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Smart Route Management for Bin Truck

Abstract. *Solid waste collection is crucial to maintain the cleanliness and avoid pollution to the surrounding environment. In Malaysia, there are authorities that responsible in controlling waste collections, disposals, and recycles. However, current practice in waste collections and disposals are less systematic, time consuming and energy wasted. Therefore, this research reviews on the geographical information to optimize the route taken for solid waste collections and disposal specifically in Melaka. From the geographical information, few routes were selected for pilot study and was optimized to reduce the distance of the routes and the duration taken during waste collection. A navigation app is built in assisting the workers in navigation of the optimized routes. The route optimization leads to the yield increase of waste collection since the route planning can further help the related authorities maintain the cleanliness of the area.*

Streszczenie. *Zbiórka odpadów stałych ma kluczowe znaczenie dla utrzymania czystości i uniknięcia zanieczyszczenia otaczającego środowiska. W Malezji istnieją władze odpowiedzialne za kontrolowanie zbiórki, unieszkodliwiania i recyklingu odpadów. Jednak obecne praktyki w zakresie zbiórki i unieszkodliwiania odpadów są mniej systematyczne, czasochłonne i energochłonne. W związku z tym niniejsze badanie zawiera przegląd informacji geograficznych w celu optymalizacji trasy zbierania i usuwania odpadów stałych, szczególnie w Melace. Z informacji geograficznych wybrano kilka tras do badań pilotażowych i zoptymalizowano je w celu skrócenia odległości tras i czasu trwania zbiórki odpadów. Wbudowana aplikacja nawigacyjna pomaga pracownikom w nawigacji po zoptymalizowanych trasach. Optymalizacja trasy prowadzi do wzrostu wydajności zbiórki odpadów, ponieważ planowanie trasy może dodatkowo pomóc odpowiednim władzom w utrzymaniu czystości obszaru* (***Inteligentne zarządzanie trasą dla ciężarówki na śmieci***)

Keywords: Navigation Apps, Routes optimization, Solid waste collection.
Słowa kluczowe: Aplikacje nawigacyjne, Optymalizacja tras, Zbiórka odpadów stałych.

Introduction

An improvement to the solid waste collection management system is vital to boost the system collection to a better level. Failure to upgrade the waste collection method may lead to the serious pollutions and threats to health and security keep plaguing the surrounding area, especially residential areas, which pose serious concerns. The pollution is expected to increase to 66% by 2050 [1]. By the increment of the world's population may expediate the increase in waste production. Solid waste is, in fact, hard to manage as many factors must be considered. Due to these problems, various methods were developed. One of the methods that can be executed is the optimization of solid waste collection routes [2], [3], [4]. Geographic Information System (GIS) is a platform to collect information on the Earth's surface was introduced in [2], where labor requirements and collection routes have been determined to minimise time collection effectively. A single-layer network operation was conducted through spatial modelling to determine the optimum route for hauling waste to the landfill.

Authors in [3] provide efficient routing for trucks to collect large wasted items. An optimum shortest route was determined with the minimum cost taken into account. Besides, by optimizing the collection routes, the time spent on loading and unloading can be minimized. In [4], optimized routes to reduce the emissions from the truck exhaust during the solid waste collection process has been proposed. The travel time decreased by considerable percentages, and exhaust gas emission was reduced thus, operational cost was also reduced. Another study [5] calculates the vehicle routing in terms of fuel consumption and time travel for the solid waste collection were proposed to reduce the length of the routes and minimize the time taken. 16% fuel saving and 29% distance minimization were obtained. Furthermore, the authors have proposed an optimal model for improving municipal collection [6]. As a result, the solid waste collection route length and the travel time were reduced.

This study aims to minimize the distance and time of the current route, resulting in the availability of existing equipment and labour to perform the separate collection of recyclable waste in the city, which is the most important stage of waste management, particularly with regard to waste recycling in urban areas worldwide. Hence, a smart route management system via a navigation application for garbage truck drivers is proposed to determine the shortest route for waste collection. In addition, few other parameters such as the fuel consumption, collection duration and distance travelled for waste collection is analyzed. This paper is organized, as follows. Section 2 presents a methodology. Section 3 describes the optimization results with numerical analysis. The conclusion is discussed in Section 4, while future works are in Section 5.

Methodology

The methodology involved in this study is to create the navigation application using the Android Studio and Mapbox SDK. Then, a user friendly interface is built to ease the workers on the route selection for waste collection. The details are explained below.

A. Navigation Application Development

The Navigation application development for waste collection is shown in Fig.1. The Navigation application developed can be used for real-time navigation with the pre-determined route for solid waste collection. GPS signal can keep track of the location garbage truck for the user to navigate. Earlier route patterns can be stored in a database and used to identify an area that continually encounters a problem which should be avoided when designing and optimizing new routes.

The navigation application was built using Android Studio, the Mapbox SDK. An application is built so that the user can enter the desired location, then the smart route system will navigate to its location within the shortest path. No address input is needed to optimize the application, making it easier to use.

B. Mapbox SDK

Android studio is a free to use software capable of building applications for the android operational system (OS) using Java or Kotlin language. A normal application can be built using the android studio as it is but for a navigation application such as this project, a software development kit (SDK) needs to be downloaded to the android studio library. The rich features provided by the software are enticing and fulfill a developer's need to build an application with access to gradle build support, virtual device emulator, rich and easy layout editor and many others. Although it mostly contains Kotlin and Java, other programming languages can also be used in the Android Studio. Any Android Studio application can be published directly to the Google Play Store as it already complies with the developer content policy.

Mapbox SDK is quite similar to Google Maps SDK. The main difference is the lack of the vast majority of Google data. The SDK is flexible with many customizations, and visual styling can be done. It is suitable when building a custom map with navigation, thus making it a useful tool [7]. The language used in Android Studio is Kotlin and Java. Kotlin language is an open-source programming language compatible with Java[8]. Kotlin provides similar concepts from other languages. The development of the Kotlin language was because the developer could not find the features they were looking for in other languages except for Scala, but the compilation time deficiency was hard to bear. It was designed to be better than Scala and compiled as fast as Java, and the name Kotlin was derived from the Kotlin Island in St. Petersburg. Google also announced that Kotlin language is the preferred programming language for Android application developers.

On the other hand, Java is a general-purpose language that is simple and easy to use. Java is one of the commonly used languages in developing codes. Java programming can be used on any other computer, making it portable, as long as the computer has the necessary Java interpreter. Being a commonly used language, Java is an open-sourced programming language with many references and communities available for it.

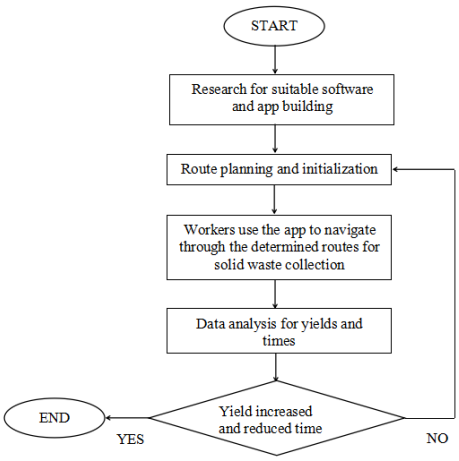

Fig.1. Navigation Application Development

C. Application Interface

The application interface is shown in Fig.2 where the application shows several locations of bin (which were already determined and confirmed with the related companies); for this study, 3 locations of bin were choosen as sample study which located at Taman Scientex, Durian Tunggal (Bin 1), Taman Nuri, Alor Gajah (Bin 2), and Taman Maim, Alor Gajah (Bin 3). Fig.3 shows the second interface for the navigation route to the selected location (will open when clicking the bin location in the first interface). The second interface act such as a map in “Google Maps” or “Waze” for the user to look at the map.

Fig.2. First interface

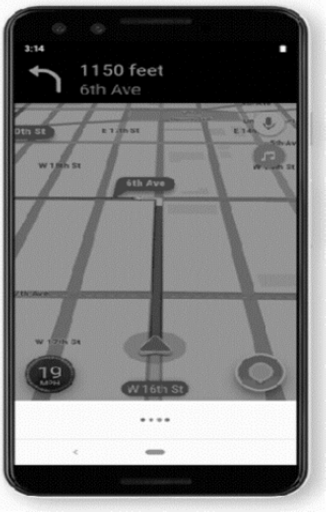

Fig.3. Second interface

Results and Analysis

From this study, the application display the location with the distance travelled. The application will perform calculations and formulas that relevant to the waste collection from those three respective locations as mentioned previously. The summary of the distance travelled and estimated amount of houses were shown in Table 1.

Table 1: Field test location information

Locations	Distance from SWM Environment Sdn Bhd	Estimated Amount of Houses	Estimated Duration Taken
Taman Maim, Alor Gajah	7.50 km	≈200	99.5 mins
Taman Nuri, Alor Gajah	14.57 km	≈600	91.5 mins
Taman Scientex, Durian Tunggal	16.77 km	≈1500	77.5 mins

Fig. 4.1(a) and 4.1(b) show that the collection route starts from SWM Environment Sdn Bhd, Alor Gajah to Taman Scientex and ends at the waste disposal site located in Sungai Udang. The route for all the testing areas can be acquired and analyzed within the shortest distance using the developed navigation apps.

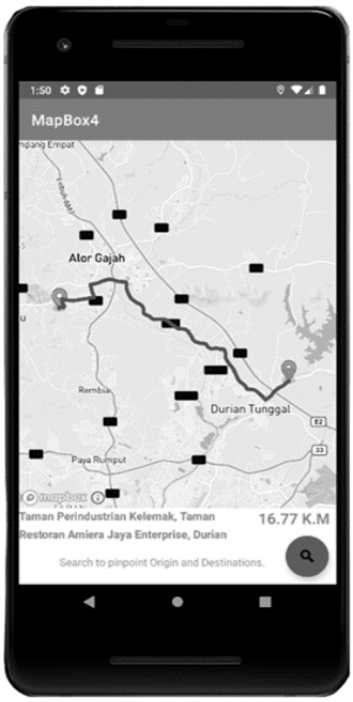

Fig.4.1(a). From SWM Environment Sdn Bhd to Taman Scientex

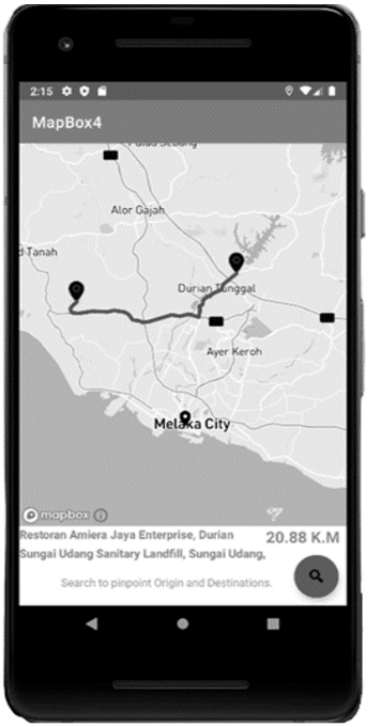

Fig.4.1(b). From Taman Scientex to Sungai Udang landfill

A. Fuel Consumption

ILP or the integer linear programming algorithm is an algorithm proposed by authors [2]. The working of this research seems complex with many constraint in the algorithm. From the ILP, several formulation parameters can be derived:

The calculation for fuel consumption per truck, f_c in liter/kg:

$$f_c = \frac{f_d - (f_{t,empty} + f_{t,full})}{W}, \quad (1)$$

where f_d is the total fuel consumption. $f_{t,empty}$ is the fuel consumption when the truck is empty given by the distance from the garage to the place of waste collection and the distance from the landfill. $f_{t,full}$ is the fuel consumption from the last collection route to the landfill. W (kg) is the amount of waste.

Calculation for cost, C in €/kg:

$$C = f_c * P_f, \quad (2)$$

where, P_f is the fuel cost per liter. Calculation for CO_2 emission, Eco_2:

$$Eco_2 = \frac{\sum L * EF_{fuel}}{F}, \quad (3)$$

where, *L* (km) is the distance covered by the truck. EF_{fuel} (kg CO_2/L) is the CO_2 emission factor. *F* (km/L) is the fuel consumption index. The calculation for fuel consumption index, *F* in km/L:

$$F = \frac{\sum L}{\sum f_c * \sum W}, \quad (4)$$

The calculation for average amount of waste collected, W_a in kg:

$$W_a = \frac{\sum W}{R}, \quad (5)$$

Where, *R* is the number of trucks involved in the collection.

B. Performance Analysis

The diesel price in 2022 had not changed since January, with the price being RM2.15 per litre as of May [10]. The collection duration and distance has impact the truck's fuel consumption as it is one of the main necessity to power up the truck bin along the waste collection process.. However, this can be negligible as the amount is not so significant as to affect the overall cost. Most collections will start in the afternoon, with the duration of each collection can last from 30 minutes to 45 minutes, depending on the housing traffic congestion and the size of the housing area. The average time for the waste collection will be used, thus, the waste collection time is 37.5 minutes for all locations.

Each collection route will start from SWM Environment Sdn Bhd in Alor Gajah and end at the waste disposal site located in Sungai Udang. The average driving speed of the truck can range between 50 to 80 km per hour. The whole duration will vary depending on the traffic congestion on the road, and almost negligible as high traffic can add up to 5 to 10 minutes to the whole collection duration. This will also affect the fuel consumption but will be negligible.

The total distance travelled can be calculated by taking the shortest route shown in each application and the sum for each test area starting from SWM Environment Sdn Bhd till Sungai Udang landfill. The comparison of the total distance travelled is presented in Fig.5. Using the developed navigation apps, the shortest route for waste collection can be attained by 18% compared to other applications.

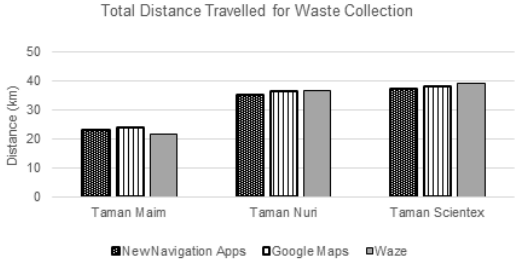

Fig.5. Total distance travelled for waste collection

For the total waste collection duration, the time can be taken from the application for Google Maps and Waze, but for the developed application, this was done after travelling

using the route taken by the garbage truck. Fig.6 presents the duration taken by the garbage truck throughout the collection session. Regarding the developed navigation app, the total time taken was reduced by 29% compared to Google Maps and Waze. This indicates that the new navigation app could reduce the time taken with an excellent performance rate compared to Google Maps and Waze.

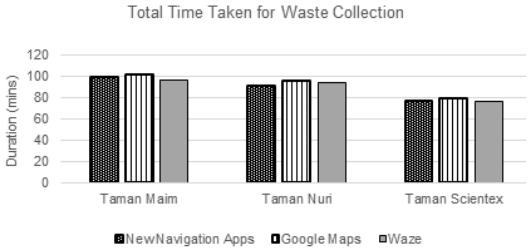

Fig.6. Total time taken for waste collection

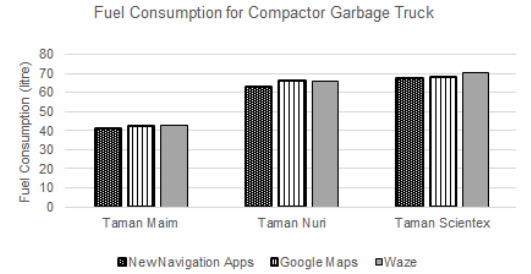

Fig.7. Fuel consumption for the compactor garbage truck

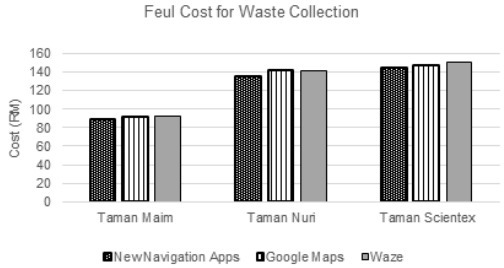

Fig.8. Fuel Cost for Waste Collection

Fig.7 display the fuel consumption of the compactor garbage truck. It can be observed by using the formula that 20% fuel saving can be acquired. From the graph, it can be seen that the new navigation apps yield better results in terms of fuel consumption. Moreover, Table 2 summarizes the comparison between the new navigation apps, Google Maps and Waze.

Fig.8 illustrates the fact that a developed navigation application saves more fuel compared with other applications. It shows that 12.5% cost saving while using the developed navigation application. Consequently, according to the results illustrated in Fig.7 and Fig.8, the fuel cost savings depend on fuel price fluctuations. Typically, the decreased in driven kilometres can result in a decrease in fuel consumption and cost.

Table 2: Comparison of performance indicators between the applications

Performance Indicators	New Navigation Apps	Google Maps	Waze
Total Distance Travelled	● Taman Maim - 23.22 km ● Taman Nuri - 35.21 km ● Taman Scientex - 37.65 km	● Taman Maim - 23.90 km ● Taman Nuri - 36.80 km ● Taman Scientex - 38.20 km	● Taman Maim - 21.60 km ● Taman Nuri - 36.70 km ● Taman Scientex - 39.00 km
Total Waste Collection Duration	● Taman Maim - 99.5 mins ● Taman Nuri - 91.5 mins ● Taman Scientex - 77.5 mins	● Taman Maim - 102.5 mins ● Taman Nuri - 96.5 mins ● Taman Scientex - 79.5 mins	● Taman Maim - 96.5 mins ● Taman Nuri - 94.5 mins ● Taman Scientex - 76.5 mins
Fuel Consumption (Compactor Garbage Truck)	● Taman Maim ≈ 41.796 litre ● Taman Nuri ≈ 63.378 litre ● Taman Scientex ≈ 67.77 litre	● Taman Maim ≈ 43.02 litre ● Taman Nuri ≈ 66.24 litre ● Taman Scientex ≈ 68.76 litre	● Taman Maim ≈ 43.0 litre ● Taman Nuri ≈ 66.06 litre ● Taman Scientex ≈ 70.20 litre

Conclusion

In conclusion, the development of smart route management application for bin truck has been successfully built using Mapbox SDK software. The length of the routes taken in waste collection can be reduced. Eventually, the time taken for waste collection has been minimized that occasionally reduce the fuel consumption as well.

Future Works

One of the proposed suggestions is to provide turn-by-turn navigation in the app providing a more immersive and useful feature. The application can be used to navigate but turn-by-turn navigation helps the user to be able to understand the road more easily with the real-life GPS locator. Further bug debugging need to be enhanced to make sure the first location of the map in the developed application appear at the desired location.

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