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A Case Study of Bus Line Passenger Volumes of Bakrajo Bus Lines in Sulaimani City

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ABSTRACT

Transit agencies constantly need information about system operations and passengers to support their regular scheduling and operation planning processes. The lack of these processes and cultural motivations to use public transportations contributes enormously to the reliance on the private cars rather than public transportation, resulting in traffic congestions. The traffic congestions occur mainly during peak hours and the accidents happening as a result of road accidents and construction works. This study investigates the effects of weekday and weekend travel variability on peak hours of the passenger flow distribution on bus lines, which can effectively reflect the degree of traffic congestion. A study of passenger traffic flow patterns during these times can impact planning decisions on transportation engineers. It can be viewed as a building block for generating a reliable schedule for a given bus route within the context of an optimization process. Collecting data sets of a two-directional bus line in Sulaimani city, connecting a residential district to the city center, for three days (Wednesday, Thursday, and Friday), and this study analyzed the flow and distribution of weekday and weekend passenger movements along with the bus stops of each direction on-peak and off-peak periods. The results indicate that Thursday passenger volume is more similar to Friday passenger volume than on Wednesday passenger volume. The passenger volume of direction D1 (from the residential district to the city center) is double that of direction D2 (from the city center to the residential district). The maximum morning peak time is on Wednesday with 442 passengers/hr, starting from 7:30 to 9:00, and the maximum evening peak hour is on Thursday with 420 passengers/hr, beginning from 14:30 to 16:30.

Keywords: Passenger traffic volumes, boarding and alighting, Data analysis, Public transit, Time schedule.

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دراسة ميدانية حول أعداد الركاب في خطوط الحافلات في بكرجو في مدينة السليمانية

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الخلاصة

تحتاج وكالات النقل العامة ان تزود بالمعلومات حول عمل المنظومة والركاب بصورة مستمرة وذلك من أجل دعم الجدولة المنتظمة و انظمة تخطيط العمليات. قلة وجود هذه الانظمة تساهم بشكل كبير في الاعتماد على السيارات الخاصة بدلاً من وسائل النقل العام وبالتالي تؤدي إلى ازدحام حركة المرور. إضافة إلى الازدحام الناتج عن الحوادث التي تحدث نتيجة حوادث الطرق وأعمال البناء، يحدث الازدحام المروري بشكل رئيسي خلال ساعات الذروة. الغرض من هذا البحث هو التحقق من تاثير الفارق الموجود في التنقل خلال أيام الأسبوع عن ايام عطلة نهاية الأسبوع على ساعات الذروة وذلك لتوزيع تدفق الركاب على خطوط الحافلات والتي يمكن أن تعكس بكفاءة درجة الازدحام المروري. ان دراسة أنماط تدفق حركة المسافرين خلال هذه الأوقات لا تؤثر فقط على قرارات التخطيط لمهندسي النقل ، ولكن يمكن أيضًا اعتبارها بمثابة حجر اساس لإنشاء جدول معتمد لمسار حافلة معين في سياق عملية التحسين. تم جمع البيانات لخط الحافلتين الاتجاهيتين في مدينة السليمانية التي ربطت منطقة سكنية بوسط المدينة لمدة ثلاثة أيام (الأربعاء والخميس والجمعة). في هذا البحث، تم تحليل تدفق وتوزيع حركات الركاب خلال أيام الأسبوع وعطلات نهاية الأسبوع على طول محطات الحافلات لكل اتجاه في فترات الذروة وخارج فترات الذروة. تشير النتائج إلى أن كثافة الركاب يوم الخميس تشبه كثافة الركاب يوم الجمعة بدلاً من كثافة الركاب يوم الأربعاء. تبلغ كثافة الركاب في الاتجاه D1 (من المنطقة السكنية إلى وسط المدينة) ضعف كثافة الركاب في الاتجاه D2 (من وسط المدينة إلى المنطقة السكنية). الحد الأقصى لوقت الذروة الصباحية هو يوم الأربعاء مع 442 راكب / ساعة ، بدءًا من الساعة 7:30 حتى الساعة 9:00 صباحا ، وأقصى ساعة ذروة مساء يوم الخميس مع 420 راكب / ساعة ، بدءًا من الساعة 14:30 حتى الساعة 16:30 مساءا.

الكلمات الرئيسية: أحجام حركة الركاب ، الصعود والنزول ، تحليل البيانات ، النقل العام ، جدولة الوقت

1. INTRODUCTION

The improvement in road infrastructure capability is to reduce congestion and enhance traffic mobility can only be carried out to an extent as the infrastructure is limited. The burden is, therefore, on traffic engineers and planners to find intelligent ways to mitigate and reduce traffic congestion **(Mohammed et al., 2016)** and **(Amjad et al., 2018)**. Lack of suitable public transport system contributes most to reliance on private cars which leads to traffic congestion. Reorganizing bus lines into trunk and feeder with reliable operating time tables and frequencies can play a vital role in relieving traffic congestion.

Many researchers have focused on data analysis of bus transit lines and investigated the effects of time of day and day of the week on the peak period of passenger flow distribution on public transit lines and the lines' subsequent scheduling. **(Furth, 2000)** worked on data analysis for bus planning and monitoring in the United States of America and Canada. The study reviewed the state of the practice in how data are analyzed and investigated various methods used for analyzing the data. The study also addressed accuracy issues, including measurement error, and other problems, including error in estimates. Statistical analysis on arriving, dwell, and departure process of three bus routes in Beijing was investigated **(Chen et al., 2013)**. Based on the collected data of these bus routes, the study computed bus delays at stops and carried out statistical analysis for evaluating the average time of the buses that are stopping at curbside and bay-style stops. The analysis results showed that passengers' different load factor in buses acts on average boarding and alighting time per person. **(Kim et al., 2013)** worked on the Seoul metro system in Korea. Based on the Seoul metro network's collected real data, the study investigated passengers' travel patterns using the clustering analysis algorithm. **(Zhao et al., 2014)** investigated the factors affecting rail transit passengers at both the station and station-to station levels of the Metro system in Nanjing, China. The study used a multiple regression model and multiplication model, respectively, for these investigations. **(Sun et al., 2015)** investigated the passenger flow distribution of a complex metro network in Singapore using the complete Bayesian statistical reasoning framework. The analysis results revealed that travel time reliability is of great significance to metro operation. **(Jiang et al., 2017)** worked on passenger flow control problems in Beijing metro while considering the passenger demand control and train capacity supply. The study proposed a mathematical model for addressing this problem, and a real case of the Beijing metro is used to validate the proposed model. **(Yang et al., 2017)** studied the problem of congestion along metro lines in Shanghai. Two mathematical models for the stations and time periods determination taking passenger flow control strategy and identification of the optimal bus-bridging services are proposed. The results showed that proposed models effectively reduce the number of stranded passengers, release the congestion pressure, and improve passengers' satisfaction. Train timetable and precise traveler stream control system on supersaturated metro lines of the Beijing metro system optimization model was proposed. **(Shi et al., 2018)** using an effective method. The study utilized the Beijing metro system's operation data for checking the performance and validity of the suggested method. **(Wu et al., 2018)** investigated the factors influencing urban metro travelers' entrance and exit mode selection using survey data in Nanjing metro in China and applied mixed logic. They summarized the transfer needs of different groups of travelers in sectors. They obtained that the result proved that the model is reliable and reproductive in analyzing access/egress mode choices of metro travelers. **(Arman et al., 2019)** developed a model to support mobility analysis in public transport networks. The model controls first by analyzing the service offer provided by mobile operators and the service demands. Then, the model allows evaluating the number of people who are picked-up and dropped-off at a stop.

The performance of the model has been validated by comparing the observed values obtained from field observation. **(Yu et al., 2019)** analyzed the space-time variation analysis of passenger flow on six metro lines in Nanjing, China. Using the smart card swiping records, the study selected five working days (Monday to Friday) for statistical analysis of passenger flow. The daily card swiping data were counted to 24 h, from 0:00 to 23:00. The analysis results showed that passenger flow increased from 1.20 million to 1.32 million from Monday to Friday and confirmed that passengers flow during morning and evening peak periods can effectively reflect the degree of urban traffic congestion. The results also showed that the number of arrivals and departures concentrated at 7:00 and 8:00 during the morning peak. The number of arrivals was concentrated at 17:00, and the number of departures was concentrated at 18:00 during the evening peak.

In the Kurdistan region in general and Sulaimani city in particular, there have been no studies concerning public transit improvement and its time scheduling reported. The overall purpose of this study is to bridge this gap and identify how weekday and weekend travel variability contributes to peak and off-peak times of the passenger flow distribution and, thus, determine passenger traffic patterns during these periods in Sulaimani city. This will, in turn, inform transport authorities to manage road network and bus line operations to relieve congestion during peak periods and reduce the operating cost during off-peak periods. Also, this study can be viewed as a building block for generating a reliable schedule for a given bus route within the context of an optimization process. The rest of this paper is organized as follows: Section 2 presents the methodology and procedures utilized in this study with a brief detail about the data collection; section 3 demonstrates and discusses the results of the statistical analysis. Finally, section 4 presents the concluding remarks of the study.

2. METHODOLOGY

2.1 Location of the study

This study was performed on a bus line of Sulaimani city in the Kurdistan region, Iraq, connecting a residential district to the city center. The line is called Bakrajo, which consists of two directions.

Direction 1 connects the Bakrajo terminal (located in the residential district) to the Baridaka terminal (located in the city center) and, direction 2 connects the Baridaka terminal to the Bakrajo terminal. Direction 1 involves 18 bus stops (including both terminals), and direction 2 involves 17 bus stops (including both terminals), as presented in **Fig. (1)**.

Figure 1. Bakrajo bus line path (Image taken from Google earth).

2.2 Experimental program

The experimental process of this study consisted of the following steps:

- Boarding and alighting passengers' data of each bus stop in both directions of the Bakrajo bus line were collected through (70) observers on three different days of the week; Wednesday, Thursday, and Friday. The observers seated within the line's buses, one observer for each bus, recording the number of passengers that have boarded and alighted at each stop along with the time of arrival at each stop.

- Each day's collected data was divided into different time intervals based on peak time and off-peak time.
- The total volume of the boarding/alighting passengers was calculated for each bus stop at different time intervals.
- Descriptive and statistical comparison of the total boarding and alighting passenger of the time-intervals of one day, and one day to another day was performed.
- Regression statistical analysis of the boarding and alighting passenger volumes were conducted to find the relations between passenger volumes of the two directions on the one hand, and between passenger volumes of the morning and evening time intervals on the other hand

3. RESULTS AND DISCUSSION

3.1 Data presentation

Comparison of time-intervals of each day and each paired days for the boarding and alighting passenger volumes was carried out separately. Two directions of the Bakrajo bus line, including direction 1 (D1) (Bakrajo terminal to the Baridaka terminal) and direction 2 (D2) (Baridaka terminal to the Bakrajo terminal), were investigated. D1 consists of 18 bus stops, including the terminals, while D1 consists of 17 bus stops covering the terminals.

Fig. (2) shows the fluctuation in the number of boarding and alighting passengers of both directions (D1 and D2) over the three days of the data collection.

3.2 Peak and off-peak times

Figure 2 depicts the boarding and alighting passenger flow fluctuations over time of the three days of data collection in both directions (D1 and D2). Based on this, both peak and off-peak periods of passenger flow (boarding and alighting) have been found for each direction and illustrated in **Table 1**.

The peak period of boarding passenger flows in both directions occurs two times each day, as depicted in **Table 1**. However, peak times do not exactly occur in the same period. There is a shift between the peak times. For example, on Wednesday, the peak periods of D1 are at 7:30-9:00 and 11:00-15:30, while on Thursday, the peak periods of D1 are at 7:30-10:00 and 11:30-15:30.

On Friday, the peak periods of D1 occur at 8:30-11:00 and 13:00-16:00. The same remarks could be realized for the peak periods on Wednesday, Thursday, and Friday in D2. This shift between the peak time periods between Wednesday and Thursday can be explained by the fact that on Thursday, the working period is different (half-time or shorter). On Friday, it is expected that the peak periods be different compared to the weekdays because Friday is a weekend, and thus, the behavior of people, the time going out, and the place they are going to are different. It is very interesting to note the equivalent between alighting and boarding data in all three days, which indicates the correctness of the collected data. Alighting data is also useful for further study detail and modeling the bus line to optimize both directions' time scheduling, which is not the subject of this research.

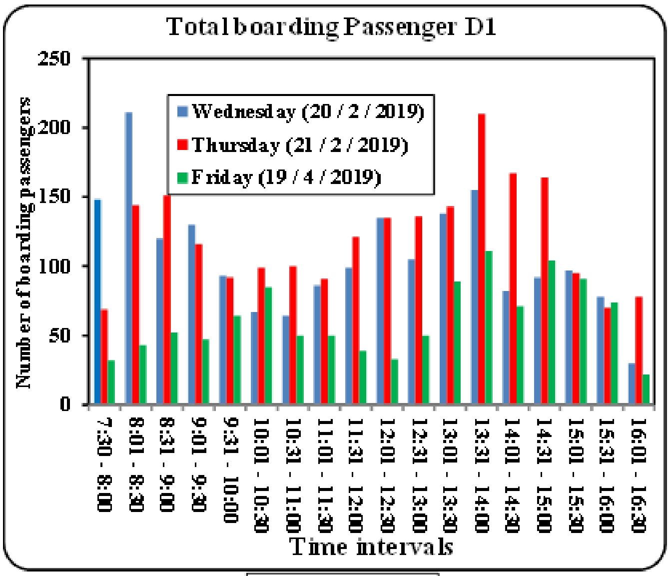


Figure 2-a

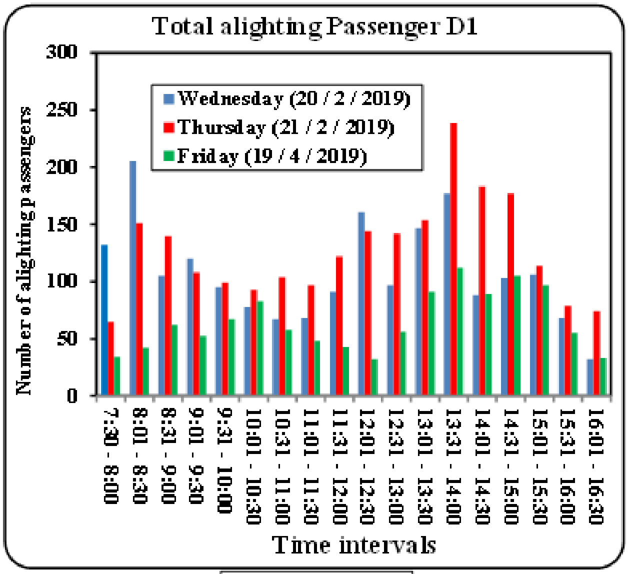


Figure 2-b

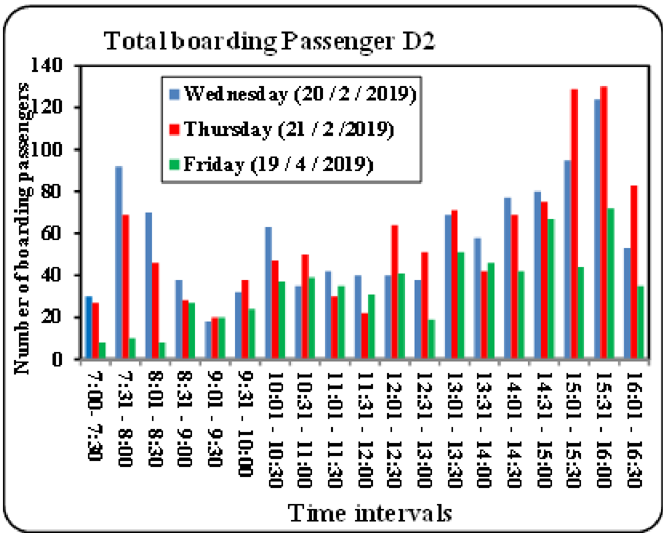


Figure 2-c

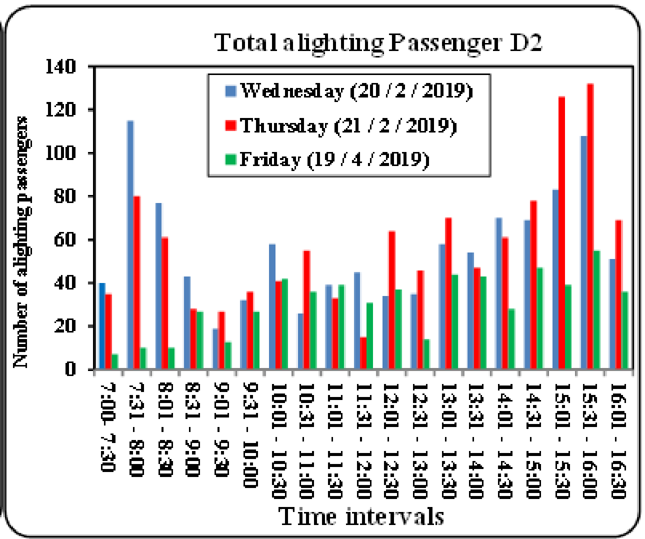


Figure 2-d

Figure 2. Distribution of boarding and alighting passenger numbers over the three days: (a) Total boarding passenger number of D1, (b) Total alighting passenger number of D1, (c) Total boarding passenger number of D2, (d) Total alighting passenger number of D2.

Table 1. Time intervals of peak and off-peak periods for boarding and alighting passengers in both directions D1 & D2.

Time Intervals - Boarding (D1 and D2)				
Time intervals	Traffic situation	Wednesday	Thursday	Friday
TI11B*	Off- peak time	---	---	7:30-8:30
TI21B	Peak time	7:30-9:00	7:30-10:00	8:30-11:00
TI31B	Off- peak time	9:00-11:00	10:00-11:30	11:00-13:00
TI41B	Peak time	11:00-15:30	11:30-15:30	13:00-16:00
TI51B	Off-Peak time	15:30-16:30	15:30-16:30	16:00-16:30
TI12B	Peak time	7:00-9:00	7:00-9:00	-----

TI22B	Off- peak time	9:00-11:30	9:00-11:30	7:00-9:30
TI32B	Off- peak time	11:30-14:00	11:30-14:30	9:30-14:00
TI42B	Peak time	14:00-16:30	14:30-16:30	14:00-16:30
Time Intervals -Alighting (D1 & D2)				
TI11A**	Off- peak time	---	---	7:30-8:30
TI21A	Peak time	7:30-9:00	7:30-10:00	8:30-11:00
TI31A	Off- peak time	9:00-11:00	10:00-11:00	11:00-12:30
TI41A	Peak time	11:00-15:30	11:00-15:30	12:30-16:00
TI51A	Off-Peak time	15:30-16:30	15:30-16:30	16:00-16:30
TI12A	Peak time	7:00-9:00	7:00-9:00	---
TI22A	Off- peak time	9:00-11:30	9:00-11:30	7:00-9:30
TI32A	Off- peak time	11:30-14:00	11:30-14:00	9:30-14:00
TI42A	Peak time	14:00-16:30	14:00-16:30	14:00-16:30

* TI11B: Time Interval 1, Direction 1, Boarding
** TI11A: Time Interval, Direction 1, Alighting

Also, the mean, median, and mode times for each peak and off-peak times of the three days are computed as illustrated in **Table 2**. The table shows the mean and median of most of the time intervals are almost the same, which can be explained by the data's normal distribution. However, further tests are needed to decide whether the distributions are normally distributed or not, and accordingly, these tests will be carried out later in this section.

Table 2 depicts the mean peak times of direction D1 is different over the days. On Wednesday, the morning and evening mean peak times are at 8:14 and 13:13, respectively, while the morning and evening mean peak times on Thursday occur at 8:48 and 13:33, respectively. On Friday, the morning & evening mean peak times are shifted more, and they occur at 9:49 and 14:28, respectively. On the contrary, the morning mean peak times of direction D2 on Wednesday and Thursday are almost the same, 8:05 and 8:04, respectively. It can be noticed that on Friday, the morning peak time does not occur. The evening mean peak times on Wednesday, Thursday and Friday are almost happening simultaneously, 15:15, 15:04, and 15:10, respectively. The variation of the Friday mean peak times with the other two days' mean peak times can be attributed to the fact that Friday is a weekend day, and thus, most people do not need to meet the morning hour rush time, but they can decide to travel after 9 AM.

Table 2. Mean, median and mode times for boarding and alighting passengers in both directions (D1 and D2) for different time intervals.

Mean, median, and mode - Boarding (D1 and D2)										
Time intervals	Traffic	Wednesday			Thursday			Friday		
		Mean	Median	Mode	Mean	Median	mode	Mean	Median	Mode
TI11B	O[1]	-----	-----	-----	-----	-----	-----	8:05	8:06	8:23
TI21B	P[2]	8:14	8:13	8:15	8:48	8:44	8:45	9:49	9:51	10:15
TI31B	O	9:51	9:49	9:23	10:44	10:45	10:08	12:00	11:57	12:53
TI41B	P	13:13	13:14	13:45	13:33	13:38	13:45	14:33	14:30	14:45
TI51B	O	15:58	15:57	15:53	15:58	16:02	16:08	16:13	16:12	16:08
TI12B	P	8:07	8:02	7:45	8:04	7:59	7:45	-----	-----	-----
TI22B	O	10:24	10:24	10:23	10:22	10:25	10:53	8:35	8:42	8:53
TI32B	O	12:53	12:57	13:23	12:56	12:52	14:23	11:56	11:57	13:53
TI42B	P	15:15	15:21	15:31	15:04	15:17	15:45	15:10	15:08	15:31
Mean, median and mode - Alighting (D1 & D2)										
TI11A	O	---	---	---	---	---	---	8:05	8:05	8:23
TI21A	P	8:14	8:13	8:15	8:48	8:43	8:15	9:49	9:48	10:15
TI31A	O	9:53	9:52	9:53	10:28	10:32	10:08	11:41	11:39	11:08
TI41A	P	13:18	13:20	13:45	13:35	13:40	13:45	14:17	14:17	14:45
TI51A	O	15:54	15:53	15:38	15:58	15:59	15:38	16:14	16:13	16:08
TI12A	P	8:05	7:58	7:45	8:04	8:01	7:45	---		
TI22A	O	10:22	10:22	10:23	10:22	10:26	10:53	8:29	8:39	8:53
TI32A	O	12:51	12:55	13:23	12:39	12:34	13:53	11:50	11:44	13:53
TI42A	P	15:15	15:20	15:45	15:29	15:30	15:45	15:14	15:11	15:31

1 Off-peak time
2 Peak time

3.3 Passenger volumes

The mean, median, and 85% of mode values for boarding and alighting passenger volume are computed for each time intervals and days, as demonstrated in **Table 3**. The maximum values between these three values can be selected as a design value for each time interval. The mode values of the boarding and alighting passenger volumes are reduced to 85% for economic reasons. The maximum design value (211 passengers/30minutes), representing the boarding passenger volume at morning peak time, occurs on Wednesday. In contrast, the maximum boarding passenger volume (210 passenger/30 minutes) at evening peak time occurs on Thursday. It should be noted that the direction in which these extreme values occur is D1.

The boarding and alighting passenger volumes at each direction D1 and D2 for Friday is about a half of those of weekdays (Wednesday and Thursday). It is important to note that the morning peak time of D2 on Friday does not exist. This implies that most travelers that use D2, are those who are either moving to their workplace, school, office complex, or a regular activity for the day.

That is for Friday, which is a weekend. It is reasonable that there will be more passenger volumes during off-peak hours since most people do not need to meet during the morning peak hours.

Table 3. Mean, median and mode values for boarding and alighting passenger volume in both directions (D1 and D2) for different time intervals.

Mean, median, and mode - Boarding (D1 and D2)													
Time intervals	Traffic	Wednesday				Thursday				Friday			
		Mean	Median	85% Mode	Design value	Mean	Median	85% mode	Design value	Mean	Median	85% Mode	Design value
TI11B	O	---	---	---	---	---	---	---	---	43	43	37	43
TI21B	P	211	211	179	211	151	151	128	151	64	64	72	72
TI31B	O	93	93	111	111	100	100	84	100	39	39	43	43
TI41B	P	138	138	132	138	210	210	179	210	104	104	88	104
TI51B	O	78	78	66	78	70	78	66	78	2	22	19	22
TI12B	P	70	70	78	78	46	69	59	69	---	---	---	---
TI22B	O	63	63	54	63	47	47	43	47	27	27	23	27
TI32B	O	38	38	59	59	51	51	59	59	31	31	39	39
TI42B	P	95	95	105	105	129	129	111	129	44	44	61	61
Mean, median, and mode - Alighting (D1 & D2)													
TI11A	O	---	---	---	---	---	---	---	---	42	42	36	42
TI21A	P	205	205	174	205	140	140	128	140	67	67	71	71
TI31A	O	95	95	81	95	93	104	79	104	43	43	41	43
TI41A	P	147	147	150	150	239	239	203	239	89	89	89	89
TI51A	O	68	68	58	68	79	79	67	79	33	33	28	33
TI12A	P	77	115	98	115	61	61	68	68	---	---	---	---
TI22A	O	58	58	49	58	41	41	47	47	10	27	23	27
TI32A	O	35	35	49	49	46	46	40	46	31	31	37	37
TI42A	P	83	83	92	92	126	126	112	126	39	39	47	47
Note: Mean, median and mode units are in passenger/30 minutes													

It should be noted that on Wednesday, the design value of boarding passenger volume at, the morning peak time is greater than that of the evening at D1. It is contrarily true for Thursday and Friday, which indicates that the trend of boarding passenger volume at Thursday is similar to that of Friday rather than that of Wednesday. However, At D2, the boarding passenger volume for evening peak time is greater than that of morning peak time for all the days.

At D1, during the first off-peak time, the boarding passenger volume on Wednesday is greater than that of Thursday. However, they have the same boarding passenger volume during the second off-peak time. The same results for D2 have been noticed.

In all the time intervals (peak and off-peak times), the boarding passenger volume of D1 is greater than that of D2. It means that the boarding passenger volumes between the two directions D1 and D2 are not balanced, and the number of buses and headways will be different in each direction.

This issue should be dealt with carefully in the design of the time scheduling planning, and providing a store (garage) in each terminal should be considered in order to have a number of buses parked and ready at any time to enter the system according to the time scheduling planning. In the end, it is interesting to mention that these design values, shown in the table, can be used in any modeling and design of time scheduling and any operating cost study for the bus line under consideration.

3.4 Bus stop

In time scheduling planning, besides the peak and off-peak time intervals and the boarding and alighting passenger volumes, it is useful to know the distribution of boarding, and alighting passenger volumes along the bus line stops, which could be one of the key points in modeling a correct time scheduling for any public transit. Therefore, the distribution of boarding and alighting passenger along the bus stops for different peak and off-peak time intervals of the two directions D1 and D2 are computed as demonstrated in **Fig. (3)** and **(4),** respectively.

The following point can be figured out from **Fig. (3)** and **(4)**:

- In both directions and at all peak times, the rate of boarding passenger volumes is high, and it is decreased where the bus close to its destination. Conversely, the rate of alighting passenger volumes is low and increased where the bus is close to its destination.
- The passenger volume values at each figure cannot be compared. Since the boarding/alighting time intervals are different, it is difficult to compare their corresponding passenger volume values. If such a comparison is required, the values should be expressed per equal unit time.
- The stops with high rate boarding passenger volume at peak times have a high rate of boarding passenger volume at off-peak times.
- In both directions, at terminals, the boarding passenger volume rate is very high compared to that of the other stops.

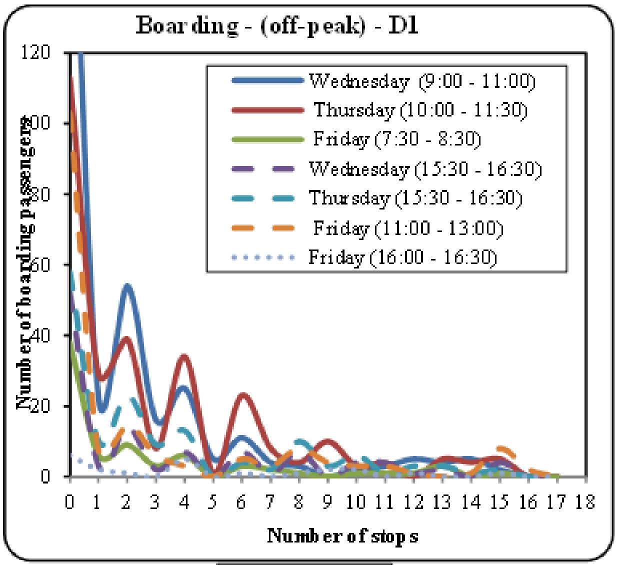


Figure 3-a

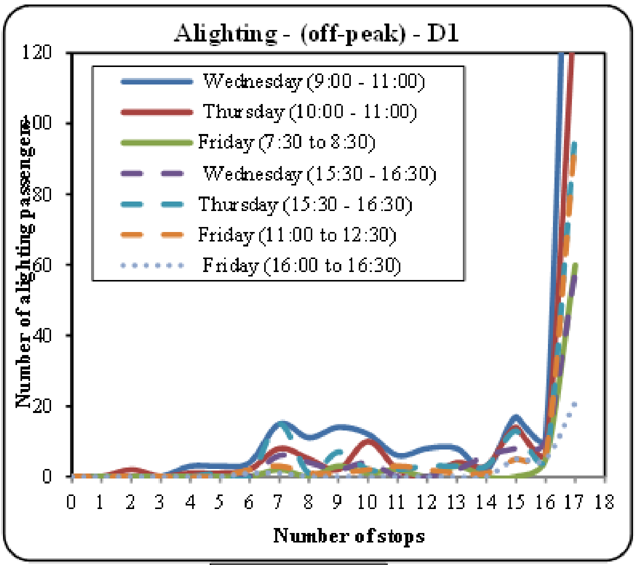


Figure 3-b

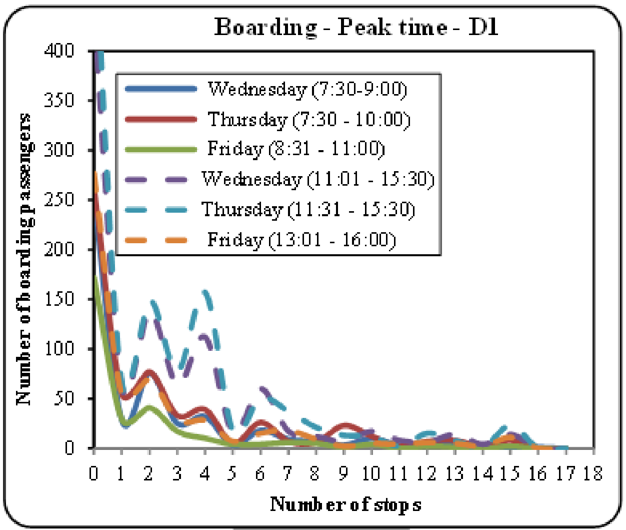


Figure 3-c

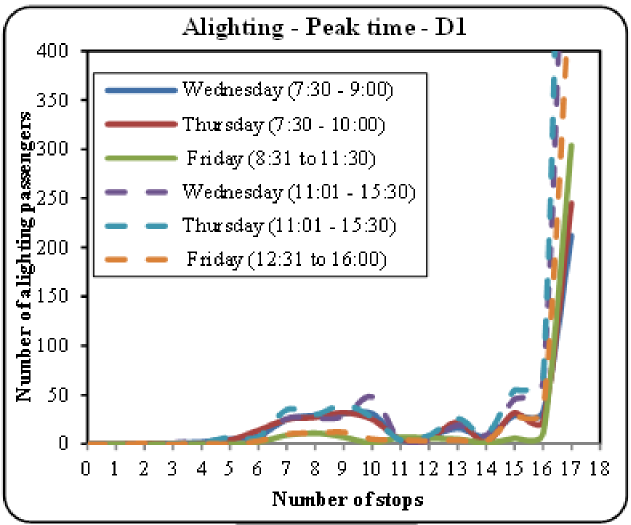


Figure 3-d

Figure 3. Distribution of passenger volumes along the bus stops of D1: (a): boarding passenger volumes at off-peak times, (b) Alighting passenger volumes at off peak times, (c) Boarding passenger volumes at peak times, (d) Alighting passenger volumes at peak times

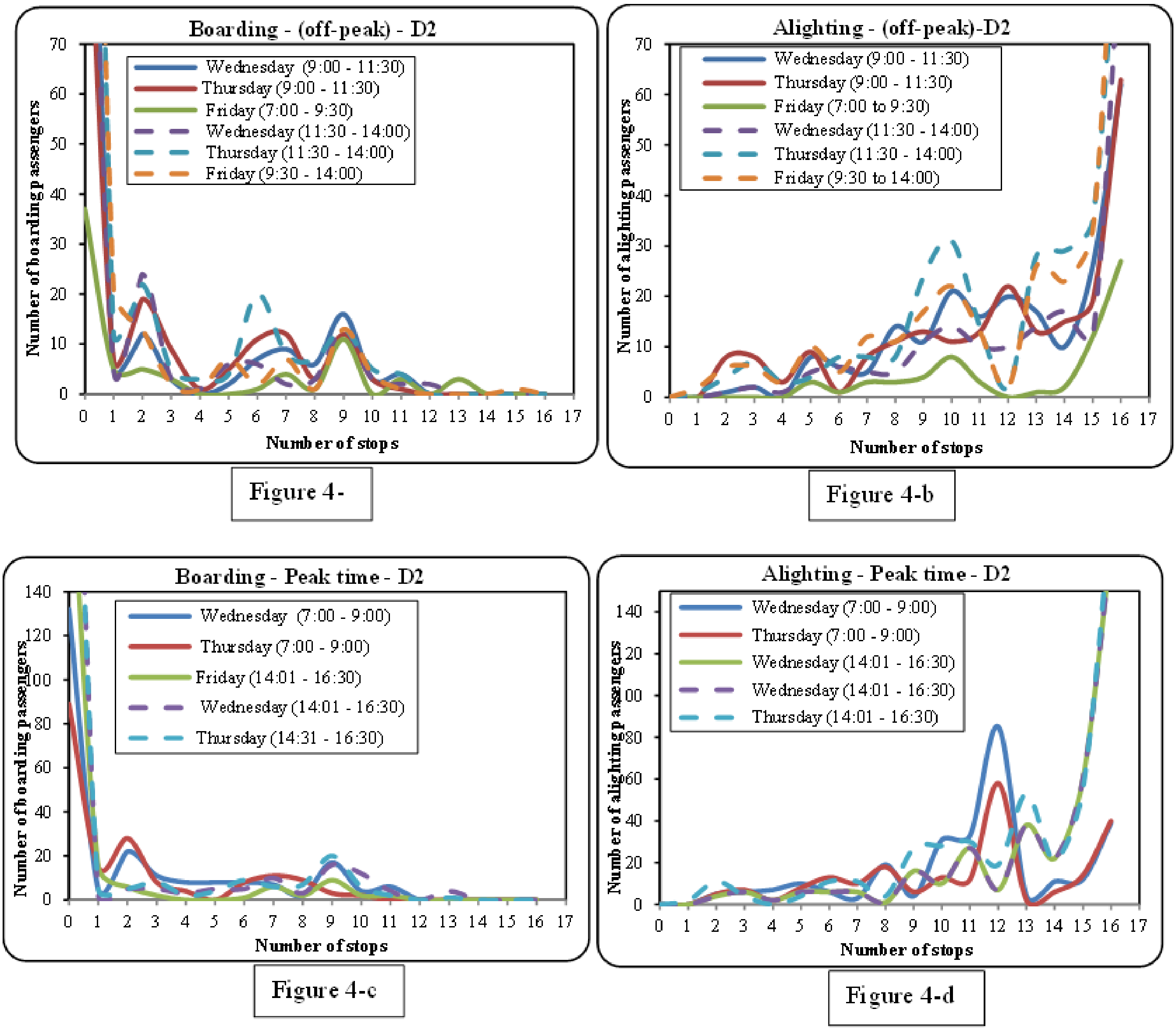


Figure 4. Distribution of passenger volumes along the bus stops of D2: (a) Boarding passenger volumes at off-peak times, (b) Alighting passenger volumes at off-peak times, (c) Boarding passenger volumes at peak times, (d) Alighting passenger volumes at peak times.

3.5 Normality test

Even though mean and median values for each time intervals are almost equal, using Mini-Tab 18 software, the normality tests are carried out for each time intervals in order to be assured that the data distribution at each time intervals are normally distributed, as discussed in section 3.2.

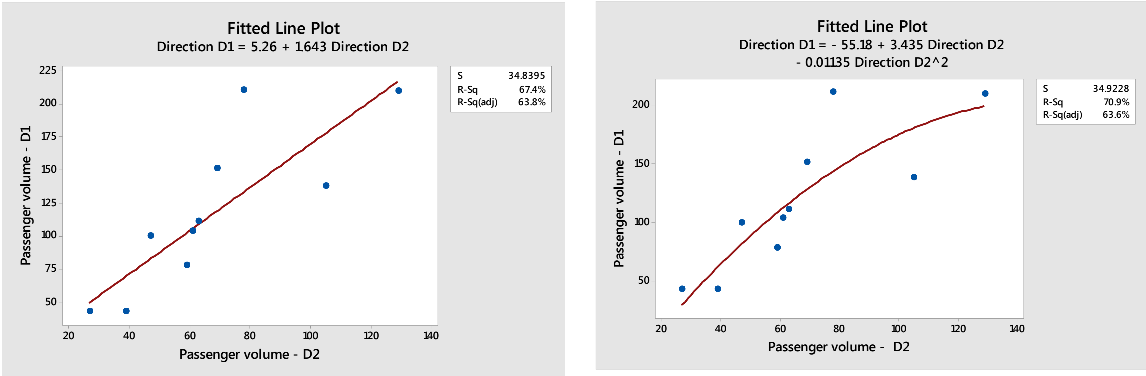
Table 4. Normality test p-value for both boarding and alighting passenger volumes in both directions (D1 and D2) for different time intervals.

p-values from normality test - Boarding (D1 and D2)				
Time intervals	Traffic situation	Wednesday	Thursday	Friday
TI11B	Off- peak time	---	---	0.153
TI21B	Peak time	0.108	0.215	0.184
TI31B	Off- peak time	0.567	0.234	0.055
TI41B	Peak time	0.379	0.065	0.734
TI51B	Off-Peak time	0.313	0.548	0.227
TI12B	Peak time	0.140	0.87	-----
TI22B	Off- peak time	0.053	0.083	0.105
TI32B	Off- peak time	0.007	0.236	0.126
TI42B	Peak time	0.038	0.655	0.636
p-values from normality test -Alighting (D1 & D2)				
TI11A	Off- peak time	---	---	0.328
TI21A	Peak time	0.074	0.185	0.321
TI31A	Off- peak time	0.503	0.563	0.245
TI41A	Peak time	0.849	0.042	0.218
TI51A	Off-Peak time	0.255	0.578	0.227
TI12A	Peak time	0.131	0.539	-----
TI22A	Off- peak time	0.111	0.038	0.891
TI32A	Off- peak time	0.035	0.207	0.562
TI42A	Peak time	0.135	0.235	0.347

The p-values of the normality test for each time intervals are shown in table 4. In these results, the null hypotheses follow (H0: there is normality) and alternative (H1: there is no normality). In this study, a 5% significance level has been considered. Therefore, according to table 4, most of the time intervals have a degree of significance equal to or above 0.05, indicating that they are normally distributed.

3.6 Regression analysis

A regression-based model to predict the boarding passenger volumes in each direction of the bus line is developed, as shown in **Fig.5**. however, it seems there is no strong relation between the two directions' passenger volumes. This confirms that traffic is a complex phenomenon, and it is more complicated than could be treated or expressed in terms of a mathematical equation or a mathematical model.



(a) (b)

Figure 5. Regression-based model of boarding passenger volumes: (a) linear model, (b) quadratic model.

4. CONCLUSIONS

This study investigated the distribution of weekday and weekend passenger flow patterns along a two-directional bus line in Sulaimani city on-peak and off-peak periods. Also, the distribution of boarding and alighting passenger and the bus stops of the line for different peak and off-peak time intervals, which can be considered the key points for modeling a reliable bus route schedule, is analyzed. The results postulated that weekday and weekend influence peak and off-peak period traffic in different ways. The main findings and significance of this study are as follows:

- In direction D1, the morning peak time on Wednesday starts from 7:30 to 9:00, and the evening peak time starts from 11:00-15:30, while the morning peak time on Thursday starts from 7:30 until 10:00 AM and the evening peak time starts from 11:30 until 15:30. The morning peak time on Friday starts from 8:30 until 11:00 AM and the evening peak time starts from 13:00 until 16:00
- In D2, the morning peak time on Wednesday and Thursday occurs simultaneously, and it starts from 7:00 until 9:00 AM, and the evening peak time starts from 14:00 until 16:30 and 14:30 to 16:30, respectively. There is no peak time marked on Friday, while the evening peak time is from 14:00 to 16:30.
- For direction D1, the boarding passenger volumes on Wednesday's morning peak time are maximum compared to the other peak times' other design values, which is equal to 211 passengers/30 minutes. The boarding passenger volumes on Thursday's evening peak time are maximum compared to the evening peak times equal to 210 passengers/ 30 minutes.
- Thursday boarding passenger volume is more similar to that of Friday rather than that of Wednesday.
- For direction D2, the boarding passenger volumes are less by around 50% than that at D1. It means that the two directions are unbalanced in terms of passenger volumes.
- The regression analysis for predicting the boarding passenger volumes in each bus line direction shows no strong relation between the two directions' passenger volumes.

It is also worth noting that this study can be viewed as a building block for generating a reliable schedule for a given bus route within the context of an optimization process, which will be considered in our future work.

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