Area-Specific Traffic Peak Hour Timing Using Traffic Signal Detectors: A Case Study of Qatar

Almodather Mohammed
Public Works Authority – Ashghal, Doha, Qatar
amohamed5@ashghal.gov.qa

Ali Al-Saudi
Public Works Authority – Ashghal, Doha, Qatar
aabdullah@ashghal.gov.qa

Mohammed Al-Marri
Public Works Authority – Ashghal, Doha, Qatar
malmarri6@ashghal.gov.qa

Abstract

This case study addresses peak hour traffic timing in Qatar after COVID-19 as traffic conditions returned to normal. Traffic data were provided for multiple areas, mainly around Doha City. Flow data were obtained from traffic signal detectors for 318 intersections. The peak periods in morning, mid-day, and evening were 06:30 am–08:30 am, 12:30 pm–2:30 pm, and 5:15 pm–7:15 pm, respectively. These findings align with the Ministry of Transport's state-wide study (Transportation Masterplan for Qatar, 2018). We found traffic in Qatar to differ on Thursday, Friday, and Saturday versus the rest of the week due to the weekend effect. Results offer useful insights for policymakers to reduce congestion and provide complex traffic solutions (e.g., understanding land use–specific peak hour timing, imposing zone-specific working hours). In addition, this case study highlights the potential to use existing infrastructure to expand traffic studies in Qatar at minimum cost.

Keywords: Traffic; Vehicles; Peak hour; Qatar; Congestion; SCAT

1 Introduction

Traffic congestion, which continues to increase, affects the economy and can disrupt cities' development (Downs & Downs, 2004). Qatar's road network is improving thanks to vast investment in new highways and roads. People's number of hours spent commuting in the area declined by 6% between 2018 and 2019 (QMIC, 2019). Although the COVID-19 pandemic decreased traffic congestion across most cities in 2020, this effect is diminishing. Yet congestion could assume a new pattern as it resumes (TomTom, 2022).

Gathering traffic data is crucial for accurately measuring congestion and understanding its patterns. Conventional temporarily installed traffic data collection methods, such as automatic pneumatic tube counts (ATCs), manual counts (MCs), and video-based turning movement counts (TMCs), are most common in practice (Leduc, 2008). Other traditional permanent methods like inductive loop detectors (ILDs) are also used, depending on the purpose of data collection. More technologically advanced methods of traffic data acquisition (e.g., based on cell phone tower data, GPS data, or Bluetooth data) are available as well; however, privacy and legal concerns have impeded their broader adoption. As state-wide data collection projects are typically initiated and overseen by government planning agencies, these concerns are given significant consideration (Losavio et al., 2018).

The Transportation Masterplan for Qatar (TMPQ) project, a state-wide data collection initiative, has been considered the most reliable source of traffic data in Qatar. The project was spearheaded by Qatar's Ministry of Transport. Data collection for this project took place between 2018 and 2019. The study was based on temporary conventional traffic data collection methods, namely ATCs, MCs, and TMCs (Ministry of Transport, 2020). In the current study, we aim to set the stage for in-depth research on traffic data collection using a conventional permanent method (i.e., ILDs) which already exists in Qatar and will require limited resources.

Our work makes two contributions in that we 1) reconfirm peak traffic periods in Qatar after the pandemic compared to TMPQ and 2) illustrate traffic patterns and peak hours in areas across the state. Results are intended to facilitate traffic studies among traffic engineers and to enable stakeholders to monitor traffic more efficiently using our data processing framework.

The remainder of this paper is organized as follows: Section 2 summarizes related work on traffic peak hour identification. Section 3 describes our traffic data collection procedure along with information about TMPQ. Section 4 presents our results, and Section 5 concludes.

2 Related Work

Traffic engineers have been interested in counting vehicles since urban congestion began rising (Goetz, 2019). Several widely accepted counting methods are available. TMCs are considered the most accurate vehicle-counting method, yet relevant literature is lacking (Zheng & Mike, 2012). Data processing is time-consuming and costly irrespective of whether this task is completed manually or via software. Therefore, ATCs have been deemed most feasible for long periods (i.e., more than a day; Puan et al., 2019).

Other traffic-counting technologies include the radio frequency identification system; license plate recognition systems; and ILDs, which are wires installed on the road pavement to detect vehicles (Oluwatobi et al., 2021). These approaches are unique in that they gather real-time data (vs. conventional TMCs and ATCs, which require post-processing). ILDs have an additional advantage over other methods because vehicle counting is not the sole purpose: ILDs are also used to optimize traffic signal timing under the Sydney Coordinated Adaptive Traffic System (SCAT) (NSW Government Department of Main Roads, n.d.).

ILDs are widely used in intelligent transport systems but not in traffic data collection. ILDs cannot measure a vehicle's speed and length, which are key factors when obtaining traffic data (Belenguer et al., 2019). Most traffic signals in Qatar have already installed and use ILDs via SCATS (SICE, 2020).

The largest data collection project in Qatar, carried out between 2018 and 2019, leveraged 500 ATC locations, 500 TMC locations, and 100 MC locations to evaluate traffic patterns across the country (Ministry of Transport, 2020). The study categorized traffic peaks into three blocks of a 3-hour period each: morning (6–9 am), mid-day (12–3 pm), and evening (5–8 pm). Peak traffic is thus apt to occur during these periods in any part of Qatar. ILDs can identify peak hours, and Qatar was equipped with this technology in 2018. However, ILDs have few data collection attributes, and their accuracy has yet to be determined in this state.

3 Methodology

In this case study, raw data from ILDs were obtained from 318 intersections connected to the road monitoring center system in Qatar's Roads Operation and Maintenance Department. Data were collected between October 14, 2022, and October 20, 2022, after which they were processed to

determine general traffic patterns. These patterns were then analyzed to identify area-specific peak hours.

3.1 Data Processing

Raw ILD data were processed via SCAT Traffic Reporter software based on data dumps in 5-min intervals. Sample data are presented in **Fig. 1**.

```
Friday 14 October 2022 00:05
Int 5632    1=0     2=6     3=4     4=0     5=6     6=2     7=3     8=119
 9=0    10=3    11=10   12=5    13=9    14=7    15=4    16=1
17=4    18=5    19=5    20=5    21=5    22=0    23=4    24=4
25=8    26=7    27=4    28=7
```

Fig. 1: Raw Data Snapshot for One Intersection (5-min Interval)

The number following "Int" is the intersection number. The detector number appears before "=", and the number after "=" denotes the vehicle count during the 5-min period.

A program was written in Anaconda Python to organize the raw data into hourly traffic data for each intersection (**Fig. 2**).

	A	B	C
1	time	intersection	sum
2	14-10-22 00:00	601	3771
3	14-10-22 00:00	2102	5267
4	14-10-22 00:00	2202	3754
5	14-10-22 00:00	2307	14079
6	14-10-22 00:00	3001	7993
7	14-10-22 00:00	3199	910
8	14-10-22 00:00	5107	24600
9	14-10-22 00:00	5108	1412

Fig. 2: Reorganized Detector Data

3.2 Understanding Data Patterns

Our data spanned a week in October (from Friday to Thursday) as shown in **Table 1**.

Table 1: Data and Day of Week

Date	Day	Type	Note
14-Oct-22	Friday	Weekend	Day off for all public/private sectors and schools
15-Oct-22	Saturday	Weekend	Day off for all public/some private sectors and schools
16-Oct-22	Sunday	Weekday	Workday for all
17-Oct-22	Monday	Weekday	Workday for all
18-Oct-22	Tuesday	Weekday	Workday for all
19-Oct-22	Wednesday	Weekday	Workday for all
20-Oct-22	Thursday	Weekend	Workday for all; some private sectors worked a half day

We assembled a daily profile for all intersections (**Fig. 4**) to further understand behavioral traffic patterns in Qatar over the focal week.

3.3 Area-specific Peak Hours

For the purposes of determining peak hours by area, we mapped the areas as arbitrary 2km squares covering all traffic signals with detectors. The 101 areas are depicted in **Fig. 3**. Distinctive patterns are discussed in Section 4.

Fig. 3: 2km × 2km Areas (N = 101) Covering All Signals with Detectors

4 Results

4.1 Daily Profile

Given the hourly traffic flow at each location throughout the week (as presented in Fig. **2**), we plotted a daily profile to clarify traffic patterns in Qatar (**Fig. 4**).

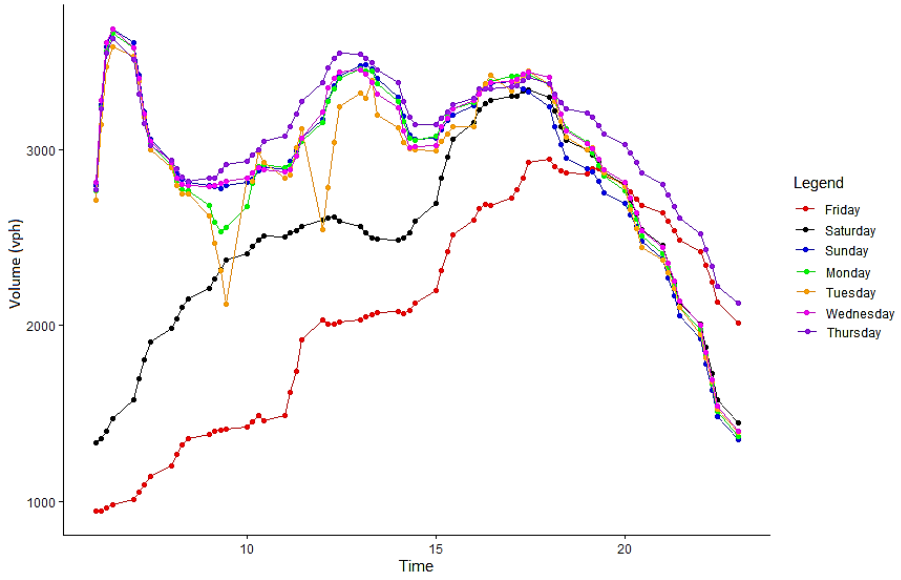

Fig. 4: Weekly Traffic Profile (October 14, 2022–October 20, 2022)

Traffic followed a typical pattern from Sunday to Thursday. The peak period was higher on Thursday evening, possibly due to leisure travel because most people in Qatar were not working the next day. This information is important when planning events for later in the day. We therefore treated Thursday as a distinctive pattern. Saturday's pattern resembled that of Friday: most people were not working, but the peak period was higher due to some work trips in the private sector.

Overall, traffic in Qatar assumed four patterns: 1) Sunday–Wednesday were typical workdays; 2) Thursday featured work in the morning and leisure in the evening; 3) All offices were closed on Friday; and 4) Saturday was a free day for some of the population. We focus on the weekday result (Pattern 1) in this section given that most traffic design is based on weekday volumes. Results for the other patterns are provided in the Appendix.

Fig. 5: Morning Result (Pattern 1)

Fig. 6: Evening Result (Pattern 1)

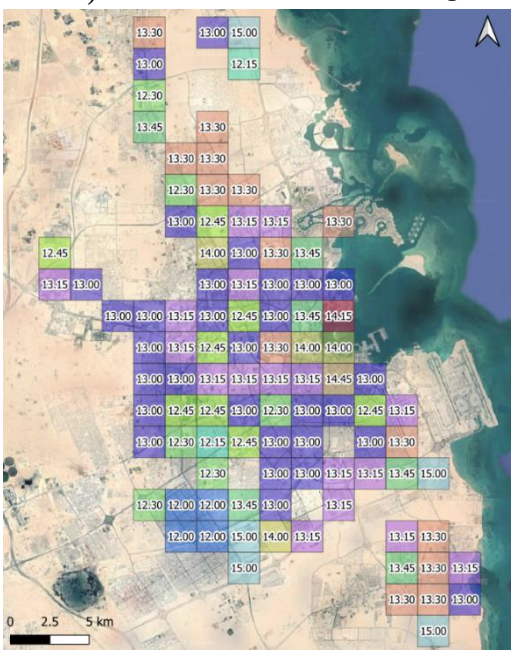

Fig. 7: Mid-day Result (Pattern 1)

The weekday results from Fig. **5** to Fig. **7** show that 6:45–7:45 was the most common peak hour in

the morning; 13:00–14:00 was the most common peak hour during mid-day. The most common evening peak hour was 17:45–18:45. The morning peak hour pattern was related to land use in the city: the further one is from Inner Doha, the earlier the peak hour tended to be, presumably due to vehicles traveling to offices in the area. An exception to this trend appeared in the Industrial Area, whose peak was later at 9:00. The mid-day and evening peak hour patterns were more complicated and merit further study along with land use.

4.2 Discussion

Although the accuracy of ILD results has not been studied in Qatar, peak hour periods confirm the TMPQ findings. In addition, the daily profile in this research aligns with that produced in TMPQ's Data Collection, Inventories and Survey Summary (Figure 4-2 in the original document). These consistencies are reassuring. However, studies which compare accuracy are still lacking.

This paper shed light on a possible use case of ILDs that may save costs and time. This research is intended to be a proof-of-concept of a framework to complete such a task rather than to serve as a reference for peak hours. One could argue that the accuracy (not volume) of peak hour timing can be used safely: even though ILD counters' accuracy may not be high, the error is eliminated because figures were consistent throughout the data collection period. A longer period of ILD data collection, to be verified with TMCs and ATCs, is needed for further verification.

5 Conclusion

Qatar has an advanced transportation infrastructure featuring more than 400 intersections with ILDs which are linked with one system and monitored constantly. This case study offers initial insight into capabilities of gathering ILD data. We examined traffic patterns over a week and identified distinctions. The peak hour for each area in Qatar aligns with research conducted in 2018. As such, traffic seems to have returned to normal since the COVID-19 pandemic. Practically, this case study can benefit traffic engineers who evaluate different areas in Qatar based on peak traffic during the morning, mid-day, and evening. We have also provided a framework for engineers to duplicate for mass traffic data collection in Qatar. Researchers can apply the developed framework to explore traffic patterns' relationships with land use. It will then be possible to modify peak hours based on transport demand management if needed to reduce traffic congestion. It is worth noting that a longer period study is required to take place and be verified against TMCs and ATCs to validate the accuracy of using ILDs for peak hour determination. Fortunately, introducing a longer period and more data points does not complicate this task or raise costs as with the on-site data collection method used in TMPQ.

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Appendix

Table 2: Peak Hour Results for All Patterns

Area	Pattern 1 (Sunday-Wednesday)			Pattern 2 (Thursday)			Pattern 3 (Friday)			Pattern 4 (Saturday)		
	AM	MD	PM	AM	MD	PM	AM	MD	PM	AM	MD	PM
1	6.30	13.30	17.30	6.30	12.45	17.45	9.00	15.00	17.45	9.00	15.00	17.30
2	7.45	13.00	20.00	7.45	14.00	20.00	7.00	15.00	18.30	9.00	15.00	17.00
3	7.30	15.00	17.00	7.45	12.15	17.30	7.30	15.00	19.00	9.00	15.00	17.00
4	6.30	12.15	19.45	6.30	12.00	17.00	-	-	-	9.00	13.00	19.45
5	6.15	13.00	17.30	6.15	12.45	17.45	8.00	15.00	17.45	9.00	15.00	16.15
6	6.30	12.30	17.45	6.30	12.15	17.45	8.45	15.00	17.45	9.00	15.00	17.45
7	6.30	13.30	17.00	6.30	12.15	17.15	9.00	15.00	19.15	9.00	13.30	17.00
8	6.45	13.45	17.00	6.45	14.00	17.45	8.45	15.00	18.00	9.00	15.00	17.15
9	6.30	13.30	17.45	6.45	12.15	17.45	9.00	15.00	19.45	9.00	15.00	17.45
10	6.45	13.30	17.00	6.45	12.45	18.00	9.00	15.00	20.00	9.00	14.30	18.30
11	7.00	13.30	17.00	6.45	13.30	17.00	8.45	15.00	19.30	9.00	15.00	17.00
12	6.45	13.30	17.00	6.45	13.45	17.00	9.00	15.00	18.15	9.00	15.00	17.00
13	9.00	12.30	17.45	9.00	14.00	18.45	9.00	15.00	17.00	9.00	13.45	17.45
14	6.45	13.00	17.45	6.30	12.45	18.00	9.00	15.00	20.00	9.00	15.00	17.45
15	6.45	12.45	17.45	6.45	12.30	17.45	9.00	15.00	18.00	9.00	15.00	17.30
16	7.00	13.15	17.00	6.45	13.45	17.00	8.30	15.00	19.15	9.00	15.00	17.00
17	6.45	13.15	17.00	6.45	13.15	17.15	8.15	15.00	18.00	9.00	15.00	17.00
18	8.15	13.30	17.45	8.30	14.00	18.15	9.00	15.00	19.45	9.00	15.00	17.45
19	7.00	13.45	17.30	6.45	14.00	19.45	9.00	15.00	18.00	9.00	15.00	17.30
20	7.00	13.30	17.00	6.45	12.30	17.00	9.00	15.00	18.00	9.00	15.00	17.15
21	7.00	13.00	17.00	6.45	13.45	17.00	8.45	15.00	18.00	9.00	15.00	17.00
22	6.30	14.00	17.00	6.30	12.45	17.00	9.00	14.00	19.15	9.00	15.00	18.00
23	6.45	12.45	17.00	7.15	15.00	17.45	7.30	14.45	18.00	9.00	15.00	18.15
24	6.45	13.15	17.30	9.00	13.15	18.30	9.00	14.45	20.00	8.30	15.00	17.30
25	6.30	13.00	17.30	6.30	13.45	18.00	8.30	14.30	19.15	9.00	15.00	17.45
26	6.45	13.00	17.00	7.00	13.15	17.00	9.00	15.00	18.00	9.00	12.45	17.45
27	6.45	13.15	17.45	6.45	12.45	17.45	8.45	15.00	18.00	9.00	12.45	18.00
28	6.45	13.00	17.45	6.45	13.00	19.15	8.45	15.00	18.15	9.00	15.00	17.30
29	7.00	13.00	17.30	6.45	12.30	17.45	8.45	15.00	19.45	9.00	12.30	17.45
30	7.30	13.00	17.00	8.00	13.00	17.00	8.45	15.00	18.00	9.00	14.30	17.00

Area	Pattern 1 (Sunday-Wednesday)			Pattern 2 (Thursday)			Pattern 3 (Friday)			Pattern 4 (Saturday)		
	AM	MD	PM	AM	MD	PM	AM	MD	PM	AM	MD	PM
31	7.30	14.15	17.00	7.30	14.15	17.00	9.00	15.00	19.30	9.00	15.00	17.00
32	7.15	13.45	17.00	7.15	13.45	17.00	9.00	14.00	19.15	9.00	15.00	17.30
33	6.45	13.00	18.00	6.45	12.45	17.45	9.00	12.00	19.30	9.00	12.15	17.45
34	6.45	12.45	18.00	7.00	12.45	18.00	9.00	12.00	17.45	9.00	12.00	18.15
35	6.45	13.00	17.15	6.45	13.15	15.15	8.30	12.00	17.45	8.30	15.00	17.15
36	6.45	13.15	17.00	6.45	13.30	17.45	8.45	15.00	18.00	9.00	15.00	17.45
37	6.30	13.00	17.45	6.30	12.45	18.45	9.00	13.45	18.00	9.00	12.15	18.30
38	6.30	13.00	17.45	6.30	12.30	17.45	9.00	15.00	19.30	9.00	15.00	18.00
39	6.30	13.00	17.45	6.45	12.45	17.45	9.00	15.00	18.00	9.00	15.00	17.45
40	6.30	13.15	19.15	6.30	13.00	17.45	9.00	15.00	18.00	9.00	15.00	17.45
41	6.45	12.45	17.45	6.45	12.45	17.45	9.00	12.00	18.00	9.00	15.00	17.45
42	6.45	13.00	17.30	6.45	13.15	18.00	9.00	12.00	18.00	9.00	15.00	17.30
43	6.45	13.30	17.30	7.00	13.30	17.30	8.45	13.30	19.30	9.00	15.00	17.30
44	7.00	14.00	17.00	7.00	14.00	17.30	9.00	13.45	19.30	9.00	15.00	17.30
45	7.15	14.00	17.45	7.00	14.45	17.45	9.00	15.00	19.00	9.00	15.00	17.30
46	-	-	-	-	-	-	-	-	-	-	-	-
47	6.45	13.00	17.30	6.30	14.45	17.15	6.00	12.00	18.45	9.00	12.30	17.30
48	7.15	14.45	17.00	7.15	15.00	17.45	9.00	15.00	18.30	9.00	15.00	18.00
49	7.00	13.15	17.15	7.00	13.15	19.00	9.00	15.00	19.30	9.00	12.30	18.00
50	7.15	13.15	17.30	7.00	13.30	17.30	9.00	13.30	19.45	9.00	12.30	17.30
51	6.45	13.15	17.15	6.45	12.45	17.00	9.00	15.00	17.45	9.00	15.00	17.45
52	6.45	13.15	17.45	6.30	12.45	17.45	9.00	15.00	17.45	9.00	15.00	17.45
53	6.45	13.00	17.30	6.30	12.45	17.45	9.00	15.00	17.45	9.00	15.00	17.45
54	6.30	13.00	17.15	6.15	13.15	17.00	9.00	12.00	17.45	9.00	15.00	17.00
55	6.30	13.00	17.45	6.30	12.45	17.45	9.00	15.00	17.45	9.00	15.00	17.45
56	6.30	12.45	17.45	6.30	12.45	17.45	9.00	15.00	18.00	9.00	15.00	17.30
57	6.45	12.45	17.45	6.45	12.45	18.00	9.00	15.00	17.45	9.00	15.00	17.45
58	6.45	13.00	17.30	6.45	13.30	17.30	8.45	15.00	18.00	9.00	12.45	17.00
59	6.45	12.30	17.45	6.45	12.30	17.45	9.00	12.30	17.45	9.00	12.15	17.45
60	7.00	13.00	17.15	6.45	12.45	18.00	9.00	12.15	18.45	9.00	12.30	17.45
61	7.15	13.00	17.45	7.30	12.45	17.30	9.00	15.00	18.00	9.00	12.30	17.45
62	7.15	12.45	18.00	7.15	12.30	17.15	9.00	12.00	18.00	9.00	12.30	18.00
63	7.00	13.15	17.30	6.45	12.45	17.45	8.30	13.00	20.00	9.00	12.15	17.30
64	6.45	13.30	17.15	6.45	13.15	17.00	9.00	12.30	18.00	9.00	12.15	17.45
65	6.45	13.00	17.45	6.45	12.45	18.15	9.00	12.30	17.45	9.00	12.45	17.45
66	6.15	13.00	19.15	6.15	13.15	18.45	6.00	12.00	20.00	8.00	12.30	20.00
67	6.45	13.00	17.45	6.45	13.00	17.45	6.00	12.00	19.30	8.00	12.15	17.45
68	6.45	12.45	17.45	6.45	12.45	17.45	9.00	12.00	18.00	9.00	12.00	17.45
69	6.30	12.15	18.00	6.30	12.30	19.15	9.00	12.00	19.45	9.00	12.15	17.45
70	6.30	12.30	17.00	6.30	12.45	17.30	9.00	15.00	18.00	9.00	15.00	17.45
71	6.30	13.00	17.15	6.45	12.45	17.45	9.00	15.00	18.00	9.00	12.30	18.00
72	-	-	-	-	-	-	-	-	-	-	-	-
73	-	-	-	-	-	-	-	-	-	-	-	-
74	6.30	12.30	17.45	6.45	12.45	18.30	9.00	12.00	18.00	9.00	12.00	18.00
75	6.30	13.00	17.45	6.30	12.45	19.30	9.00	12.00	18.00	9.00	12.30	18.00
76	6.30	13.00	17.45	6.30	13.00	18.00	8.45	12.00	17.45	8.30	12.45	17.00
77	6.30	13.15	17.45	6.30	12.45	17.45	9.00	14.45	19.00	8.30	15.00	17.45
78	6.45	13.15	17.45	6.45	12.30	18.15	9.00	12.00	18.15	9.00	12.15	18.00
79	6.45	13.45	17.15	6.45	13.15	17.45	6.00	12.30	19.30	9.00	12.00	17.45
80	7.45	15.00	17.00	7.45	13.00	17.00	6.00	13.00	17.45	9.00	12.45	17.00
81	6.15	13.15	17.00	6.30	13.15	19.45	8.45	12.30	17.30	8.15	12.00	18.00
82	6.30	13.00	17.30	6.30	12.30	17.00	9.00	12.00	17.45	9.00	15.00	17.45
83	6.30	13.45	17.00	6.30	13.45	17.45	9.00	12.00	17.45	9.00	15.00	17.00
84	9.00	12.00	17.00	9.00	12.00	17.00	8.45	15.00	17.45	9.00	12.00	17.00
85	9.00	12.00	17.00	9.00	12.00	17.00	9.00	15.00	17.15	9.00	12.00	17.00
86	8.00	12.30	17.00	9.00	12.30	17.00	9.00	15.00	17.15	8.00	15.00	17.00

Area	Pattern 1 (Sunday-Wednesday)			Pattern 2 (Thursday)			Pattern 3 (Friday)			Pattern 4 (Saturday)		
	AM	MD	PM	AM	MD	PM	AM	MD	PM	AM	MD	PM
87	9.00	12.00	17.00	9.00	15.00	17.00	9.00	15.00	17.30	9.00	12.00	17.00
88	7.15	12.00	17.00	6.45	12.15	17.15	9.00	15.00	17.45	9.00	15.00	17.00
89	7.45	15.00	17.00	9.00	15.00	17.30	9.00	15.00	18.00	9.00	15.00	17.15
90	7.15	14.00	17.00	7.30	13.45	17.45	8.45	15.00	17.00	7.45	12.00	17.00
91	6.30	13.15	17.00	6.30	13.30	17.45	9.00	12.00	17.45	8.30	15.00	17.00
92	6.45	13.15	17.45	6.45	13.00	17.45	9.00	12.00	18.15	7.45	12.45	17.45
93	6.30	13.30	17.45	6.45	12.45	18.00	9.00	12.00	18.00	8.45	12.15	17.45
94	6.30	13.15	17.45	6.30	12.30	19.15	9.00	12.00	19.30	9.00	12.30	18.30
95	6.30	13.30	17.45	6.30	13.45	18.00	9.00	15.00	18.00	8.45	15.00	17.45
96	6.45	13.45	17.45	6.45	13.15	18.15	8.45	12.00	18.30	9.00	15.00	18.15
97	9.00	15.00	17.00	8.45	14.45	17.00	9.00	15.00	18.00	8.15	12.00	17.00
98	6.30	13.30	17.45	6.30	13.30	17.00	9.00	12.00	17.45	8.15	15.00	17.45
99	6.30	13.30	17.45	6.30	12.30	17.45	9.00	12.00	17.45	9.00	12.15	18.00
100	6.30	13.00	17.45	6.30	12.30	19.15	8.45	12.00	18.00	9.00	15.00	17.00
101	6.15	15.00	17.00	6.15	15.00	17.00	6.15	15.00	18.00	6.15	15.00	17.15

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