

The City College
of New York

**Computational Investigation of the Connectivity,
Resilience and Demand of the Bus Network in Ho
Chi Minh City (HCMC), Vietnam**

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Introduction & Related work

Bus is the only public transport option in Ho Chi Minh City (HCMC). Bus accounts for only 9.6% of all trips with widely reported issues on on-vehicle experience, redundant and ineffective routes, and delays and poor punctuality of bus services. The immediate objective of this project is to provide a comprehensive evaluation and measurements of the bus services performance, improving the connectivity, reliability, and resilience of the bus network to changes in operational environment, and understanding and quantification of mobility patterns across the city.

We aim to achieve this by leveraging the wealth of existing GPS data of daily bus movements and call detail records (CDRs) data from mobile phones. While these data have already been collected by the city, they are not widely available to the research community. This is mainly because the data is sensitive and needs to be safeguarded at all stages of the data lifecycle ranging from data acquisition to running analyses. The problem is exacerbated by the large volume of data and the computation needed to perform the analysis. The project will also contribute in algorithms for reconstructing bus timetable from GPS data, analytical models for evaluating spatial and temporal dimensions of the bus network connectivity and accessibility, a discrete event simulation model for improving the network resilience to disruptions.

We will develop a graph-based model to analyze and evaluate geographical coverage, accessibility and connectivity of the bus network in HCMC based on historical GPS data of the bus operation. The use of historical GPS data is critical as it allows to capture and examine the temporal variability of geographical coverage and connectivity of the bus network. Such variability may be by design, i.e. less frequent bus services in a certain time period, or from operational issues, i.e. bus services failing to follow the timetable. The metrics and indicators will be visualized on a web-based map effectively monitoring and reporting the network performance on an ongoing basis to bus operators, government agencies and the people as more data becomes available.

Real-time GPS tracking data of all bus services across HCMC will be acquired from the city for the duration of the project. Historical data of bus ridership will also be acquired for previous years for better model constructions, and for validating our experimental results. This

data should include timestamped information of the number of passengers boarding and alighting at each stop by each bus service. Considering the reportedly large number of bus routes (144 routes as in 2018) and an even much larger number of vehicles registered for public transport service provision (2,568 vehicles as in 2017), the acquired historical GPS data will be large.

Transit timetable is a critical input to the analysis of a public transport network and was available to many recent studies on transport network analysis in the standardized format of GTFS. To the best of our knowledge such GTFS timetable was not available for bus services in HCMC at the time of this project proposal. Importantly, because one of the project's key objectives is capturing the temporal variability of the bus network coverage, we propose that the timetable of the bus services to be reconstructed from the historical timestamped GPS data of each of the buses.

The exercise of reconstructing the route of a vehicle from its GPS signals is commonly referred to as map matching in the literature and has attracted numerous studies [1, 2]. While route reconstruction normally comprises the identification of road links from historical GPS records of the vehicles, the reconstruction of a bus timetable to be undertaken in this project requires only the identification of stops from GPS records of the bus movements. A detail algorithm for stop identification from vehicular GPS signals was reported in [3, 4, 5] and will be adapted in this project. Different to the original algorithm in which stops were not known, the adapted algorithm will be informed by location of existing bus stops across the city. It is worth noting that the accuracy of stop identification and the quality of the reconstructed timetable depends on the ping rate, which is the time between two consecutive GPS records for a vehicle. Higher ping rate means shorter time between consecutive GPS records and presumably results in more accurate reconstructed timetable. The adapted algorithm for stop identification will be further revised to accommodate the quality of GPS bus movement data available to the project.

In order to capture the day-to-day operational variability of the bus network, whole-day timetable will be reconstructed for each day in the period that GPS data is available for. It is possible that not all physical bus stops will be present in the reconstructed timetable for a given day. Stops are excluded either because they are not serviced by any bus on the day or because they are not captured in the GPS data as a result of the GPS data quality.

There are a number of ways the topology of a public transport network can be represented, namely L-space, P-space, B-space and C-space [6]. In this project, we propose to construct the graph presentation of the bus network in a variation of L-space, called L'-space. In such a presentation, graph nodes are consecutive bus stops present in the reconstructed timetable and a graph link between two nodes represents a single bus service connecting them. Multiple links may exist between a pair of nodes. In order to effectively assess intra-day operational variability of the network (e.g. evaluating travel time between parts of the network at different times of day) attributes of a link will include departure time and trip duration between the two consecutive bus stops.

Once the graph representation of the timetable is ready, the accessibility of the bus network will be evaluated from both spatial and temporal perspectives. Thanks to bus timetable being reconstructed from GPS data for each day, the day-to-day variability of these accessibility measures will also be examined to evaluate the consistency of the network performance. It is worth noting that graph computation can be quite computationally expensive for transportation applications in which networks can be fairly large.

A well-established timetables example is provided by Metropolitan Transportation Authority (MTA) of the State of New York. At any time we can check for any stop what the time for coming buses are. What helped them to construct such great timetables is that Their GPS data contain information about location as latitude and longitude of the buses during trips, stops location, and times for next stop. Thus, it is easy to loop over the data to extract the time for each stop and build the timetables [7]. However, Our GPS data is harder since it does not have any information about next stop. It captures only distance for last stop and time at which data is reported. Thus, if buses move from the first stop every 15 minutes, passengers at other stops do not know what times buses will reach them.

Our analysis is computationally expensive since it a big data. Can we image how long it takes to run the analysis for a route which has many trips in a day, then multiply that to a year + 100s of routes. We will need to use big data frameworks. We will use Hadoop computing environment by running Hadoop Streaming jobs on the clusters at NYU-HPC/CUSP. We got access to NYU CUSP cluster. In general, both CUSP and HPC clusters are protected by a firewall, thus, no direct SSH access are allowed. In order to access the Hadoop clusters, we must first login

to a gateway or a bastion host, i.e. gw.cusp.nyu.edu. From this gateway, we can then access the Hadoop client machine, cluster.cusp.nyu.edu. This machine is equipped with a Hadoop environment for us to develop and run Hadoop jobs. Modern Hadoop distributions come a Web User Interface, HUE (Hadoop User Experience) for monitoring and managing resources. We should be able to see all of our jobs being run. Sometimes when our job fails to run, we need to inspect the error messages to correct the issue. Since NYU CUSP runs in cluster mode, all of the error messages (which are produced on the driver side) cannot be seen on the console. We need to look into the log files.

Design

Besides the historic GPS data, we have another dataset for route data. The historic GPS data captures records about the bus during its trips as shown in figure 1. It has route id to show which route the moves as it is not a must that the bus is on the same route every day, trip id to show the direction of the bus since the route can have more than one trip and for each trip we have different stops. Data also has bus or plate id, and time at which record was reported to the system. Last column is distance only to last stop, so at any time what we can know from the data is information about last stop. The data has millions of records for all days.

route_id	trip_id	plate	time_reported	distance_to_last_stop
3	5	51B30879	2020-06-29T03:59:43+07:00	16485.57
3	5	51B30511	2020-06-29T03:59:47+07:00	16725.46
3	5	51B30037	2020-06-29T03:59:40+07:00	16742.04
3	5	51B30879	2020-06-29T04:00:03+07:00	16485.56
3	5	51B30511	2020-06-29T04:00:07+07:00	16725.46

Figure 1: Historic GPS Data

As mentioned above in the previous work they did not know information about the stops which is different in our case. We could have information about the routes' stops. The route dataset

captures the stops' ids and their distances to last stop for each trip in each route. Tables 1 and 2 show examples of the data for 2 different trips. The dataset is JSON file format so each combination of the route and trip ids is represented by dictionary to access them quickly. For constructing the timetables we will use the stops data and GPS data to find for each stop the time at which bus reach the stop.

Table 1

Route id	Trip id	Stops	
4	7	ID	Distance to last stop
		35	16573.959
		7276	16357.972
		7277	16017.692
		7278	15779.699
		7266	15088.096
		.	.
		.	.
		.	.
		166	0

Table 2

Route id	Trip id	Stops	
5	2	ID	Distance to last stop
		8	35332.075
		2393	34446.440
		2	34207.944
		3	33642.885
		5	33507.214
		.	.
		.	.
		.	.
		7208	0

Since we have big data which we can only run the analysis on it on the Hadoop cluster environment, we took samples from both datasets for only a one route to start building our spark program on our local machine. It is also useful for investigating the data easily and tracking errors. First, we setup the environment, wrote a python code to access the environment and datasets, got samples and downloaded.

We started our analysis by creating Resilient Distributed Datasets (RDD) from the historic GPS records. RDD is the fundamental data structure of Spark to run and operate on multiple nodes to do parallel processing on a cluster. After preparing the records we did data cleaning to remove the bad records which miss some information. Then ordering the records by time for each bus to check if the distances are going down during the trip. We found unexpected issues in the data such that during some trips distance of the bus is getting down, then up and going back down which definitely refer to bad measurements. Thus we did more cleaning to filter these bad records. Finally we have right records which show decreasing in distances during the trips. Table 3 shows the format of the data after cleaning and ordering. As time is increasing, distances are decreasing.

Table 3

Bus	Time	Distance to last stop
51B30037	2020-06-29T03:59:40+07:00	16742.04
51B30037	2020-06-29T04:00:00+07:00	16740.44
51B30037	2020-06-29T04:00:40+07:00	16738.66

We ordered the data also to create intervals for time and distance. Each two consecutive records form one time interval and one distance interval. Table 4 shows how will be the results for table 3. Another issue we found is that for a bus can have two consecutive time intervals for the same stop, for example, one interval is from 8:01 to 8:02 and the second one is 8:02 to 8:03. It does not make sense that a bus passes by a stop in two consecutive times. It is possible that the bus got stuck for few minutes and records were not accurate. We decided to combine them in one, thus we will be sure that the bus definitely passes by the stop in this interval.

Table 4

Bus	Time interval	Distance interval
51B30037	(2020-06-29T03:59:40+07:00, 2020-06-29T04:00:00+07:00)	(16742.04, 16740.44)
51B30037	(2020-06-29T04:00:00+07:00, 2020-06-29T04:00:40+07:00)	(16740.44, 16738.66)

Here comes the role of stops data. We will use the stop distance to search in the distances intervals we created from GPS data and find the interval which stop belongs to. We will use bisection searching algorithm due to its computation efficiency. Bisection algorithm is working by giving it sorted list and a number which we need to know where it should be in the list. For example, if we have a list of 1,3,6,8 and the number we need to know its location is 7, thus the algorithm will give us location 4 between 6 and 8. How we will use it in our analysis by giving it sorted list of stops distances and one of the distance interval limits. Then giving it the second limit. If the location results are the same, that means no stop distance between them, but if they are different meaning that there is a stop in this interval. Continuing on our example above, if we give it 7 and 7.5, the results will be same, but if we give it 7 and 9, the results will be different since 8 exist between them. Using the algorithm on all distance intervals will give us for each stop its distance and time intervals in which a bus passes by this stop. Table 5 shows how the results will be.

Table 5

Stop	Bus	Time interval	Distance interval	Stop distance
7277	51B30037	(2020-06-29T04:28:40+07:00, 2020-06-29T04:29:00+07:00)	(16658.41, 16652.03)	16654
7278	51B30037	(2020-06-29T04:57:20+07:00, 2020-06-29T04:57:40+07:00)	(16452.98, 16373.52)	16429

Now we can use the stop distance to estimate the time when buses pass by the stop by doing linear interpolation. Simply linear interpolation is a method of constructing new data points within the range of a discrete set of known data points by drawing straight line between points and solving slope equation. Let us say that we have two known points x_1, y_1 and x_2, y_2 which represent our two intervals limits. x represents the distance and y represents the time. Now we want to estimate the time when we have some distance value. Since I have the time in a date time format, I could not use them directly in doing the interpolation as I need discrete numbers to solve the equations. Thus, how I decided to do it is by normalization idea. First, converting time interval to discrete interval by taking the difference between times in seconds so the interval will be from 0 to the difference in seconds. For example: I have a time interval from 8:15:20 to 8:16:20 so the interval will be from 0 to 60 seconds. Therefore, doing interpolation gives us a value which represents the difference between the time of bus passes by the stop and the time before the stop (the left side on the time interval). Then, since I need the time when a bus passes by the stop, I can add the interpolated value to the time before the stop. Continuing on our example, if the interpolated value is 30, the time when a bus passes by the stop is 8:15:50. Table 6 shows the result for table 5.

Table 6

Stop	Bus	Time
7277	51B30037	2020-06-29 04:28:46
7278	51B30037	2020-06-29 04:57:33

After estimating the time for all stops. We built timetables for trips in the sample data we had. Figure 2 shows part of the timetable for 3 trips. The first column on left represents the stops ids. We also visualized the timetable as shown in figure 3. We decided to use Marey's schedule chart for plotting. Each line represent a trip. The x-axis represents the time and y-axis represents distance, but setting y-ticks to stops distances. Thus, points on y-axis are stops and the distance between two points represents how far the stops from each other. Therefore, the slope of the line plot will represent the velocity of the bus.

	Trip 1	Trip 2	Trip 3
7277	04:28:46.175549	07:46:05.921412	10:36:03.436721
7278	04:57:33.964259	07:48:43.286401	10:36:53.570182
7265	04:57:44.488075	07:50:02.187852	10:37:39.703704
1256	04:59:11.176143	07:50:13.747048	10:38:10.328972
32	04:59:58.293610	07:53:12.425694	10:41:23.154406
34	05:02:42.712747	07:54:36.194143	10:42:01.943439
42	05:04:02.898438	07:54:46.994824	10:43:50.040192
44	05:04:43.201517	07:55:46.976027	10:44:26.942236
39	05:05:09.361115	08:00:36.592420	10:47:43.561624
41	05:07:02.729293	08:03:25.094855	10:50:08.346310
43	05:07:40.147374	08:04:36.837247	10:51:27.084639
46	05:08:49.904092	08:07:33.523329	10:52:55.479248
47	05:10:42.978594	08:08:29.339777	10:55:12.065608
45	05:13:07.827527	08:09:10.934264	10:56:12.809268
49	05:13:49.222811	08:10:18.472479	10:57:50.319293

Figure 2: Part of timetable for 3 trips

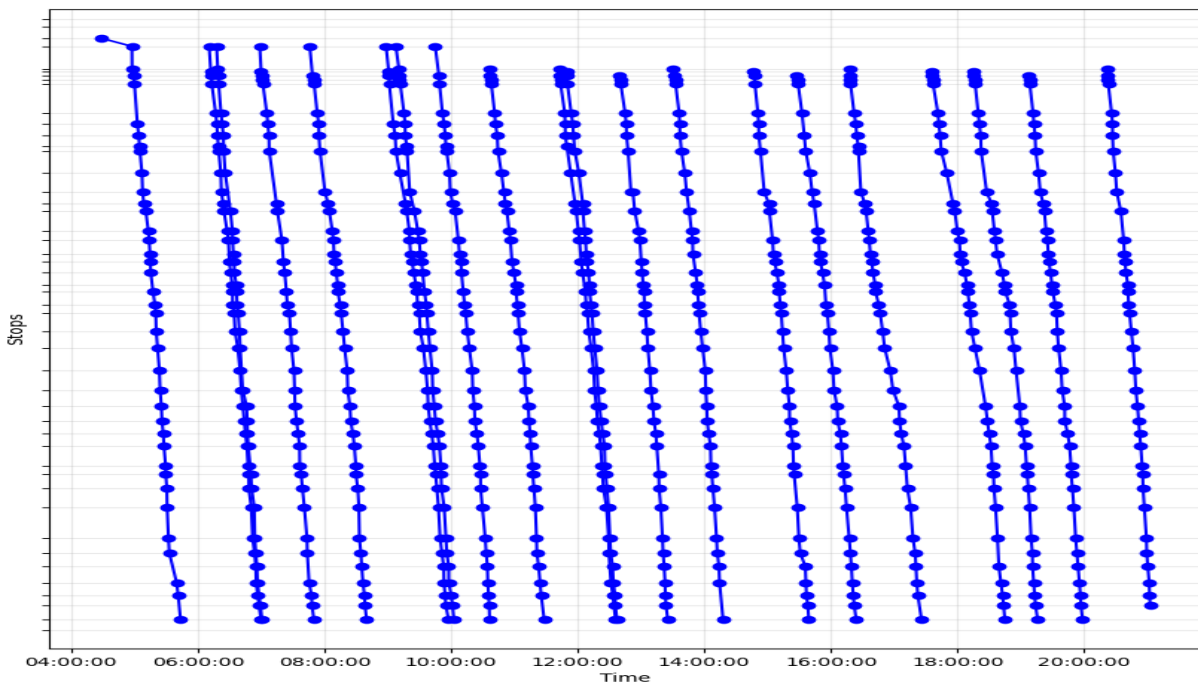


Figure 3: Marey's chart for trips.

After we could establish timetable for our sample and our spark program run right, we are going to use the whole datasets on the cluster to build timetables for all trips. However, before running the program on the whole data, we did more data cleaning first because we found in the whole data some dirty records which we did not saw in the sample data such that for example a bus at the same time in the same trip may have four different distances. We found also that a bus may exist at the same time in different trips. This error can be due to the sensors which in practice can happen. Another issue was found that from 10 PM to 4 AM the distance records are the same because the data stream stops at this period of time.

On cusp, running the spark program on the whole dataset to find for each route trip its list of the stops ids and distances from stops data, construct the time intervals, construct distance intervals, doing interpolation and predicting the time for each stop. As a result, we could get the times of all stops for all trips of each route for every day in whole one month (October, 2020). Then, we could build the timetable for each route trip for each day separately. We ignored trips which have too many missing records such that a trip has 14 stops, but we got estimated time for only 2 stops.

Since we cannot evaluate the timetables by right and wrong, the outcome of these analyses will be in the form of a distribution of estimated travel time, which gives not only an estimated average travel time but also the confidence intervals suggesting how reliable the network performance was. Thus, we grouped days together such Mondays, Tuesdays, so on. Then, we clustered trips together based on 15 minutes threshold such first trips, second trips, so on. Therefore, if we have 4 Mondays, we should 4 trips for each cluster. However, this is not the case because sometimes trip records are missing or number of trips are not the same every Monday. That is why we are using a threshold so for example in the first Monday, the first trip is at 8:00 and the first trip in the second Monday is 8:10, they will be in the same cluster, but if the first trip in the third Monday is 8:25, it will not be with them. We used 15 minutes threshold since a bus should move from the first stop every 15 minutes.

After clustering trips, average time and standard deviation in minutes are computed for each stop in all route trips. Then final timetables are built by the average times and standard deviation interval are mapped into the tables by coloring the cells as we will see in the results. Finally we have for each route trip 7 timetables; one for each week day.

Results

As we mentioned above, the final timetables are built by average times. Standard deviation are mapped into intervals by coloring tables' cells. Table 7 shows the color for each intervals.

Table 7

Standard deviation interval (minutes)	color
0 to 3	Yellow
4 to 7	Orange
8 to 11	Red
12 to 15	Green
15 and up	Blue

Thus, if we have a time and its cell color is yellow, this means that we are confident about the time which can be more or less by maximum 3 minutes. The maximum is going up as we see in the table.

We built timetables for 13 routes trips. We expected number more than this, but after getting the results, we tried to investigate what is the reason. We found the data quality is very bad such for some days there are no records for even a one complete trip. Thus, we should investigate the data for more months to check the quality of the data is the same or it was only for the month data we used. In table 8 we list all route trips we built for them timetables, number of stops for each route trip, and number of stops we could estimate the time for them. It is worth noting that sometimes we do not find records for the first and last stops which can be reasonable. After turning on the bus sensor, it takes like minute or two to start sending records. Therefore we do not get any records about first stop since the bus has already moved from it. For last stop, it is possible that machine is turned off before sending last records. We will mention how we can solve this later in the future work.

Table 8

Route id	Trip id	Number of stops	Number of estimated stops
10	19	15	13
10	20	14	12

179	1	17	16
215	1	11	8
37	1	17	15
179	2	17	15
215	2	11	5
73	2	18	16
95	1	11	6
107	1	12	10
73	1	17	15
107	2	12	9
215	1	11	8

We will show some timetables, but all of them are available on the github repository (<https://github.com/samialisayed/BusAll>). For example route 10 and trip 20, we estimated all stop between first and last stops which is high percentage almost 85% and we can improve it by estimating first and last stop. Here are its timetables for days. Each column represents all times it can be for this stop and our certainty by color as mentioned.

Timetable of Monday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:10:16'	5:13:05'	5:14:42'	5:17:26'	5:21:06'	5:23:19'	5:25:36'	5:29:12'	5:36:40'	5:42:31'	5:52:34'	5:59:58'
5:54:11'	5:57:26'	5:59:43'	6:03:34'	6:06:56'	6:13:34'	6:15:18.50	6:15:49'	6:28:21'	6:34:07'	6:49:32'	6:44:11'
6:15:38'	6:18:31'	6:22:49'	6:25:55'	6:30:46'	6:34:57'	6:37:15'	6:43:25'	6:52:47'	6:59:33'	7:09:19'	6:58:30'
6:42:20'	6:43:41'	7:13:06'	6:53:53'	7:23:22'	7:27:56.50	7:30:46'	7:13:05'	7:24:49'	7:32:31'	7:45:10'	7:20:36'
8:09:42'	7:09:36'	8:15:41'	7:17:48.50	7:47:07'	7:47:31.50	7:50:45'	7:33:38'	7:47:54'	7:53:18'	8:01:41.50	7:56:29'
8:58:42'	8:12:16'	9:05:32'	8:19:26'	8:01:56'	8:05:18'	8:09:28'	7:59:08.50	8:14:00'	8:26:11.25	8:33:10.66	8:10:32'
9:49:59'	9:02:03'	9:56:56'	9:08:53'	8:23:11.50	8:27:36'	8:30:26'	8:14:01'	8:28:53'	8:51:51.50	8:58:18.66	8:52:01.33
13:07:53'	9:53:23'	12:27:48'	12:30:24'	8:59:28'	9:03:52'	9:06:37'	8:33:32.50	8:46:48.50	12:35:44'	9:35:26'	9:41:09'
13:58:20'	12:24:18'	13:16:47'	12:55:36'	9:15:46'	9:20:59'	9:24:45'	9:11:35'	9:22:17'	13:53:27'	9:58:34'	12:08:55'
14:21:58'	13:11:44'	14:05:56'	13:19:32'	12:01:24'	12:05:04'	12:08:11'	9:29:38'	9:42:50'	14:42:06'	12:02:22'	12:50:52.8
14:51:03'	14:01:26'	14:25:08'	14:08:51'	12:14:36'	12:22:02'	12:24:19.5	12:18:30'	12:30:32.3	15:03:26'	12:44:45.5	13:39:08'
16:29:16'	14:21:32.5	14:59:22'	14:28:32.5	12:35:38'	12:39:23'	12:41:52'	12:44:45'	13:18:46'	15:42:12'	13:32:13'	14:11:33'
17:18:50'	14:55:08'	16:05:05'	15:03:14'	13:00:59'	13:03:23'	13:05:04'	13:09:17'	13:46:41'	15:59:43.5	14:02:56'	14:58:15'
19:41:49'	16:01:07'	16:36:59'	16:09:42'	13:24:23'	13:28:37'	13:31:22'	13:35:11'	14:36:13'	16:18:08'	14:51:41'	15:19:12.50

Timetable of Tuesday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:15:55'	5:18:59'	5:22:17.50	5:24:47.50	5:29:47.50	5:33:58'	5:37:23.50	5:40:31.50	5:53:51.66	5:59:25.66	6:08:40.33	6:15:42.66
5:31:05'	5:34:02'	5:38:15'	5:41:18'	5:46:48'	5:50:41'	5:53:51'	5:56:49'	6:40:33.50	6:45:02'	6:54:07.50	7:00:58.50
12:41:50'	6:08:14'	6:11:33'	6:14:14'	6:19:27'	6:22:56'	6:24:59'	6:28:39.50	8:15:41'	8:20:24'	8:29:49'	8:38:26'
13:11:26'	7:20:04'	7:30:32'	7:34:41'	8:49:24'	7:37:12'	7:52:56'	8:01:38'	8:37:05'	8:40:57'	8:50:58'	8:59:07'
13:52:17'	8:36:24'	8:39:27'	8:43:09'	9:14:55'	8:14:59'	8:15:38'	8:23:13'	8:58:04'	9:02:46'	9:09:49'	9:15:49'
16:30:38'	9:01:48'	9:05:33'	9:08:44'	9:45:32'	8:33:22'	8:39:03'	8:45:13'	9:14:16'	9:20:27'	9:28:59'	9:36:59'
20:23:20'	12:45:26'	12:48:58'	12:03:17'	12:08:17'	8:53:51'	8:55:23'	9:02:14'	9:43:40'	9:48:53.50	9:54:59'	9:59:41'

Timetable of Wednesday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:15:15'	5:18:45'	5:22:45'	5:26:17'	5:31:45'	5:45:46.66	5:47:51'	5:50:43.33	6:00:38.66	5:58:43'	6:15:52.66	6:23:37'
5:31:14'	5:34:21'	5:38:05'	5:41:47'	5:46:45'	6:09:33'	6:10:52'	6:13:56'	6:23:59'	6:13:07'	6:36:56'	6:47:53'
5:54:39'	5:57:12'	5:59:29'	6:01:59'	6:05:58'	6:22:15'	6:24:24'	6:28:32'	6:39:31'	6:29:04'	6:56:51'	7:04:08'
6:59:22'	7:02:34'	6:43:46'	6:50:06'	6:56:51'	7:03:17'	7:03:49'	7:08:49'	7:19:24'	6:46:24'	7:34:38'	7:43:56'
9:26:52'	9:29:22'	7:07:11'	7:11:39'	7:17:29'	7:20:26'	7:22:37'	7:26:05'	7:40:06'	7:26:06'	7:57:40'	8:05:41'
9:49:45'	9:53:03'	7:51:30'	7:54:55'	8:00:48'	8:04:17'	8:06:20'	8:10:49'	8:23:21'	7:45:23'	8:35:55'	8:44:26'
13:58:39'	13:39:02'	9:32:59'	9:21:09'	9:33:33.75	9:03:49'	9:06:35'	9:08:58'	9:22:45'	8:28:14'	9:35:26'	9:44:26'
14:13:59'	14:01:39'	9:57:46'	9:35:55'	13:00:37'	9:37:58.75	9:40:34.25	9:44:07.50	9:51:44'	9:27:28'	12:10:47'	12:18:38'
15:11:51'	14:18:34'	13:18:03'	12:56:14'	13:23:49.5	12:02:26'	12:04:25'	12:08:14'	12:20:07'	9:53:08'	12:33:23'	12:41:33'
17:19:19'	15:15:51'	13:40:07'	13:18:29'	13:47:33'	13:04:10'	13:06:18'	13:08:45'	13:19:31'	12:01:55'	13:31:09'	13:37:05'
20:22:40'	17:22:07'	14:04:34'	13:42:57.5	14:15:18'	13:27:22'	13:29:53.5	13:29:59'	13:43:17'	12:23:42'	13:56:52.5	14:03:26'

Timetable of Thursday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:12:23.50	5:15:28'	5:18:11'	5:21:05'	5:25:11'	5:27:49.50	5:29:54.50	5:32:43'	5:40:25'	5:45:42'	5:53:33'	6:01:20.50
5:31:23.50	5:37:32'	5:42:56.40	5:43:03.50	5:48:06.50	5:51:19.75	5:52:58.25	5:55:35.25	6:04:07'	6:09:41.50	6:17:33.50	6:24:23.25
6:19:20'	6:23:12'	6:24:57'	6:28:03.33	6:33:17.66	6:37:23.33	6:34:09'	6:43:49.66	6:55:58.33	7:01:40.33	7:10:58.33	7:19:40.66
7:05:35'	7:07:09'	6:45:16'	7:03:46.25	7:03:53.50	7:05:39.66	6:47:17'	7:11:14'	7:24:58.33	7:30:59.66	7:42:31.33	7:49:16.66
9:20:27'	9:02:43'	7:10:56'	8:32:20'	7:20:46'	7:25:36.50	7:07:47.66	7:31:40.50	7:44:14.50	7:49:43'	7:58:12'	8:06:03.50
13:07:35'	9:27:51.66	8:30:07'	9:08:54'	8:37:56'	7:43:40'	7:27:48.50	7:47:53'	8:05:49'	8:10:36'	8:18:39'	8:24:06'
13:31:19.2	13:12:07.5	9:05:34'	9:34:36'	9:15:28.50	8:42:58'	7:46:19'	8:48:13'	9:00:15'	9:05:47'	9:15:03'	9:21:16'
14:25:27'	13:36:59.2	9:31:04.33	12:30:10'	9:40:00.50	9:19:51.50	8:44:03'	9:27:05.50	9:39:18.50	9:44:45'	9:55:09'	12:05:18'
14:49:12'	14:27:50.5	13:15:55'	13:18:34'	12:34:17'	9:44:01.25	9:23:31'	9:49:38'	12:08:21'	12:09:48'	12:17:02'	12:23:04.5
17:21:56'	14:52:21'	13:40:27.5	13:43:24.2	13:24:26.5	12:38:45'	9:46:27'	12:43:37'	12:52:41'	12:56:53'	13:04:13'	13:12:25'
17:40:21'	17:25:59'	14:30:59.5	14:31:06.6	13:48:50'	13:29:10'	13:31:13.5	13:34:08'	13:44:19'	13:50:03.5	13:57:47.5	14:00:27'

Timetable of Friday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:13:36.50	5:17:05.50	5:20:24.50	5:23:14.50	5:27:49.50	5:31:23'	5:33:22'	5:36:12.50	5:44:57'	5:50:25.50	5:54:54'	6:05:57'
5:30:59'	5:33:41'	5:37:48'	5:41:15'	5:45:44'	5:48:19'	5:50:53'	6:47:48'	6:02:26'	6:08:36'	6:16:12'	6:22:09'
6:24:28'	6:28:07'	6:31:04'	6:33:58'	6:39:11'	6:43:04'	6:45:24'	7:31:28.75	7:00:45'	7:06:12'	7:11:53'	7:21:39'
7:02:22'	7:06:05'	7:11:07.66	7:14:52.66	7:21:01.50	7:25:05.75	7:27:42'	8:32:03'	7:44:11'	7:49:56.75	7:58:56.75	8:03:45.33
14:23:02'	14:25:46'	14:34:53'	13:19:18'	8:41:45'	8:24:39'	8:28:34'	8:51:18'	8:44:18'	8:50:20'	8:59:37'	8:24:31'
14:50:51'	14:53:48'	14:59:36'	14:37:36.5	9:18:03'	8:45:47'	8:48:27'	9:14:18'	9:05:01'	9:10:58'	9:20:11'	9:06:52'
19:53:28'	18:24:31'	18:27:14'	15:02:51'	13:23:16.5	9:02:16'	9:09:20'	9:30:31.50	9:28:25'	9:33:38'	9:50:36.33	9:27:34'

Timetable of Saturday

729	1	5	439	442	1397	1909	731	730	477	483	7159
5:11:04'	5:13:10'	5:18:36'	5:21:01'	5:25:37'	5:28:37'	5:29:31'	5:31:51'	5:37:58'	5:43:27'	5:50:17'	5:58:34'
6:20:54.33	6:19:52.75	6:23:00'	6:26:24.25	6:31:42.75	6:35:59.75	6:33:29.16	6:26:49.50	6:46:10.66	6:54:19.40	6:54:43.50	7:09:25.83
6:53:57'	7:02:45'	7:08:55.50	7:12:04'	7:17:10.50	7:20:10'	7:21:42.50	6:49:48'	7:33:37.50	7:38:28.50	7:46:09.50	7:51:59.50
8:08:51'	8:11:32'	7:50:48'	7:54:19'	7:59:29'	8:04:07'	8:06:53'	7:25:01.50	8:18:41'	8:24:12'	8:31:52'	8:38:44'
14:15:08'	8:29:15.50	8:14:23'	8:18:25'	8:23:02'	8:26:03'	8:27:56'	8:10:28'	8:43:07'	9:06:17.66	8:55:45'	9:01:30'
14:28:16'	14:24:04.5	8:33:05.50	8:35:47'	8:41:15'	8:45:15.66	8:48:06.33	8:31:38'	9:01:12.66	9:46:51'	9:15:09'	9:21:32.66
15:12:31'	15:15:47'	14:33:55.7	12:09:09'	9:18:45'	9:22:34'	9:25:55'	8:51:16.33	9:42:40'	12:12:53'	9:54:53'	12:13:35'
15:40:02'	15:43:06'	15:18:57'	14:32:18.6	12:12:56.5	12:16:27.5	12:18:41.5	9:30:25'	12:09:08'	12:36:34'	12:05:01'	12:32:05'
18:33:55'	18:38:07'	15:46:16'	15:23:09.5	12:40:54'	12:45:48.5	12:52:36.5	12:21:47.5	12:35:24.5	13:14:57.5	12:21:00'	12:56:07.5
19:55:45'	20:00:52'	18:41:24'	15:55:25.5	14:37:35.5	14:41:34.6	14:43:50'	12:55:29.6	13:09:16.6	13:45:03'	12:48:22.5	13:29:42.6

Timetable of Sunday

729	1	5	439	442	1397	1909	731	730	477	483	7159
6:07:44'	6:11:11.16	6:14:12.16	5:52:42'	5:56:24'	5:59:31'	6:17:41'	6:04:44'	6:17:49.50	6:17:08'	6:25:50'	6:48:19.75
6:39:25'	6:42:01'	6:44:21'	6:21:47.80	6:17:44.66	6:21:22'	6:47:53.66	6:26:08'	6:38:27'	6:38:24.33	6:47:11.66	7:17:29'
7:01:39'	7:05:52'	7:08:46'	6:47:35'	6:37:58.50	6:41:53'	7:20:56'	6:51:01'	6:58:30.66	7:03:40'	7:11:40'	7:52:28'
7:22:20'	7:24:48'	7:28:35'	7:11:57'	6:52:19'	7:19:36'	7:42:28'	7:23:42'	7:31:14'	7:36:18'	7:44:47'	8:16:21'
7:46:39'	7:49:30.50	7:54:46'	7:32:14'	7:16:20'	7:40:02'	8:07:12'	7:44:45'	7:53:46'	7:59:34'	8:08:38'	8:40:12.50
9:49:37'	9:53:41'	9:55:25'	7:57:39'	7:36:58'	8:05:42.50	8:20:41'	8:10:32'	8:19:23.50	8:24:59'	8:33:16.50	8:55:05'
14:07:58.1	13:56:45'	12:02:26'	8:32:01'	8:02:20'	8:18:34'	8:43:03'	8:24:32'	8:34:55'	8:39:18'	9:11:05'	9:16:30'
14:49:47'	14:25:04.6	14:01:02'	9:55:02'	8:36:47'	8:41:11'	12:22:05'	8:45:43'	8:58:09'	9:04:17'	12:15:48.5	12:05:51'
15:15:12'	14:52:54'	14:29:01.3	12:09:42.5	9:59:40'	12:20:12.3	14:13:41'	12:25:15.3	12:03:30'	12:06:57'	12:50:09.6	12:21:36.5
15:38:35'	15:19:09'	14:56:09'	14:07:55'	12:16:01.6	14:11:54.6	14:41:58'	14:17:07.6	12:35:28.3	12:43:42'	14:40:48'	12:55:03'
15:59:53'	15:41:55'	15:45:22'	14:37:30'	14:08:23'	14:34:19'	15:35:41'	14:45:29.6	14:26:40'	14:31:55.6	15:01:21'	14:46:56.6
18:07:22'	16:03:21'	16:06:52'	14:58:00'	14:36:22.3	14:50:58'	15:58:52'	15:09:24'	14:48:14'	14:59:12.6	15:17:55'	15:09:36'
18:32:17'	17:36:18'	17:40:06'	15:25:57'	15:01:58'	15:04:12'	16:17:09.5	15:38:05'	15:04:56'	15:23:57'	15:33:59'	15:26:28'
18:56:59'	17:57:22'	18:00:27'	15:47:55'	15:30:05.5	15:33:23'	16:34:11'	16:01:33'	15:18:24'	15:53:16'	16:02:42'	15:40:24'
19:38:32'	18:10:21'	18:13:34'	16:09:25'	15:52:36'	15:56:36'	17:58:46'	16:20:18'	15:47:43'	16:18:12'	16:26:07'	16:08:24.5

Another example is route 179 and trip 2. We also estimated 15 out of 17 and the missing is first and last stop. The records for this route was more than others as shown in timetable, we a lot of trips in all days. It is definitely the condition of bus sensors on this route is functionally great.

Timetable of Monday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
5:04:14'	6:02:00.50	5:10:54'	5:12:39'	5:13:36'	5:15:36'	5:20:07'	5:27:05'	5:32:08'	5:34:40'	5:37:08'	5:40:05'	5:42:49'	5:44:55'	5:48:07'
5:59:55.50	6:33:22'	6:06:27.50	6:08:24'	6:09:39.50	6:12:19'	6:16:44'	6:23:34.50	6:29:20.50	6:30:39.50	6:32:56'	6:37:44.50	6:39:33.50	6:40:30'	6:43:24'
6:29:38.50	7:03:43'	6:37:22'	6:39:23.50	6:40:37.50	6:42:51'	6:46:46.50	6:52:59.50	6:58:44'	7:00:08'	7:02:21'	7:04:39'	7:07:08'	7:09:16.50	7:11:39'
6:59:13'	7:34:36'	7:07:12'	7:09:37'	7:10:11'	7:12:48'	7:16:24'	7:23:21'	7:29:39'	7:30:32'	7:32:31'	8:09:38'	7:37:45'	7:39:31'	7:43:01'
7:30:40'	8:33:33'	7:39:04'	7:40:51'	7:41:25'	7:43:33'	7:47:50'	7:54:22'	7:59:27'	8:02:03'	8:03:53'	9:06:48'	8:09:46'	8:11:53'	8:14:41'
8:30:02'	9:03:59'	8:38:51'	8:39:59'	8:40:11'	8:42:04'	8:46:59'	8:53:39'	8:59:11'	9:00:56'	9:03:00'	9:34:50.50	9:08:24'	9:09:45'	9:12:41'
8:59:51'	9:32:24.50	9:08:06'	9:09:53'	9:08:14'	9:12:01.50	9:16:28'	9:23:30.50	9:29:10'	9:29:51'	9:32:22'	12:08:46'	9:38:31'	9:39:49.50	9:42:53.50
9:29:19'	12:39:30'	9:36:00.50	9:37:57.50	9:38:34.50	9:41:10'	9:45:22'	9:52:32'	9:58:12'	9:59:46.50	12:06:38'	13:13:28'	12:12:13'	12:00:40'	12:10:00'
10:38:38'	13:46:10'	12:23:02'	12:23:30'	12:24:40'	12:26:50'	12:32:26'	12:39:18'	12:02:25.5	12:04:32.5	12:48:52'	14:18:38'	13:14:02'	12:13:38.5	12:59:41'
12:36:26'	14:02:09'	12:44:04'	12:44:56'	12:45:40'	12:49:17'	12:53:35'	13:00:34'	12:45:04'	12:46:23'	13:09:25'	14:34:53'	14:19:54'	12:55:23'	13:18:31'
13:42:31'	14:17:56'	13:49:49'	13:51:08'	13:53:10'	13:55:19'	13:59:09'	14:06:12'	13:05:47'	13:07:28'	14:14:55'	14:49:37'	14:36:44'	13:15:23'	14:24:19'
13:58:44'	14:36:34'	14:05:32'	14:08:12.5	14:08:49'	14:11:09.5	14:15:43'	14:22:04.5	14:11:48'	14:13:08'	14:30:54.5	15:04:56'	14:52:03'	14:21:54'	14:41:43'
14:14:37.5	14:49:21'	14:21:58'	14:23:53'	14:24:37.5	14:27:11'	14:31:26.5	14:37:00'	14:27:57.5	14:28:55.5	14:46:02'	15:17:59'	15:07:00'	14:38:19'	14:56:20'
14:28:29'	15:46:56'	14:36:37'	14:38:40'	14:39:47'	14:42:25'	14:45:38'	14:52:26'	14:42:15.5	14:43:57.5	15:02:14'	16:19:24'	15:21:09'	14:53:36'	15:11:43'
14:45:20'	16:18:49'	14:52:16'	14:54:23'	14:54:56'	14:57:14'	15:00:51'	15:06:18'	14:57:41'	15:00:01'	15:15:21'	16:52:07'	16:22:14'	15:09:01'	15:25:21'
15:42:47'	16:47:43.5	15:50:39'	15:52:23'	15:53:28'	15:55:46'	15:59:55'	16:08:13'	15:12:33'	15:13:39'	16:15:50'	17:19:05'	16:54:21'	15:23:40'	16:27:20'
16:14:06.5	17:04:01'	16:21:56.5	16:23:41.5	16:24:41.5	16:27:34.5	16:32:06'	16:40:07.5	16:11:45'	16:13:29'	16:49:31.5	17:36:01'	17:21:45.5	16:23:49'	17:00:09'
16:42:08.6	17:19:13'	16:51:20.5	16:53:47'	16:54:45.5	16:56:11'	17:00:20.5	17:06:51'	16:45:37.5	16:46:40.5	17:16:17'	17:51:15'	17:40:17'	16:56:31.5	17:25:43'
16:59:03'	18:09:21'	17:07:19'	17:09:01'	17:25:47'	17:10:18'	17:16:03'	17:22:16'	17:12:17'	17:14:14.5	17:34:14'	18:22:44'	17:54:18'	17:23:26'	17:46:07'
18:04:32.5	18:38:02'	17:23:16'	17:24:52'	17:54:24'	17:27:49'	17:31:48'	17:39:54'	17:29:28'	17:30:57'	17:48:19'	18:38:00.5	18:35:56.6	17:42:14'	17:59:52'
18:33:31'	19:04:42'	18:11:17.5	17:52:21'	18:14:27.5	17:56:52'	18:02:31'	18:08:52'	17:44:49'	17:46:22'	18:19:33'	19:09:19.5	19:12:12'	17:55:25'	18:41:47.3
19:01:33'	19:41:42'	18:41:16'	18:15:35'	18:44:26.5	18:16:15.5	18:20:38'	18:26:34.5	18:15:28'	18:16:41'	18:35:46.5	19:37:24'	19:40:03'	18:28:04'	19:17:35.5

Timetable of Tuesday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
5:04:09.50	5:08:06'	5:11:18'	5:12:50'	5:13:47.50	5:16:33'	5:20:48.50	5:27:41'	5:33:14'	5:35:15.50	5:37:28'	5:40:13.50	5:42:34.50	5:44:22.50	5:47:34'
5:59:20.50	6:03:36'	6:07:39.50	6:09:14'	6:10:14'	6:11:00.50	6:16:57.50	6:23:10.50	6:28:29'	6:30:27.50	6:32:06'	6:35:07'	6:37:28'	6:38:55'	6:42:20.50
6:29:25'	6:33:14'	6:37:25'	6:39:08'	6:39:32'	6:41:43'	6:45:52'	6:53:21'	6:59:59'	7:01:13'	7:03:42'	7:06:57'	7:08:49'	7:10:13'	7:13:19'
8:00:14'	7:05:11'	7:09:38'	7:10:59'	7:11:37'	7:13:48'	7:18:40'	7:24:28'	7:30:18'	7:32:11'	7:33:29'	7:36:37'	7:39:26'	7:40:50'	7:43:56'
8:28:41.33	8:04:11'	8:08:37'	8:10:13'	8:10:47'	8:12:57'	8:16:16'	8:22:43'	8:27:32'	8:58:21'	8:31:28'	8:33:49'	8:36:27'	8:38:20'	8:42:16'
9:00:03'	8:32:36'	8:36:17'	8:38:18'	8:39:04.50	8:41:03'	8:45:30'	8:51:36'	8:56:40'	9:31:00'	9:00:37'	9:04:58'	9:05:59.50	9:08:05.50	9:11:17'
10:37:19'	9:02:34.50	9:07:36'	9:09:36'	9:10:40.50	9:12:44'	9:16:56.50	9:23:39.50	9:29:38.50	12:03:41'	9:35:50'	9:37:45.50	9:38:54'	9:40:29.50	9:43:15'
12:50:44'	9:34:23'	9:38:29'	9:39:38'	9:41:37'	9:43:00'	9:47:16'	9:53:33'	11:01:35'	12:48:14'	12:05:35'	12:08:29'	12:56:02'	12:12:38'	12:02:27'
13:14:59'	13:18:49'	12:22:42'	12:24:00'	12:25:03'	12:28:13'	12:33:27'	12:42:59'	12:46:27'	13:46:20'	12:50:38'	12:53:46'	13:56:15'	12:59:01'	13:01:33'
13:59:54.5	13:48:23'	13:22:59'	13:25:01'	13:25:36'	13:28:57'	13:34:05'	13:40:01'	13:45:34'	14:13:40'	13:49:42'	13:53:08'	14:21:18'	13:57:40'	14:01:18.50
14:30:46'	14:03:35.5	13:51:25'	13:53:02'	13:54:12'	13:56:10'	13:57:41'	14:04:07'	14:12:18'	14:29:21.5	14:15:46'	14:18:51'	14:36:37'	14:23:15'	14:25:29'
15:13:44'	14:38:05'	14:06:52'	14:08:42.5	14:10:02.5	14:11:49'	14:15:42'	14:22:39'	14:27:23'	15:01:30'	14:33:32.5	14:35:24.5	15:08:34'	14:40:07'	14:41:17.50
15:43:10.5	15:17:36'	14:38:09'	14:39:17'	14:40:55'	14:42:12'	14:46:35'	14:52:09'	14:59:15'	15:43:03'	15:03:21'	15:06:46'	15:50:53'	15:10:00'	15:12:31'
16:14:25.5	15:46:39.5	15:21:09'	15:23:09'	15:23:42'	15:25:52'	15:29:56'	15:35:25'	15:40:39'	16:13:28'	15:45:06'	15:47:34'	16:24:26'	15:53:08'	16:26:11.50
16:44:12'	16:17:55.5	15:49:54.5	15:52:22.5	15:53:08.5	15:54:56.5	15:59:42'	16:04:12'	16:13:14'	16:45:48.5	16:15:57.5	16:21:25'	16:53:30'	16:22:36'	16:58:27'
16:59:32'	16:48:21'	16:22:06.5	16:23:52.5	16:24:33.5	16:26:59'	16:31:06.5	16:37:43.5	16:43:34'	17:13:49'	16:47:50.5	16:50:13.5	17:20:24'	16:55:29.5	17:41:45'
17:29:13'	17:02:49'	16:51:49'	16:53:54'	16:54:50'	16:56:38'	17:00:23'	17:06:38'	17:12:28'	17:29:21'	17:15:00'	17:18:20'	17:36:44'	17:22:00'	18:29:33.50
18:34:39'	17:32:09'	17:06:57'	17:07:39'	17:08:16'	17:10:50'	17:14:34'	17:23:04'	17:28:03'	17:59:08'	17:30:58'	17:35:06'	18:18:41.6	17:38:19'	18:46:27'
19:03:09'	17:45:01'	17:35:36'	17:46:49.3	17:47:29'	17:40:05'	17:53:53.3	17:52:10'	17:58:02'	18:14:22'	18:02:50'	18:05:17'	18:42:05.5	18:20:55.6	19:14:45'
20:01:05'	18:07:12'	17:49:39'	18:13:08'	18:14:14'	17:55:30.5	18:20:53'	18:08:18'	18:12:49'	18:34:08.5	18:17:09.5	18:19:59'	19:10:46'	18:43:37.5	19:45:54'
20:47:17'	18:38:21'	18:10:24'	18:44:04'	18:44:35'	18:16:57.5	18:51:12'	18:27:00.5	18:32:31'	19:03:28'	18:36:24.5	18:39:37'	19:41:51'	19:12:33'	20:46:13'

Timetable of Wednesday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
5:04:13'	5:08:14'	5:11:30'	5:13:39'	5:14:15.50	5:16:26.50	5:21:00'	5:27:07.50	5:32:45.50	5:36:09'	5:38:27'	5:40:33'	5:43:13'	5:45:18'	5:48:39'
5:58:28'	6:02:20'	6:05:45'	6:08:20'	6:08:55'	6:11:38'	6:16:35'	6:22:51'	6:29:23'	6:31:14'	6:33:34'	6:34:48'	6:38:14'	6:39:07'	6:44:23'
6:29:55'	6:33:53'	6:38:44'	6:39:22'	6:40:35'	6:42:38'	6:46:42'	6:53:56'	7:00:04'	7:01:22'	7:04:16'	7:06:01'	7:09:28'	7:10:41'	7:13:59'
7:28:33'	7:32:37'	7:37:24'	7:39:10'	7:39:44'	7:41:59'	7:45:12'	7:51:03'	7:54:40'	7:57:54'	8:31:44'	8:04:20'	8:37:45'	8:39:14'	8:41:31'
7:58:32'	8:01:48'	8:04:57'	8:07:15'	8:08:51'	8:11:10'	8:15:23'	8:21:38'	8:26:17'	8:29:20'	9:02:12.50	8:37:05'	9:07:42'	9:09:55'	9:12:44.50
8:29:57.50	8:33:44'	8:37:27'	8:39:21.50	8:39:45.50	8:42:29'	8:45:02.50	8:52:13'	8:57:14.50	8:59:44'	9:31:16'	9:04:03'	9:38:34'	9:38:45'	9:40:40'
8:59:46'	9:03:04'	9:07:52'	9:08:36'	9:09:17'	9:12:31'	9:16:09'	9:22:06'	9:28:40'	9:29:57'	12:08:24'	9:33:23'	13:11:54'	12:15:30'	12:03:28'
9:30:44'	12:36:48'	9:38:34'	12:41:28'	9:41:18'	9:43:00'	9:43:48'	9:54:15'	12:04:37'	12:06:48'	13:05:59'	12:15:24'	13:55:52'	13:12:42'	12:18:27'
12:33:10'	13:17:56'	12:40:17'	13:23:23'	12:43:10'	12:45:18'	12:49:27'	12:59:26'	13:02:14'	13:03:43'	13:50:45'	13:11:26'	14:23:09'	13:59:41'	13:17:46'
13:14:07'	13:47:35'	13:21:21'	13:54:29.5	13:24:13'	13:27:24'	13:32:08'	13:39:54'	13:43:46'	13:48:05'	14:24:05.3	13:54:19'	14:39:56'	14:32:08.3	14:02:01'
13:45:03'	14:03:49'	13:52:36'	14:09:19'	13:55:07'	13:57:41.5	14:02:34'	14:13:26.3	14:14:55'	14:21:55.6	14:49:44'	14:26:38.6	14:54:30'	14:55:46'	14:34:09.3
13:59:57'	14:23:10'	14:08:31'	14:25:50'	14:09:55'	14:11:57'	14:15:53'	14:39:17'	14:28:37'	14:47:33'	15:16:09'	14:51:43'	15:22:17'	15:24:15'	14:58:27'
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15:44:30.5	15:48:31.5	15:18:59'	15:53:53'	15:20:16'	15:23:07'	15:27:08'	16:07:42.5	15:43:58'	16:14:28'	16:43:54'	16:45:53'	16:49:31'	16:50:05'	16:26:52'
16:11:21'	16:17:36'	15:51:46.5	16:23:06'	15:54:57.5	15:56:47.5	15:59:16.5	16:37:37'	16:12:26'	16:43:02'	17:15:50'	17:20:20'	17:21:28'	17:23:04'	16:53:36'
17:14:32'	16:51:25'	16:20:42'	16:52:44'	16:23:42'	16:26:00'	16:29:26'	17:06:36'	16:41:10'	17:14:03'	17:47:19'	17:49:47'	17:53:07'	17:55:49'	17:26:18'
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Timetable of Thursday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
4:22:32'	4:29:05'	4:29:22'	4:31:08'	4:32:10'	4:34:25'	4:38:32'	4:43:42'	4:47:43'	4:51:17'	4:53:02'	4:55:41'	5:00:33'	5:01:57'	5:04:58'
5:03:43'	5:11:19'	5:11:56'	5:12:47'	5:14:20'	5:16:46'	5:20:56'	5:27:09'	5:33:43'	5:34:38'	5:36:36'	5:39:51'	5:42:26'	5:43:25'	5:46:43'
5:59:51'	6:04:14'	6:09:03'	6:10:07'	6:10:42'	6:13:43'	6:18:30'	6:25:41'	6:31:08'	6:32:46'	6:34:58'	6:38:31'	6:40:06'	6:41:26'	6:44:32'
6:29:35.6'	6:29:17'	6:35:49'	6:38:12'	6:38:50'	6:41:41'	6:46:34'	6:53:00'	6:58:12'	6:59:50'	7:02:20'	7:04:38'	7:08:00'	7:09:52'	7:13:47'
6:59:37'	6:57:20'	7:05:37'	7:07:32'	7:08:08'	7:10:09'	7:14:17'	7:20:55'	7:25:30'	7:26:53'	7:29:19'	7:31:17'	7:34:54'	7:36:24'	7:39:34'
7:13:34'	7:33:16'	7:37:09.5'	7:38:34'	7:39:19.5'	7:41:19'	7:45:59'	7:52:55'	7:56:34'	7:59:52.5'	8:01:45'	8:02:32'	8:07:41'	8:09:20'	8:11:46.50'
7:29:36'	8:04:09.5'	8:08:14.5'	8:10:26'	8:11:17.5'	8:13:25'	8:17:41.5'	8:23:19'	8:26:28'	8:30:03.5'	8:32:01'	8:36:40.5'	8:38:14.5'	8:39:45'	8:42:21'
8:00:22.5'	8:34:09'	8:39:20'	8:40:26'	8:40:39'	8:42:37'	8:46:52'	8:52:23'	8:56:16.5'	9:00:22'	9:02:02'	9:05:07'	9:07:47'	9:09:00'	9:12:02'
8:59:59'	9:04:04'	9:08:36'	9:09:36'	9:10:13'	9:12:29'	9:16:03'	9:21:56'	9:28:36'	9:30:44'	9:32:49'	9:37:26'	9:37:53'	9:39:34'	9:43:10'
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13:13:55.5'	13:17:51.5'	13:21:56'	13:23:33'	13:24:55'	13:27:26.5'	13:31:31'	13:37:36.5'	13:39:25'	13:04:54.5'	13:46:05'	13:48:53.5'	13:51:27'	13:13:04'	13:15:49'
13:43:55'	13:47:23'	13:51:19'	13:52:41'	13:53:14'	13:55:20'	13:59:18'	14:04:18'	14:07:53'	13:44:38.5'	14:13:55'	14:17:36'	14:20:12'	13:53:20'	13:56:48.5'
14:00:18'	14:13:22.5'	14:15:07.5'	14:10:19'	14:11:10'	14:13:28'	14:17:48'	14:24:02'	14:29:47'	14:12:41'	14:39:08'	14:36:08'	14:38:48'	14:21:29'	14:24:03'
14:14:06'	14:33:50'	14:37:08'	14:22:39'	14:24:23'	14:26:25'	14:30:37'	14:36:30'	14:42:03'	14:30:58'	15:01:50'	14:49:14'	14:51:15'	14:41:02'	14:44:37'
14:30:41'	14:46:55'	14:50:01.5'	14:40:16'	14:40:28'	14:42:58'	14:47:36'	14:53:00'	14:56:24'	14:43:08'	15:16:10'	15:05:02'	15:08:20'	14:53:18'	14:56:39'
14:43:36'	15:17:48'	15:21:12'	14:52:36.5'	14:53:19'	14:55:45.5'	15:00:35.5'	15:06:40'	15:11:50.5'	14:59:40'	15:45:06'	15:18:48'	15:22:45'	15:18:21.5'	15:21:20.3'
15:13:59'	15:48:39'	15:51:55'	15:23:05.5'	15:24:26'	15:26:43.5'	15:30:36.5'	15:36:28'	15:40:27'	15:13:55'	16:17:55'	15:48:17'	15:51:03'	15:53:08.5'	15:55:52'
15:44:57'	16:23:00'	16:23:13'	15:53:44'	15:54:59'	15:57:22'	16:00:41'	16:07:55'	16:46:43'	15:43:13.5'	16:51:09'	16:20:34'	16:23:14'	16:24:57'	16:27:54'
16:15:01'	16:47:53'	16:51:42'	16:24:42'	16:55:38'	16:24:56'	16:31:46'	16:43:03'	17:13:16'	16:16:19'	17:19:07'	16:54:39'	16:57:00'	16:59:05'	17:02:54'
16:43:53'	17:02:38'	17:15:11'	16:53:26.5'	17:09:06'	16:57:52'	17:02:39'	17:08:52'	17:46:35'	16:47:35'	17:50:52.5'	17:21:54'	17:25:12'	17:28:08'	17:31:37'
16:58:29'	17:15:47.5'	17:36:05'	17:16:45.5'	17:22:04.5'	17:20:32.5'	17:25:12.5'	17:39:56'	18:31:52'	17:16:23'	18:18:01'	17:53:19.5'	17:56:49.5'	17:59:05.5'	18:08:11.5'
17:12:19.5'	17:32:11'	17:50:57'	17:37:25'	17:38:21.5'	17:40:33.5'	17:44:53.5'	18:08:25'	18:58:38'	17:48:05.5'	18:35:54'	18:21:31'	18:24:41'	18:26:20'	18:44:39'
17:28:52'	18:12:17'	18:12:23'	17:53:11'	17:54:11'	17:57:16'	18:02:11'	18:27:23'	19:27:32'	18:15:39'	19:04:23'	18:39:26'	18:41:07'	18:42:41'	19:16:51'

Timetable of Friday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
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6:27:54'	6:31:50'	6:35:03'	6:08:34'	6:09:43'	6:12:22'	6:17:31'	6:23:36'	6:30:40'	6:32:04'	6:34:03'	6:38:21'	6:39:38'	6:41:17'	6:44:25'
6:59:06'	7:01:42.25	7:06:38.33	6:36:23'	6:37:36'	6:39:42'	6:43:05'	6:49:17'	6:54:27'	6:56:58'	7:31:28'	7:02:26'	7:04:25'	7:05:46'	7:08:42'
7:30:04'	7:33:57'	7:37:23'	7:08:25'	7:09:36'	7:11:42.33	7:15:55'	7:22:24.66	7:28:00'	7:29:21.66	8:02:56'	7:34:36.66	7:37:08'	7:38:44'	7:42:20.66
7:59:32'	8:03:04'	8:07:09'	7:40:11'	7:41:10'	7:43:19'	7:47:30'	7:52:56'	7:58:55'	8:00:21'	8:31:24'	8:07:13'	8:36:43.50	8:10:17'	8:14:53'
8:32:05'	8:36:38'	8:40:02'	8:08:34.50	8:09:59.50	8:12:13'	8:16:10.50	8:21:58'	8:27:18'	8:29:38'	9:03:38'	8:34:05'	9:08:02'	8:38:43.50	8:41:58.50
8:59:42'	9:03:23'	9:07:31'	8:40:41'	8:42:03'	8:44:18'	8:47:54'	8:56:06'	9:00:43'	9:02:00'	9:33:08'	9:06:18'	9:39:13'	9:10:10'	9:12:01'
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10:57:50'	12:37:44.5	12:41:44.5	12:22:53'	12:24:01.5	12:25:27.5	12:32:06.5	12:40:05'	12:05:36'	12:07:01'	13:06:50.5	12:52:29.5	13:11:54'	12:17:00'	12:21:36'
11:46:23'	13:17:51.5	13:22:47'	12:43:53.5	12:44:48.5	12:47:47'	12:52:20'	13:00:28.5	12:45:35.5	12:47:08.5	13:49:33'	13:12:13'	13:54:46.5	12:56:51'	13:00:12'
12:34:52.5	14:03:06'	13:53:37'	13:24:26.6	13:26:07.5	13:29:10'	13:33:10.5	13:39:35.5	13:03:46.5	13:05:05.5	14:16:55'	13:53:11'	14:22:28'	13:14:40'	13:18:12'
13:14:51.5	14:33:25'	14:07:14'	13:54:47'	13:56:11'	13:58:12'	14:01:57'	14:07:27'	13:45:41.5	13:47:09'	14:39:39.5	14:17:07'	14:51:23'	13:56:16.5	13:59:32.5
13:45:34'	14:48:32'	14:36:35'	14:10:01'	14:10:39'	14:13:08'	14:17:24'	14:24:16'	14:13:15'	14:14:29'	15:01:29'	14:42:18'	15:06:48.5	14:24:06'	14:26:53'
13:59:36'	15:17:07'	14:52:20'	14:38:44'	14:39:27'	14:41:41'	14:30:48'	14:36:42'	14:29:57'	14:37:29'	15:16:23.5	15:04:45.5	15:53:00'	14:47:17.5	14:50:09.5
14:30:18'	15:50:05'	15:22:03'	14:54:28'	14:55:01'	14:57:17'	14:46:38.5	14:52:43.5	14:42:08'	15:06:38.7	15:47:25'	15:21:59'	16:24:05'	15:16:58.2	15:19:14.7
14:45:37'	16:15:42'	15:53:52'	15:23:56.5	15:24:54.5	15:27:20.5	15:00:44'	15:06:58.5	15:04:42.7	15:45:48'	16:19:52'	15:49:54.5	16:53:12'	15:54:46'	15:58:05'
15:14:21.5	16:46:24'	16:21:23'	15:55:39'	15:56:14'	15:58:27'	15:31:46.5	15:38:41.5	15:43:14'	16:16:26'	16:48:16'	16:22:15'	17:22:44'	16:25:45'	16:29:42'
15:32:36'	17:01:57'	16:49:51'	16:23:58'	16:24:49'	16:27:48'	16:02:22'	16:08:53'	16:14:57'	16:45:14'	17:16:24'	16:51:39'	17:42:59.3	16:55:34'	17:01:02'
16:12:17'	17:18:29'	17:05:36.5	16:52:26'	16:53:26'	16:56:11'	16:32:53'	16:38:28'	16:43:15'	17:14:28'	17:40:51.2	17:19:05'	18:15:26.3	17:23:48'	17:28:28'
16:42:49'	17:33:16'	17:21:38'	17:07:48'	17:08:46.5	17:11:40.5	17:00:12'	17:07:05'	17:13:02'	17:38:08'	18:04:19.5	17:51:42.3	18:39:57'	18:00:50'	17:46:00'
16:58:43.5	17:49:11'	17:37:10.5	17:25:03'	17:25:35'	17:28:49'	17:16:32'	17:30:49.5	17:35:45.7	18:01:51.5	18:17:58'	18:21:45'	19:14:15'	18:42:00'	18:16:51.5

Timetable of Saturday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
5:02:26'	5:03:30'	5:09:42'	5:12:49'	5:13:24'	5:16:12'	5:20:05'	5:26:11'	5:31:20'	5:34:10'	5:35:51'	5:38:01'	5:41:16'	5:42:58'	5:45:06'
5:58:12'	5:59:13'	6:05:32'	6:07:37'	6:08:16'	6:11:11'	6:15:41'	6:24:21'	6:28:36'	6:30:36'	6:33:10'	6:36:28'	6:38:13'	6:40:21'	6:43:51'
6:29:11'	6:32:31'	6:36:33'	6:37:05'	6:39:47'	6:42:15'	6:46:26'	6:53:13'	6:58:57'	7:00:16'	7:02:47'	7:06:15'	7:08:17'	7:10:02'	7:13:13'
7:00:00.33	7:03:23.33	7:06:39.66	7:09:11'	7:10:07.33	7:12:37'	7:16:31'	7:23:01.66	7:29:14'	7:30:59.66	7:32:54.33	7:35:56'	7:38:17.66	7:39:50.66	7:43:44'
7:29:39'	7:32:00'	7:37:29.50	7:39:21.50	7:40:19.50	7:42:15'	7:46:31'	7:53:28.50	7:59:08'	8:00:54.50	8:03:45.50	8:06:29.50	8:09:24'	8:10:54'	8:13:03.50
7:59:59'	8:33:22'	8:07:59'	8:09:17'	8:09:56'	8:11:47'	8:15:52'	8:21:58'	8:28:19'	8:29:58'	8:31:35'	8:35:32'	8:37:45'	8:39:43'	8:40:55'
8:30:15'	9:01:54'	8:36:40'	8:38:42'	8:40:00'	8:42:20'	8:46:49'	8:53:54'	8:57:25'	9:00:44'	9:02:31'	9:05:06'	9:08:39'	9:11:57'	9:14:01'
8:57:52'	9:32:54.50	9:05:34'	9:07:33'	9:08:10'	9:10:46'	9:15:28'	9:22:45'	9:28:20'	9:29:52'	9:32:36'	9:36:08'	9:38:22'	9:40:53'	9:44:39'
9:29:35'	12:17:48'	9:36:47'	9:38:59.50	9:39:48'	9:42:19'	9:46:45'	9:54:34'	9:57:30'	12:02:51.5	12:05:04.5	12:09:35.5	12:11:05'	12:12:16.5	12:01:18'
10:31:16'	12:38:27'	12:20:27.5	12:23:03'	12:23:38.5	12:25:54'	12:30:31'	12:36:42'	10:36:44'	12:44:10.5	12:46:24.5	12:49:41'	12:51:44'	12:53:46'	12:15:32'
12:14:15'	13:47:17'	12:42:04'	12:44:27'	12:45:09'	12:48:03.5	12:53:05'	13:00:56.5	12:00:14'	13:08:00'	13:09:43'	13:12:14'	13:15:42'	13:17:14'	12:55:36'
12:35:02.5	14:01:44'	13:23:21'	13:23:53'	13:24:33'	13:26:40'	13:29:59'	13:36:40'	12:42:22.5	13:43:52'	13:45:33'	13:49:27'	13:50:29'	13:52:37'	13:21:20'
13:15:03'	14:32:50.5	13:58:43.5	13:53:52'	13:54:06'	13:56:36'	14:01:54'	14:08:18'	13:06:20.5	14:21:39.5	14:23:48'	14:29:25.5	14:25:16'	14:33:22.5	13:56:39'
13:43:11'	14:48:35'	14:20:58'	14:06:30'	14:07:35'	14:10:23'	14:15:20'	14:32:46.3	13:42:10'	14:44:26.5	14:46:09'	14:49:13'	14:52:42'	14:54:22'	14:35:50'
13:58:10'	15:18:40'	14:36:10'	14:23:12'	14:23:48'	14:26:15'	14:31:01'	14:53:38.5	14:12:30'	14:59:08.5	15:01:06'	15:03:07'	15:06:55'	15:08:52'	14:57:46.5
14:13:29'	15:45:52'	14:51:43'	14:38:37'	14:39:26'	14:42:27'	14:46:30'	15:08:07'	14:26:22'	15:15:16'	15:16:52'	15:19:22'	15:21:46'	15:24:29.5	15:17:28.6
14:29:43'	16:17:25'	15:22:18'	14:54:08'	14:55:18'	14:57:17'	15:01:22'	15:33:35'	14:41:50'	15:39:58'	15:41:57'	15:49:58'	15:52:08'	15:52:18'	15:55:13'
14:45:40'	16:48:12.5	15:52:29'	15:22:58'	15:23:06'	15:25:09'	15:29:13'	16:08:26'	14:57:56.5	16:14:37'	16:17:06'	16:21:12'	16:23:05'	16:25:25'	16:29:48'
15:14:11'	17:02:32.5	16:21:13'	15:53:15'	15:53:53'	15:57:20'	16:01:41'	16:37:49'	15:13:35'	16:45:57'	16:48:26'	16:52:20'	16:54:16'	16:56:17'	16:59:33'
15:45:09'	17:17:44'	16:52:11'	16:23:37'	16:24:13'	16:26:45'	16:32:09'	17:08:45'	15:39:13'	17:15:37.5	17:17:41'	17:20:49'	17:23:17'	17:25:34.5	17:28:54.5
16:12:12'	17:46:41'	17:06:28'	16:53:42.5	16:55:08.5	16:57:21'	17:01:37.5	17:22:39.5	16:11:56'	17:30:26.5	17:32:40'	17:36:54'	17:38:17.5	17:40:42.5	17:44:32.5
16:44:32.5	18:06:12'	17:21:43'	17:08:41.5	17:09:42.5	17:12:13.5	17:22:51.2	17:37:33.5	16:43:55'	17:45:14.5	17:47:22'	17:54:05'	17:57:52.6	17:59:42.3	18:03:31.6

Timetable of Sunday

6886	3667	3669	6900	7101	7103	6901	6902	6903	6904	6905	6906	6907	6908	6909
5:03:29'	5:06:53'	5:09:50'	6:06:53'	5:13:24'	5:15:22'	5:19:51'	5:25:42'	5:31:44'	5:33:40'	5:35:06'	5:39:50'	5:41:02'	5:43:10'	5:45:50'
5:57:55'	6:01:43'	6:04:53'	6:39:37'	6:07:40.50	6:09:43.50	6:14:03.50	6:20:01'	6:25:25'	6:28:10.50	6:29:55'	6:32:30'	6:35:23'	6:36:31'	6:40:51'
6:30:47.66	6:33:49.66	6:37:38.33	7:10:02'	6:40:21.33	6:42:25'	6:46:11.66	6:51:24.33	6:56:35.33	6:58:40'	7:00:24.50	7:03:45'	7:05:26'	7:07:13'	7:10:23'
6:58:49'	7:35:38'	7:07:39'	7:40:31'	7:11:14'	7:12:49'	7:16:38'	7:23:54'	7:28:20'	7:31:59'	7:35:04'	7:37:05'	7:40:07'	7:41:29'	7:44:15'
7:31:27'	8:33:23'	7:39:38'	9:08:15.50	7:41:11'	7:43:05'	7:47:48'	7:52:26'	7:58:55'	7:59:29'	8:01:59'	8:04:47'	8:07:09'	8:08:38'	8:12:25'
8:29:27'	9:01:41.50	8:37:24'	9:38:47.50	8:39:31'	8:42:38'	8:46:33'	8:53:14'	8:58:28'	9:00:06'	9:01:43'	9:09:00'	9:09:20'	9:09:27'	9:12:31'
8:58:30'	9:32:34.50	9:06:07.50	12:23:43'	9:09:02.50	9:11:11.50	9:15:31'	9:21:30'	9:26:47'	9:29:00.50	9:31:59.50	9:32:06.50	9:35:59.50	9:38:27.50	9:41:32.50
9:29:19.66	12:17:52'	9:36:13'	12:45:28'	9:39:37'	9:41:59'	9:46:07.50	9:52:25'	9:56:51'	9:58:07'	12:05:39'	12:09:32'	12:13:03'	12:14:06'	12:02:15.50
12:36:03'	12:43:44'	12:21:21'	14:09:20.5	12:24:20'	12:26:24'	12:30:13'	12:35:54'	10:54:06'	10:18:12'	12:46:26'	12:48:29'	12:51:46'	12:53:03'	12:16:29'
13:44:14'	13:47:09'	12:44:03'	14:22:31'	12:46:03'	12:48:38'	12:52:48'	12:59:18'	12:01:08'	12:03:36'	13:08:09'	13:09:53'	13:13:14'	13:15:23'	12:57:03'
13:59:08'	14:02:56.5	14:06:54.5	14:38:37'	14:14:14'	13:52:36'	14:00:30'	14:06:44'	12:40:22'	12:44:29'	14:16:44'	14:19:28'	14:21:55'	14:23:08'	13:18:11'
14:13:21'	14:17:02'	14:20:08'	15:53:28'	14:39:31'	14:12:33.5	14:23:36.5	14:23:01'	13:04:40'	13:05:23'	14:39:34.5	14:42:05'	14:45:27.2	14:47:46'	14:27:59'
15:43:45'	14:33:36'	14:36:40'	16:24:39'	15:54:32'	14:25:24'	14:46:31'	14:37:31.5	14:12:19'	14:14:23'	15:04:31'	15:06:53'	15:10:08'	15:12:03'	14:50:13.2
16:13:51'	16:17:51.5	15:50:22'	16:53:31'	16:25:29'	14:41:35'	15:02:17'	14:53:53'	14:28:13.5	14:37:32.5	15:17:10'	15:20:21'	15:23:18'	15:25:33'	15:12:59'
16:44:23.5	16:51:53.3	16:22:19.5	17:09:12'	16:54:10.5	15:56:51'	16:00:44'	15:08:57'	14:43:16.5	15:02:42'	16:16:05'	16:20:50'	16:22:04'	16:24:06'	15:28:10'
16:58:36'	18:03:51'	16:51:45'	17:52:56'	17:09:25'	16:27:52'	16:32:33'	16:06:47'	14:58:05'	15:15:35'	16:48:50'	16:48:36'	16:54:21.5	16:55:57'	16:27:16'
17:43:15'	18:36:25.5	17:07:06'	18:12:18'	17:53:48'	16:56:45'	17:01:22'	16:38:52.5	15:14:12'	16:13:16'	17:17:33.5	17:19:25'	17:22:39'	17:24:53'	16:59:59.50
18:02:51'	19:07:54'	17:50:31'	18:41:53'	18:12:22.5	17:13:19'	17:17:49'	17:07:47.5	16:12:31'	16:46:27.5	17:33:38'	17:35:49'	17:39:26'	17:41:07'	17:27:25.50
18:32:50.5	19:38:27'	18:10:07'	19:12:53'	18:42:16.5	17:56:45'	17:30:37'	17:24:01'	16:44:28'	17:15:25'	17:46:05'	17:48:28'	17:51:48'	17:53:09'	17:44:01'

Conclusion

Most of our estimation are in yellow which means we are confident about our estimation since the maximum delay can have is 3 minutes maximum. Therefore 3 minutes maximum is not really a problem. As a result, these timetables will help people to know what times buses will reach their stop and also how many minutes they may wait. Timetables will also encourage for more analysis such studying in what time more traffic or when bus bunching is happening. Thus, more performance analysis can be done by using our results.

There are many future work we can do. First we can use more data for other months for the whole year which helps us to validate and test our algorithm more. It can also provide us more records about routes which we could not cover by the month we used. We can also build live dashboard and interactive graph presentation for people to use. It will help them to track buses during trips and points on the graph show the stop location, its distance from other stops and times of next buses. People also can access anytime of any day and see all the times for any stop they are interested in.

Another idea we can work on it. Predicting the time for first and last stop. We can build a machine learning algorithm which we will train by estimated times we have. Then, trying to predict times not only for first and last stop, but for any missing stop in the trip. We can use like regression models. We have enough points for training hence building such a model will not be hard or complicated. Another way to estimate the first stop time is just trying to get just the time of first trip in the beginning of each day, thus we can build times for all next trips since we know a bus moves from the first stop every 15 minutes. This way is easier since the system can inform us by only the first trip time every day.

What is most important future work should be done is using different approach from what we used to compare results and investigate which one is better. We can use different clustering algorithm such as k-mean and use elbow method to detect what number of clusters gives us most correct estimations. We should also use other prediction methods other than linear interpolation. Trying different approaches will give us more insights about the data and which approach should be used for more analysis.

We believe what we could achieve will help to address limitations and overcome challenge that current transportation system is facing. It also will encourage them to increase the quality of collecting data. Our analysis is just the beginning for more useful application.

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