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Determination of Expansion Factors to Estimate Average Annual Daily Traffic for Arterials in Amman

Maisa Al Maaiteh [1)] ***and Rana Imam*** [2)*]

[1)] M.Sc. in Transportation Engineering, Faculty of Engineering and Technology, The University of Jordan.
[2)] Associate Professor of Civil Engineering, Faculty of Engineering, The University of Jordan.
* Corresponding Author: E-Mail: r.imam@ju.edu.jo

ABSTRACT

Average Annual Daily Traffic (AADT) is an important traffic parameter used in transportation infrastructure planning, as well as in related research activities, such as air quality modeling or noise and vibration modeling. The main objective of this research is to provide expansion factors for arterials in Amman, including the Hourly Expansion Factor (HEF), Weekly Expansion Factor (WEF) and Monthly Expansion Factor (MEF), which can be used to provide an accurate estimate of AADT from available short-term traffic counts. The analysis was conducted on 8 arterials and 8 intersections in Amman. The obtained expansion factors were validated through random sampling of existing traffic data from permanent traffic counting stations in Amman. Finally, AADT was generated by applying the identified expansion factors and then comparing the values obtained with values described in literature and previous studies using comparable methods for similar roadways. The identified p-factors and expansion factors were found to be compatible to the factors obtained and described in literature.

KEYWORDS: Average annual daily traffic, Expansion factors, Amman arterials, Traffic volume, Short-term traffic counts.

INTRODUCTION

Modern day urbanization trends exert tremendous pressure on decision-makers to accommodate the growing mobility demands within cities. Amman's population according to 2010 estimates comprised almost 3 million residents (DOS, Yearbook 2010). The increase in population has led to a significant rise in the number of registered vehicles in the city. According to a study by the Jordan Traffic Institute (2015), the number of registered vehicles in Jordan has doubled over the past 20 years, with the annual growth rate at 5.5% on average (Jordan Traffic Institute, 2015).

Annual Average Daily Traffic (AADT) is a commonly used measurement tool of traffic volume that gives a daily estimate of traffic volume specific to particular locations. AADTs are essential for such planning parameters as selection of project, pavement design, capacity and safety analyses, air quality and traffic simulations (AASHTO, 1992). Conventionally, AADTs were estimated for the majority of road segments from short-term traffic counts by applying a set of expansion factors obtained from permanent traffic counts (FHWA, 2001). Usually, AADT is estimated using a combination of permanent and temporary traffic counts. Normally, the field collection of traffic counts involves a significant cost; therefore, the permanent traffic counts are used for main roads (Wang, 2012). These are locations where traffic counting is conducted 24 hours a day, 365 days a year using a variety of permanent detectors and data communication interfaces

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to communicate the results to a remote computer for further storage and analysis (Zhao, 2004). At the majority of intersections, the traffic volumes were counted at the departure from intersections, since turning movements cannot be determined until the vehicles exit the intersections. This approach does not take into consideration the buildup of traffic queues when the demand exceeds the capacity of intersections; therefore, the results might have a higher degree of error (Roess, 2004). At signalized intersections, the queue buildup was identified during the red light interval and was not fully cleared by the green interval.

Permanent or continuous traffic counting is considered the most reliable and precise method for estimating AADT. The sensors are embedded into a road and traffic data is collected continuously for 365 days a year with the exception of the periods where the counters are shut down for maintenance. In addition to the cost of using the PTCs, there are other considerations in using alternative short-term counts, such as time constraints for collection of data on roads not equipped with permanent traffic counters and when specific information on traffic characteristics is needed (Roess, 2004), such as vehicle occupancy, turning movements at intersections and vehicle classification. The collected data is then extrapolated to compute the AADT using the adjustment or expansion factors. Due to the difference in protocols in data collection, the methods used for estimating AADT are not error free and there is a need to make further adjustments (Murray, 2007).

The accuracy of AADT estimates from short-term counts can be improved by identifying the expansion factors or so-called adjustment factors. Upon determining the expansion factors, they can be used to estimate AADT values for road segments or any other feature by multiplying the short-term counts by the identified adjustment factors using Equation 1.

$$\boldsymbol{AADT = ADT \times F} \ldots\ldots \text{(1) (FHWA, 2001)}$$

where:
AADT = Average Annual Daily Traffic;
ADT = Average Daily Traffic obtained from short-term traffic counts;
F = correction factor.

The shape of a daily flow profile can have distinct AM and PM peaks or have a flat appearance over the daytime hours between peaks. Such pattern is most common on busy arterial roads due to the existence of traffic congestion, where demand exceeds road capacity. This limitation of capacity can lead to spreading the peak flow into the hours in between the AM and PM peaks, thus giving a flatter appearance to the traffic flow profile. In some cases, due to severe congestion, the traffic flow profile can show a reduction of traffic during peak hours, significantly affecting the accuracy of estimation (NRA, 2012).

In order to represent the peaks of traffic flow over the 24-hour traffic flow profile, the Peak Hour Factor, or p-factor, is used. P-factor can be evaluated using Equation 2.

$$\boldsymbol{p = a + b - 2c} \ldots\ldots\ldots\ldots \text{(2) (NRA, 2012)}$$

where:
p = p-factor;
a = the maximum hourly proportion of traffic between 0:00 and 12:00 on a weekday;
b = the maximum hourly proportion of traffic between 12:00 and 24:00 on a weekday;
c = the minimum hourly proportion of traffic between 08:00 and 18:00 on a weekday.

The value of the p-factor ranges between 0 and 1. AADT is calculated using Equation 3.

$$\boldsymbol{AADT = ADT/p} \ldots\ldots \text{(3) (NRA, 2012)}$$

where:
AADT = Average Annual Daily Traffic;
ADT = Average Daily Traffic obtained from short-term traffic counts;
p = Peak Hour Factor.

The main objective of this research is to compute and summarize expansion factors for arterials in Amman, including the Hourly Expansion Factor (HEF), Weekly Expansion Factor (WEF) and Monthly Expansion Factor (MEF). The research has the following specific objectives:

- Provision of descriptive statistics of traffic flow patterns (traffic flow profile) and pattern distribution in Amman.
- Development of a simple procedure for allocating short-duration counts to the factor groups for estimating Annual Average Daily Traffic (AADT).
- Provision of a direct mechanism for computing the statistical precision of the factors being applied.
- Comparison analysis between the expansion factors of the arterial roads and intersections.
- Determining the most appropriate time for short counts within the year for hourly, weekday and monthly counts.

METHODOLOGY

The choice of arterials and intersections was based on the availability of traffic data from the permanent traffic counters installed around the city. The traffic data was obtained from Transportation and Traffic Planning Department within Greater Amman Municipality.

The sample size was computed based on the normal distribution. The confidence level was assumed to be 95%, the margin of error to be tolerated is 5% and 0.50 as an estimate of the population proportion. This proportion will result in the maximization of variance, which will also produce the maximum sample size (Bartlett et al., 2001). The population size is 112 intersections with permanent traffic counters and 98 operational permanent traffic counters on arterial roads in Amman (GAM, 2010). The sample size for the intersections was determined as 8, while for the arterials it was 6. The sample size of the arterials was increased to 8 to match the number of intersections. The arterials and intersections selected for this study are presented in Tables 1 and 2, respectively.

Table 1. Arterials

No.	Arterial Name	Length (km)	Number of Lanes	Direction
1	Zahran Street	8.279	4	E-W
2	Shaheed Street	14.833	6	E-W
3	Jordan Street	16.501	6	N-S
4	Istiqlal Street	6.762	4	E-W
5	Prince Hasan Street	7.785	4	N-S
6	Prince Hashem bin Hussein Street	5.532	4	N-S
7	Al-Aqsa Street	2.584	4	N-S
8	Queen Alia Street	2.341	6	N-S

Table 2. Intersections

No.	Serial Number	Location of Intersection	Number of Detectors
1	108	Jordan Street	12
2	201	Al-Aqsa Street	14
3	203	Queen Alia Street	7
4	302	Istiqlal Street	16
5	501	Zahran Street	10
6	502	Prince Hasan Street	8
7	812	Prince Hashem bin Hussein Street	12
8	914	Shaheed Street	7

Permanent inductive loops are used for traffic detection, vehicle classification and constant traffic counting in Jordan. The inductive loop is installed under the roadway, which allows the loop sensor to detect the presence of a vehicle. Figure 1 shows the locations of the arterials and intersections examined in this study.

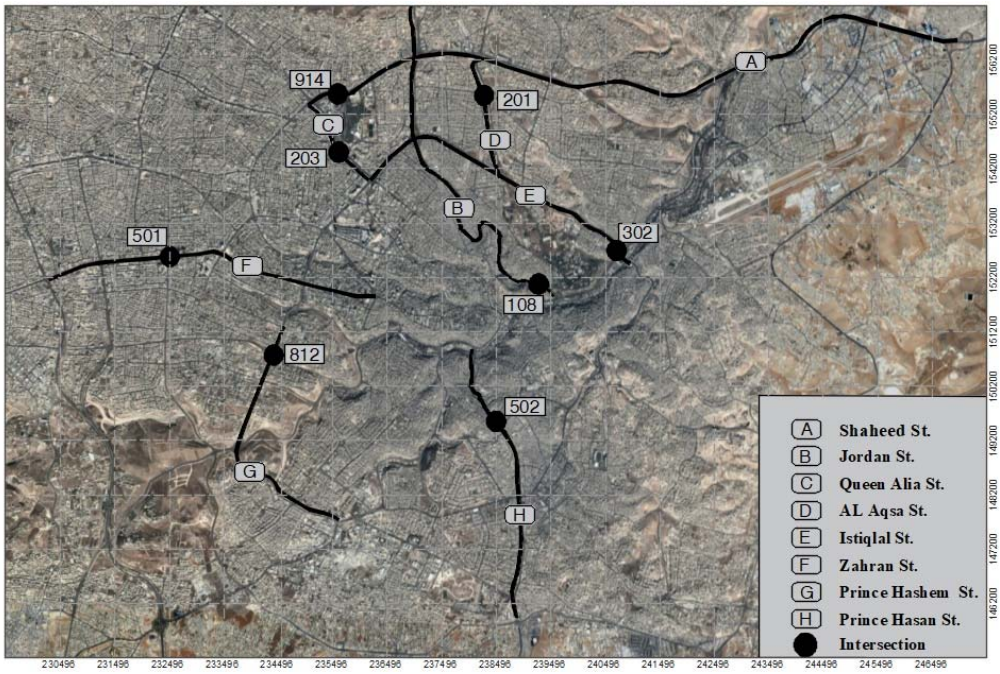

Figure (1): Locations of the arterials and intersections under study

Average Annual Daily Traffic (AADT) is defined as the total traffic volume transient over the road segment for the period of one year divided by the number of days in the year (Mannering, 2009). AADT is a very important parameter, based on which all further calculations are made. The AADT is calculated according to Equation 4 (Garber and Hoel, 2009).

$$AADT = \frac{total\ traffic\ volume\ for\ 1\ year}{365\ days} \quad (4)$$

Table 3. AADT for arterials

No.	Location	AADT (veh/day)
1	Zahran Street	70,540
2	Shaheed Street	130,856
3	Istiqlal Street	50,546
4	Jordan Street	103,111
5	Queen Alia Street	159,110
6	Al-Aqsa Street	47,633
7	Prince Hashem bin Hussein Street	103,442
8	Prince Hasan Street	54,005

Table 4. AADT for intersections

No.	Location	AADT (veh/day)
1	Intersection 108	36,724
2	Intersection 201	41,073
3	Intersection 203	29,727
4	Intersection 302	46,364
5	Intersection 501	31,344
6	Intersection 502	25,054
7	Intersection 812	28,102
8	Intersection 914	42,144

ANALYSIS AND RESULTS

In this study, two methods were applied in the estimation of factors that convert short-period traffic counts into any period of the year or AADT for a specific location or for a similar roadway:

1. **Generic Expansion Factor Method.** The annual traffic flow profiles were developed considering time of day, day of week and month of year and a number of factors were generated to allow extrapolation of short-period traffic counts into any period of the year or to AADT.
2. **Peak Hour Factor.** Conversion of short-period traffic counts into AADT depends on the shape of traffic flow profile over a specific period of time. The shape of traffic flow profile may be more or less flat; meaning a relatively uniform distribution of traffic flow over the defined period. A significant increase of traffic flow during certain hours leads to increased variability in the traffic flow profile.

The average hourly distribution of traffic flow was estimated for the 24-hour period and traffic flow profiles were generated for each arterial in the study. It must be noted that highways do not exhibit uniform distribution of AM and PM peaks. The 24-hour traffic flow profiles are presented in Figure 2. The identified AM and PM peaks for the arterials and p-factors are presented in Table 5.

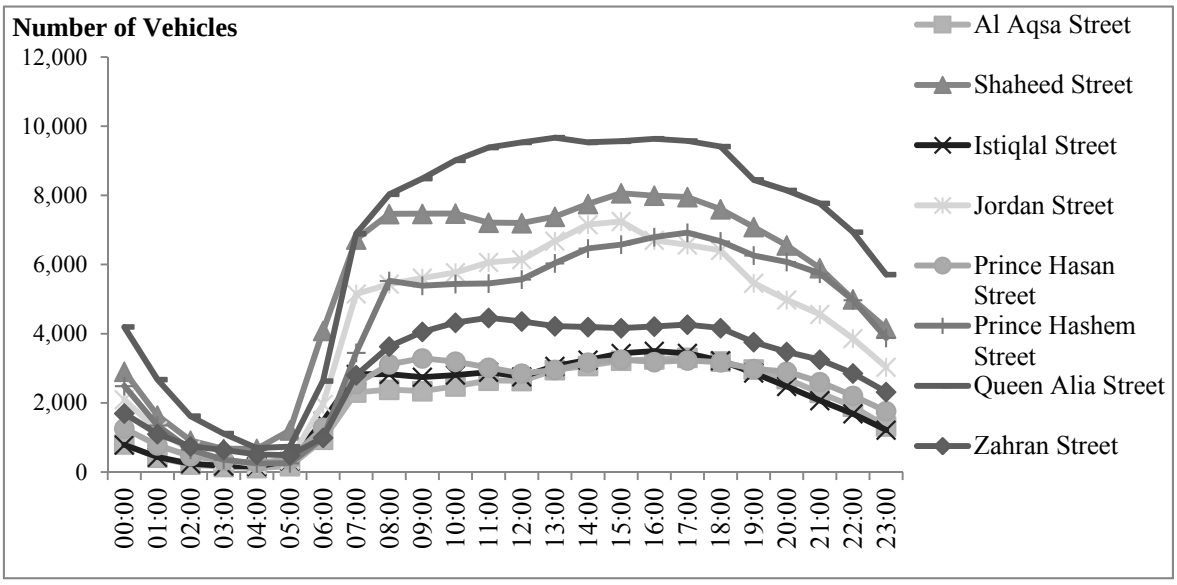

Figure (2): 24-hour traffic flow profiles of the arterials

Table 5. AM and PM peaks and p-factors of the arterials

No.	Arterial	AM Peak	PM Peak	Value of a	Value of b	Value of c	p-factor
1	Al-Aqsa Street	07:00	18:00	0.0619	0.0672	0.0645	0.0053
2	Zahran Street	11:00	17:00	0.0586	0.0643	0.0681	0.0043
3	Jordan Street	07:00	15:00	0.0588	0.0650	0.0694	0.0046
4	Shaheed Street	08:00	15:00	0.0571	0.0616	0.0550	0.0086
5	Istiqlal Street	06:00	16:00	0.0559	0.0691	0.0543	0.0165
6	Queen Alia Street	11:00	17:00	0.0567	0.0658	0.0519	0.0015
7	Prince Hashem Street	08:00	17:00	0.0534	0.0669	0.0527	0.0149
8	Prince Hasan Street	09:00	17:00	0.0608	0.0597	0.0527	0.0152

The p-factors were also calculated for intersections and are summarized in Table 6. The 24-hour traffic flow profiles of the intersections are presented in Figure 3.

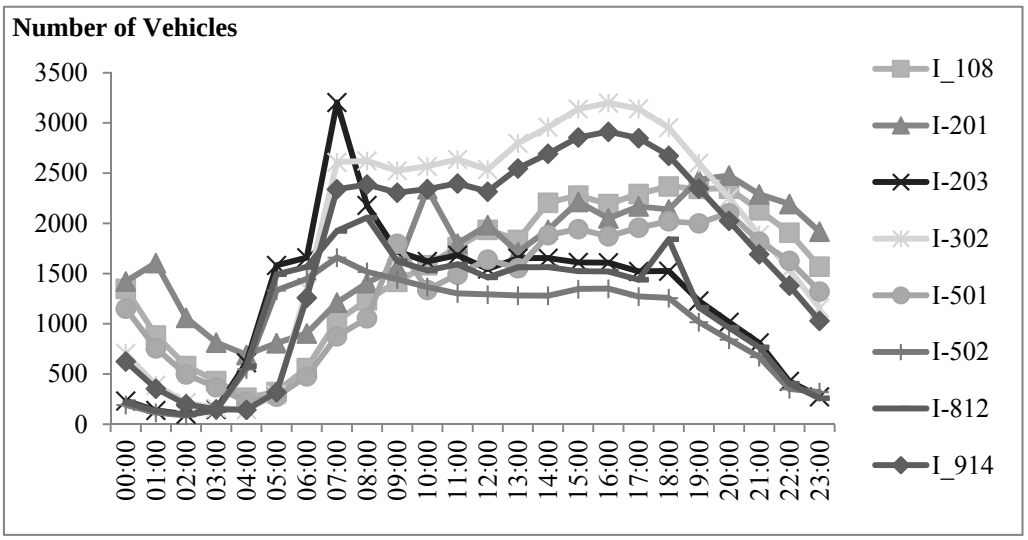

Figure (3): 24-hour traffic flow profiles of the intersections

Table 6. AM and PM peaks and p-factors of the intersections

No.	Intersection	AM Peak	PM Peak	Value of a	Value of b	Value of c	p-factor
1	108	11:00	16:00	0.0620	0.0638	0.0072	0.111
2	201	10:00	17:00	0.0586	0.0602	0.0417	0.0338
3	203	07:00	15:00	0.0669	0.0598	0.0317	0.0594
4	302	07:00	18:00	0.0591	0.0653	0.0681	0.0032
5	501	09:00	16:00	0.0569	0.0502	0.0377	0.0253
6	502	08:00	15:00	0.0663	0.0538	0.0511	0.2222
7	812	08:00	18:00	0.0674	0.0541	0.0513	0.2427
8	914	08:00	16:00	0.0529	0.0654	0.0531	0.0143

Hourly Expansion Factors (HEFs) are based on the average hourly distribution of the traffic flow for the 24-hour period over the extended time (Roess, 2004). HEFs are calculated using Equation 5:

$$\boldsymbol{HEF} = \frac{\boldsymbol{AADT}}{\boldsymbol{HADT}} \text{ ….. (5)} \quad \text{(Roess, 2004)}$$

where:

HEF = Hourly Expansion Factor;
AADT = Average Annual Daily Traffic;
HADT = Hourly Average Daily Traffic per specific hour within the 24-hour period.

Weekly Expansion Factors (WEFs) are based on the average weekday distribution of the traffic flow (Roess, 2004). WEFs are calculated using Equation 6:

$$\boldsymbol{WEF} = \frac{\boldsymbol{AADT}}{\boldsymbol{WADT}} \text{ ….. (6)} \quad \text{(Roess, 2004)}$$

where:

WEF =Weekly Expansion Factor;
AADT = Average Annual Daily Traffic;
WADT = Weekly Average Daily Traffic per weekday.

Monthly Expansion Factors (MEFs) are based on the average monthly distribution of the traffic flow (Roess, 2004). MEFs are calculated using Equation 7:

$$\boldsymbol{MEF} = \frac{\boldsymbol{AADT}}{\boldsymbol{MADT}} \text{ ….. (7)} \quad \text{(Roess, 2004)}$$

where:

MEF = Monthly Expansion Factor;
AADT = Average Annual Daily Traffic;
MADT = Monthly Average Daily Traffic.

In order for the identified expansion factors to be applicable to any similar roadway in Amman, or in Jordan as a whole, the standardized expansion factors were calculated by computing the mean of expansion factors and determining the Confidence Interval (C) (Bartlett et al., 2001).

Confidence intervals were evaluated at a 95% confidence level. The confidence interval for the mean of the normal population is estimated using Equation 8:

$$\bar{\boldsymbol{X}} \pm \boldsymbol{Z_{1-\alpha/2}} \times \frac{\boldsymbol{\sigma}}{\sqrt{(\boldsymbol{n})}} \text{ ……. (8)} \quad \text{(Bartlett et al., 2001)}$$

where:

$\bar{X}$ = the sample mean;
$Z_{1-\alpha/2}$ = critical value of standard normal distribution;
σ = standard deviation;
n = sample size.

The calculated confidence intervals for the arterials and intersections are presented in Tables 7 and 8, respectively. The time intervals that yield confidence interval values greater than ± 20% (NRA, 2012) suggest that the use of "one single hour data" for these periods will not produce reliable results. In order to achieve a reliable estimation of traffic flow for these periods, they should be combined with flows from other periods to improve the accuracy of the estimation.

Table 7. Expansion factors and confidence intervals of the arterials

Arterial	Al-Aqsa Street	Jordan Street	Shaheed Street	Istiqlal Street	Queen Alia St.	Prince Hashem St.	Prince Hasan St.	Mean	Standard Deviation	C (%)
p-factor	0.0053	0.0046	0.0086	0.0165	0.0015	0.0149	0.0152	0.0089	0.0059	0.41%
Time	**HEF**									
00:00	59.269148	49.200	45.05	64.349	37.94	41.54	42.886	47.73	9.364	16.38%
01:00	113.93679	86.202	79.89	116.648	59.51	76.76	69.715	83.35	21.483	14.89%
02:00	218.07552	163.085	143.62	209.102	98.47	159.51	116.828	150.42	46.663	22.63%
03:00	320.09115	293.016	195.10	281.638	143.13	287.99	164.937	224.51	80.384	26.62%
04:00	409.08402	473.416	194.37	308.377	229.62	409.26	202.601	295.68	122.735	8.50%
05:00	274.60507	292.283	108.59	153.911	217.91	403.18	145.151	217.57	99.814	19.50%
06:00	50.869932	52.548	32.05	34.418	60.45	105.20	42.003	56.05	23.712	16.43%
07:00	20.67833	20.016	19.45	17.884	23.09	30.00	21.231	22.19	3.867	9.47%
08:00	19.994653	18.977	17.53	17.871	19.82	18.71	17.334	18.71	1.030	2.07%
09:00	20.351378	18.379	17.52	18.413	18.75	19.20	16.423	18.30	1.206	1.43%
10:00	19.215185	17.868	17.51	18.016	17.65	19.02	16.900	17.81	0.975	5.16%
11:00	18.00501	17.009	18.15	17.492	16.96	18.97	17.882	17.54	0.952	3.59%
12:00	18.056321	16.789	18.18	18.327	16.69	18.57	18.957	17.72	1.013	0.92%
13:00	16.142276	15.439	17.72	16.508	16.46	17.13	18.283	16.80	0.899	6.23%
14:00	15.50759	14.411	16.88	15.597	16.69	16.00	17.053	16.12	0.914	6.33%
15:00	14.779487	14.226	16.23	14.729	16.64	15.73	16.612	15.74	1.036	2.48%
16:00	14.615756	15.386	16.37	14.454	16.51	15.22	16.961	15.79	0.987	6.84%
17:00	14.402981	15.695	16.46	14.713	16.62	14.95	16.730	15.76	0.955	6.62%
18:00	14.878054	16.083	17.22	15.681	16.91	15.51	17.009	16.28	0.862	5.97%
19:00	16.042667	18.871	18.47	17.634	18.83	16.52	18.101	17.90	1.092	6.37%
20:00	17.693216	20.710	19.97	20.402	19.54	17.02	18.583	19.28	1.362	25.07%
21:00	20.788055	22.606	22.18	24.440	20.49	18.02	20.739	21.37	1.870	20.58%
22:00	25.114951	26.714	26.19	29.978	22.94	20.81	24.483	25.12	2.705	4.89%
23:00	35.983641	33.964	31.45	41.547	27.87	26.67	30.669	32.32	4.781	5.41%
Weekday	**WEF**									
Monday	0.958	0.949	0.975	0.969	0.933	1.002	0.967	0.963	0.021	1.43%
Tuesday	0.954	1.011	0.977	0.971	0.939	1.017	0.964	0.971	0.030	2.11%
Wednesday	0.984	0.975	0.999	1.013	0.946	0.990	0.971	0.975	0.028	1.97%
Thursday	0.906	0.881	0.962	0.939	0.929	0.970	0.983	0.945	0.039	2.70%
Friday	1.200	1.248	1.183	1.079	1.399	1.038	0.938	1.181	0.159	10.99%
Saturday	1.073	1.074	0.989	1.062	1.047	0.994	1.222	1.069	0.072	5.01%
Sunday	0.995	0.943	0.945	0.978	0.943	0.996	1.003	0.971	0.025	1.76%
Month	**MEF**									
January	1.050	0.997	1.112	1.001	0.994	1.060	0.648	0.994	0.146	10.15%
February	1.034	0.990	1.114	1.045	1.118	1.052	0.637	1.008	0.156	10.79%
March	0.983	0.931	1.039	1.010	0.995	1.032	0.604	0.955	0.146	10.14%

Arterial	Al-Aqsa Street	Jordan Street	Shaheed Street	Istiqlal Street	Queen Alia St.	Prince Hashem St.	Prince Hasan St.	Mean	Standard Deviation	C (%)
April	0.976	0.892	1.042	0.990	0.993	1.007	0.659	0.952	0.128	8.90%
May	0.966	0.966	1.031	0.981	0.988	0.987	1.882	1.105	0.315	21.84%
June	1.026	0.937	1.096	0.973	0.993	0.913	1.921	1.099	0.337	23.38%
July	0.991	1.052	0.897	0.973	0.992	1.015	N/A	0.984	0.048	3.31%
August	1.027	1.090	0.972	0.986	0.988	0.964	2.161	1.143	0.414	28.68%
September	0.951	1.009	0.976	0.988	0.997	0.992	1.938	1.103	0.338	23.41%
October	1.036	1.083	0.958	1.006	0.985	N/A	1.834	1.125	0.315	21.86%
November	1.016	1.078	0.893	1.037	0.997	N/A	0.607	0.941	0.159	10.99%
December	0.958	1.016	0.976	1.021	0.984	N/A	1.957	1.127	0.367	25.41%

Table 8. Expansion factors and confidence intervals of the intersections

Intersection	108	201	203	302	501	502	812	914	Mean	Standard Deviation	C %
p-factor	0.11	0.03	0.06	0.00	0.03	0.22	0.24	0.01	0.0890	0.0947	6.56%
Time	**HEF**										
00:00	27.23	28.89	65.68	27.22	27.22	130.47	128.25	67.38	62.79	44.465	23.88%
01:00	41.49	25.58	119.06	41.46	41.46	219.72	217.17	118.77	103.09	79.746	26.31%
02:00	63.27	38.73	214.96	63.21	63.21	293.45	298.85	211.86	155.94	110.497	7.69%
03:00	85.25	50.50	289.81	85.11	85.11	179.71	202.33	284.56	157.80	95.096	23.53%
04:00	138.80	59.44	317.82	138.58	138.58	45.75	48.62	294.09	147.71	105.978	7.34%
05:00	114.03	50.88	158.31	113.99	113.99	18.79	18.82	131.79	90.08	53.196	23.00%
06:00	65.70	45.41	34.37	65.75	65.75	17.31	17.95	33.46	43.21	20.732	14.37%
07:00	35.80	33.91	17.77	35.81	35.81	15.09	14.60	18.02	25.85	10.220	7.08%
08:00	29.71	29.23	17.68	29.72	29.72	16.52	13.66	17.66	22.99	7.173	12.02%
09:00	25.90	26.29	18.37	17.44	17.44	17.36	17.31	18.27	19.80	3.910	13.23%
10:00	23.18	17.55	18.05	23.43	23.43	18.34	18.36	18.00	20.04	2.749	12.12%
11:00	20.82	22.82	17.59	21.04	21.04	19.25	17.66	17.58	19.72	1.997	13.84%
12:00	18.97	20.72	18.29	19.12	19.12	19.39	19.23	18.20	19.13	0.776	19.14%
13:00	20.01	23.95	16.58	20.17	20.17	19.56	17.99	16.55	19.37	2.403	16.65%
14:00	16.65	21.21	15.68	16.65	16.65	19.58	17.98	15.65	17.51	1.973	13.68%
15:00	16.13	18.55	14.78	16.13	16.13	18.62	18.45	14.76	16.69	1.630	11.29%
16:00	16.75	20.04	14.49	16.75	16.75	18.57	18.49	14.47	17.04	1.956	13.55%
17:00	16.01	18.93	14.76	16.02	16.02	19.70	19.54	14.79	16.97	2.080	14.41%
18:00	15.51	19.20	15.70	15.51	15.51	19.93	15.26	15.76	16.55	1.880	13.03%
19:00	15.66	16.85	17.84	15.67	15.67	24.62	24.21	17.96	18.56	3.732	18.93%
20:00	15.65	16.58	20.57	14.91	14.91	29.72	29.25	20.80	20.30	6.126	7.81%
21:00	17.24	17.94	24.58	17.24	17.24	37.37	36.73	24.89	24.15	8.585	10.99%
22:00	19.25	18.73	30.08	19.25	19.25	71.70	69.63	30.54	34.80	22.674	15.71%
23:00	23.39	21.42	40.07	23.71	23.71	78.21	108.84	40.90	45.03	31.956	22.14%

Intersection	108	201	203	302	501	502	812	914	Mean	Standard Deviation	C %
Weekday	**WEF**										
Monday	0.966	1.026	0.983	0.974	0.989	1.002	0.985	0.977	0.988	0.019	1.32%
Tuesday	0.940	1.025	0.947	1.016	0.975	0.971	0.948	0.967	0.974	0.031	2.18%
Wednesday	0.944	0.998	0.919	0.984	0.969	0.933	0.919	0.980	0.956	0.031	2.15%
Thursday	0.951	0.964	0.926	0.963	1.015	0.938	0.925	0.971	0.957	0.029	2.03%
Friday	1.000	1.095	1.248	1.370	1.079	1.146	1.246	1.028	1.151	0.127	8.79%
Saturday	0.971	0.982	1.128	1.061	1.044	1.121	1.126	1.021	1.057	0.064	4.42%
Sunday	0.960	0.927	0.934	0.947	0.973	0.933	0.934	0.992	0.950	0.023	1.58%
Month	**MEF**										
January	0.957	0.972	0.985	1.022	0.980	0.969	1.024	0.990	0.987	0.024	1.68%
February	0.968	0.987	0.981	0.980	0.992	0.965	0.989	0.984	0.981	0.010	0.67%
March	0.997	1.053	1.010	0.947	1.021	0.978	1.002	0.952	0.995	0.035	2.46%
April	0.975	1.019	0.987	0.925	0.998	0.957	0.979	0.924	0.971	0.034	2.34%
May	0.982	0.972	0.992	0.949	1.006	1.070	0.985	0.947	0.988	0.039	2.68%
June	0.954	1.006	0.992	0.962	0.977	1.057	0.985	0.961	0.987	0.033	2.31%
July	0.996	1.036	0.984	1.009	1.020	1.067	0.977	1.009	1.012	0.029	2.01%
August	0.979	0.983	1.008	1.051	1.002	1.081	1.000	1.050	1.019	0.037	2.55%
September	0.972	0.983	0.980	1.008	0.996	0.942	0.972	1.008	0.983	0.022	1.52%
October	0.943	0.978	1.081	1.047	0.966	0.971	1.079	1.098	1.020	0.062	4.31%
November	0.988	1.026	1.042	1.079	1.012	1.011	1.035	1.079	1.034	0.032	2.22%
December	1.022	1.012	0.982	1.042	1.047	0.950	0.975	1.041	1.009	0.036	2.50%

Equation (9) estimates AADT from the single hour count based on Equation (1), with the addition of the confidence interval to improve the accuracy of the AADT.

$$AADT = HV \times HEF \pm C \quad \ldots\ldots\ldots\ldots (9)$$

where:
AADT = Annual Average Daily Traffic (veh/day);
HV = Traffic Volume (number of vehicles);
HEF = Hourly Expansion Factor; C = Confidence Interval.

Validation of the computed expansion factors was performed by selecting a random sample of existing traffic flow data from permanent counters (for the year 2015) which was not used in generating the factors. The AADT was calculated by applying the identified expansion factors and confidence interval, as shown in Table 9.

Table 9: Random sampling of identified expansion factors

Source	Value	EF	Generated AADT	Confidence Interval (±)	Adjusted AADT	Actual AADT	Error (%)
Shaheed Street, at 17:00, June 8th	8,263	15.76	130,256	6.62%	130,342	130,856	0.39
Jordan Street, Average traffic flow for Monday	107,116	0.963	103,166	1.43%	103,151	103,111	0.04
Al-Aqsa Street, Average traffic flow for July	48,047	0.984	47,277	3.31%	47,293	47,633	0.71
Istiqlal Street, Average hourly traffic flow at 09:00	4,345	0.089	49,443	0.41%	50,144	50,546	0.80
Intersection 108 at 12:00, February 4th	1,913	19.128	36,592	19.14%	36,662	36,724	0.17
Intersection 203, Average traffic flow for Wednesday	42,757	0.956	40,865	2.15%	40,874	41,073	0.48
Intersection 501, Average traffic flow for February	31,997	0.981	31,384	0.67%	31,386	31,344	0.14
Intersection 914, Average hourly traffic flow at 11:00, March 11th	3,698	0.089	41,552	6.56%	41,579	42,144	1.34

Another validation method of the expansion factors is to apply them in the calculation of AADT as described by Garber and Hoel (2009). The data was collected on a weekday (Wednesday) in January 2016 for the hours described in Table 10.

Table 10. Collected data

Hours	Number of Vehicles	HEF
05.00-06.00	2219	56.1
06.00 -07.00	4202	22.2
07.00–08.00	6122	18.7
08.00-09.00	5114	18.3

Step 1: Estimation of the 24-hour volume using the identified Mean HEF values given in Table 7 as (106,450.6).

Step 2: Adjust 24-hour volume for Wednesday using the WEF for Wednesday given in Table 7: $106{,}450.6 \times 0.975 = 103{,}789.01$.

Step 3: Calculate AADT using MEF for January, since data was collected in January: 103,789.01×0.994=103133.67.

Step 4: Compare the computed value with the actual AADT: Actual AADT is 103,110.97 and the calculated value is 103,133.67. The calculated value exceeds the actual AADT by 0.022%. As shown, the obtained expansion factors provide an accurate estimation of AADT from the short-term traffic counts.

CONCLUSIONS

In general, the identified expansion factors were found to be reliable for both the arterials and the intersections. The Hourly Expansion Factors showed greater variance for the intersections than for the arterials.

The calculated p-factors are comparable to the

factors obtained in previous studies described in literature. However, the confidence interval for the HEFs shows that the values that yield intervals greater than ± 20% (NRA, 2012) suggest that the use of one single hour data from these periods will not produce reliable results.

The values of Weekly Expansion Factors ranged from 0.963 to 1.18 for the arterials and from 0.934 to 1.02 for the intersections. The weekly traffic flow profiles were similar for the arterials and the intersections, with a significant decrease in traffic volumes on weekends. The WEF for Friday has the highest confidence interval value, which means a lower degree of accuracy. The values for Monthly Expansion Factors ranged from 0.92 to 1.12 both for the intersections and the arterials. These values are similar to the results obtained in previous studies in different countries. The monthly traffic flow profile has no specific pattern and shows no significant seasonal variation.

RECOMMENDATIONS

Based on the results of this research, the following recommendations are suggested:

- Since the single hour counts for the periods with a confidence interval greater than 20% do not produce reliable results, reliable estimation of traffic flows for these periods requires combining them with other periods to improve the accuracy of the estimation.
- In order to achieve reliable estimates of the AADT using the Expansion Factors presented in this research, short-term counts need to be conducted at urban arterials and at intersections.
- If the duration of traffic counts is limited to several days, it is recommended that one-to-three day 24-hour samples are taken at certain locations in order to create the approximate traffic flow profile. In this case, it is preferable that Expansion Factors from a location with similar traffic profile are used *versus* the mean Expansion Factors presented in this study.
- The mean Expansion Factors provided in this study are to be used for urban arterials and intersections if the traffic flow profile cannot be established for the roadway feature.
- In this research, the cumulative data for the arterials as a whole was used for computing the value of the Expansion Factors. However, the researchers recognize that there are differences in traffic flow depending on the direction of the travel and unequal distribution of traffic flow over the lanes. Therefore, it is recommended that further research is conducted considering the distribution of the traffic flow over the lanes and using the direction of travel in estimating the expansion factors of arterials.
- Similarly, the cumulative data for intersections in all directions as a whole was used for computing the values of the Expansion Factors. The travel demand and variance in the traffic flow in different directions was not assessed separately. Therefore, it is recommended that further research should consider modeling of the traffic flow at intersections taking separate approaches and directions of the intersections into account.
- Jordan, and the Middle East region as a whole, witnessed a number of political uncertainties as well as an influx of refugees into the country. Further research will need to take into consideration the natural traffic growth as opposed to these remarkable sudden changes in the traffic flow profiles to accurately reflect the situation.

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