Applying A Spatial Information Approach and Community-based Sourcing for Smart Container Allocation in the Post-Pandemic Era

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***Abstract*—The COVID-19 pandemic has globally changed ways of living. People have had to accept and adapt to a "new normal", with lockdowns, working from home, using masks, and ATK. As a result, plastic and infectious waste production have drastically increased, which requires prompt and proper ways of management. In this paper, we apply spatial Information Technology and a community-based sourcing method to establish a framework and a web application for visualizing the positions of all types of waste containers in Saensuk, a tourist town. The study aims to optimize the allocation coverage of infectious waste containers and pickup routes. The experiment shows that 19 current infection waste containers cover only 27.69% of all area. The recommended number is 15 infection waste containers in a specified area which represents 68.73% of coverage.**

Keywords — coverage area prediction, infection waste containers, shortest path, smart city, waste management,

I. Introduction

The epidemic situation of the coronavirus disease of 2019 (COVID-19) has rapidly changed the way that people live and work. It also has exacerbated economic and social challenges across the globe. Many areas have used the crisis as an opportunity to change social patterns. Efforts are being made, for instance, to manage the growth of the city in a more balanced way, in terms of housing that is convenient, safe, pollution-free, increasing the efficiency of the transportation system, as well as the development of a good public health system, and so on. Waste management is one important challenge and requires a new management approach because of the new normal and the concentration of population in the city has changed. There is also an increased amount of infectious waste, especially used masks, and Antigen test kits (ATK). Saensuk Sub-district, Chonburi is one example that shows the need to change waste management.

Smart Cities provide both opportunities and obstacles for addressing sustainability, resource conservation, economic growth, and technological advancement projects [1]. Saensuk Municipality has been announced as a Smart City in two areas: 1. Environment (Smart Environment) that addresses the influence on the environment and climate change circumstances by utilizing technology to assist in systematic management, and 2. The quality of life (Smart Living), which focuses on the creation of facilities that provide people with good health and a high quality of life in order for them to be safe and happy in life.

Policymakers and local officials are considering how to deliver new services to a large population in an efficient, responsive, and sustainable manner. In response to global problems, the Saensuk Municipality has undergone a digital transformation. Waste management has been highlighted as one of the most important challenges in transforming a city into a smart city.

Before the epidemic situation, the Saen Suk sub-district received as many as 1,200,000 tourists per year [2]. As a result, the tourist attractions, especially Bangsaen beaches, generated up to 100 tons of waste per day [3]. But in 2021, the number of tourists and the passive population has decreased. Now people are working from home. As a result, the amount and types of waste have changed. Solid waste in tourist destinations has decreased, while the waste for residences is increasing. And most importantly, the amount of infectious waste that is disposed of with general waste has also increased. Burapha University, which is a university in the area which has the opportunity to work with the Saensuk municipality continuously, recognizes the importance and urgency of the issue. Therefore, social innovations using information technology and artificial intelligence have been proposed to reduce manual management in order to deal with the growing amount of infectious waste promptly and comprehensively.

Together with the employment of the spatial information technology, we have proposed distribution guidelines for infectious waste containers to cover all areas, especially residential areas, as well as buildings and public spaces. This would support use by the population in the area, and also by future tourists, by using geographic information system (GIS) mapping and spatial analysis. In addition, efficient route management for garbage trucks is an essential component of our final proposal.

This paper presents the results of our first operation phase, which focuses on the distribution of infectious waste containers to all target areas by applying spatial information technology with the participation of the local population. The framework and web application for waste container management with the visualization of their allocation will be introduced. The remainder of this paper is structured as follows. Section 2 provides an overview of related research. The research methodology is introduced in section 3. The research results and discussion are presented in section 4, Limitations and suggestions for future work are provided in section 5.

II. RELATED WORK

In Kerman Municipality Geographic Information System (GIS) software was used to find optimal locations for establishing waste collection and sorting centers in the city [3], based on criteria such as population density, the road network, distance to health centers, distance to disposal centers, waste sorting culture, land space, and land cost, all of which were weighted by an analytical hierarchy process. Some research focused on waste container monitoring [5]. They experiment with waste management on Jeju Island by monitoring waste containers, ensuring timely collection, and using solid waste area production prioritization. They applied the history of solid waste generation and residential data for prediction. For the case of solid waste management in India, [6] presents methods for optimal waste collection and transportation utilizing GIS techniques through network analysis. The analysis shows that optimal waste collection and transportation routes reduce travel distance. Moreover, some research proposed methods to analyze the optimal location of waste container sites with a GIS technology application. Their method based on the classes of suitability for placing waste containers provides sufficient rationale for landscaping measures on a local level within a quarter or a distinct residential area [7]. In 2019, Nakhon Ratchasima Municipality, Thailand, adopted garbage truck routes using the global positioning system (GPS) to empty waste receptacles. This research studied, analyzed, and proposed a model for new garbage receptacle locations and allocations by marking appropriate and efficient spots to maximize an attendance function from the previous spots [8]. Previous studies attempted to design patterns for establishing waste collection by considering specific factors such as population, nearby roads, residential areas, universities, hospitals, and other parameters, while spatial coverage was ignored. A design methodology which failed to consider spatial coverage causes bin locations to have abnormally high density in some particular regions, especially in urban areas.

In addition, many kinds of research discuss developing applications to support waste management. In 2021 Sanjiban et., al. presented a smart waste management system [9]. The software consists of three main functions: a report, a garbage collector application, and an admin panel. A dashboard provides features for tracking vehicles, booking features, and feedback. The admin panel tracks of garbage collector vehicles, bins garbage collection levels, and shows feedback. The booking feature allows users to monitor the garbage level in the bins and accept the booking for the garbage collection from any location. These studies focus on monitoring waste containers and sending feedback to the waste collector vehicles to empty the waste containers, while the coverage area of waste containers and the optimal waste transportation route is ignored. In addition, in Malaysia (2018), they proposed My Intelligent Bin (MIB) which is an android mobile application to manage and monitor waste management with a real-time system [10]. The application combines all of the functions for picking up garbage, showing garbage status, checking the garbage collection schedule, launching a report, and checking the report status. On the other hand, in 2020 they demonstrated a holistic solution for recycling waste management in Smart City. The system focuses on collecting data using a web-based waste management application. The mobile application is used to motivate people to dispose of their waste properly, and produced a machine to categorize three types of waste automatically, namely glass bottles, plastic bottles, and metal cans [11].

Our study proposes a methodology to find proper locations for waste container installment in order to maximize the coverage area for infectious waste to provide better waste management in cities.

III. RESEARCH METHODOLOGY

After the research review in the previous section and a study of new technology and tools, Saensuk Municipality is beginning to transform data to support the policy of being a smart city. Waste management is considered to be a challenge. In response, we decided to create a framework for smart container allocation in the post-pandemic era for a tourist city to support the goals of the municipality and support reducing infectious waste and pollution sustainability.

A. Development Tools

- Django is a python library that supports rapid development and simple, practical design. It is appropriate for both frontend and backend development.
- JavaScript: JavaScript is a web-based programming language. It provides dynamic interactivity on websites. Both HTML and CSS can be updated and changed. Data can be calculated, manipulated, and validated using JavaScript.
- Leaflet is an open-source JavaScript library used to build web or mobile mapping applications. The library also supports many plugins which are based on map providers, search and popup controls, and layer switching controls. It aids JavaScript developers in the creation of web mapping and web-GIS features. MySQL is an Oracle-developed relational database management system (RDBMS) based on structured query language (SQL).
- The React Framework is a JavaScript library for building web pages or user interfaces. It can also be used to create complex web pages by dividing them into smaller sections. Each part works independently from the others and makes it possible to reuse parts of a web page.
- Overpass Turbo is an OpenStreetMap-compatible API. It is a read-only API that provides configurable portions for processing Open Street Map (OSM) map data. The Overpass API is designed to allow users to search with criteria including location, object type, tag characteristics, proximity, and combinations of these.

- OpenStreetMap is an open-source and free map of the world. OSM data can be used for a variety of purposes, including the creation of paper and electronic maps, the geocoding of addresses and place names, and route planning.
- QuickOSM is a QGIS plugin to download data from the Overpass server by writing or configuring a query with a key/value.

B. Study Area

Implementing new waste management for Saensuk Municipality must begin with a study of spatial information of the city. Saensuk City is located south of Mueang Chonburi district on the eastern seafront of the Gulf of Thailand. The total area is 20.268 square kilometers [12]. The city is a tourism and educational destination as well as a residential region. The majority of the residents own and operate their own businesses, trading products, and services. There are various businesses that assist locals to make money, such as fishing, farming, and providing tourist guides. Fig. 1 shows the commercial area in red and brown represents high-density residential. Although the large area presents low-density residential use, there is a tourist area on the weekend or holidays which fills with tourists.

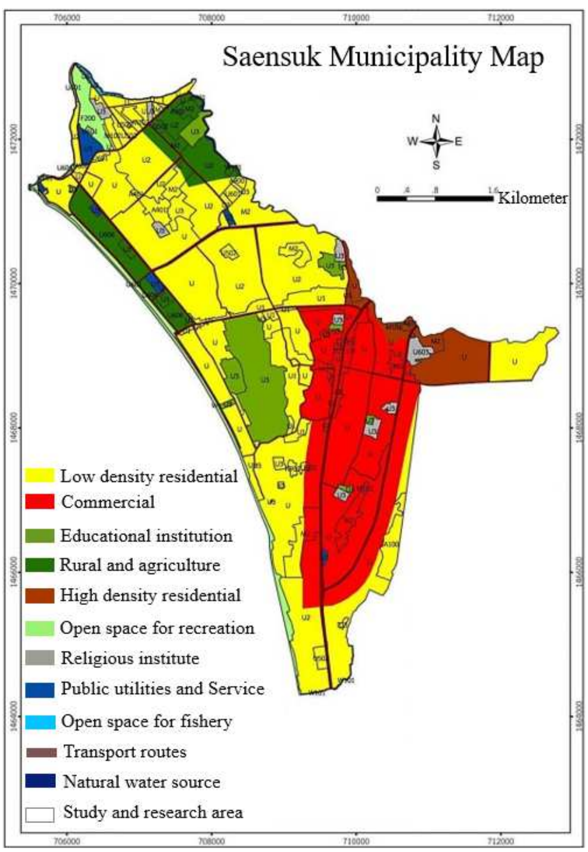

Fig. 1. Map of Land Use in Saensuk Municipality for a Saensuk [13]

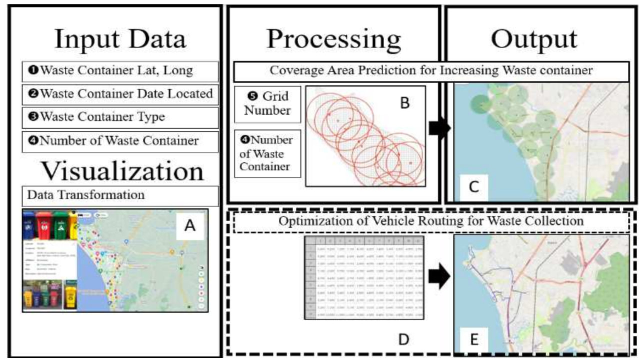

Fig. 2. A framework for smart container allocation in the post-pandemic era

C. A framework for Smart Containers Allocation in the Post-Pandemic Era for a Tourist city

In Fig. 2 the framework is divided into three sections: Input and Visualization, Processing, and Output. To collect data for the processing step, we produced a web application called "Waste Container Management and Tracking System in Saensuk City: WMTSS". The system provides information using visualization to support decision-makers. Processing consists of two main functions: 1) coverage area prediction for increasing coverage by waste containers, and 2) optimization of vehicle routes for waste collectors. The second feature is under construction. The output will show the result of the analysis. The design is described next.

D. Input Data

Data Visualization shows a feature of the system which allows a municipal officer to input latitude, longitude, location, an affiliation of a waste container, and type of a container (green for compossible waste, yellow for recycled waste, red for hazardous waste, and blue for general waste), date and time, location, and description.

E. Data Visualization

The purpose of visualization of the position of the waste containers is to support an overflow detection system in the future. We produced Waste Container Management and Tracking System in Saensuk City (WMTSS) to transform data for prediction and to produce accurate information. The flow of the system is shown in Fig. 3.

The system is used to manage waste container locations in the Saensuk subdistrict municipality. The policymakers can use the visualization to support making decision. All waste container positions over the municipality area are presented on the map. It also supports policymakers who need to find suitable positions for installing new infectious waste containers in the areas where people need to dispose of waste. In addition, it is the duty of the municipal officer to assign garbage truck drivers to collect from waste containers. Therefore, it is necessary to know the exact location of the waste containers. Currently, the developers are producing a new feature to find the shortest route for collecting infectious waste containers.

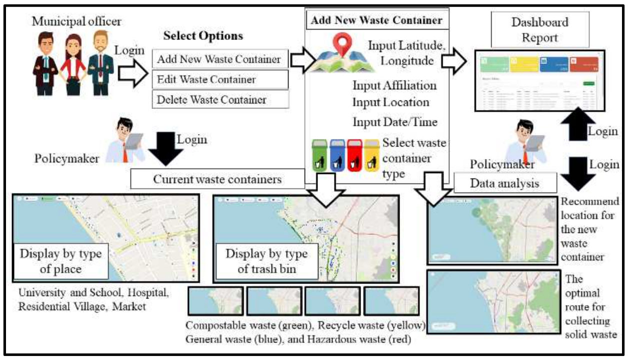

Fig. 3. WMTSS workflow

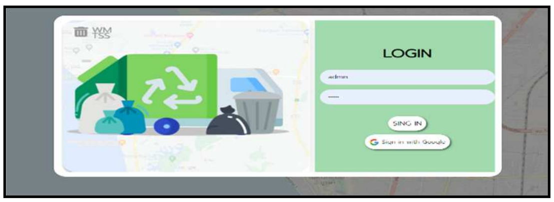

Fig. 4. Login Page

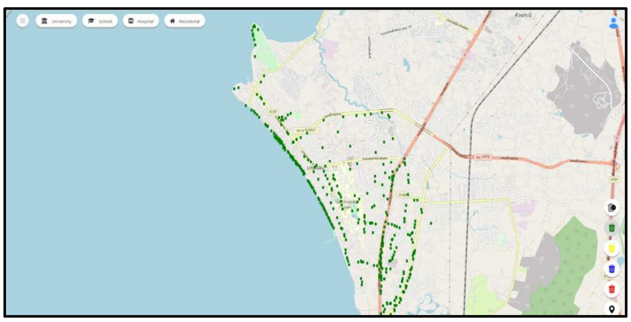

Fig. 5. Main page with Current Waste Containers

The system meets the five functional requirements: provide a map of municipality waste container locations, waste container management, recommend locations for new waste containers, find optimal routes for collecting solid waste, and reports.

1) Login Page: Employees in a municipality are required to authenticate through the system before accessing the initial screen. The system allows only authorized municipal officers or policymakers to login with a username and password to get into the system. The login page is shown in Fig. 4.

2) Main Page: Once the user login is successful, the system will present current waste container locations on the map. As mentioned before, the number of containers and the location of each municipality waste container will be shown depending on the date selection. During the weekend, during Thai holidays, or local festivals, the spots of waste containers shown on the map will have a higher density than normal as shown in Fig. 5. This shows the process of retrieving, analyzing, and filtering data from OSM. The application program interfaces (APIs) offered by the OSM called Overpass Turbo API are used for this.

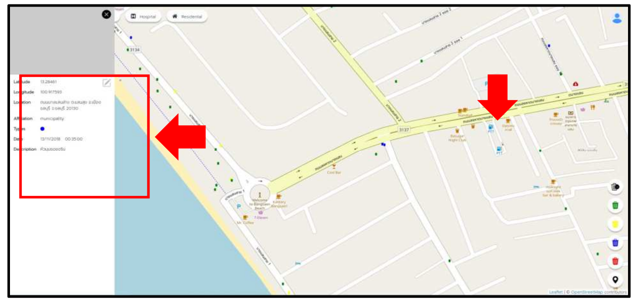

Fig. 6. Waste Container Details

Fig. 7. Specific nearby places

Fig. 8. Hazardous waste containers

3) Waste Container Details: Fig. 6 shows the details of a selected waste container. When the content of the waste container is filled then the information of the waste container will be updated in the application which will be visible to the user. If the user wants to see the location of the waste containers, he or she can click on the Map button. The information about the waste container, such as Latitude, Longitude, Location, Affiliation, Type of container, Date/time installment, and Description, will then be displayed.

4) Place Selection: The system, using the Overpass API, is designed to allow users to select and display specific nearby places such as Universities and Schools, Hospitals, Residential Villages, and Markets, as shown in Fig. 7.

5) Waste Container Type Selection: The system allows users to select a specific type of waste container. Choices are general waste (blue), compostable waste (green), recycled waste (yellow), and hazardous waste (red). It will display the current location of those selected as shown in Fig. 8.

6) Back Office Management: The system also allows an authorized municipal officer to add, edit, or delete a waste container as shown in Figs. 9 to 11. Date and time are detected automatically. Then user only inputs Latitude, Longitude, Location, Affiliation, Type of container, Date/time installment, and Description. The system allows adding five pictures for each item.

7) Report: The Menu Report supports users by displaying the summarized number of current waste containers categorized by type as shown in Fig. 12. A table is used to display the details of current waste containers and the system allows users to export information into an excel file.

Fig. 9. Add a new waste container

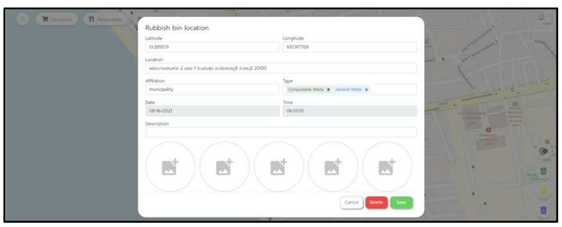

Fig. 10. Delete an existing waste container

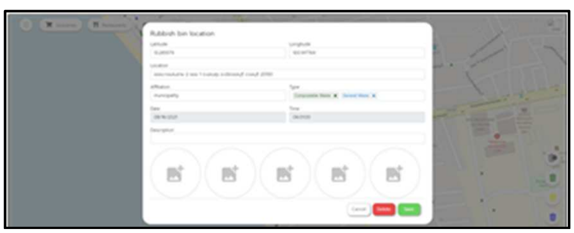

Fig. 11. Update waste container data

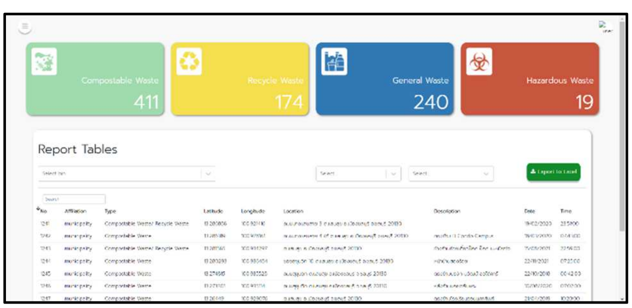

Fig. 12. Report

F. Coverage Area Prediction for Adding Waste Containers

We applied the Euclidean Distance and an Adjustable Surrounding Sphere (ED+ASS) method [13] to cover the area proportionally.

- **Processing:** To find the optimal location for new waste containers, the Saensuk Municipality map was divided into a 100x100 square meter grid. The total number of cells is 1,760. After the grid was produced, the next step was finding the coverage.

  We assume that the coverage of one waste container location is 10% and used the Euclidean Distance and an Adjustable Surrounding Sphere (ED+ASS) method to calculate the current coverage percentage of an existing one. For estimating the diameter range, we choose a station in the middle of the map. Then, using the Euclidean Distance equation [14], we calculated ED from all points on the map to the center. Our study area has 4 types of waste containers: Green, Yellow, Blue, and Red containers. The current number of each type and coverage percentage is shown in Table I.

  The result with the lowest ED value will be at the beginning of the selection lists. Finally, we calculate the cut-off position value. We modified the above-mentioned algorithm by adding criteria and weight for calculation [7]. The weight was predefined as shown in Table II.

  Output: The experiment shows that the recommend starting point for the waste collector truck is in the middle of the map in grid cell number 900. In addition, the recommend a number of new waste containers is 15. The display screen shown in Fig. 13 was created for municipal policymakers. When they click on the item “Analyze Location for New Container”, then the system displays the results of the suggested location with the new infectious waste container.

TABLE I. CURRENT COVERAGE INFORMATION

Topics	**Waste Container(s)**			
Color	Green	Yellow	Blue	Red
Type	Compost-able	Recycle	General	Hazardous
Number of existing	412 (44%)	259 (28%)	244 (26%)	19 (2%)
Coverage Percentage	92.28%	92.96%	92.11%	27.69%

TABLE II. WEIGHT AND CRITERIA FOR AREA COVERAGE

Criterion	**Type**	**Weight**
Primary Road	Road	0.7
Residential road	Road	0.3
Tertiary road	Road	0.1
University, Hospital, and School	Amenity	0.4
Marketplace, Restaurant, Cafe, Bar, and Pub	Amenity	0.3
Pharmacy, Clinic, Dentist, Post Office, and Bank)	Amenity	0.3

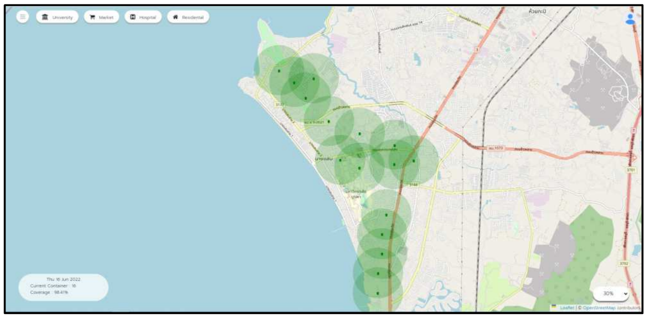

Fig. 13. The recommended coverage area for 15 waste containers

IV. RESULT AND DISCUSSION

In conclusion, this research presents a process to support Saensuk municipality in its management of waste in the post pandemic era. The research created a web application for the sustainable management of solid waste. The first step to achieve this is transforming data into digital form so the municipality can use the data for planning and operating their work. The process consists of input and visualization, processing, and output. We produced the Waste Container Management and Tracking System in Saensuk City (WMTSS). The system consists of five modules: a map of municipality waste container locations, waste container management, recommend locations for new waste containers, optimal routes for collecting solid waste, and the Dashboard. The system used collected data for the processing. Processing of coverage area prediction for installing infectious waste containers uses the Geographic Information System to collect locations of the waste containers. Then the Overpass Turbo API from OpenStreetMap is used to retrieve necessary streets and places. Coverage Area Data analysis recommends the coverage area for good waste container installation. Important criteria such as nearby main roads and community areas were considered. The experiment recommended 15 stations with 10% coverage yielding overall coverage of 68.73%, a huge improvement over the original 27.69%.

V. LIMITATIONS AND FUTURE WORK

According to a framework of smart waste management for a tourist city in Fig. 2, “optimization of vehicle routing for waste collection” is necessary. That was omitted and is necessary future work. In consideration of the reduction of pollution, we should analyze and find the fastest route for collecting waste containers. Furthermore, in the future, we will add more features to support Smart City monitoring better. For instance, we plan to adopt IoT and wireless network technology to monitor levels and also support notification when a container is full, so we can then recommend locations to install waste containers more accurately [15].

VI. AUTHOR CONTRIBUTION

Conceptualization A.O. and W.S., Methodology A.O. and W.S., Supervision A.O., W.S. and TH.C., Validation A.O., W.S and TH.C., Coding and Resource, T.C., Visualization, T.C. and W.S., Writing—Original Draft, W.S., Writing—Review & editing W.S., T.C. and A.O., All authors have read and agreed to the published version of the manuscript.

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