DETERMINING RELIABLE SECTION-WISE BUS TRAVEL TIMES USING GPS DATA: A CASE STUDY OF KANDY CITY

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ABSTRACT- Reforming bus operations in Kandy City is a part of the ongoing Strategic City Development Project. This study carries out under the GPS data analysis of the Kandy Bus Reforms Project (KBRP). The GPS data consists of device id number, device time, GPS coordinates, and bus speed at that moment. Capturing bus trips of selected bus routes, obtaining arrival times, dwell times, and departure times from waypoints, performing a summary of monthly bus trips, and providing reliable bus travel times to the passengers in different periods are the main objectives of this study. The data cleaning, reading, and analysis are executed using Python programming language with several data manipulating libraries. The initial study has done for Kandy – Amunugama route with the GPS data collected for 2 months.

Keywords: GPS Data; Bus Travel Time; Travel Time Prediction; Intelligent Transportation System

1. INTRODUCTION

Enhancing the standards of public transportation can increase the modal shift from private vehicles to public transportation. The proposed methodology tries to contribute to that by creating the required base to predict reliable bus arrival times to each waypoint of the route. The usage of GPS data to determine bus travel times can overcome the limitations of traditional methods of travel time estimations with many more advantages [1]. Since the GPS data does not give information regarding the bus stations, it is required to capture arrival times and departure times at bus stations [2]. The proposed methodology does that according to the proposed section time calculation function. The travel time estimation can also be done by combining the multiple regression model with the Kalman filter [3]. Furthermore, the fast-growing Machine Learning techniques can be used to detect bus routes, detect bus stations, and estimate travel times by developing Artificial Intelligence based algorithms [4]. Outputs of these kinds of traffic data analysis can be combined with data visualization techniques to obtain possible trip patterns and trends further [5]. It is worthy to mention that although the required basic analysis to utilize GPS data in obtaining bus travel statistics have been done in Sri Lankan context, in depth studies have not been conducted yet [1].

2. MATERIALS AND METHODS

2.1. Dataset & Required other Input Data Files

The GPS dataset of the Kandy – Amunugama bus route with around 2.5 million records is used as raw data to identify the bus travel times under this research. The dataset includes GPS data of January and February in 2022. The initial data cleaning process consists of 2 steps: (1) remove all the data that does not belong to the selected time frame, (2) remove data rows where either latitude or longitude equals to zero. In addition to the raw data set, several input data files are required to capture the bus trips using the GPS data. This mainly includes the route unique identifier data regarding the bus unique identification that comes with GPS data to assign the buses with the required routes. Furthermore, since this study attempts to identify the travel time between the sections, data are required regarding the positions of section breaking points (waypoints).

2.2. Trip Capturing Programming Functions

The trip capturing process from the raw GPS data is a combination of 4 designed programming functions.

Trip capturing function – This first function identifies trip start and trip end times of all possible trips. The positional data of these should be within a 150m buffer zone from the bus terminals. In addition, the bus speed should be equal to zero in all these data points. **Reliable trips function** – This function filters reliable bus trips based on two criteria. The travel time of a particular bus trip should be less than the allocated maximum travel time for a bus trip and the trip GPS count should be within the pre-defined range of minimum and maximum GPS counts. These values can be defined based on the distance of the selected bus route and the frequency of GPS data. **Actual trips function** – The obtained reliable bus trips will be attached to new data frames based on the trip direction. In these data frames, a single row includes trip data such as GPS device id, trip start and end time, GPS coordinates of the data point, trip travel time, and the GPS data count of that bus trip. **Section time calculation function** – This function identifies the arrival times and departure times at each waypoint of the route using a 50-meter buffer zone. By using these arrival and departure time pairs, the dwell time at each waypoint can be calculated.

2.3. Bus Travel Time Analysis

The selected Kandy – Amunugama bus route has 4 waypoints which divide the route into 5 route legs. The section-wise travel times of each bus trip can be calculated using the trip start times, arrival and departure times of waypoints, and the trip end times. The average route travel times and average section-wise travel times can be calculated using all the captured bus trips. Furthermore, the analysis has extended to obtain total and section-wise travel times for each 1 hour from 6 am to 6 pm. Besides, variance, std. deviation, 80th, 85th, 90th, and 95th percentile values have been calculated to identify predicted time points which can be offered to the bus passengers. Moreover, the travel time analysis has been done for all the buses in Kandy – Amunugama route separately to identify the variations in travel times of each bus. The programming script writing has been done using Numpy, Pandas, and Streamlit python libraries. The data validation has been done with time-keeper's app and with Electronic Ticketing Machine (ETM) data.

3. RESULTS AND DISCUSSION

The Table 1 shows the results of travel time analysis including averages for total travel time and section-wise travel times for Kandy-Amunugama direction. Similarly, the results can be generated for Amunugama - Kandy direction as well. When considering all the bus trips together, the average travel time from Kandy to Amunugama direction is 35.3 minutes. However, it has been reduced to 32 minutes during the 5 pm-6 pm period. Moreover, the 1 pm-2 pm period has the highest average travel time according to the analysis results. The first 2 route legs have the highest variations in average travel times for direction 1 and only the 1st route leg's average travel time varies considerably for direction 2. The "Day of the week" analysis has been performed to identify the travel time variations in weekdays and weekends. According to the results, the average travel times are slightly lesser in weekends.

Table 1. Section-wise travel time analysis for Kandy-Amunugama direction

Period	Entire Route	Section 1	Section 2	Section 3	Section 4	Section 5
Entire Day	35.3	8.5	8.8	3.5	6.4	7.8
6am-7am	37.0	9.1	9.8	3.4	6.5	7.8
7am-8am	35.5	8.4	9.4	3.3	6.2	7.9
8am-9am	35.0	8.6	9.1	3.5	6.1	7.4
9am-10am	36.0	9.0	9.4	3.3	6.4	7.8
10am-11am	37.0	9.0	9.9	3.5	6.4	7.8
11am-12pm	36.3	8.6	9.5	3.4	6.5	7.8
12pm-1pm	36.0	9.0	9.4	3.3	6.4	7.8
1pm-2pm	37.2	9.3	9.3	3.5	6.6	7.7
2pm-3pm	34.9	8.5	8.2	3.5	6.4	8.0

3pm-4pm	34.8	8.6	8.1	3.4	6.3	7.7
4pm-5pm	35.1	8.2	8.2	3.4	6.9	7.8
5pm-6pm	32.0	6.4	7.1	3.5	6.9	7.7

4. CONCLUSION

The developed python script can be used with any other route to obtain section-wise travel time data. A mobile application has been developed for bus passengers under the KBRP. The results of this study can be provided to bus passengers through that application with the predicted bus arrival and departure times at route start point, route end point and at waypoints. Moreover, these results can be used to monitor the travel patterns of buses which will help for planning and decision-making processes to enhance passenger experience. The corridor analysis and bus bunching are in focus as future research areas.

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