Evaluating Miami-Dade Transit's On-time Performance

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We conducted an analysis of Miami-Dade Transit's on-time performance using GTFS data as well as data acquired from the Swiftly API from October 2022 to March 2023. During this period, there are 99 routes running in total, including Metrorail, trolleys, Metromovers, and transit buses. We computed the daily service time for each route and the daily number of transit vehicles serving each transit stop to understand the transit service supply. We applied two measurements for analyzing the on-time performance of transit vehicles: arrival time difference and headway difference. The major findings of this analysis include:

1. Route 119, MMO, 2300 and Metrorail have the longest service hour, while routes 301 and 302 have the shortest.
2. Weekdays tend to have longer delays than weekends. Transit vehicles often delay for over 15 minutes during afternoon peak hours (4-7pm) on weekdays.
3. Route 132 is the worst route in times of on-time performance whereas Route 155 and 286 appear to have the best on-time performance.
4. Late trips mostly happen in Miami downtown and Miami Beach. For most delayed routes, delay usually happen at the beginning or end of the bus routes.
5. The number of buses during peak hour is positively correlated with passenger ridership. The passenger waiting time is positively correlated with the route's total length.

1. Data

The main data sources used in this study include the on-time performance data, speed data, ridership data, and GTFS static. Both the *on-time performance data* and *speed data* are collected through Swiftly APIs from October 2022 to March 2023 for Miami-Dade Transit. On-time performance data provides schedule-adherence information on all routes in the system (e.g., scheduled arrival time, actual arrival time, and their arrival time differences). This dataset also includes detailed trip information such as arrival stops, vehicle ID, bus routes, direction, trip destination, stop sequence, as well as status (delay or not). Speed data is collected at the route and stop segment level, including travel distance, travel and dwell time. *Ridership data* is requested from Miami-Dade DTPW, which includes daily and monthly ridership of all bus routes, rail stations, and metromover stations. *GTFS static data* contains planned itineraries including transit routes, stops, and trip schedules. The GTFS static data can be compared to the on-time performance data to show the difference between actual trips and scheduled trips, especially in terms of daily transit service time and daily number of transit vehicles serving each stop.

2. Methods

We first provide an overview of the **daily transit service time** and the **daily number of transit vehicles serving each stop**. To calculate the daily transit service time, we grouped the on-time performance data by *date, route_id*, and *trip_id*, then calculate the trip length by subtracting the *maximum and minimum*

actual arrival time of each group. We added all the time differences by *date* and *route_id* to get the operating time across dates and routes. We computed separate measures for weekdays and weekends.

To calculate the daily number of transit vehicles serving each stop, we grouped the on-time performance data by *date* and *stop_id* then count the *trip_id*. We then computed the average daily trip counts by each stop.

To compare the actual situation with the scheduled operations, we also calculated the **planned daily transit service time** and **the planned daily number of transit vehicles serving each stop** based on the GTFS Static data. We merged the files in the GTFS static dataset into a table as Figure 1 shows and repeated the similar calculation process for the on-time performance data.

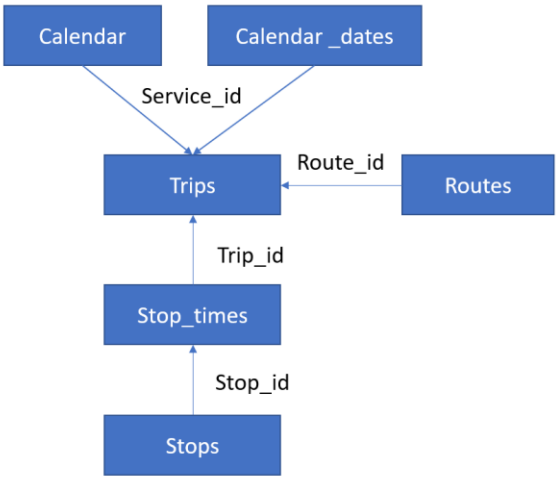


Figure 1. GTFS dataset table integration

We then evaluated on-time performance by first measuring the difference between scheduled and actual arrival time (to be termed as **arrival time difference**). This measure reflects the experience of passengers who checks the train/bus schedule. We conducted the on-time performance on route level by routes, day of time, weekday or weekend, and different route types.

A second measurement of on-time performance assesses the difference between actual headway and scheduled headway (to be termed as **headway difference**). The headway is calculated by finding the time difference between two continuous trips with the same destination, passing by the same stop on the same route and on the same date. The headway difference measures the experience for passengers who do not check the transit schedule but have some sense of the headway of the routes they take. If the transit system has perfect on-time performance, the headway difference value should be close to 0 with little variation (i.e., the actual bus operation strictly follows its schedule).

3. Transit service supply measures

3.1 Daily transit service time

Figure 2 shows the daily number of vehicle trips for each route. Metromover (MMI, MMO), Metrorail (2300) and rail are the top modes that have the highest number of trips. On the contrary routes with the lowest number of trips include route 302, 301, 136, 200 and 246.

Figure 3 shows the average daily transit service time on each route and the service time variation by weekdays and weekends for *actual operations*, while Figure 4 shows the average daily transit service time on each route for *scheduled operations*. The service time of bus routes varies significantly, with a few routes typically operating more than 200 hours in total (route 119, 2300, and railway on weekdays; route MMO and 119 at weekends) while some only run for a few hours (for example, routes 301 and 302 operate for less than an hour per day). The service time of some routes fluctuates greatly, for example, routes 120 & 112 at weekends and route 11 on weekdays.

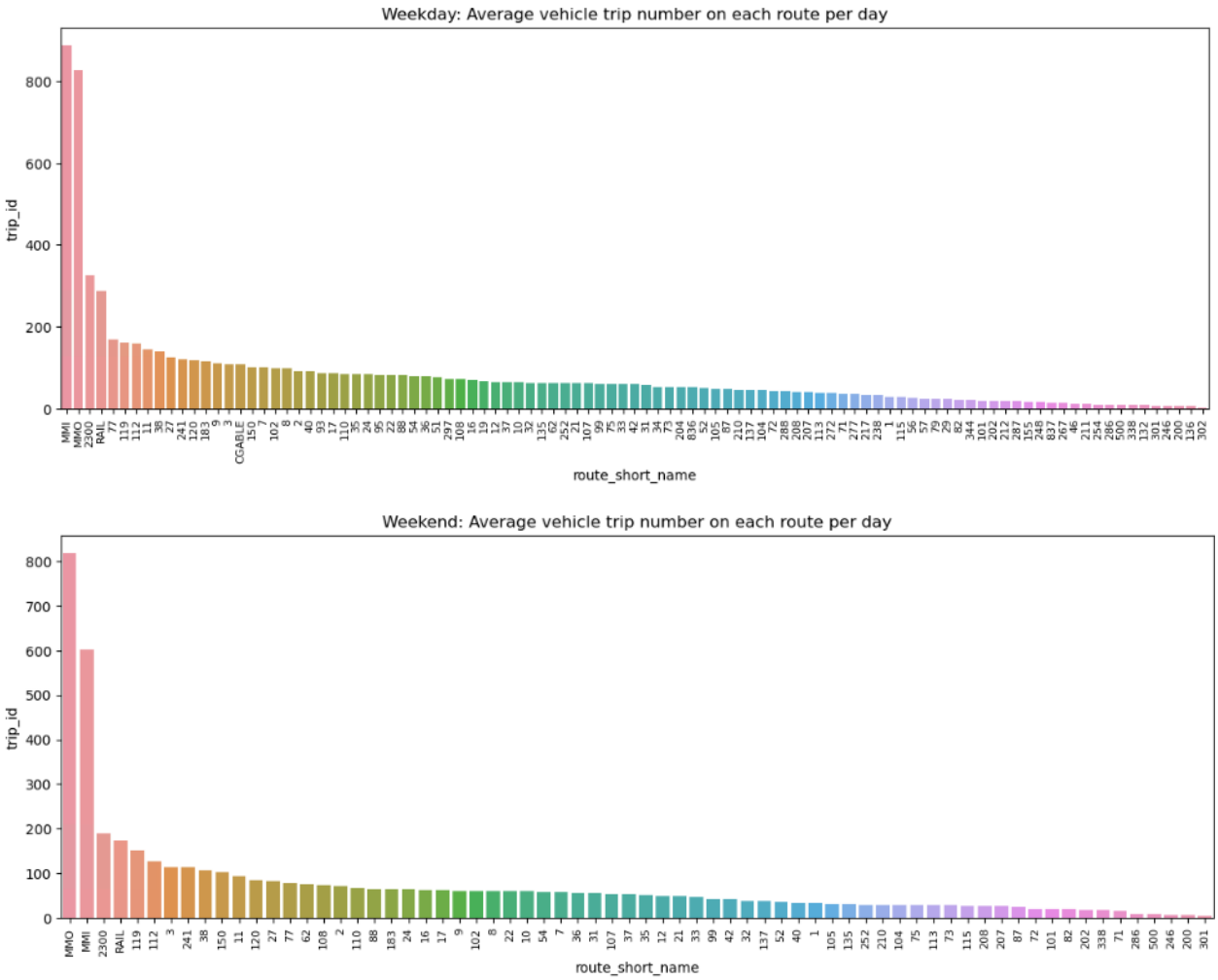
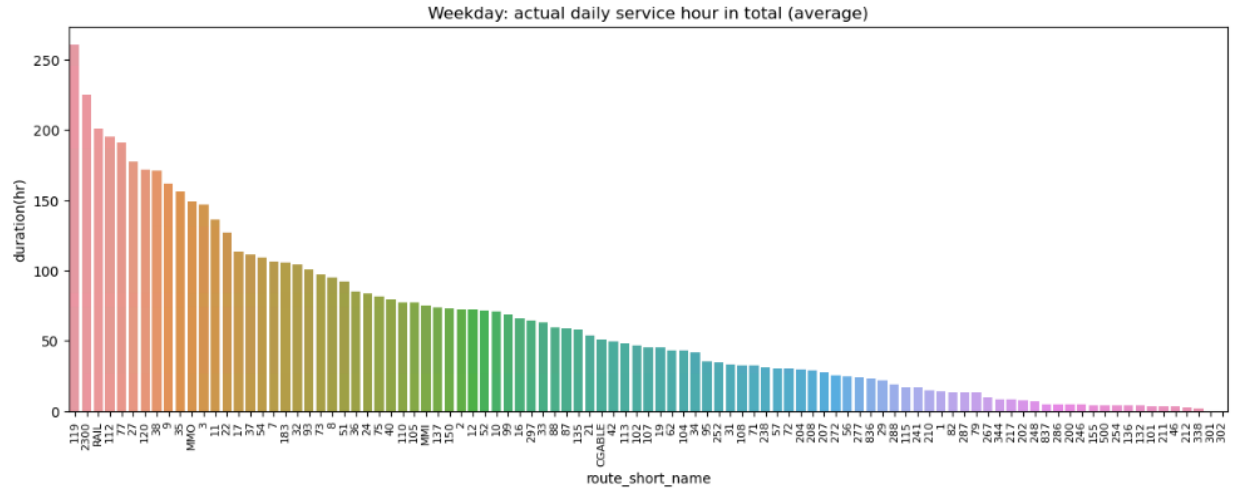
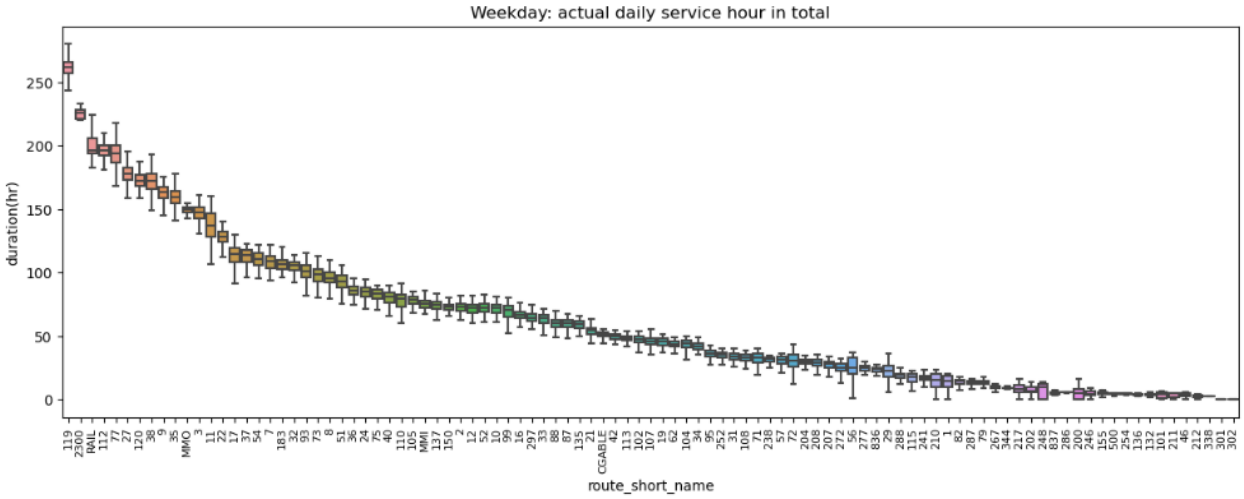
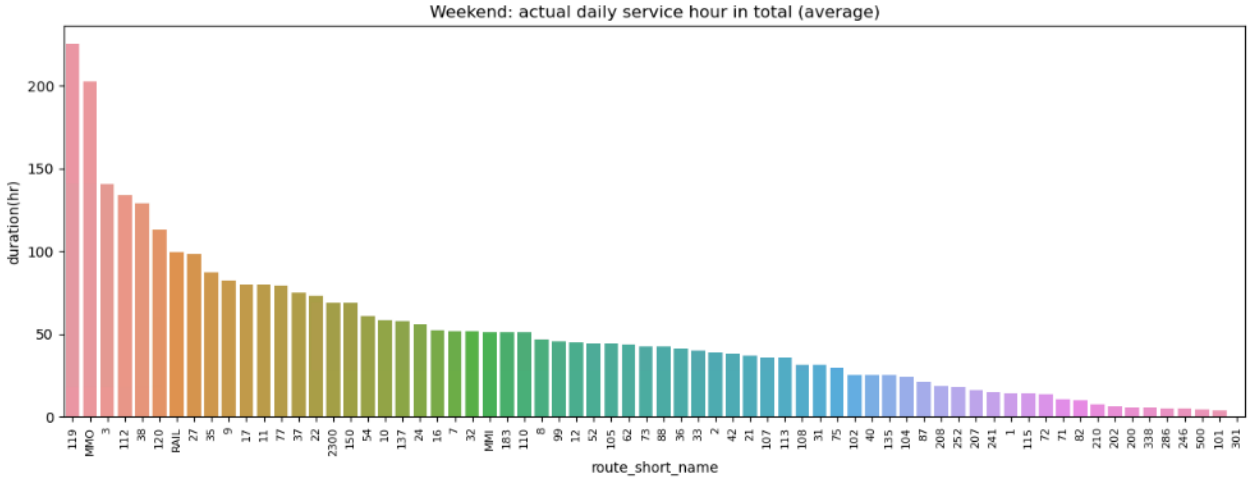


Figure 2. The daily number of vehicle trips for each route


Weekday: actual daily service hour in total (average)
duration(hr)
route_short_name


Weekday: actual daily service hour in total
duration(hr)
route_short_name


Weekend: actual daily service hour in total (average)
duration(hr)
route_short_name

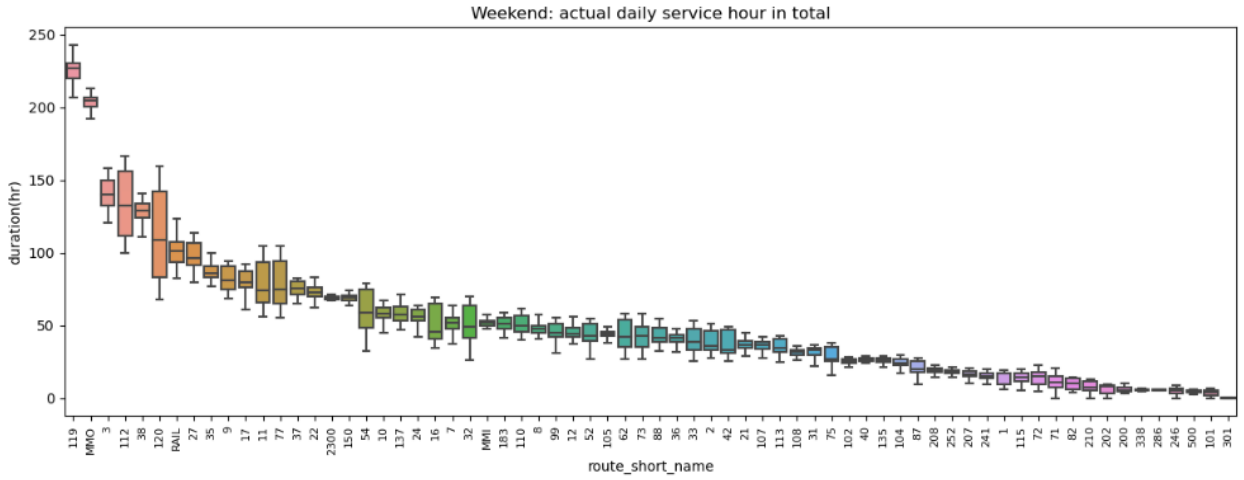


Figure 3. bus service hour by weekday and weekend

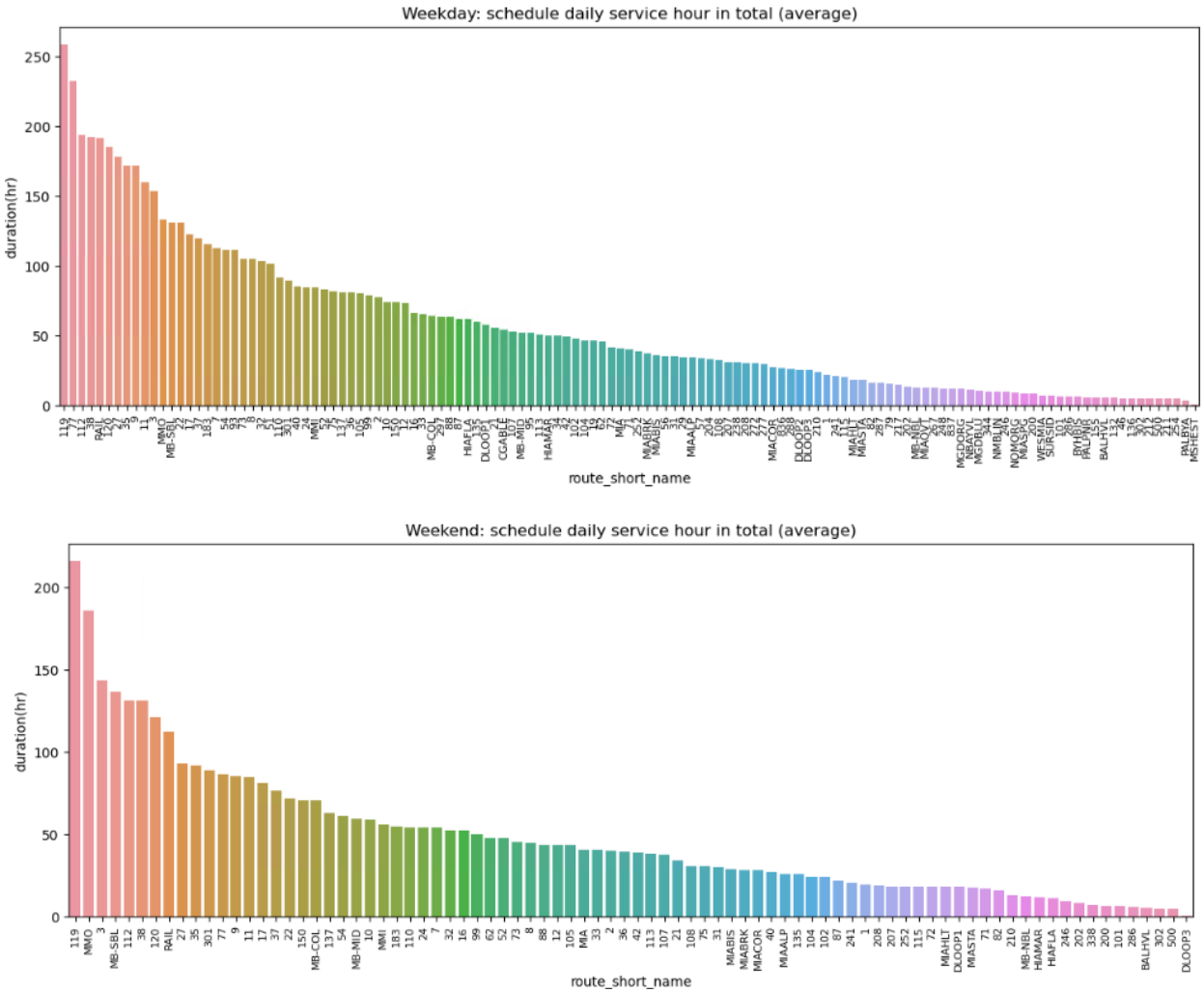


Figure 4. scheduled daily hour by weekday and weekend

Table 1 summarizes the top 10 routes with the longest or shortest service time during scheduled and actual operations for weekdays and weekends.

Table 1. Top 10 routes with the highest and lowest service hours

weekdays

top 10 routes with highest service hour				top 10 routes with lowest service hour			
actual		schedule		actual		schedule	
route name	service hour	route name	service hour	route name	service hour	route name	service hour
119	260.60	119	258.07	254	4.23	132	5.23
2300	225.16	77	232.06	136	3.94	46	5.00
RAIL	201.14	112	193.46	132	3.91	136	4.80
112	195.22	38	192.21	101	3.63	302	4.67
77	191.39	RAIL	191.52	211	3.58	212	4.62
27	177.30	120	184.76	46	3.46	500	4.58
120	171.78	27	177.57	212	2.71	211	4.53
38	171.45	35	171.69	338	2.30	254	4.40
9	162.02	9	171.68	301	0.12	PALBYA	3.37
35	156.53	11	159.61	302	0.04	MSHEST	0.80

weekends

top 10 routes with highest service hour				top 10 routes with lowest service hour			
actual		schedule		actual		schedule	
route name	service hour	route name	service hour	route name	service hour	route name	service hour
119	224.96	119	215.71	82	9.658782	200	10.60
MMO	202.32	MMO	186.12	210	7.599129	246	9.33
3	140.40	3	143.38	202	6.193729	202	8.11
112	134.06	MB-SBL	136.64	200	5.41317	338	6.78
38	128.80	112	131.19	338	5.311554	101	6.30
120	112.87	38	131.09	286	4.748727	286	5.87
RAIL	99.45	120	121.33	246	4.681677	BALHVL	5.26
27	98.00	27	92.98	500	4.571202	302	4.67
35	87.12	35	91.50	101	3.493574	500	4.58
9	82.05	301	88.99	301	0.088034	DLOOP3	0.58

3.2 Daily number of transit vehicles serving each stop

We computed the daily number of transit vehicles going through each transit stop based on both actual and scheduled operations. Results are shown in Figure 5. Most stops have less than 50 buses passing by, whereas some stops in Miami Beach and downtown Miami have more than 500 transit vehicles serving them each day. At some stops at Miami beach and Miami downtown, the number of actually dispatched buses passing through is less than the number of scheduled buses.

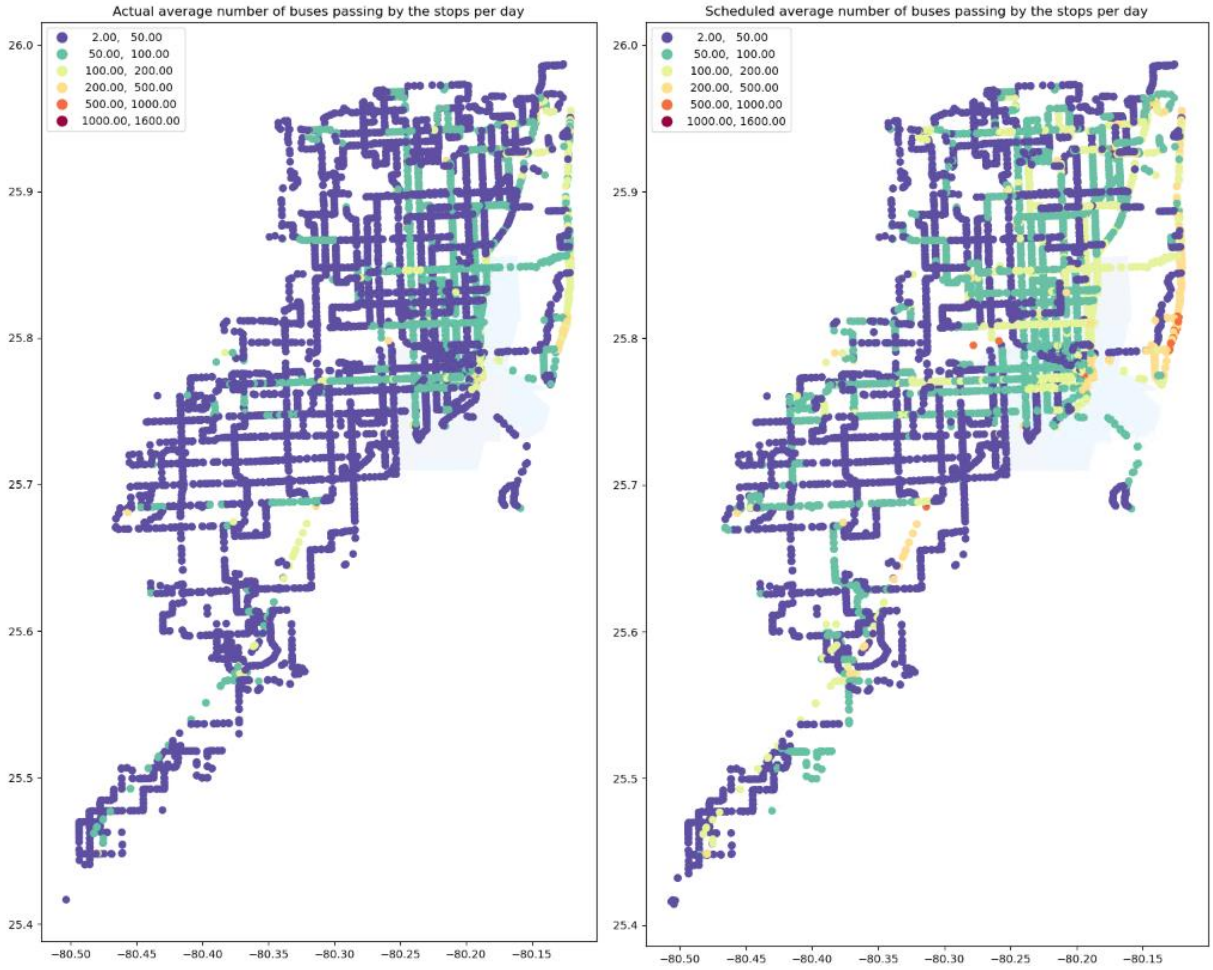
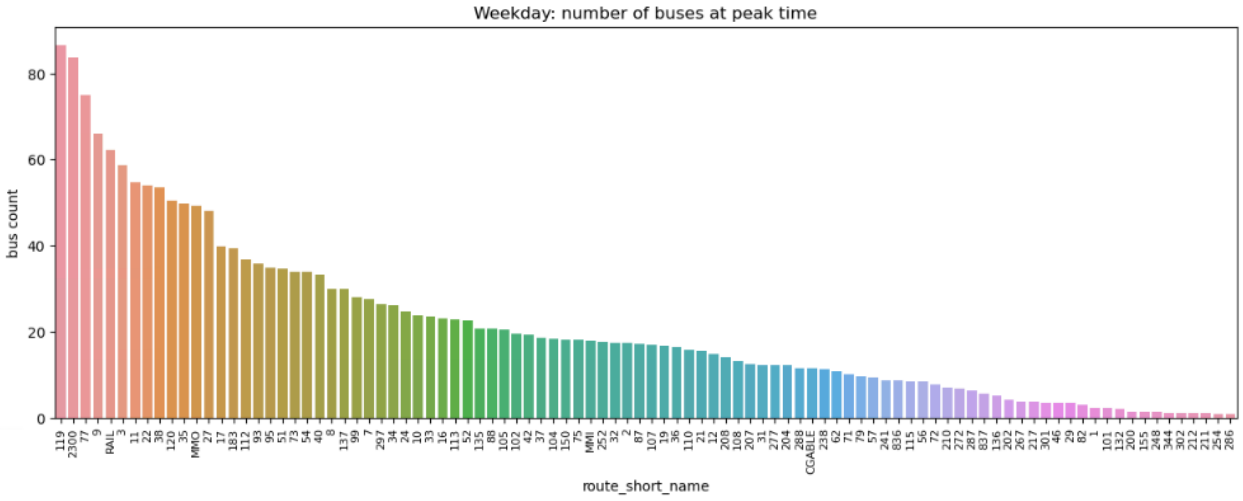


Figure 5. Actual and scheduled daily number of transit vehicles serving each stop

3.3 Daily number of vehicles operating in peak hours

The number of transit vehicles running during peak times (6:30-9:30 am and 4:30-7:30 pm) is shown in Figure 6 and Table 2.



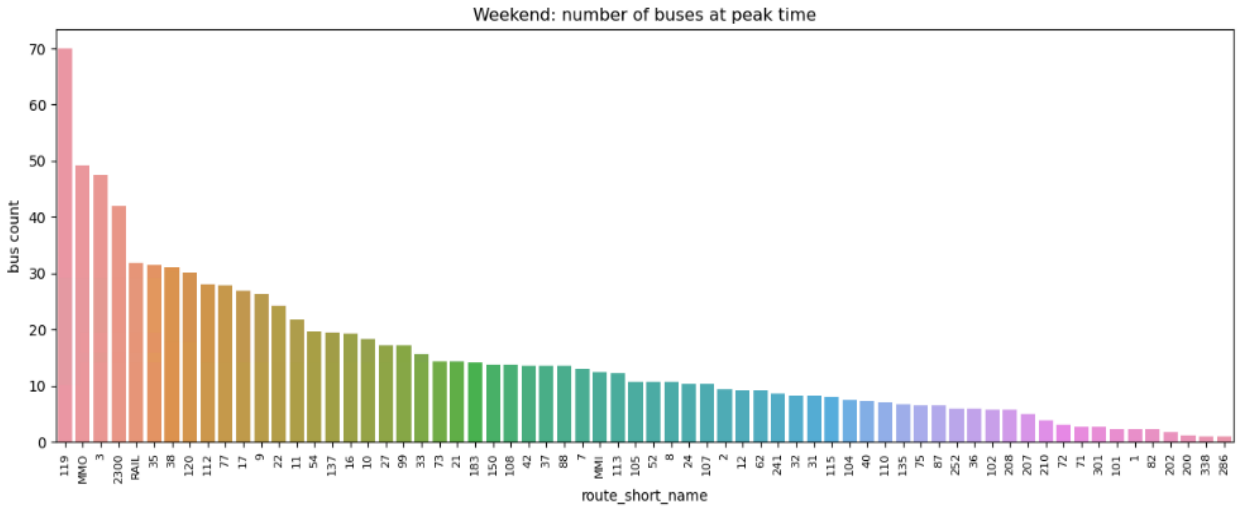


Figure 6. number of buses during peak times (6:30-9:30 am) and (4:30-7:30 pm)

Table 2. routes with most/least bus counts during the peak time

weekday			
top 10 most		top 10 least	
route name	average bus count	route name	average bus count
119	86	132	2
2300	84	200	1
77	75	155	1
9	66	248	1
RAIL	62	344	1
3	59	302	1
11	55	212	1
22	54	211	1
38	53	254	1
120	50	286	1

weekend			
top 10 most		top 10 least	
route name	average bus count	route name	average bus count
119	70	72	3
MMO	49	71	3
3	48	301	3
2300	42	101	2
RAIL	32	1	2
35	32	82	2
38	31	202	2
120	30	200	1
112	28	338	1
77	28	286	1

4. Arrival time difference

4.1 Arrival time difference by routes

We visualize the distribution of the arrival time difference across transit routes using a boxplot in Figure 7. The median line of each box represents the median arrival time difference for all trips of a transit route. The length of the "box" for each transit route indicates the variation in arrival time difference; the longer a box is, the more uncertain the arrival time. The horizontal red line denotes the 0 value of arrival time difference, which is compared with the median value of each 'box'. Ideally, the median arrival time difference should be close to the red line. Transit routes such as **Route 286 and Route 155** have an arrival time difference close to zero and a low variation in arrival time, which means that they have the best on-time performance. By contrast, the worst performing transit routes are routes **302, 29, and 57**. The arrival time of these routes fluctuates a lot, with a high frequency of delays.

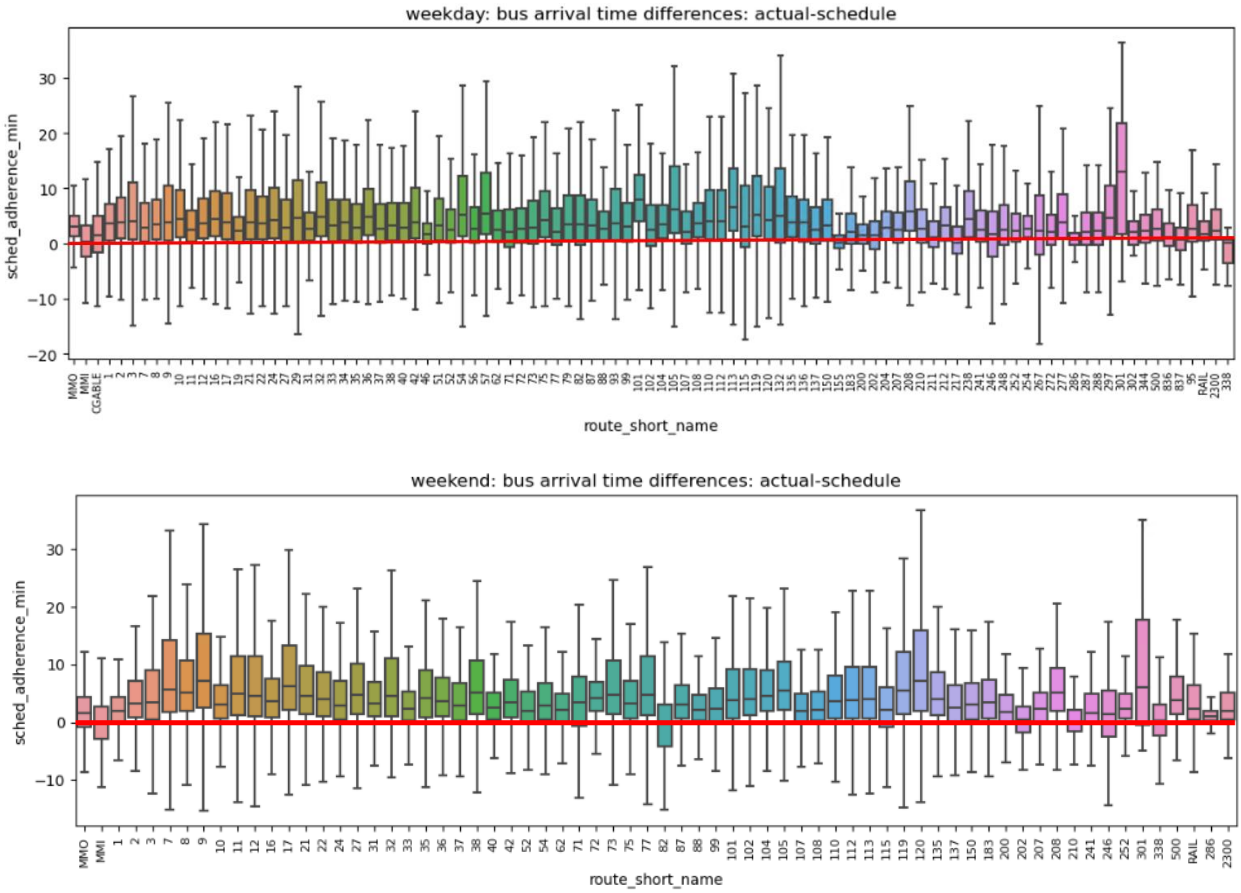


Figure 7. The arrival time difference and arrival uncertainties of all transit routes

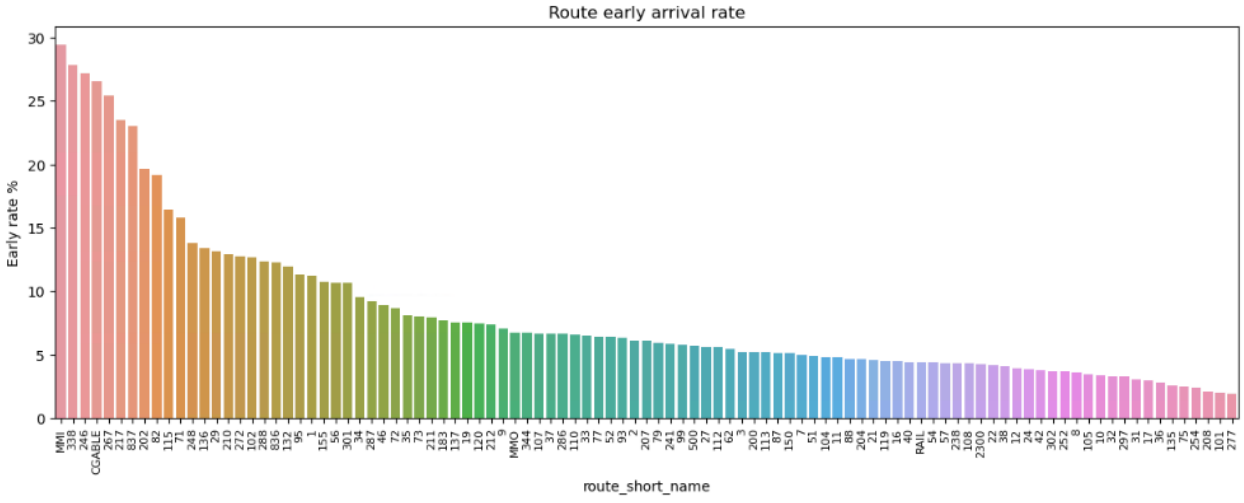
Table 3 shows the top 10 best and worst routes with the best on-time performance according to the arrival time difference measure.

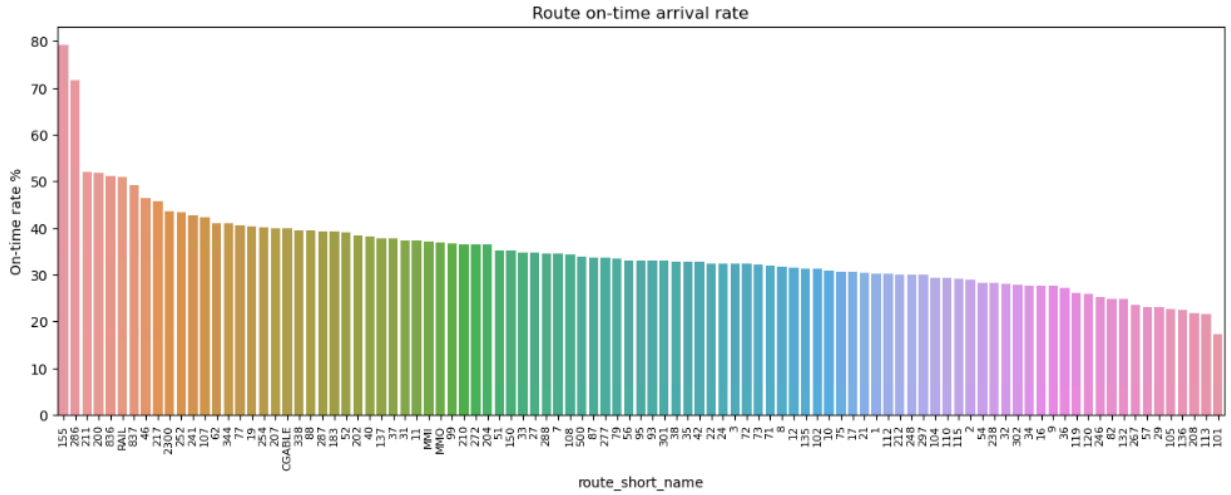
Table 3. the top/worst on-time 10 routes (measured by arrival time differences)

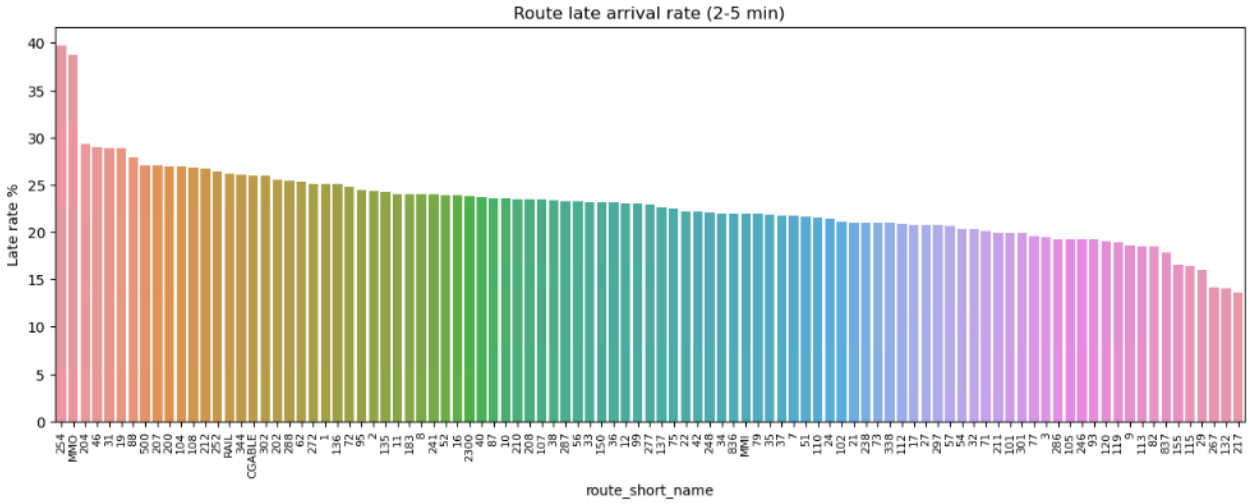
weekend			
top 10 best routes		top 10 worst routes	
route name	average arrival time difference	route name	average arrival time difference
82	0.03	120	10.81
MMI	0.13	9	10.25
210	0.50	7	9.67
202	0.70	17	9.14
338	0.73	119	8.55
286	1.23	301	8.46
246	1.39	77	8.34
MMO	1.91	11	7.96
1	2.38	12	7.92
88	2.98	8	7.90

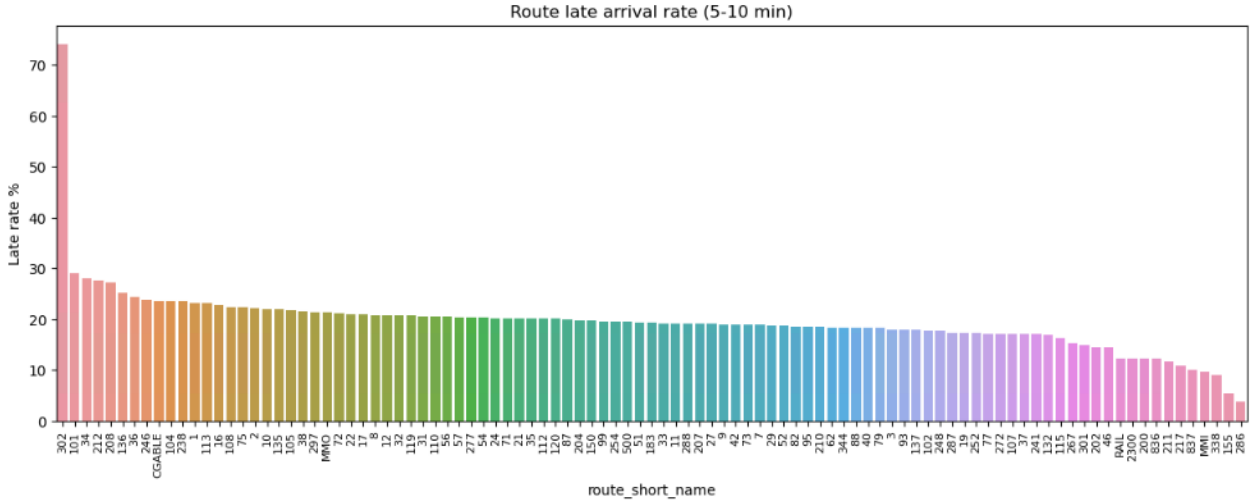
weekday			
top 10 best routes		top 10 worst routes	
route name	average arrival time difference	route name	average arrival time difference
338	-1.45	301	12.49
837	0.30	113	9.97
155	0.70	101	9.75
MMI	0.89	105	9.42
286	1.02	132	9.09
246	1.52	119	8.61
202	1.60	57	8.60
217	1.71	54	8.15
836	1.88	3	8.06
CGABLE	1.99	208	7.99

We then visualized the proportion of vehicle trips are needed for various arrival time difference on each route in Figure 8: <=-2min, on time (-2 to 2 min), 2-5 min, 5-10 min, 10-30 min, >=30 min. Routes with the top 5 highest/lowest proportion are summarized in the Table 4.




Route on-time arrival rate
On-time rate %
route_short_name


Route late arrival rate (2-5 min)
Late rate %
route_short_name


Route late arrival rate (5-10 min)
Late rate %
route_short_name

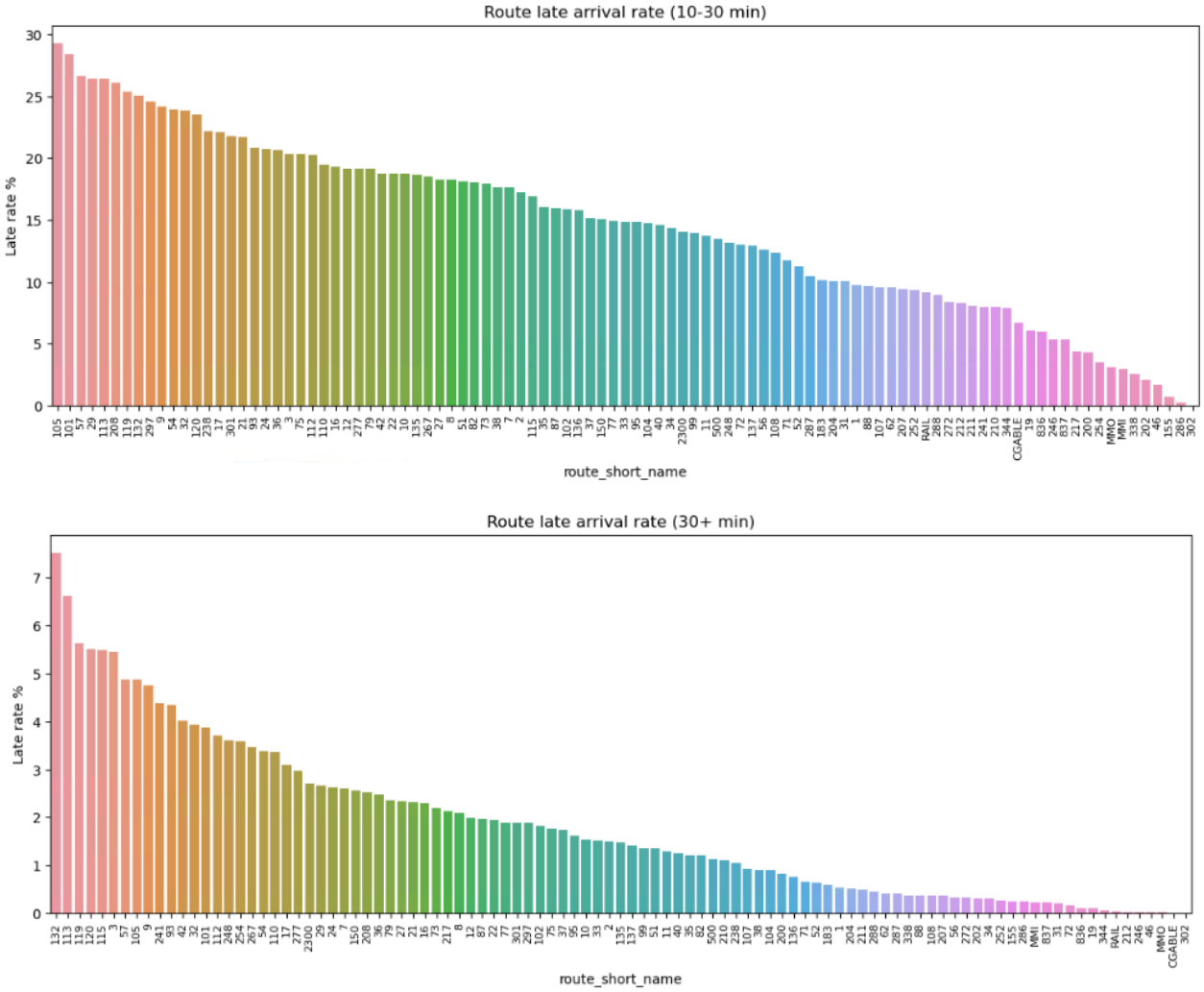


Figure 8. proportion of buses arrive late for different periods.

Table 4. routes with the highest or lowest proportion of different arrival time difference ranges

arrival time difference	routes with highest rate	routes with lowest rate
<=-2 min	MMI, 338, 246, CGABLE, 267	217, 101, 208, 254, 75
on time (-2 to 2 min)	155, 286, 211, 200, 836	101, 113, 208, 136, 105
2-5 min	254, MMO, 204, 46, 31	217, 132, 267, 29, 115
5-10 min	302, 101, 34, 212, 208	286, 155, 338, MMI, 837
10-30 min	105, 101, 57, 29, 113	302, 286, 155, 46, 202
30 min +	132, 113, 119, 120, 115	302, CGABLE, MMO, 46, 246

The on-time performance measures for the system, metro bus, trolley, metro trail, and metromover, are visualized in pie charts as Figure 9. Only about 33% of the whole system trips have good on-time performance. About 60% trips have different extent of delays. Among different transit modes, rail has the best on-time performance, as about half of its trips arrive timely.

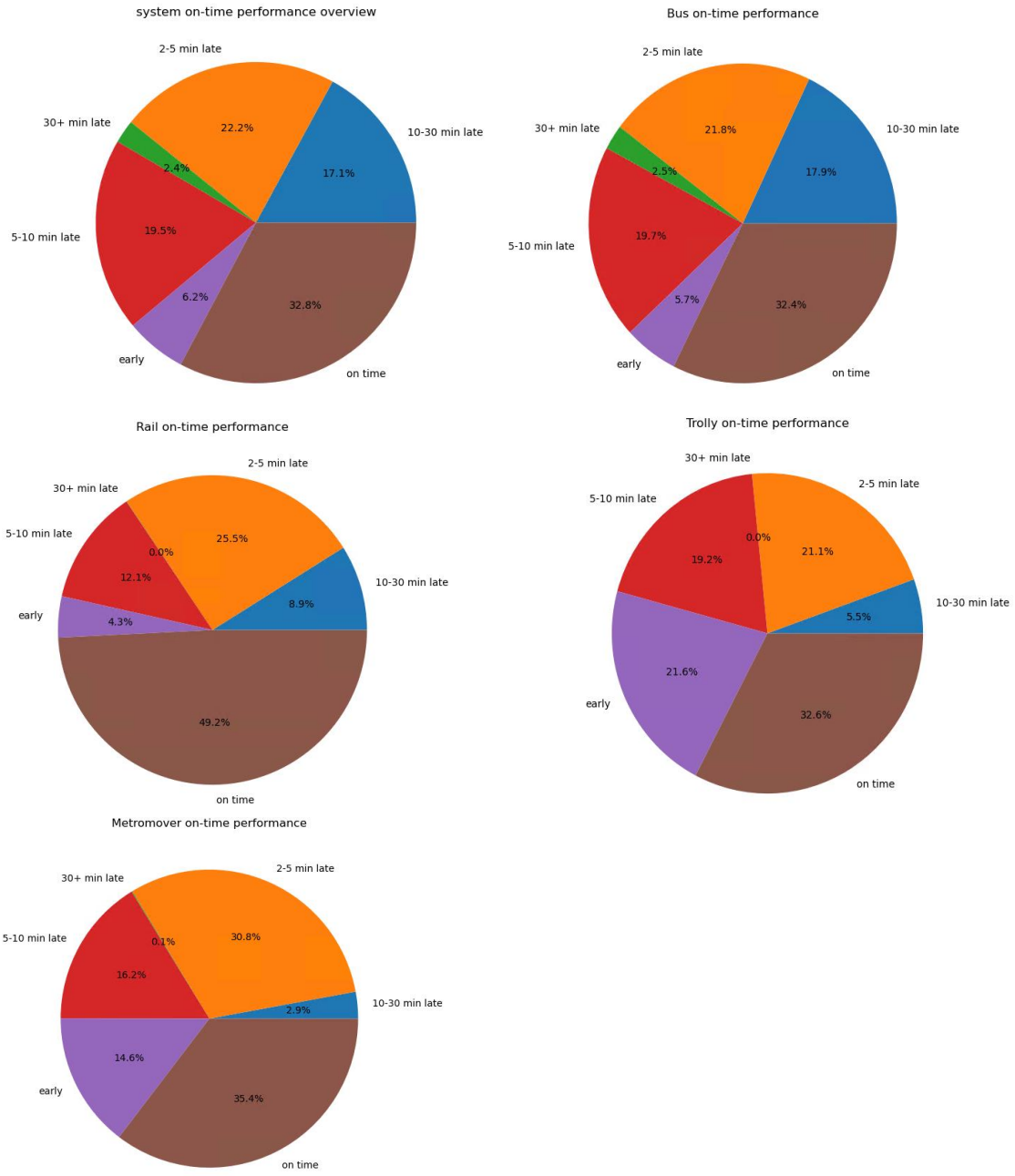


Figure 9. pie charts of on-time performance proportion

We created a correlation plot and found a positive correlation between route length and arrival time difference: passengers may wait longer for routes with longer distance and vice versa (Figure 10).

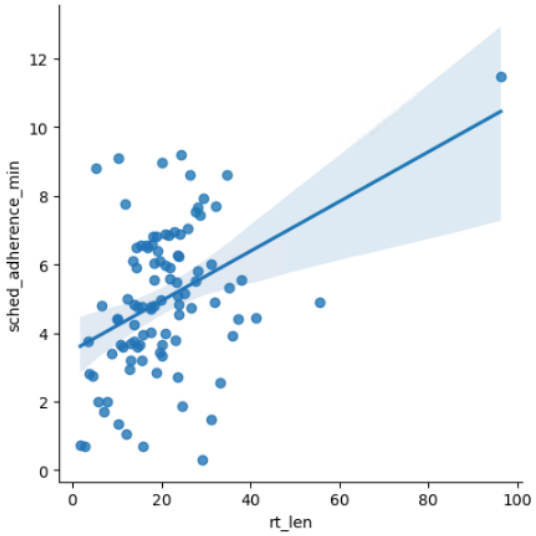


Figure 10. positive correlation between route length and arrival time difference

Specifically, we may care more about dedicated routes: route 38, 51, and 120. So we visualized the number of buses arrive late for different period in Figure 11. Table 5 summarizes the following information of dedicated routes: route length, speed, daily service hours, daily trips, daily peak hour, arrival time difference and headway difference.

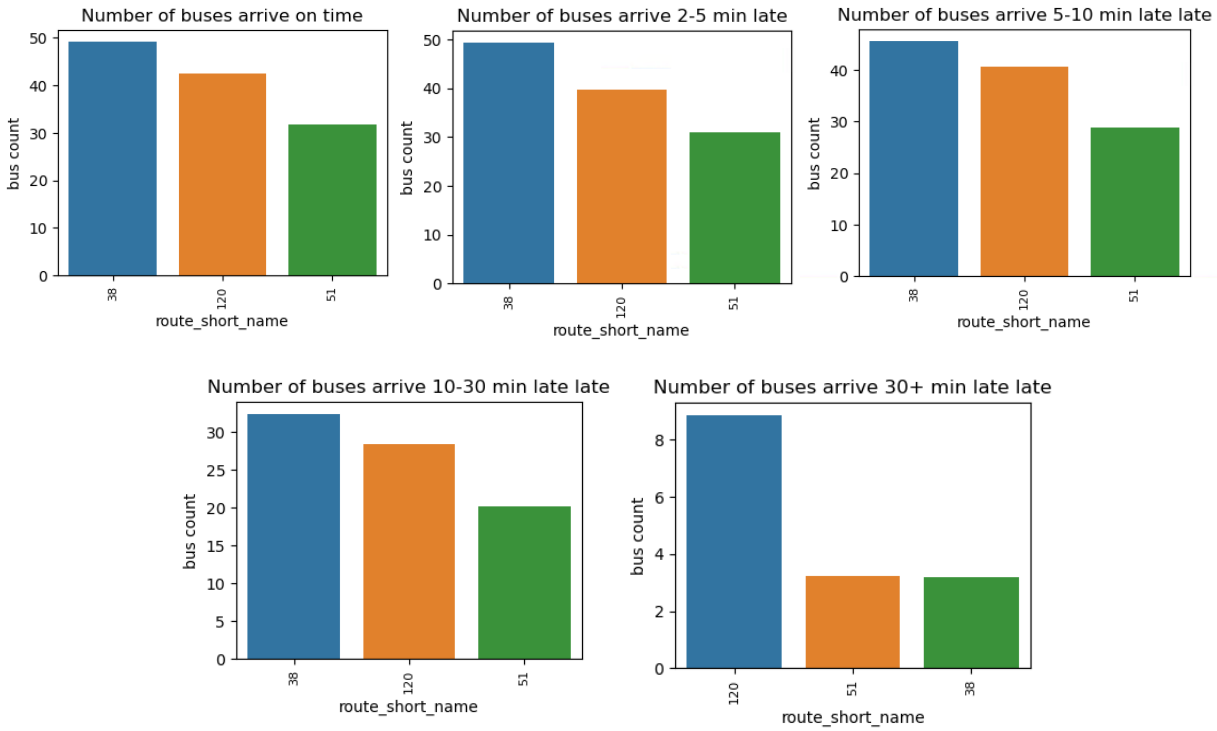


Figure 11. number of buses on dedicated routes arrive late for different periods.

Table 5. on-time performance and trip information of dedicated routes

Route ID	route length (km)	speed (km/h)	daily service hour	daily trips	daily peak hour trips	arrival time difference	headway difference
38	35.31	26.11	159.20	130.18	74.27	5.31	-0.11
120	29.39	19.69	154.95	108.09	65.56	7.94	0.22
51	27.70	21.25	92.16	77.13	56.21	5.52	0.10

4.2 Arrival time difference by time of day and by weekday/weekend

To further analyze when delay or early arrivals happen for each route, we generated pivot tables showing the mean arrival time differences by route and hour in Figure 12. The pivot table can summarize the on-time performance dataset by grouping and aggregating the arrival time differences by hour and route. The x-axis shows the hour of day, and the Y-axis shows the route_id. The average arrival time difference is filled at the cells. As the colormap on the right shows, red zones denote that the buses have been delayed on average for more than 20 minutes. Orange zones represent the bus delayed on average for 15-20 minutes and yellow zones for 5-10 minutes. Cyan zones (lighter color zones) represent very small arrival and actual time differences and suggest that the buses perform on-time. Blue zones represent early arrival at 5-10 minutes. For each route, having more cells in with lighter color (cyan zones) indicates better on-time performance. The Figure 12 shows that weekdays tend to have more and longer delayed trips than weekends, and transit vehicles frequently arrival early during the weekends. Transit vehicles often delay for over 20 minutes during afternoon peak hours (4-7pm) especially on weekdays.

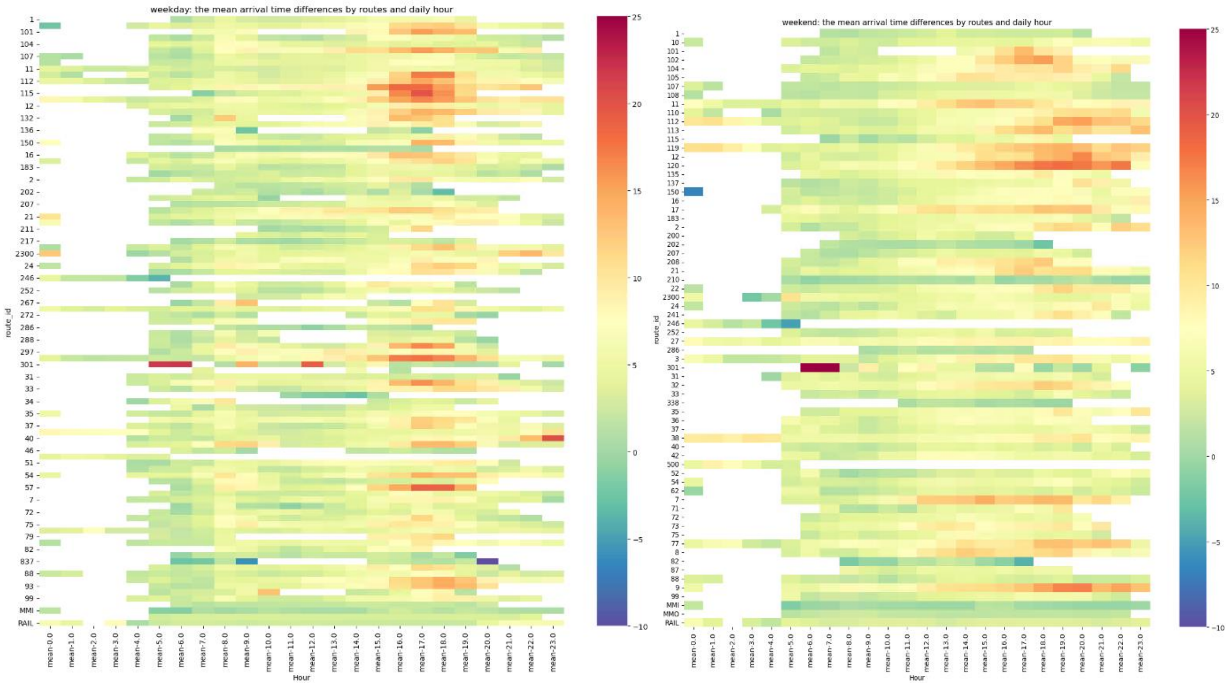


Figure 12. pivot table of mean arrival time differences by routes and daily hour by weekdays and weekends

4.3 Arrival time differences by route types

In this section, the arrival time differences are measured by different route types, including transit modes, operators and routes with different headways in Figure 13. Among different transit modes, bus has the highest variation of arrival time difference and average highest arrival time difference at about six minutes, since bus occupies the highest proportion among all transit modes. Other travel modes have relatively smaller variation and lower average arrival time difference, which is lower than 3 minutes.

These routes can then be categorized based on the headways (0-10 min, 10-20 min, 20-30 min, 30-40 min and 40+ min). The routes with the highest headways (40+ min) also have the higher average arrival time difference with higher variation, while routes with 10-20 min headway have the smallest arrival time difference with smaller variation.

Private and public routes are categorized: 1, 29, 46, 56, 71, 72, 82, 101(A), 115,155, 202, 210, 211, 212, 217, 246, 248, 254, 267, 272, 286, and 344 are privatized routes while others are public. Both the average arrival time difference and the variation of private routes is slightly smaller than the public routes.

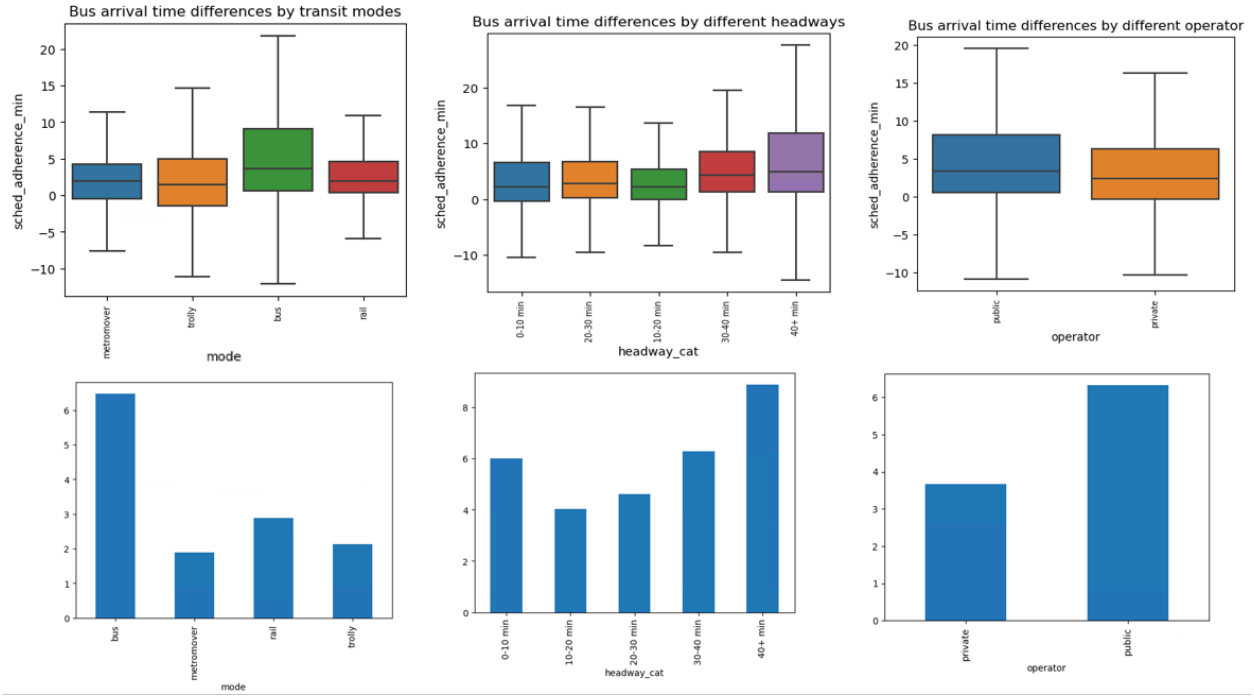


Figure 13. Arrival time differences by different route types

4.4 Early or late arrival rate by stops

In Figure 14, we map the proportion of early or late arrival (for 5 minutes or more) at each stop to visualize where early or late arrivals typically happen. The colormap represent the percentage oor late arrival at stop level. On the left, most stops appear to dark blue, which means that these stops have close to 0 percent of early arrival rate. On the right, blue stops suggest that these stops have less than 10% of late arrival trips, but very few stops have an ideal on-time performance rate. This plot appears

mostly in yellow and green, which suggests that at most stops have a delay rate of 30-40%. Notably, some red and orange stops have a very high delay rate at 60-80%.

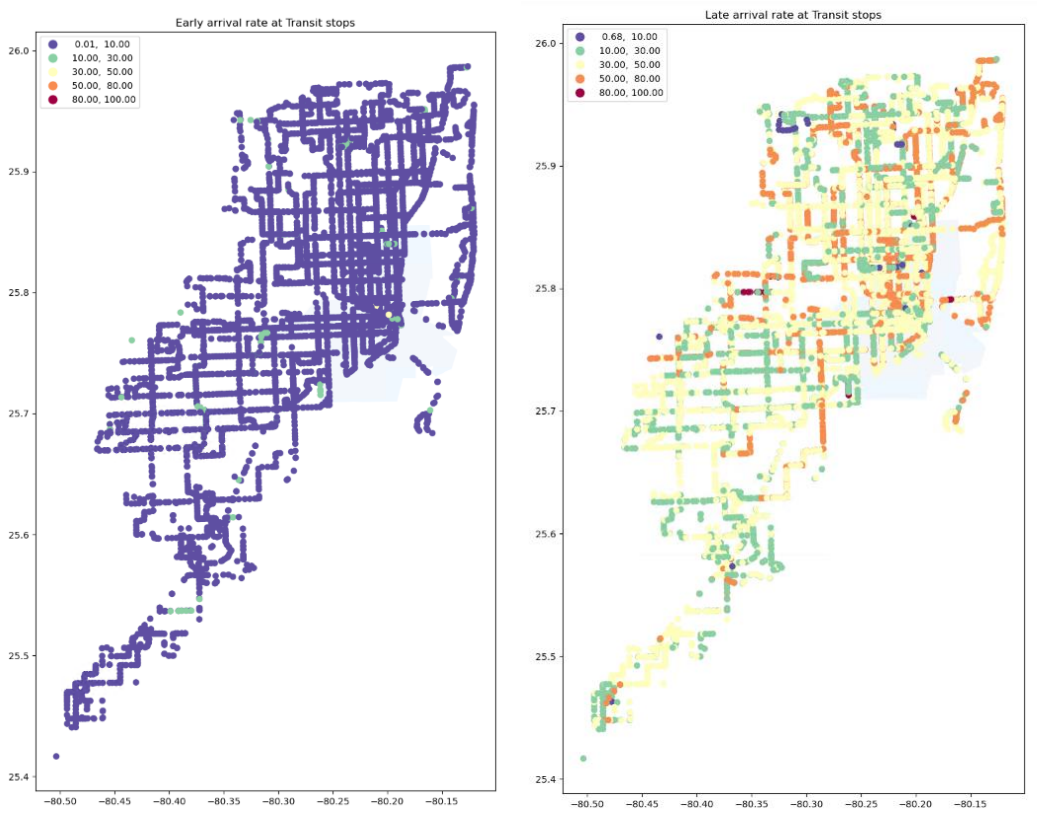


Figure 14. Early and late arrival rate at stop level

4.5 Arrival time difference by route and stops

From the above analysis, routes 105, 29, 132 and 113 are most delayed routes. To explore where delay usually happens, we visualized the arrival time difference by routes and stops in Figure 15, where red zones suggest the highest arrival time difference along this route, while green zones represent the lowest. Delay trips usually cluster at the beginning or the end of the routes.

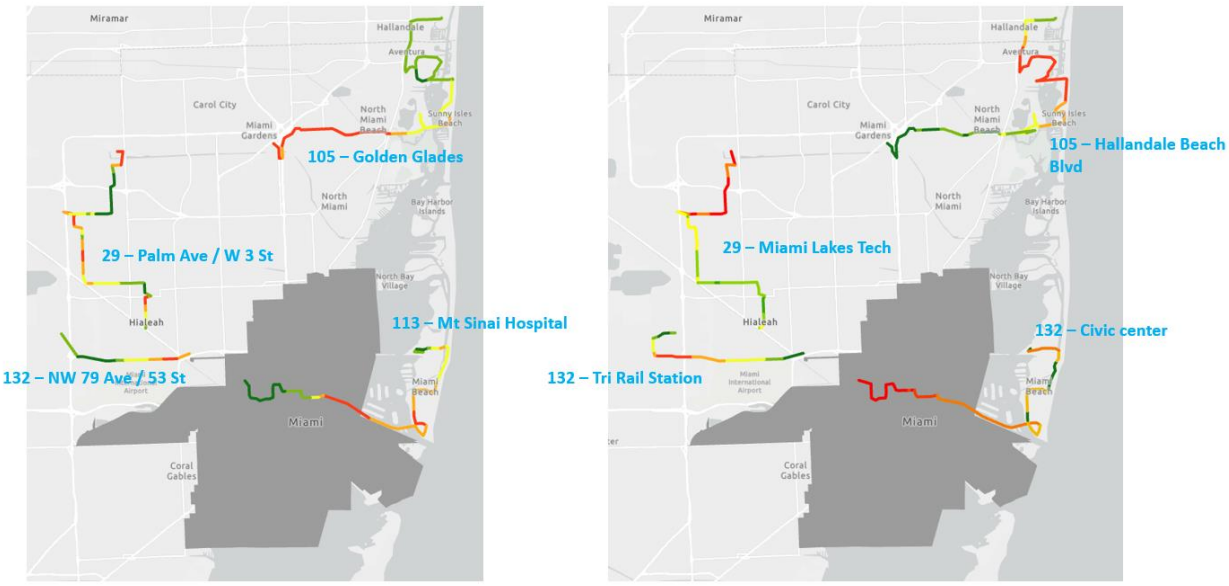
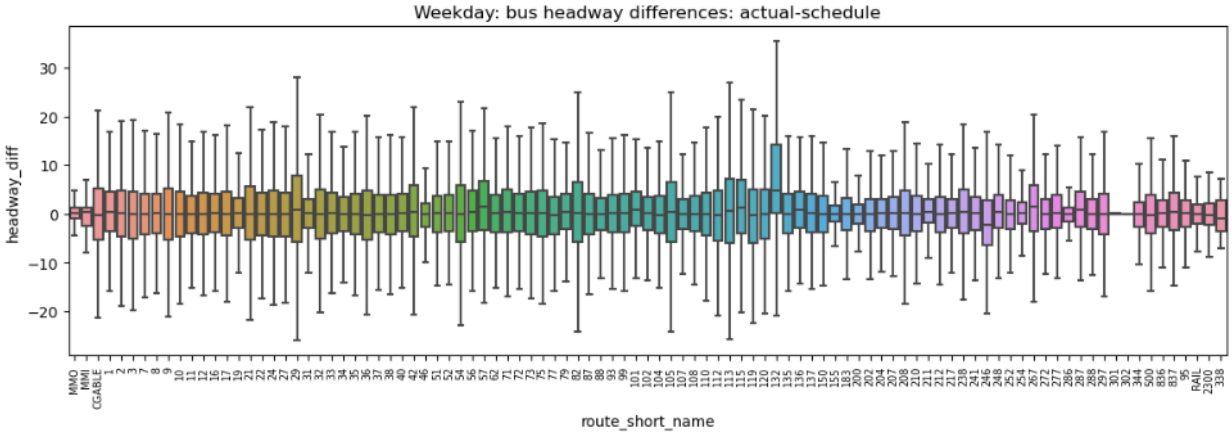


Figure 15. Average arrival time difference by most delayed routes and their stops

5. Headway difference

5.1 Headway difference by routes

Like section 4.1, the headway differences of all the routes are visualized in Figure 13. Routes with the best on-time performance should have a median headway difference value close to 0 as well as a low variance in this value, such as route 286, 301 and 302 The mean of the difference between the actual and scheduled headway for most routes is close to 0, but the difference has relatively high variation (±10-20 min), such as route 9, 29, 17 and 77. The headway difference of route 132 at weekdays is about 5 minutes, which suggests that the service of Route 132 is highly unreliable, with significant delays (sometimes for about an hour) at many stops. The on-time performance is slightly better during the weekend.



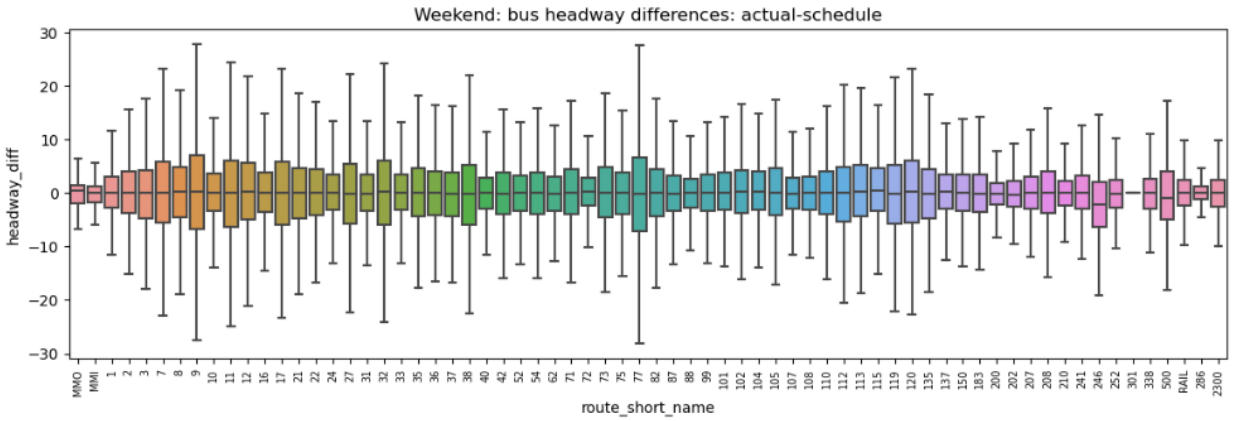


Figure 16. the headway difference between actual and schedule time by routes

5.2 Headway difference by routes and daily hour

We also generated pivot tables showing the mean headway differences by routes and daily hours to see when the transit service is stable. The colormap on the right represents the headway difference in minutes. Ideally, most regions should appear in yellow, as the headway difference should be close to 0. Red/orange zones represent that the actual headway typically exceed more than 10 minutes ahead of schedule headway, while blue zones represent that the actual headway typically lag behind the schedule headway for more than 10 minutes. According to Figure 17, the headway difference of weekend is slightly greater than the weekdays, suggesting more irregular transit arrivals at weekends. The headway difference does not vary greatly by hour. However, route 132 and 297 has a very high headway difference at more than 15 min on weekdays. At midnight, headway difference tends to enlarge as dark red and blue appears at 11pm-1am.

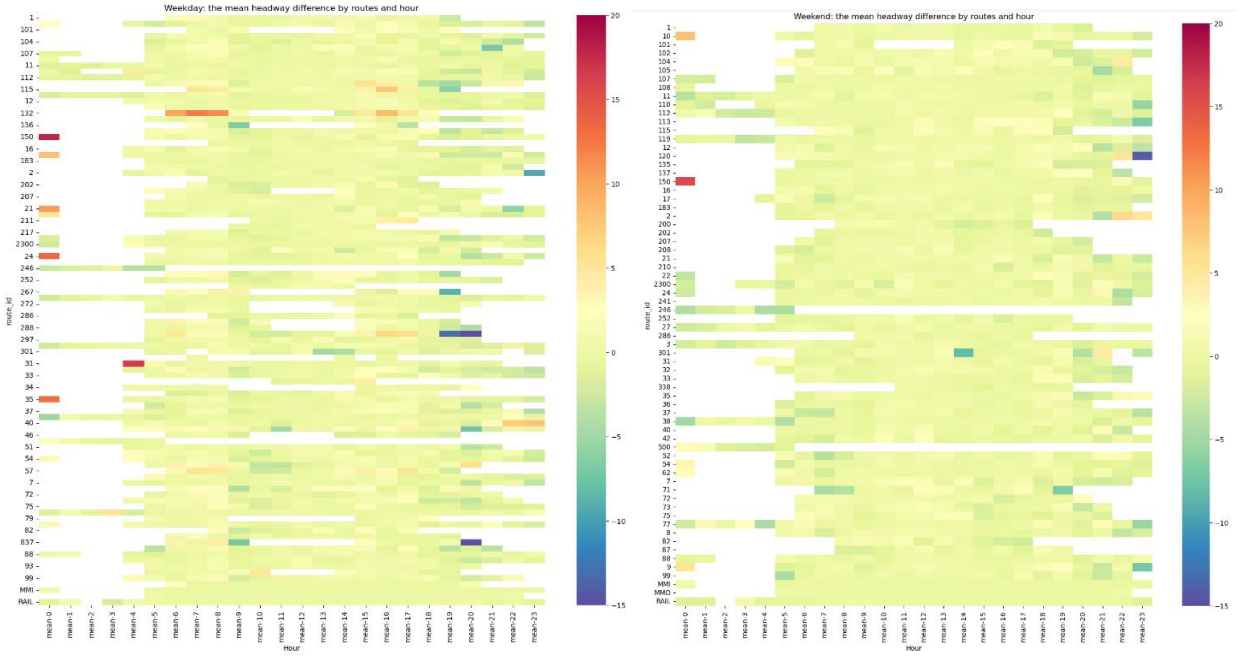


Figure 17. pivot table of mean headway differences by routes and daily hour

6. Vehicle speed

Finally, we analyzed the average bus route speed as Figure 18 shows. Fastest routes include route 302, 837 and 836 at about 50km/h, while slowest routes include route 155 and CGABLE as Table 5 shows. We are particularly interested in the following routes: 8, 208, 3, 93, 207, 11, 51, 150, 241, 120, 110. So we visualize them separately in Figure 19 and Table 6.

Table 5. top 10 fastest and slowest routes

top 10 fastest		top 10 slowest	
route	speed(km/h)	route	speed(km/h)
302	51.69	155	10.74
837	51.45	CGABLE	11.61
836	50.95	208	14.06
338	48.76	211	14.24
34	44.82	MMO	14.56
2300	44.16	207	15.07
RAIL	42.77	113	16.87
241	38.68	62	17.15
246	36.61	21	17.35
204	35.56	12	17.98

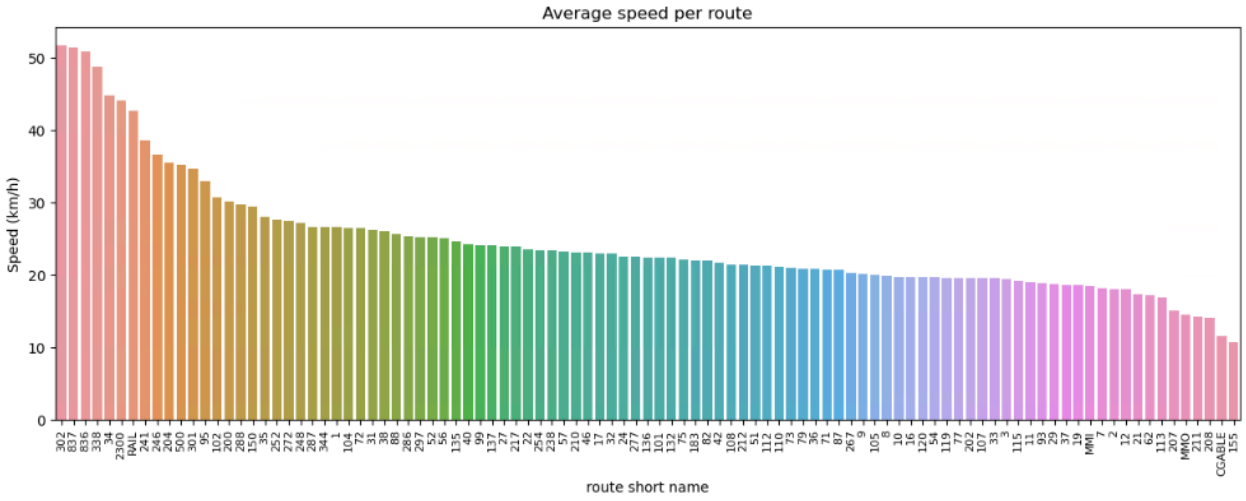


Figure 18. average speed (km/h) per route

routeShortName	spd
241	38.683773
150	29.457332
51	21.245122
110	21.207134
8	19.894427
120	19.693963
3	19.464585
11	18.963276
93	18.826988
207	15.069281
208	14.062841

Table 6. route speed of selected routes

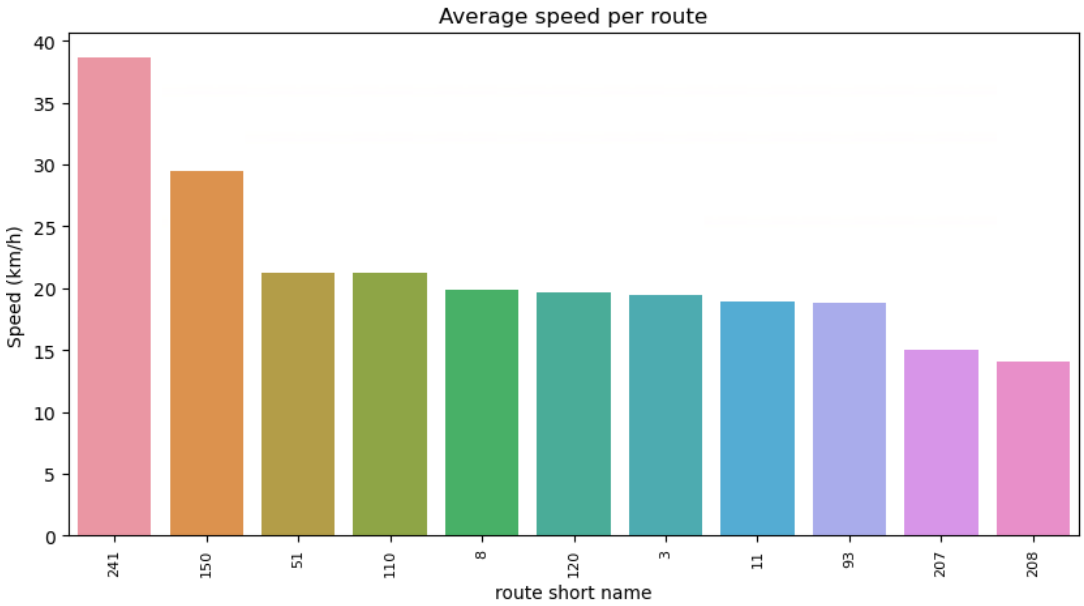


Figure 19. average speed (km/h) on selected routes

7. Passenger ridership

We identified the top 10 bus routes with the highest and lowest ridership at weekdays and weekend respectively as Table 7 shows. We then find a positive correlation exists between daily ridership and the total bus number during peak hours as Figure 20 shows.

Table 7. top 10 bus routes with the highest and lowest ridership

weekday			
top 10 routes with the highest ridership		top 10 routes with the lowest ridership	
Bus route	ridership	Route	ridership
119	10165.04517	132	45.316348
112	8725.507941	155	40.979961
77	8565.782519	RS	22.441667
11	8315.823337	212	21.889499
120	7040.634108	46	21.873682
27	6876.487628	KC	18.45
38	5947.137118	AS	17.566667
9	5892.66715	SL	15.166667
3	5147.713271	254	6.330424
8	4735.161237	GH	5.525

weekend			
top 10 routes		top 10 routes	
Bus route	ridership	Route	ridership
119	8544.329	200	111.25
112	6148.042	210	87.18333
11	5273.1	302	85.4375
3	5201.97	115	62.35833
120	4927.546	500	59.74167
38	4669.025	246	55.9875
77	4453.333	101	51.14583
27	3659.458	286	30.54583
9	3052.34	202	26.85417
8	2195.91	82	19.57917

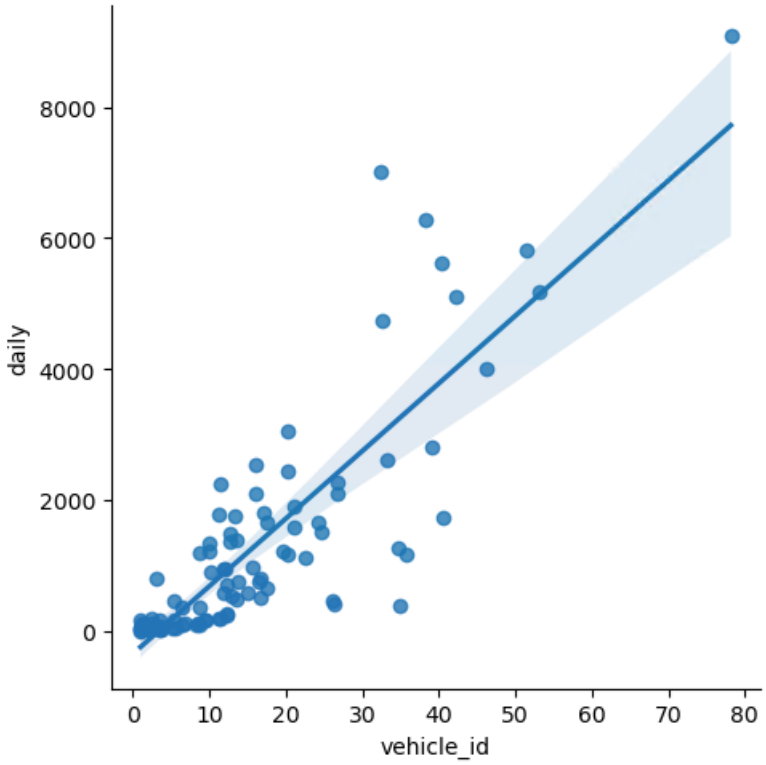


Figure 20. positive correlation between peak hour's bus number and daily ridership