. The candidate region is selected as thrombus if the distance to the closest line is less than 0.1 of the height of the brain region.



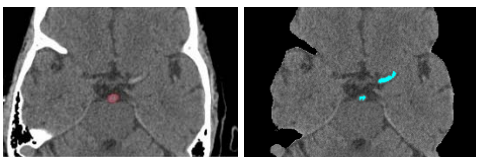
a. b. c.

Fig. 10. a. The line drawn from willis center point to both sylvian center b. The line drawn over the previous candidate region c. The candidate region after the MCA filter

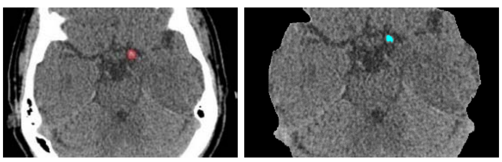
IV. RESULT

The segmentation is visually compared with the corresponding ground truth from the radiologist. The ground truth images are shown in Fig. 11a(1) and b(1). The segmentation result of our proposed method of the corresponding images are shown in Fig. 11a(2) and b(2), respectively. The result in Fig. 11a show an additional region is wrongly segmented. This ncCT was taken from red blood cell / fibrin composite. The result of Fig. 11b shows that the proposed method can correctly segmented the thrombus region of red blood cell / fibrin composite

More segmentation result can be found in Fig. 12.



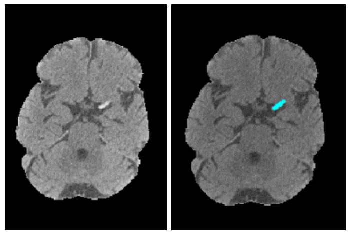
a(1) a(2)



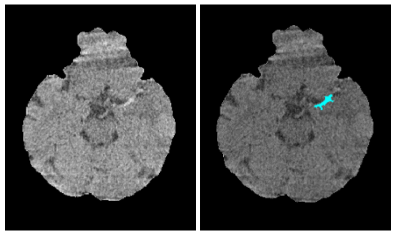
b(1) b(2)

Fig. 11. a(1).,b(1). The ground truth from radiologist Figure a(2).,b(2). Corresponding region from our method.

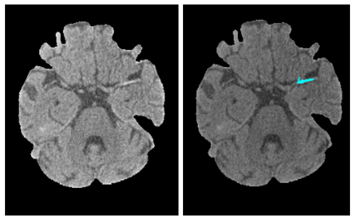
Image segmentation result of other ncCT of AIS patient.



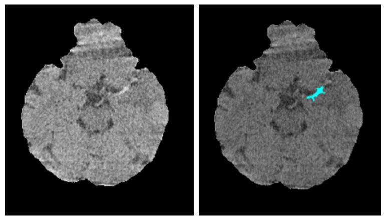
a.(1) b.(1)



a.(2) b.(2)



a.(3) b.(3)



a.(3) b.(4)

Fig. 12. a.(1)(2)(3)(4) The brain region b.(1)(2)(3)(4) the corresponding result image with thrombus region

V. CONCLUSION

The method can highlight the area of MCA that have thrombus inside according to the ground truth as show in Fig. 11. Our method might select some of the result region that are the MCA, so further work might try to eliminate that problem.

However, the thrombus localization method has some limitation. The first limitation is when the thrombus region does not have a highest k-mean center value inside. The second limitation is the resolution of the image affect time to compute for the method directly, because the region growing method need to calculate every pixel of the image.

In the future work, we can use this method to create an application to help radiologist detect the thrombus faster.

VI. Acknowledgement

This paper is partially supported by Thailand Science Research and Innovation (TSRI) under the contract number RTA6280015

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Segmentation Stroke Objects based on CT Scan Image using Thresholding Method

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Abstract — Brain image segmentation is one of the most important parts from a clinical diagnostic tool to determine the characteristics of a particular stroke type. Find anatomical contours and the location of the stroke to characterize the type of stroke perfectly in segmentation is very difficult this research proposes an approach to Image segmentation by the process of separating objects from other objects in CT Scan images. CT scan image segmentation uses the thresholding method with the Binarization process. Implementation of the Threshold method is Global binary thresholding, and Otsu thresholding. Preprocessing images to make repairs before segmentation. The dataset is used from Surabaya Hajj General Hospital and public data. The results of this experiment is improved image evaluated using peak signal-to-noise ratio (PSNR) and mean-square error (MSE), the best results were seen in bilateral filtering with a PSNR value of 69% MSE which was the lowest 0.008%. The best stroke object segmentation results using Otsu Thresholding by determining the lower threshold with a High Value of ≤170.

Keywords – Stroke, Segmentation, Thresholding, Noise removal

I. INTRODUCTION

Type of stroke is divided into two types of ischemic stroke when the blood supply to part of the brain is suddenly interrupted, the Stroke Hemorrhagic when the brain blood vessels rupture. Computed Tomography Scanning / CT Scan is one of the diagnostic tests performed to find out how the brain is seen when a stroke occurs. CT scan images that have a thick size will produce a picture with low detail, on the contrary a thin size will produce high detail. If the thickness rises, artifacts will arise and if too thin there will be noise [1][2].

Brain image segmentation is one of the most important parts of a clinical diagnostic tool. Finding the anatomic contour and location of the stroke to characterize the type of stroke perfectly in segmentation is very difficult. this research proposed an approach to image segmentation with the process of separating the object from the location of the stroke with other objects from the CT Scan image. CT scan image segmentation is performed using the Thresholding method with the binary process. The threshold method that will be implemented to be compared is adaptive thresholding, Global binary thresholding, Otsu thresholding.

Before doing segmentation, image repairs will be done, because the CT scan of the brain contains mostly noise, artifacts. It is important to remove noise before image segmentation start. the most common noise seen in CT images are Salt and Pepper noise, Speckle noise, Gaussian noise [3][4]. Image repair will be done by applying Noise Removal to CT scan images. Filters that will be implemented are median Filtering, Gaussian Filtering and Bilateral Filtering, from the three filters the Best filter will be taken for Image repair Performance is evaluated using Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE). The best results will be implemented in Stroke Object Segmentation.

II. RELATED WORK

Jodiaman et al. conducted a study of stroke classification which was classified as three ischemic stroke classes, hemorrhagic stroke and normal through CT Scan image images as a dataset. The steps taken are preprocessing digital images consisting of gray scaling to convert images to gray, scaling to reduce image pixels so that time is efficient. Process the Contrast Limited Adaptive Histogram Equalization (CLAHE) to increase image contrast[5].

Siddique et al. In this study the implementation of segmentation using the Thresholding Otsu method on digital images by setting the threshold for the image in Otsu applied. The Otsu method is carried out to study thresholds that can maximize the variance between classes or the equivalent of making light in the class variance of the entire image. The result of this paper is to compare three types, namely original image, Otsu thresholding level 2 image and Otsu Thresholding level 3 image[6].

Pannirselvam et al. in this paper analyzed various filters and proposed a new methodology for fingerprint pre-processing. In this paper use Bilateral Filters, High boost filters and Gaussian filters for efficient fingerprint image quality. In the proposed methodology, the original is filtered using a High Pass and Gaussian filter to remove noise[7].

Shima et al. this study detected kidney lesions using abdominal CT scans. This paper was conducted for the pre-processing of abdominal CT scan images so that the kidneys were grouped for further analysis of lesion detection. Various noise filters and segmentation techniques have been tried to select the best filters and segmentation techniques for CT image pre-processing. Experimental studies found that the Median filter combination followed by Wiener filter was more effective for removing the different noise present in CT images. Different segmentation techniques have been carried out on CT image test data sets and it was observed that Edge-based active contours yield better results than Graph Cut and region-based active contours[8].

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III. PURPOSE

The purpose of this study was to segment stroke objects based on CT scan images. Finding the contour of anatomical organs and the location of a stroke to characterize the type of stroke perfectly in segmentation is very difficult. This study proposes an approach to image segmentation with the process of separating objects from other objects in CT Scan images. CT scan image segmentation is done using the thresholding method with the binarization process. The threshold method that will be implemented to be compared is adaptive thresholding, binary thresholding, Otsu thresholding and combining between the Binary and Otsu thresholding methods. patients with three types of image dataset classes namely Ct Scan imagery to be implemented are adaptive Thresholding, and Global Binary Thresholding and Otsu thresholding,

IV. THE PROPOSED METHOD

A. Data Collection

The dataset used comes from two sources, the first is the dataset from Surabaya Hajj General Hospital in Indonesia for data on Ischemic Stroke and Hemorrhagic Stroke, because the not Stroke CT Scan dataset is not available in the Hajj Hospital, to complete the non-stroke CT image using data provided on the website https://radiopaedia.org/, the second source is also used in a paper written by Jodiaman et al [3].The image is taken with a thickness or slice thickness of 5.0 mm, retrieval of data with that size is based on the size of the CT scan image has a thickness range between 1.0 - 10.0 mm, where the value is the middle value of the CT scan parameter size generated by each patient. With a thickness of 5.0 mm, 25 images were obtained for each patient. Of the 25 images taken by one patient, a good picture was found where strokes were seen between 1-5 images. Currently the drawing dataset produced by 102 patients is 233 which are divided into two classes of labels namely 226 ischemic strokes and 7 images of hemorrhagic strokes. To homogenize data between the two data sources, it is necessary to process data, then make improvements to CT scan images

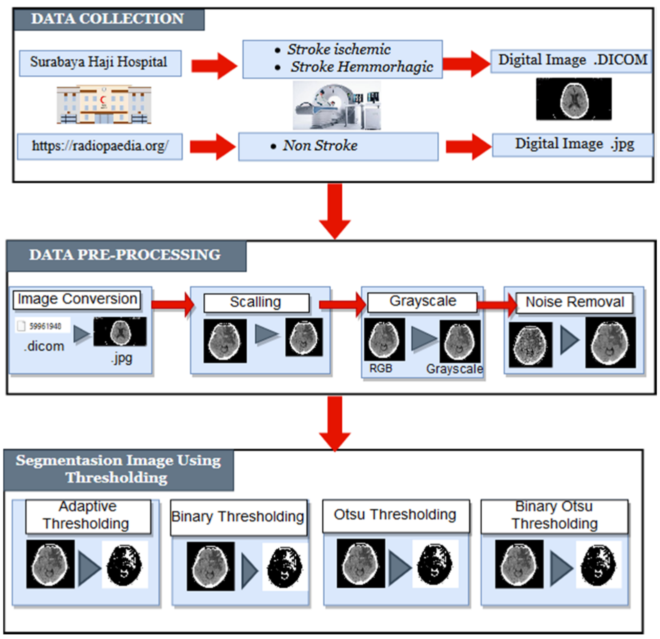


Fig.1 System Design

B. Data Preprocessing

Pre-processing Data is the data processing stage to prepare the Image to be processed and improve the quality of the image data. This process consists of data conversion, from the Dicom extension to jpg. Then apply scaling which functions to adjust the pixel dimensions so that the dimensions of the image have the same size because the data comes from different sources so that the size of the initial dimension is different. The results of the original dataset still represent RGB colors. so that the image that has been processed to scaling will be processed into a Grayscale image that serves to convert the color representation into a gray scale. Then do a Noise Removal, which serves to eliminate noise found on CT scan data. Removal of noise in medical images is an important task in preprocessing images to eliminate noise and improve images better [12]. In this study, the Noise removal method was compared with 3 filters, namely the Median filter, Gaussian Filter and Bilateral Filter. Performance was evaluated using Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE)

C. Median Filtering

The median filter method [9]is a nonlinear filter that serves to reduce noise and smooth the image. It is said to be nonlinear because the workings of this filter are not included in the category of convolution operations. Nonlinear operations are calculated by sorting the intensity values of a group of pixels, then replacing the pixel values that are processed with a certain value. The Median Filter output is obtained from:

$$Q^2_{med} = \frac{1}{4n\, f^2\,(n)} \approx \frac{\sigma i^2}{n+\frac{\pi}{2}-1} \cdot \frac{\pi}{2} \tag{1}$$

Where:

σi^2 : Input Noise Power (the variance)
n : Size of the Median Filtering mask
$f(n)$: Function of the noise density

D. Gaussian Filtering

Gaussian Filter [10] is a method commonly used in image processing to smooth, reduce interference, and make derivatives of a computational image, and is a convolution based filter that uses a Gaussian Kernel matrix Gaussian filtering is used to obscure images and eliminate noise and detail. The output of the Gaussian Filtering is obtained from:

$$G_\sigma\,(x) = \frac{1}{2\pi\sigma^2} \exp\left(-\,\frac{x^2+y^2}{2\sigma^2}\right) \tag{2}$$

Where:

σ : Standard deviation
x : Distance horizontal axis
y : Distance vertical axis

E. Billateral filtering

Bilateral filter [10] functions to smooth images while maintaining edges, with nonlinear synthesis methods of adjacent pixel values. Bilateral filters take into account variations in intensity to maintain edges. The output of the Bilater filter is obtained from:

$$BF[I]_p = \frac{1}{w_P}\, G_{\sigma_s}(\|p-q\|)\, G_{\sigma_r}(|I_p - I_p|) I_q \tag{3}$$

Where:

Ip : Filtered Images
I : Original Input Image
X : Pixel Coordinates

Gσs : Gaussian Spatial Kernel
Gσr : The Gaussian range reduces the effect of pixels

F. Peak Signal-to-Noise Ratio (PSNR)

The ability of filters to improve image quality is generally assessed by using PSNR which gives the image quality value in the unit of the two origin images and images. The higher the value of PNSR shows the ability of the filter is good in improving the image quality of the filter [10]. PNSR output is obtained from:

$$PNSR = 10.log_{10}\ (MAX_1) - 10.log_{10}\ .MSE \quad (4)$$

Where:
MAX_1 : Maximum possible pixel value of the I image
MSE : Difference between each original image pixel and filter image using equations,

G. Mean Squared Error (MSE)

Mean Square Error (MSE)[10]: Mean Square Error (MSE) can be estimated to measure the difference between the value implied by the estimate and the actual quality that has been certified . MSE output is obtained from:

$$MSE = \frac{1}{m.n} \sum_{i-0}^{m-1} \sum_{j-0}^{n-1} [I(i,j) - K(i,j)]^2 \quad (5)$$

Where:
m : Row size image
n : Columns size image
i : Position point row in the image
j : Position point column in the image

H. Segmentasi image Using Thresholding

Image thresholding is a type of segmentation technique that has a process based on gray scale differences in an image. The results of thresholding will produce binary images 0 and 1.

The threshold that will be compared in the Segmentation Implementation is Adaptive Threshold where each pixel image is Thresholding based on neighboring pixel histograms, both Global Thresholding, global thresholds are based on the assumption that images have a bimodal histogram and, objects can be extracted from the background with simple operations that compare values the image with the predetermined and final threshold value with Otsu thresholding divides the gray level image histogram into two different regions automatically without requiring user assistance to enter the background threshold value with a mean of µ0 and foreground with an average of µ1.

V. EXPERIMENT AND ANALYSIS

A.Data Conversion

The dataset used comes from two sources, the first is the dataset from Surabaya Haji General Hospital for data on Ischemic Stroke and Hemorrhagic Stroke, because the not Stroke CT Scan dataset is not available in the Hajj Hospital, to complete the not stroke CT image using the data public /. The overall data of the Patients amounted to 102 people, the number of Ischemic data was 226 and Hemorrhagic data were 7 images. From several shots for one patient a good picture between 1-5 images could be used as a dataset

The dataset obtained from the hospital is still in the form of data extension in the form of Dicom CT Scan has dimensions of 512 x 512, Gray scale color representation, and 8 Bit depth, so the Dicom image needs to be converted into jpg format to be processed. Data conversion determines the next stage of the process that must be done because each image has different information results, from the dimensions, number of bits and color representation is different. So that the steps taken must be based on the image conversion information.

B.Scalling Dataset

The scaling stage serves to regulate the dimensions of the image used, this is done to uniform the dimensions of the CT scan image, because the datasets have different image dimensions. The dataset from the Hajj Hospital after conversion has an image dimension of 1105x650, while the second data source obtained from the public has a dimension of 300x300. So that the image will be uniformed according to the lowest dimensions by resizing the data that has a larger dimension.

C. Gray Scale

Gray scale functions to scale the gray scale of the image, this is done because the converted digital Ct scan image still represents RGB color, while the Ct Scan image only has light intensity level information that describes the number of photos that penetrate the object, so that the image has been scalloped will be processed into the Gray scale image. In addition, in the segmentation process using the original input image thresholding must be changed to Gray scale first

Not Stroke Ischemic Hemorrhagic

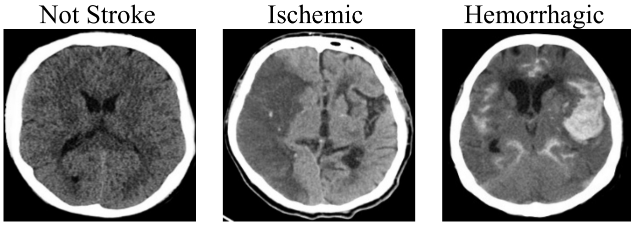


Figure 2. Result Grayscale image

D. Noise Removal Using Median filtering

Median Filtering obtained from the output pixel value is determined by the median of the area mask or specified dimension. Median is searched by sorting the pixel value of the specified mask, then looking for the middle value. The dimensions of the kernel used in this filter are 5 x 5 dimensions.

E. Noise Removal Using Russian Filtering

The Gaussian Filtering functions to ensure that only the closest pixels are considered blurred, while the intensity gaussian function ensures that only pixels with the same intensity as the central pixels are considered blurred. In the implementation the parameters used are the Grayscale image, and the Kernel used is the 5 x 5 dimension, the sigma used is the default parameter with a value of 0.8, the kernel can only be set with an odd value. The standard deviation of a Gaussian distribution will be calculated based on the size of the kernel.

F. Noise Removal Using Bilateral Filtering

Bilateral filtering is defined as a weighted pixel average that takes into account variations in intensity to maintain edges. the parameters used are 8-bit Grayscale image, Pixel diameter initialized with value 9 and Sigma Color sigma filter in color space initialized with 75 and Sigma Space or sigma Filter in the coordinate space initialized value 75. Larger parameter values mean farther pixels will mutually affect as long as the color is close enough.

After the pre-processing with the parameters that have been determined, the filter results can be measured by the accuracy of high image quality, using the value of PSNR & MSE. From Table 1 and Table 2 show the results of filter values that have been done, it can be concluded that the Bilateral Filter gives the highest PSNR value with values and the MSE value is lower when compared with the median and gaussian filters.

Table1 PNSR Value

Filters Name	PNSR VALUE %		
	Non stroke	Ischemic	Hemorrhagic
Median	34.856397	36.170086	36.67901
Gaussian	32.390228	31.842203	30.423184
Bilateral	67.774283	68.975047	68.749674

Table 1 is the result of the assessment of filters that are implemented for Noise removal, the higher the value of PNSR the higher the level of image repair is done. The results of the highest Bilateral assessment of the other 2 filters are Median and Gaussian Filters. Where the stroke ischemic value reaches 69%, and the lowest value is in the gaussian filter with a value of 30%.

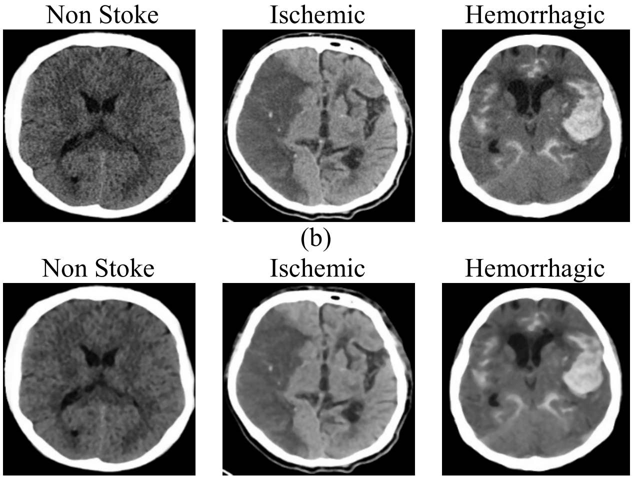
Table 2 Mean Square Error

Filters Name	MSE VALUE %		
	Nonstroke	Ischemic	Hemorrhagic
Median	21.254	3.963108	13.969453
Gaussian	37.50227	42.546133	7.680349
Bilateral	0.010856	0.008233	0.008672

Table 2 show, the MSE assessment can be estimated to measure the difference between the values implied by the estimation and the actual quality, the smaller the MSE value, the better the image produced from image improvement. The smallest MSE value is found in the Bilateral image with a value of 0.008% and the highest is the Gaussian Filtering with a value of 42.5%

(a)

Non Stoke Ischemic Hemorrhagic

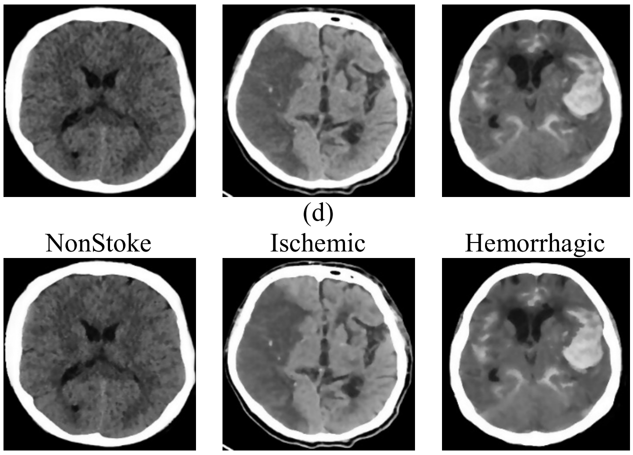


(b)

Non Stoke Ischemic Hemorrhagic

©

NonStoke Ischemic Hemorrhagic



(d)

NonStoke Ischemic Hemorrhagic

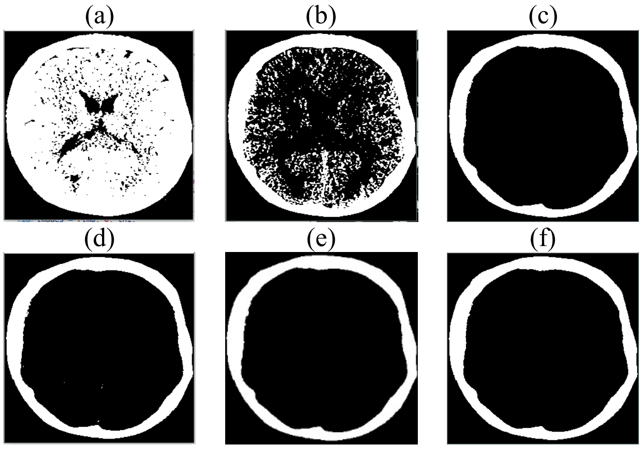
Figure 3. Result Noise removal (a) real data, (b) Median Filtering, (c) Gaussian Filtering, (d) Bilateral Filtering

E. Thresholding

This threshold aims to convert grayscale imagery into binary imagery. The information contained only has two level values namely black and white. Basically, holding has 3 parameters that must be applied, First The source of the image must be Grayscale, second The threshold value used to classify pixel values and last is MaxVal which represents the value to be given if the pixel value is more or less than the threshold value.

Thresholding implementation in segmenting Stroke objects using Global Thresholding and Otsu Thresholding The Threshold Value with a value of 255 and the lower threshold is divided into 3, namely ≤ 50, ≤100 and ≤170. From the results of object stroke segmentation using Threshold can be seen in figure 4.5,6.

(a) (b) (c)



(d) (e) (f)

Figure 4 Result Segmentation not Stoke (a) Global Threshold ≤50, (b) Global Threshold ≤100, (c) Global Threshold ≤170, (d) Otsu Threshold ≤50, (e) otsu Threshold ≤100, (f) Otsu Threshold ≤100

In Figure 4 is the result of the Not Stroke Thresholding CT scan, the result of Threshold using the OTSU method produces a consistent image in each of the Lower Threshold parameters which are defined as ≤50, ≤100 and 70170, in the global thresholding method showing maximum results on the lower threshold ≤70.

(a) (b) (c)

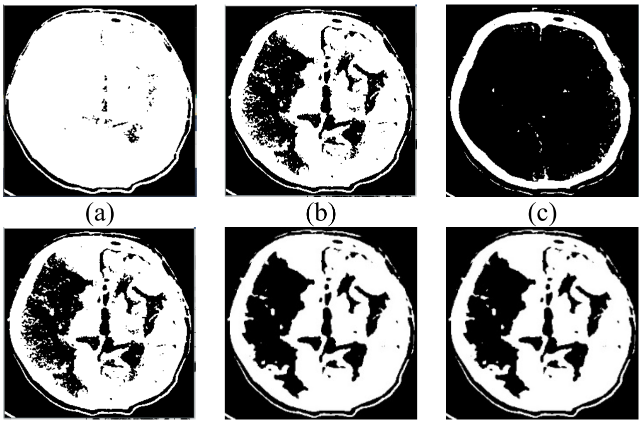


Figure 5. Result Segmentation Stoke Ischemic (a) Global Threshold ≤50, (b) Global Threshold ≤100, (c) Global Threshold ≤170, (d) Otsu Threshold ≤50, (e) otsu Threshold ≤100, (f) Otsu Threshold ≤170

In Figure 5 is the result of the Stroke Ischemic Object Segmentation resulting from the Threshold with the OTSU method still producing the Maximum Image in the Lower Threshold parameter specified is ≤170, in the method.

In Figure 6 is the result of Hemorrhagic Stroke Object Segmentation, the result of Threshold using the OTSU method produces a consistent image in each lower Threshold parameter which is specified as ≤50, ≤100 and ≤170, in the global thresholding method showing maximum results at the lower threshold ≤170

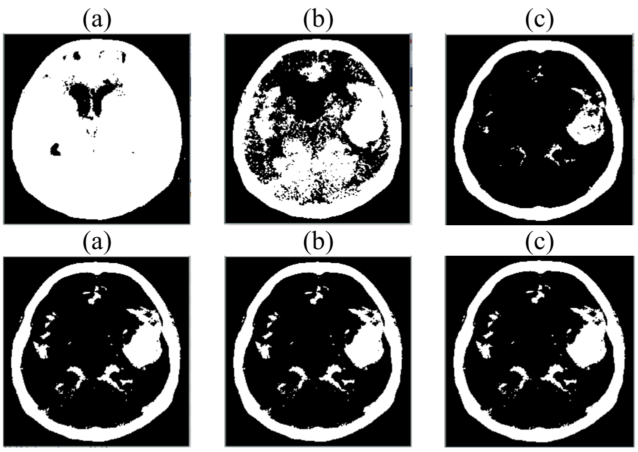


Figure 6. Result Segmentation Stoke Hemorrhagic (a) Global Threshold ≤50, (b) Global Threshold ≤100, (c) Global Threshold ≤170, (d) Otsu Threshold ≤50, (e) Otsu Threshold ≤100, (f) Otsu Threshold ≤170.

Segmentation Ischemic Stroke object produces black while the Hemorrhagic Stroke Object produces a white sting results in the not Stroke CT Image produces a Black block except for the visible part of the Brain Bone. This is based on Parameter which is set by color based on the pixel intensity of the image (x, y) higher than the threshold, then the new pixel intensity is set to Maximal Value. If not, the pixel is set to 0.

VI. Conclusion and Future Work

In this paper, CT scan image pre-processing techniques are used to support the detection of objects of Ischemic and Hemorrhagic strokes, because the CT scan of the brain contains mostly noise, artifacts. to eliminate noise for better segmentation results. Three types of noise elimination filters are applied to CT Scan images, namely Median filters, Gaussian Filters and Bilateral Filters. This experiment resulted in improved image evaluated using PSNR and MSE, the best results were seen in bilateral filtering with a PSNR value of 69% MSE which was the lowest 0.008%. The best stroke object segmentation results using Otsu Thresholding by determining the lower threshold with a High Value of ≤170. Thresholding segmentation needs to be optimized by repairing other images such as sharpening the edges of removing the brain skull part in the image, so that the cerebral scalp is not visible. In addition, it is necessary to do Morphological Techniques to remove noise and unite objects. The morphological operation function is dilated to develop pixel points according to the dimensions of the kernel used.

Among thresholding segmentation methods, the best result is obtained from a combined method of Binary and Otsu Threshold. However, the drawback to this combined method is that objects that are not ischemic or hemorraghic stroke remain to be detected as an illnes, meaning that corrections on the thresholding segmentation process have to be made. One strategy that can be done is by applying sharpening edges which are sharpening edges that become objects. One way is to erase part of the brain skull line so that the line is not visible when segmented

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Lesson Learns of Success factors from 10 Smart Cities Development: Thailand Context

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Office of the National Economic and Social Development Board (NESDB) has established a 20-year national strategic framework (2017 - 2036) which is the main plan to direct national development inconsistent with sustainable development goals (SDGs), including the restructuring to Thailand 4.0, as well as national reform issues. In addition, the importance of participation of all development parties can help for manage to utilize the knowledge of science, technology and innovation to implement on an area that responds to demonstrate the potential of technology and innovation with the efficiency of readiness, including personnel, area, organization, and various sectors in production and respond to smart city development. In order to direct the development with appropriate quality index in almost all important areas such as human quality, education and public health service as well as alleviating social inequality and preserving the quality of the environment to lead a city with a complete network of systems, case study from success stories must be reviewed. This study attempted to investigate lessons learns of successful factor from 10 foreign countries. It was found that there are 5 issues to be considered, including (1) government transparency, which builds confidence for people who can review the information that have been solved; (2) establishing a board to oversee the development of smart cities, which needs to be placed in the overall operating framework; (3) creating an environment that is conducive to further innovation by creating a space for testing equipment (test-bedding) ; (4) establish laws and regulation to protect rights and personal information (cyber security); and (5) local government needs to be the pioneer of smart city development and create an attraction for each sector to participate.

Keywords—Smart City, Quality of life, Urban Planning Integrated

I. INTRODUCTION

The urban growth and city population are growing in a fast pace causing different dynamic issues to the environment, economic and social sustainability of cities (Bibri and Krogstie, 2017; Neirotti et al., 2014). The traffic congestion, poor urban infrastructure, health issues, energy shortages, educational challenges, inadequate housing, increasing crime rates, higher unemployment, ageing infra-structure, power thefts, issues in supply connections, insufficient power generations capacity, high power loss in transmission, frequent power breakdowns and lack of real time data sharing are some of common concerns in existing cities mostly in developing countries like Thailand (Lee et al., 2013).

Resulting in efforts to solve problems of the city to reduce the effects that occur up until the year 1994, the concept of creating also known as smart city, which is derived from the obligation to bind each industrial country to reduce greenhouse gas emissions which have also known as Kyoto Protocol (Mattoni et al., 2015). As a result, each country has started to formulate a strategy that is aware of the environmental policy and become one of the main driving factors. The concept of Smart City has played a role as the choice of raising the quality of life of people and facilitate work of the government more transparent (Kramers et al., 2014).

Also, Thailand has initiated the Smart development with supportive from both public and private sectors. In 2016, the Smart City Thailand Association was established as a direct coordination center and to control guidelines development. From efforts to create a quality society of the future smart city, the Ministry of Digital Economy and Society (Depa) selected pilot cities such as Phuket, Chiang Mai and Khon Kaen which is currently in the process. In driving to become a smart city, it is important to make people truly enhance the quality of life and engaging the system. In addition, to lay the foundation for urban development by developing Smart City, it must create readiness for development that is built on existing policies. All operations, it is necessary to overcome the problems of the city that is currently facing urban development without the difficulties of existing regulations while beneath the challenges of elderly society, climate change, etc. Thus, the country must focus on an investment with the analysis of big data from the investment of the city's infrastructure with the installation of wireless internet for forecasting and planning and used trends analysis of changes in city directions and way of life of the people. Follow by establishing the infrastructure and public services by utilizing data from the analysis to find solutions of current problems by using intelligent technology to help by bringing the concept of smart city development integrated with Thailand Economy 4.0 and 10 target industry policies. Finally, it is a must to create cooperation between educational institutions and entrepreneurs including public and private agencies to contribute on technology development and linking data with the ICT based data and enable to exchange and connecting the city's systems with IoT. All process must create transparency for information sharing to lead for sustainable and smart city development.

II. LITERATURE REVIEW

A. Smart cities and infrastructure

There is no commonly standardized accepted definition or set of terminologies for a smart city. In 2014, an International Telecommunication Union report analyzed over 100 definitions related to smart cities, and the following definition was the outcome of this analysis: "A smart

978-1-7281-6435-9/19/$31.00 ©2019 IEEE

sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects" (International Telecommunication Union, 2014). Several efforts are currently underway to develop comprehensive key performance indicators for smart cities (Carriero, 2015). A United Nations inter-agency group is developing a set of key performance indicators with the aim of turning them into a global smart sustainable city. Analyses of different definitions of the term smart city reveal that different definitions emphasize different aspects. Governments and stakeholders need to work together to develop a common understanding of what smart city means in their specific national and city-level contexts.

The smart city concept offers different opportunities for different countries. The immediate need for cities in developing countries is to provide adequate urban infrastructure to meet the increasing pace of urbanization. In the process of meeting infrastructure demands, smart infrastructure applications provide a way for such cities to achieve leapfrogging in technology (Belanche, D.,2016). In developed countries, the challenge is often to maintain legacy infrastructure systems, which cannot be abandoned due to cost, space and other considerations. In such countries, smart city applications may focus more on facilitating the optimal use of existing infrastructure resources and monitoring the operations of such legacy resources. However, in both developing and developed country contexts, the primary motive behind smart infrastructure applications should be responding to the sustainable development needs of society (Lee, J.H., 2013).

B. Smart digital layers

Smart digital infrastructure helps to increase understanding and the control of operations and optimize the use of limited resources in a city. One of the key value propositions of ICT in a smart city is the ability to capture and share information in a timely manner (Slater and Khandelwal, 2016). If the information is provided in real time and is accurate, cities can potentially take action before a problem begins to escalate. One way to consider digital infrastructure is in the form of different supporting digital layers which can be explained as follows:

(a) *Urban*: The layer where physical and digital infrastructures meet which include smart buildings, smart mobility, smart grids (for utilities such as water, electricity and gas) and smart waste management systems.

(b) *Sensor*: This layer includes smart devices that measure and monitor different parameters of the city and its environment.

(c) *Connectivity*: This layer involves the transport of data and information from the sensor level to storage and to data aggregators for further analysis.

(d) *Data analytics*: This layer involves the analysis of data collected by different smart infrastructure systems, to help predict some events (such as traffic congestion).

(e) *Automation*: The digital enabling interface layer that enables automation and scalability for a large number of devices across multiple domains and verticals.

Implementing smart city technologies often requires a robust, reliable and affordable broadband network, an efficient ecosystem for the Internet of Things and the capacity to make use of the big data generated (Al Nuaimi et al., 2015).

C. Implementing smart infrastructure: Some key challenges of science, technology and innovation-driven smart city development.

The implementation of smart infrastructure concepts, especially in developing countries faces numerous challenges. This section discusses some of these challenges and the role communities can play in overcoming them, including some policy instruments that could help to address each challenge (Belanche, 2016).

1) The need to localize smart infrastructure

A given smart city solution cannot simply be transplanted from one geographic region to another. Smart infrastructure concepts need to be made locally relevant and respond to local development needs. Context, culture and economics play a role in this process. Cities should consider urban problems in a holistic manner before selecting appropriate smart technology solutions. For example, the conventional intelligent transport systems approach, involving a huge network of sensors and the aggregation of data which may be too expensive and unsuitable for developing country needs (Belanche, 2016). A more localized and simpler version of intelligent transport systems may leverage more ubiquitous mobile telephone data, which may be more suited to developing country contexts. Local communities play a key role in addressing the challenge of localization.

2) Harness the local innovation system: An overarching solution.

Harnessing a local innovation system, which comprises inter alia entrepreneurs, local universities and research centers, is key to addressing the challenge of localization. For example, in South Africa, collaboration between a local university and city administration led to the design of smart shacks, which respond to urban housing needs in informal settlements (King, S., Cotterill, S., 2007). Governments can allocate research funds to smart city projects and provide incentives to make such projects a priority within their communities. Cities need to consider how best to use existing innovation infrastructure such as science parks, technology incubators and innovation hubs to develop new smart city ideas and adapt smart city concepts. For example, in Gothenburg, Sweden, collaboration between two science parks and several other stakeholders resulted in the first modern electric bus route. Most importantly, cities need to create policy environments where massive amounts of small-scale innovation related to smart cities can flourish (King and Cotterill, 2007).

3) Promote open data, open science models

Globally open data initiatives by Governments and the private sector have been a great impetus for smart city applications. For example, the open data platform in Singapore, promoted by the Government, successfully uses the potential of open data in promoting locally relevant smart city initiatives (DuPuis and Stahl, 2016). In order to make the best use of open data initiatives, as well as promote further innovation, civic hacking events have been organized by various city governments and technology firms. Along similar lines, cities should encourage open science and innovation models that rely less on proprietary technology models. Such efforts can foster research collaborations and create opportunities for innovation (Manville et al., 2014).

4) Establish urban innovation units and living labs.

Smart city applications might benefit from new institutions such as urban innovation centers. Such innovation centers and labs may provide convenient platforms to demonstrate new ideas and concepts. Another pertinent institutional arrangement that promotes smart city innovations is that of living labs, which offer real-life test and experimentation environments in which users and producers may co-create innovations. Living labs methodologies have already been applied in developing countries, especially in Africa, promoted mainly through the Africa-European Union Strategic Partnership. Existing living labs networks may be used to test, incubate and promote smart city innovations (Kramers et al., 2014).

5) Exploit regional innovation networks and global collaborations.

When cities by themselves lack the capacity to conduct smart city-related research, make investments or create local adaptations, they can join with other cities confronting similar developmental challenges, as well as with technology partners, to conceptualize, finance, implement and exploit complementary competences and share lessons learned. A successful example in this regard is the European Innovation Partnership on Smart Cities and Communities that, by pooling resources, aims to co-fund demonstration projects, help coordinate existing city initiatives and projects and overcome bottlenecks to transition processes (Howe,2006). Similar collaborative initiatives, such as the International Summit for Smart Cities in North Africa (Howe,2006) and the Asia Africa Smart City Summit held in Bandung, Indonesia, and its declaration on smart cities, are nurturing partnerships across smart cites.

III. SMART CITY THAILAND CONTEXT

The government of Thailand has launched a national agenda to push the country to become a high-income nation. The initiative is often coined as the "Thailand 4.0" economic model and the four key objectives of Thailand 4.0 initiative include (Digital Economy Promotion Agency (depa), 2019):

1) *Economic prosperity*: To create a value-based economy driven by innovation, technology and creativity.
2) *Social well-being*: To create an inclusive society through the realization of the full potential of all members of the society.
3) *Raising human values*: To transform Thais into competent human beings in the 21st century and Thais 4.0 in the first world.
4) *Environmental protection*: To become a livable society that possesses an economic system capable of adjusting to climate change and low carbon society.

Fig. 1. Map of ASEAN Smart Cities Network and Pilot Cities

Source: Digital Economy Promotion Agency (depa), 2019

Important actions being implemented at the moment involve focusing on 10 high-value and high-tech industries, known as the S-curve industries (Digital Economy Promotion Agency (depa), 2019). The S-curve industries can be further segmented into 2 main types, the "S-curve" and the "new S-curve". S-curve includes traditional industries such as automotive, medical tourism, electronics, food technology and agriculture. These are industries which Thailand is particularly strong at, but technologies can be used to further boost their values. On the other hand, the new S-curve are industries which are somewhat technologically new to the country but, with the current ecosystem and environment, are seen to have high potential. This group of industries include robotics, biofuels, medical hubs, digital sector and aviation.

Currently, there are 7 cities (Phuket, Chiang Mai, Khon Kaen, Chonburi, Rayong, Chachoengsao, and Bangkok) that were selected for Smart City pilot cities. The development of pilot cities can be categorized into two waves. First wave consists of Phuket, Chiang Mai and Khon Kaen and the second wave consists of Chonburi, Rayong, Chachoengsao (EEC) and Bangkok as shown Figure 1.

IV. RSEARCH METHODOLOGY AND ANALYSIS

In this study, lessons learn of successful factor from 10 smart city development were taken: (1) Dublin, Republic of Ireland (2) Amsterdam. Netherlands (3) Dubai, United Arab Emirates (4) Copenhagen Denmark (5) Vienna, Austria (6) New York City, United States (7) Stockholm, Sweden (8) Tokyo, Japan (9) Republic of Singapore and (10) Seoul, South Korea. After that, it can be compared with the model of smart city development in Thailand context. To identify the gaps in development, it is useful to fill the development exactly which can be summarized for 5 developmental key points with details as follows:

A. Initiative and goal of smart city development

In Europe, most of the goals of smart city development require to reduce the amount of carbon dioxide emissions and to reduce climate change problems. The European Union (EU) is the main agency to support, motivate and provide an international budget to invest in building a smart city. While in the Middle East countries, Dubai, United Arab Emirates and Singapore, which are the major economic centers in the world are rapidly growing and have limited development space. The government is a main agency that drives and supports enormous budgets for urban development. To build cities and integrate urban planning to accommodate the population and global change must be in the direction of achieving rapid success in smart city development. While Asian countries especially Japan, the goal is to create clean energy usage and reduce the cost of electricity generation. To create clean electricity production and reduce the impact to the people as much as possible must consistent with the basis of the community. The Republic of Korea, Modern city with modern technology, there is a problem with the city with a growing population as well. Therefore, changing the pattern of production and developing innovations to answer the industry as innovations that solve urban problems.

While Thailand is currently a country that still focuses on industrial development and industrial production base by reviewing the plan of smart city development. Therefore, it needs to solve problems in many areas with appropriate prioritization. Moreover, the goal of the amendment will help to see the process guidelines and results of joint development.

B. *Government transparency*

Each country has set the framework for the development of smart cities to create a common guideline. By developing from the context of the problems that each city faces. Most of the strategic plans of smart city development focus on creating the participation of each sector. By allowing communities and people to be the center of development. That is the way to creation of smart people by building confidence in the system and acceptance of the use of new technologies. The government must make an attempt to create more user-friendly applications and create transparency for the government for the people to trust and develop design a framework for the smart city development together. Information sharing and transparency in each country in the case study is equipped with a chaser to collect city-data by displaying the results on the online website that everyone can access and download to bring information to further develop and create new ideas in the future.

While, Thailand in the process of laying the foundation of development by considering the development period of each city at least 10-15 years, therefore achieving the same success as today. From the lessons learned of each country cities have to start planning for intelligent data collection and share information with each sector so that they can be further developed.

C. *Establishing a board to oversee the development of smart cities*

It is an important part of pushing the city to upgrade to a society with a quality of life under the mechanism of driving budgets, cooperation or marketing and investment incentives. Mostly, the main duty of the board will act as a project coordination center and operation plan manager. As well as develop strategies to manage plans to meet goals and check the progress of each project. Including developing strategies and implementing plans project management and coordinate and share information for each sector to achieve mutual access to common areas. Most of the Smart City Development Committee were established in the form by comprising of the government, private and educational sectors. In which the government will consider the overall picture of all operations, including the selection of research and innovation to develop urban areas in the real area. While Thailand has the same committee for smart city development which operates under the Office of the Digital Commission for National Economy and Society and all from government sectors. Therefore, this part of the operation still lack the participation of other sectors which may have different development perspectives and can be integrated to develop smart cities that elevate to develop in a context that can solve the city problem.

D. *Creating a space for testing equipment (Test-Bedding)*

Creating a partnership for each sector is very important, especially in the initial stages of development. In most cases, each country will have public-private partnerships that operate at an international level, such as IBM, Intel. By creating a test, experiment and work areas for all groups of people (Test-Bedding) is a space that everyone can use as a test area for innovation. It will be enabled to open for public awareness and jointly develop further work together to drive new creative ideas and solutions to problems that are appropriate for the context of each country and to stimulate behavior change. Therefore, using the theory of "Living Lab" as the principle of work could be used as a testing area for equipment in the real environment so that people in the city can easily join.

While Thailand, the area for innovation development is still a non-public area and is mainly developed by the private sector. From lesson learn, it is found that the education sector will participate in the development by having the space to test innovation which comes from the work of students or encourages the start-up to grow with education and research to support.

E. *Establish laws to protect rights and personal information.*

From lessons learn, the safety of data sharing and providing personal information to the government should cover process of data collection, analyze the trend results of daily life each country. It is therefore obliged to set regulations and laws to protect the rights and personal information of people in each country. In which the country of a clear legal definition and the most secure, the Republic of Singapore is number one in giving importance to cybersecurity. In data security with the protection of privacy in public information, it has been also focusing on the public health system, therefore, the Singapore Cybersecurity Strategy has been established to build system reliability for both the citizens and foreigners who would like to invest.

While Thailand, there are also laws and regulation that specify the security of data usage. However, with the system that was forced to fix the problem after it happened, therefore cannot create security for real usage. Including the fact that it is not yet possible to establish credibility in exchanging information.

F. Local government needs to be the pioneer of smart city development

To establish large-scale innovation development and create a network of innovation development, a small organization is an important unit to start as an area for innovation development. The important thing is to create a platform for testing, including data sharing areas for further innovation. That causes endless development and to solve the problems of cities that are always require more intelligent system. Also, building cooperation is not just at the level of administration only. At the level of operations, it is also an important part, especially the people who must be able to reflect the problem and showing solutions to common problems, to create common ground, balance point and equality of joint development. Incidentally, creating cooperation in Thailand began to use the principles of design thinking to help by obvious case studies, such as the Republic of Korea that applied this principle by taking about the 20-year development. It is obviously seen from the case of the Republic of Korea of the development plan or Japan by creating communities as the base for smart city development.

Therefore, making these countries successful is depend on cooperation from all parties, therefore, the integration of the participation among sectors can help understanding the problem and ready to solve the problem together. Thailand will be able to upgrade closer to the development of smart cities.

V. CONCLUSION

As discussed earlier, national and city governments have a variety of policy instruments to promote smart city projects including inter alia output-based contracting, public–private partnerships, procurement policies, long-term contracting and targeted research funds. In addition, Governments may play a variety of roles in promoting smart city concepts. For instance, in their roles as regulators, they need to review their regulatory frameworks to ensure that such frameworks are conducive to smart city innovations. In their roles as investors, they need to determine which skills development programmed or infrastructure component they should invest in to drive innovation. City governments can effectively play their roles as consumers to support small-scale smart city innovations by giving them preference and access to public procurement contracts. Governments need to actively make use of such policy instruments and engage in these diverse roles to create and shape well-functioning markets for smart infrastructure that responds to local sustainable urban development needs.

Table 1 Comparison of Smart City Development, Thailand Context.

Country	Initiative	Goal	Strategic Plan	Established a board	Local government needs to be the pioneer	Establish laws to protect rights	Test-Bedding (Living Labs)
	Smart City Development						
Dublin, Republic of Ireland	2011	Smart City Ecosystem	“Open, Engaged, Connected”	Chief Executive of the Four Dublin Local Authorities	√	√	√
Amsterdam. Netherlands	2007	New Amsterdam Climate Program	Amsterdam Smart City program	Amsterdam Innovation Motor (AIM)	-	√	√
Dubai, United Arab Emirates	2007	Technological Trust	To bring about happiness to all (Communication, Integration, Cooperation)	Smart Dubai Higher Committee	-	√	√
Copenhagen Denmark	2014	Quality of life and growth in a green city	Smart at Several Levels	Copenhagen Cleantech Cluster	√	√	√
Vienna, Austria	2011	low carbon economy	Smart City Wien Framework Strategy	the Austrian Climate and Energy Fund	√	√	√
New York City, United States	2007	the Plan for a Strong and Just City	#One NYC	-	-	√	√
Stockholm, Sweden	2007	Smart & Connected	Green-IT Strategy	KIsta	√	√	√
Tokyo, Japan	2010	Smart Energy Worldwide (JASE-W)	Smart Community	The Japan Smart Community Alliance (JSCA))	√	√	√
Republic of Singapore	2014	City in A Garden	Smart Nation	Urban Redevelopment Authority: URA	-	√	√
Seoul, South Korea	2014	Digital Social Innovation	Seoul Digital Plan 2020	Seoul Digital Foundation	-	√	√
Thailand	2017	Stability, Prosperity and Sustainability	Thailand 4.0	The Ministry of Digital Economy and Society	-	√	-

Note: √ = available, - not available

This is due to primary data analysis from the lessons learned can be considered that Thailand needs to integrate each part of operations effectively. Although, Thailand is currently defining the role of the Smart City Development Committee at the national level and provincial level, including establishing laws for determine the strategy of development as well as the guideline for smart city development, however with the development of each sector still unable to integrate and create cooperation acceptance of each party. The huge obstacle is that the government needs to break through the large wall and host the smart city development initiative and attract the private sector by invite the education sector to be developed together under research and development scheme. Finally, it will make the city upgrade to a truly smart city development as shown in Table 1.

ACKNOWLEDGMENT

This research has been funded by National Science and Technology Development Agency under project "Pathumthani Smart City Roadmap ", JRA-CO-2562-8649-TH.

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Part-based Fusion Feature Learning for Person Re-Identification

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***Abstract*—Person re-identification is the task to recognize the same person in gallery images from different cameras. Many previous researches aim to improve feature representation to separate different persons but features are only focus on local parts and a body part. Therefore, in this paper, we propose the Part-based Fusion Network (PFN) that extracted two global features from two layers of the ResNet50, split one global feature to form part-based features, and utilized both local and global features and concatenated to be a final feature for discriminating the same person. In addition, we combine the visual feature with the spatial temporal information to gain the better result on the testing phase. The experiment result shows that our method gained essential improvement and outperformed other state-of-the-art algorithms on two public datasets which are Market-1501 and DukeMTMC-reID.**

***Index Terms*—Person Re-Identification, Image Classification, Metric Learning, and Deep Learning.**

I. Introduction

Person re-identification (re-ID) is a retrieval task for searching an interesting person from multiple images in galleries. The camera caused many variations to a person image such as brightness, background, and angles. By using many cameras, an occlusion and illumination have been occurred in different scenes. In the early approaches, the handcraft-features are built from the observation of images, the results failed to discriminate the same person with different view-poses. The more powerful methods adopt Deep Convolutional Neural Network(CNN) to extract features as a feature representation. With the transfer learning technique, the model is able to learn the low-level features from the whole body. Partial information around local regions is essential to distinguish persons. For example, a person who carries a bag on the back is different from the one without it.

In order to overcome this problem, some algorithms in [1]–[4] are proposed to extract semantic partitions and learn part-level features. Some methods leverage the external information such as human pose estimation to locate the semantic parts. However, occlusion and various poses are affected to local information. Opposed to the part-based learning methods, we argued that combining the global feature with the local features will ensemble discriminative information.

A network named Part-based Fusion Network (PFN) is introduced to learn granularity information which defines the whole image as the global information and uniformly partitioned stripes as the local part features. PFC takes the input image through the backbone network with some modifications. Local parts are horizontally split in the equal portion. By increasing the number of stripes, the features become more fine-grained. From the 4th stage of the ResNet-50 backbone, the global feature is concatenated to the last layer output to balance the impact between local and global features.

To achieve the better performance, we utilize the spatial-temporal operation to boost up the accuracy. The performance of the Market-1501 dataset is increased from 95.01% rank-1 accuracy and 87.41% mAP to 98.09% (+3.08%) rank-1 accuracy and 89.09% (+1.68%), which is superior compared to other state-of-the-art methods by a significant number.

II. Related Work

A. Visual features

In early years, handcrafted features had been developed to capture visual information. In [5], a whole image is divided into stripes to exploit color and texture patterns. [6] apply HSV histograms on parts to extract spatial information. Deep CNN methods bring the new standard for generic object classification such as ImageNet 1000 objects [7]. Several recent works employ deep learning methods to learn fine-grained information that represented a person. [2], [8], [9] learn the local parts such as head, torso, and legs using attention model. [1], [10], [11] use local cues to extract body parts from the image by extracting features and concatenating them. Multiple-level features are extracted at different layers and combined in [4], [12]–[14]. [15] use multiple-scale features from every layer of the networks. [16] use multiple feature from branches to learn fine-grained features for both global and local parts. [17] use GAN to obtain more data for training original data and generated data to improve the model robustness.

B. Attributes

The hybrid deep network are introduced by using multiple networks to extract individually features and integrate to metric learning methods in [18]. For instance, the network is trained to classify whether a person or not, female or male, and person classes. The network is trained separately not end-to-end learning and may not correlate the attributes and ID

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classes. The attribute is used as supervision for unsupervised learning such as [19] leverage the model trained from labeled source data and transfer the knowledge to unlabeled data by using a joint attribute across domains. In [20], the attribute is also used as the query to retrieve the same person. [21] use the visual feature concatenated with attribute feature to represent a person .

C. Spatial-temporal information

The spatial-temporal information is typically used to eliminate irrelevant candidates in [22]–[24]. For example, a person at the timestamp t would be appeared between $t - \Delta t$ and $t + \Delta t$. [22], [24] integrate spatial-temporal information into the visual feature representation.

D. Re-ranking

The Euclidean or cosine distances are computed to measure the similarity of people for object retrieval. The k-reciprocal nearest neighbors are the most relevant identities, and used to build a group for re-ranking others in the dataset. [25] calculate a new distance between two images by comparing their k-reciprocal nearest neighbors.

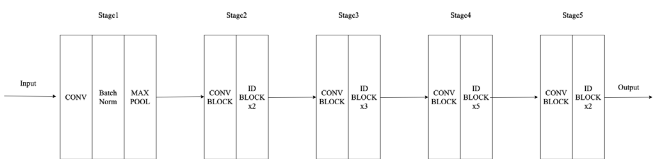

Fig. 1. The ResNet50 modification model.

III. Methodology

To obtain a robust feature, we chose the ResNet50 as the backbone network due to its performance. The ResNet50 is a network that trained on a million images from the ImageNet database. ResNet has 50 layers and 5 stages that have a different number of convolutional layers as shown Fig.1. The default image size is 224x244 for a single object, however, the human body is high in height. Therefore, we set the image size to be high in the height for smoothly semantic partitions.

A. The Architecture of PFC

The ResNet50 has been modified by removing the ReLU layer on the first stage to allow nonlinear features fed to the second stage. The structures after the fifth stage are also removed. The global average pooling layer is applied to the fourth stage and the fifth stage for extracting global features that represented overall parts. The output of the 5th stage is horizontally stripped into six parts by using a part-based average pooling layer as illustrated in Fig.2. Then, PFC employs a 1x1 convolution that followed with batch normalization and ReLu activation to reduce the feature dimension to 512-dim. Finally, each feature is fed to the batch normalization and a fully-connected layer.

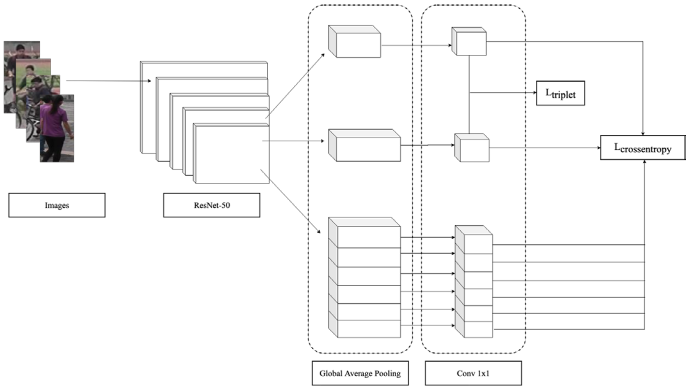

Fig. 2. Part-based Fusion Network architecture. The input image is input to the backbone network. The outputs of two layers are used to form global features. One of the outputs is split into six semantic partitions. A following 1 x 1 convolution reduces the feature dimension to lower computation complexity. Each classifier is deployed for each feature respectively. During training, global features are supervised by both Triplet loss and Cross-Entropy loss while local features are merely supervised by Cross-Entropy loss. During testing, all features are concatenated to form the final feature.

B. Loss Functions

To gain more discriminative features, we employ the cross-entropy loss proposed in [26] for classification and triplet loss for metric learning. The cross-entropy loss with label smoothing is formulated as:

$$-\frac{1}{P}\sum_{j=1}^{P}\sum_{i=1}^{N} q_{ij} log(p_{ij}), \quad \begin{Bmatrix} q_{ij} = 1 - \frac{N-1}{N}\epsilon, & y = i \\ q_{ij} = \epsilon/N, & y \neq i \end{Bmatrix} \tag{1}$$

where p_{ij} is prediction logit of class i in part j, y is the truth label, P is the number of feature parts, N is the number of classes, and q_{ij} is the mask to prevent the overfitting model. In this paper, ϵ is set to be 0.1.

While the model is trained to classify the same person based on the feature, features are used to find the closest distance or the most similarity. To ensure that the same class is close to each others, the triplet loss is employed to boost up the ranking performance. In [27], batch-hard triplet loss is an improved version of the triplet loss that covered on the hardest negative and positive pairs. For instance, the different person that has similar appearance is the hard negative cases and vice versa. This loss function is formulated as:

$$\sum_{i=1}^{P}\sum_{j=1}^{K}\left[m + \max_{p=1...K} D(f_j^i, f_p^i) - \min_{n=1...K} D(f_j^i, f_n^{i_n})\right]_+ \tag{2}$$

which is defined for a mini-batch with P selected identities and K images for each identity, f_j^i,f_p^i,$f_n^{i_n}$ are the features from anchor, positive, and negative samples respectively, and m is the margin hyperparameter to control the differences between in-class and between-class distances. ReLu function is applied at the end and defined as $max(0, x)$.

When training the model, global features are optimized by the triplet loss to avoid the misalignment due to disconnected information among local features. All features are supervised by the cross-entropy loss to enhance the feature ability.

IV. Experiment

A. Problem Definition

A pedestrian image cropped from a surveillance image is used to retrieve the same person from the images captured from different cameras. The traditional approach of person re-identification is to use a feature extracted from the image to calculate the similarity score among other features. The sorting order of the score will be used as the ranking result. To increase more accuracy, the additional data are needed to overcome the complexity.

B. Implementation

We set the image size to 384x192 for gaining more information on local parts. We adopt the pre-trained weight from the ResNet50 to initialize the network. On the training, input images are horizontally flipped, padded for cropping, and randomly erased for data augmentation. Each mini-batch is sampled with selected P identities and K images for each identity to be computed in the triplet loss. The recommend values is to set $P = 16$ and $K = 4$ to train the model. The margin parameter for the triplet loss is set to 0.3 in all experiments. We use Adam as the optimizer with the initial learning rate 0.00035, which is decreased by 0.1 at the 40th epoch and 70th epoch. The total training are 160 epochs. During testing, we extract the feature from a given image and the horizontally flipped image, then concatenate these as the final feature. Our model is implemented on PyTorch framework. All our experiments on different datasets follow the same settings.

C. Dataset and Protocol

a) Market-1501: The Market-1501 dataset in [28] are collected from six cameras in front of a supermarket which contains 32,668 labeled images of 1,501 identities. This dataset is divided into two parts: 12,936 images of 751 identities for training set and 3,368 query images and 19,732 gallery images of 750 identities for testing set.

b) DukeMTMC-reID: The DukeMTMC-reID is a subset of the DuckMTMC and used for image-based re-identification. This dataset contains 36,411 labeled images of 1,812 identities that collected from eight surveillance cameras. The DukeMTMC-reID also separated into training and testing set. The training set consists of 16,522 images of 702 identities, and 2,228 query images and 17,661 gallery images from the remaining 702 identities are the testing set.

c) Evaluation Protocol: The performance of our model is evaluated in term of Cumulative Matching Characteristic (CMC) curves which are the most popular evaluation metrics for person re-identification. We measure the ranking accuracy and mean Average Precision (mAP) on both datasets. The ranking accuracy is defined by ordering the smallest distance between the searching image and the gallery images. In addition, the rank-1 accuracy is the important factor to compare the performance of methods.

V. Result

We evaluate our method on two datasets and clearly observe the advantage of combining global and local features increased the discriminative feature. The performance of our model with the spatial temporal method gains significant improvement compared with the visual feature.

A. Evaluations on Market-1501

Market-1501 is a popular dataset for person re-identification approaches. We compare our model against several methods. When only the ResNet50 is used with the triplet loss, Triplet Loss [27] obtains 84.9% rank-1 accuracy and 68.1% mAP. Local features of 6 parts with a refine method in PCB+RPP [1] obtain 93.8% rank-1 accuracy and 77.4% mAP. BagofTricks [26] use only global feature of a model trained with tricks, and achieve 94.5% rank-1 accuracy and 85.9%. MGN [16] achieves 95.7% rank-1 accuracy and 86.9% mAP without a post-processing technique, however different scales are used to extract global and local features to concatenate as the final feature. With the spatial temporal scheme, our PFN obtains the rank-1 accuracy of 98.0% and mAP of 89.0%.

B. Evaluations on DukeMTMC-reID

DukeMTMC-reID is a challenge dataset and consists of 408 distractor identities in the testing set. We compare our method with [1], [9], [12], [14], [16], [17], [21], [24], [26], [28]–[33] state-of-the-art methods on the DukeMTMC-reID dataset. With the spatial temporal method, our PFN achieves the rank-1 accuracy of 94.2% and mAP of 83.9%. This dataset contains many distractors in the testing set and the result of combining global and local features seem to be inferior than local features.

Fig. 3. Visualization examples of our FPN for retrieving a query image across gallery images on the Martket-1501 dataset. The following images are ranked according to the similarity score. Red borders denote the wrong class.

VI. Discussion

Deep learning model is capable of extracting discriminative features but they are not represented meaningful features such as a gender, wearing a bag, and etc. To overcome appearance ambiguity, extra information is needed to cut off the candidates. By exploiting the given data of camera ID and timestamp, the probability distribution is formed to reorder the ranked results to the best possibility of the person from one camera to another.

TABLE I
COMPARISON OF THE PROPOSED METHOD ON MARKET-1501 WITH THE STATE-OF-ART METHODS. "RK" REFERS TO IMPLEMENTING RE-RANKING OPERATION. "ST" REFERS TO IMPLEMENTING SPATIAL-TEMPORAL METHOD. * DENOTES THE METHODS ARE REPRODUCED BY OURSELVES.

Methods	Rank-1	Rank-5	Rank-10	mAP
Bow+kissme [28]	44.4	63.9	72.2	20.8
KLFDA [34]	46.5	71.1	79.9	-
SVDNet [33]	82.3	92.3	95.2	62.1
PAN [29]	82.8	-	-	63.4
Triplet Loss [27]	84.9	94.2	-	69.1
HydraPlus [4]	76.9	91.3	94.5	-
PAR [11]	81.0	92.0	94.7	63.4
MultiLoss [35]	85.1	-	-	65.5
DuATM [9]	91.4	-	-	76.6
MultiScale [14]	88.9	-	-	73.1
GLAD [36]	89.9	-	-	73.9
HPM [13]	94.2	-	-	82.7
MFML [30]	92.5	-	-	89.3
APR [21]	87.0	95.1	96.4	66.8
PCB+RPP [1]	93.8	97.2	98.2	77.4
GAN [17]	83.9	-	-	66.0
Auto-ReID [3]	94.5	-	-	85.1
BagofTricks [26]	94.5	-	-	85.9
MLFN [12]	90.0	-	-	74.3
DeepCRF [31]	93.5	-	-	81.6
Mancs [32]	93.1	-	-	82.3
MGN [16]	95.7	-	-	86.9
OSNet [15]	94.8	-	-	84.9
Ours	95.0	98.1	98.8	87.4
PCB+ST* [24]	97.5	99.3	99.5	87.8
BagofTricks+RK [26]	95.4	-	-	**94.2**
MGN+RK [16]	96.6	-	-	**94.2**
Ours+ST	**98.0**	**99.3**	**99.7**	89.0

TABLE II
COMPARISON OF RESULTS ON DUKEMTMC-REID. * DENOTES AS THE RESULT REPRODUCED BY OURSELVES.

Methods	Rank-1	mAP
BoW+kissme [28]	25.1	12.2
GAN [17]	67.6	47.1
PAN [29]	71.6	51.5
APR [21]	73.9	55.5
MFML [30]	84.0	80.0
DeepCRF [31]	84.9	69.5
MLFN [12]	81.0	62.8
Mancs [32]	84.9	71.8
DuATM [9]	81.8	64.6
SVDNet [33]	76.7	56.8
MultiScale [14]	79.2	60.6
PCB+RPP [1]	83.3	69.2
BagofTricks [26]	86.4	76.4
MGN [16]	88.7	78.4
OSNet [15]	88.6	73.5
Ours	86.8	76.0
BagofTricks+RK [26]	90.3	**89.1**
PCB+ST* [24]	**94.4**	84.6
Ours+ST	94.2	83.9

Two datasets have the distractor class which is the unknown classes to lure the model. The ranking results are reviewed and apparently the distractor class is appeared to be in the testing class as shown in 3. This leads to the degrading performance of our model.

VII. CONCLUSION

In this paper, we have proposed PFN as a high-performance model combining local and global information to extract embedding representation of a person. Experiments show that our model outperforms other state-of-art algorithms. With external information, our method achieves rank-1 accuracy of 98.09% on Market-1501 and 94.25% on DukeMTMC-reID, improving from the baseline 95.01% and 86.80% respectively.

In the future work, we will use the augmentation methods to generate more robust data for classifying each augmented data. For example, the classifier can predict data for what rotation of the image taken [37] and what location of the original image [38]. Inspired from the self-supervised representation learning, the feature is fine-tune to perform better. Besides producing dataset with the label is expensive, this technique is practical in the real application.

ACKNOWLEDGMENT

This research is partially supported by DTAC under a collaborative research grant between SIIT and DTAC in Thailand, the Center of Excellence in Intelligent Informatics, Speech and Language Technology and Service Innovation (CILS) and by NRU grant at Sirindhorn International Institute of Technology (SIIT), Thammasat University Thailand.

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