MEASUREMENT OF DIFFERENCES OBSERVED IN TWO CONTINUES MANUAL VEHICLE COUNT DATA SETS

Darçın Akın, Gebze Institute of Technology, Department of City and Regional Planning, Istanbul Cad. No: 101, 41400 Gebze, Kocaeli Turkey.Tel: +90-262-605-1642, Fax: +90-262-653-8495, E-mail: dakin@gyte.edu.tr, darcinakin@gmail.com

Ahmet Koçaslan, BİMTAŞ İstanbul Metropolitan Municipality, Beyoglu, Istanbul. Tel: +90-212-245-9900, Fax: 90-212-245-9891, E-mail: ahmetkocaslan@yahoo.com

Aykut Toros, Professor, Head, Department of Sociology, Yeditepe University, Kayışdağı Cad. 34755 Kayışdağı, İstanbul, Tel: 0216 578 1887, E-mail: atoros@yeditepe.edu.tr. Department of Research Development and Statistics, Istanbul Metropolitan Planning and Urban Design Center, Tel.: +90-212-245-9800, fax.: +90-212-245-9891, e-mail: atoros@bilkent.edu.tr

ABSTRACT

In this paper, errors associated with manual vehicle counts by two trained personnel are analyzed. Vehicle and occupant counts as well as roadside interviews to collect O-D data are conducted manually for a traffic survey study to determine the movements of goods and passenger traffic through the metropolitan city of Istanbul, Turkey, from east to west and vice-versa, on the 8th (Thursday) and 9th (Friday) of January in 2008 only on exiting lanes of the two major highways (E5/D100 highway, speed limit (SL) = 90 km/hr and E80/TEM highway, SL = 120 km/hr) at four selected locations, two of which were at the east and the other two were at the west borders of the city. When the differences in the two data sets including vehicle counts by two personnel by day of week, time of day, location and flow rate were analyzed, it was seen that peak period counts (morning-noon-afternoon and evening peaks) included the highest differences in percent (equal or over 100%). Night-time counts (between 12-7 am) were the least problematic ones regarding the differences in percent (equal or less than 100%) except at one location on E80/TEM highway at the west exit on Friday night, probably due to a snow blizzard effective from midnight to around 7 am. On the contrary to the expectations, at high-speed and high volume locations no significantly high errors were observed between the counts, probably due to controlled lane drops for the purpose of pulling vehicles from the flowing traffic onto interview locations to conduct roadside interviews. Although high errors in the counts observed regarding some types of vehicles (some small- or mid-size vehicles were sometimes confused with their larger sizes, and some motorcycles were ignored or missed), differences between total vehicle counts varied about between 5 and 26%. Except those two limit values, the other ones were about

10%, which is pretty much inside the acceptable limits. As a result, it is concluded that there is no explainable trend observed in differences between the counts based on day of week, time of day or location other than the tiredness and/or weak integrity of the count personnel and their supervisors in the field. However, the models develop to explain the relationship between the flow rate (veh/hr) and absolute difference between the counts indicate that the higher the flow rate is, the higher the error is.

Keywords: Data collection, traffic counts, cordon counts, vehicle classification, count errors, Istanbul

INTRODUCTION

Travel demand models require the amount of actual travel demand as input for various levels of the modeling process as well as for the calibration process. Travel demand for a study area needs to be estimated by estimating internal and as well external passenger and cargo movements in terms of their origins and destinations, number of passengers and amount of cargo and vehicle types. Data regarding internal movements are usually collected by household, workplace and passenger terminal surveys for passenger transportation and workplace and cargo terminal surveys for cargo movements. However, for surveying the external-external or external-internal movements, traffic flow counts and roadside driver interviews are required at external stations for highway and ferry exit and entrance hubs. Regarding the budget and accuracy constraints, there can be two methods used to count and classify vehicle flows: 1) automated counts and 2) manual counts. Automated counts can include various types of technological equipments and provide fewer details regarding the types of vehicles and number of occupants. Though manual counts can provide more details for such measurements; however, the level of accuracy for flow counts cannot match with that of automated counts due to the fatigue of counters and/or distractions causing counting errors.

In this study a manual vehicle count method was preferred over automated counts in order to collect detailed vehicle classification and vehicle occupancy data for the study of external-external and internal-external passenger and goods movements. One of the disadvantages of the manual count was the reliability due to human errors in terms of the classification of vehicle types and recording the amount of flow as correctly as possible. The source of human errors can be many, but to mention some of them, they can be fatigue, distraction or sickness during the counting period. In this study, it is attempted to analyze the differences between two continues manual vehicle counting data sets at the four external stations (only outbound cross-sections were counted) on the two major highways (E5/D100 and E80/TEM).

The structure of this paper is as flows: The next section gives some brief information on the characteristics of the study area and the flows of cargo vehicles over the area. The following section presents the data collection and analyses of the findings. The last section of the paper presents the conclusions of the current research and some recommendations for future research.

CHARACTERISTICS OF THE STUDY AREA

City of Istanbul

City of Istanbul is situated at the north-west of Turkey, a bridge between Asia and Europe. Its population is almost 13 million according to 2009 census. Istanbul is in the first 10 urban agglomerations out of 100 with its 5389 km^2 territory. The rate of population growth has been slowly declining in Istanbul, but it is yet high at over 3% per annum. The recent annual increase ranged from 0.4 to 0.5 million. With an annual growth of 3%, the population of Istanbul will have exceeded 20 million in 2023. At a lower growth derived from the past trend, the population will have reached 18 million. The 2023 comprehensive urban plan of the Istanbul Metropolitan Municipality suggests some measures to control the growth of population over 16 million. It is requisite to implement decisive policy instruments to curb the population density (IMM, Almec and Nippon Koei, Co, 2009).

2006 household travel survey revealed that the registered automobiles in the metropolitan region totaled to 1.33 million. With the expected economic growth, the number of motorized vehicles will increase rapidly by more than 3.14 times to 4.19 million in 2023. Registered automobiles per thousand of population were 111 vehicles in 2005 and will increase to 245 by 2023. In 2006, 31% of the metropolitan households owned one passenger car and 4% two or more. The passenger car ownerships are estimated to increase to 67% of the households in 2023 (IMM, Almec and Nippon Koei, Co, 2009).

Istanbul's highway network is classified by functional class from 1 to 5. Function class (FC) 5 stands for highways and expressways with 90 and 120 km/hr speed limit. FC from 1 to 3 stands for primary and secondary arterials and collectors. FC 4 is not mentioned here because the travel demand model does not include them. Table 1 shows the roadway network lengths by functional classification.

Table I – Functional Classification of Roads in 2006

Functional Class	No, of Links	Length (km)*
1. Primary Arterial	5,891	3,907.6
2. Secondary Arterial	4,958	4,743.1
3. Collector	1,574	3,274.4
5. Highway and Expressway (D-100 and E-80)	842	2,025.2
6. Ramps	1,748	517.8
Total	**15,013**	**14,468.0**

* Length equals to the multiplication of link length by the number of lanes,

Figure 1 shows the master plan projects by their completion period. The total investment required for the master plan projects amounts to US$24.2 billion. US$ 11 billion is required for 52 road projects and US$13.2 billion for 16 railway projects. The total cost of 10 projects scheduled for completion after 2023 is US$5.5 billion. Figure 2 shows the base network of railway lines. Gray lines represent the lines in operation. Red lines are the ones completed

by 2013 and the green ones are to be completed between 2014 and 2018 (IMM, Almec and Nippon Koei, Co, 2009).

Figure 3 shows the Bosporus crossing demand by daily 1000 passengers. The master plan proposes the completion of the 3rd bridge by 2023 as both railway and highway links across the Strait. The new bridge is needed simply to meet the expected growth of demand. However, there are many arguments against the new bridge. Main arguments of the contention are the problem of land acquisition and the adverse impact on natural environment and landscape. The natural environment includes fresh water reservoirs and forest areas. It is necessary to undertake careful studies over these issues and explain the circumstances of project formulation until a general consensus begins to emerge (IMM, Almec and Nippon Koei, Co, 2009).

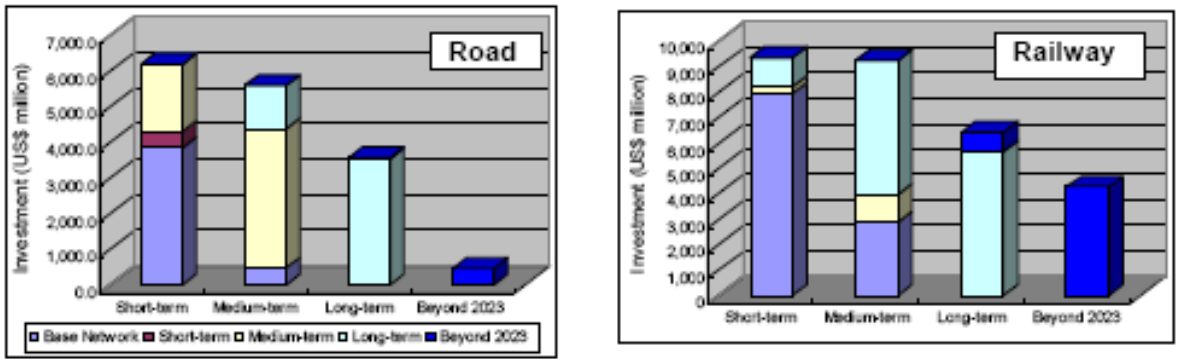

Figure 1 – Master Plan Projects by completion period

Figure 2 – Base network of railway lines

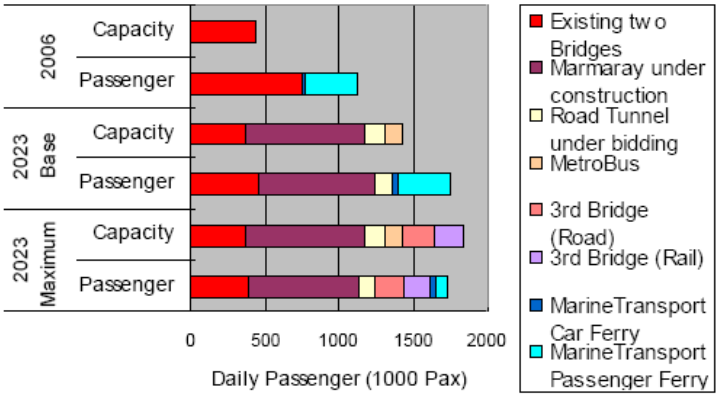

Figure 3 – Bosporus crossing demand by daily passenger (1000 pax)

Figure 4 shows the distribution of truck movements over the metropolitan city of Istanbul (IMM, 2009). As seen, truck movements inside the European side (30,088) are higher than those in the Asian side (8,751). Regarding truck movements, however, the linkage of the city with the Asian External (18,748+16,304=35,052) is 2.9 times higher than that with the European External (1,433+10,590=12,023). The number of trucks crossing the Bosporus Strait is 47,771. Considering the total crossing volume of 414,124 vehicles in 2009, truck traffic crossing the Strait constitutes about 11.5%.

Distribution of Truck Movements over the City of Istanbul

Truck Movements	Asian Side	European Side	Asian External	European External	Total
Asian Side	8,751	14,223	9,374	716	**33,064**
European Side	12,809	38,088	8,152	5,295	**64,344**
Asian External	9,374	8,152	786	1,501	**19,813**
European External	716	5,295	1,501	178	**7,690**
Total	**31,650**	**65,758**	**19,813**	**7,690**	**124,911**

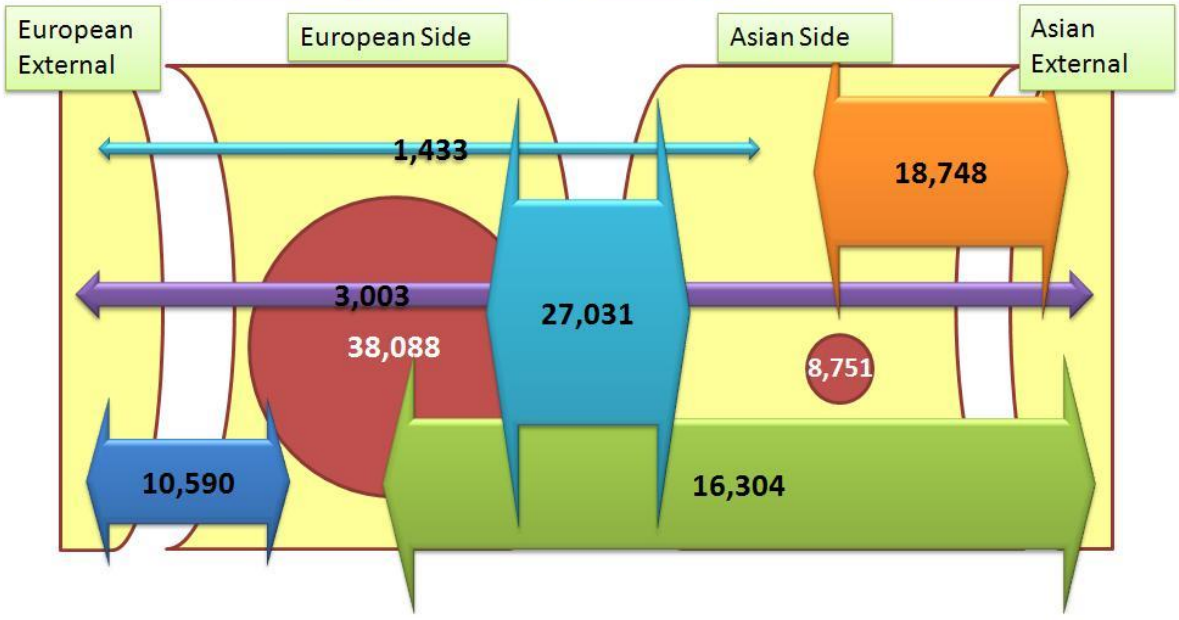

Figure 4 – Distribution of truck movements over the city of Istanbul (IMM, 2009)

DATA COLLECTION AND ANALYSIS OF DATA

Data Collection

Data collection on the 8th and 9th of January in 2008 was conducted only on exiting lanes of the two major highways (E5/D100 highway, speed limit (SL) = 90 km/hr and E80/TEM highway, SL = 120 km/hr) at selected four locations, two of which were at the east and the other two were at the west borders of the city (see Figure 5). North and south sides of the city are bordered by Black and Marmara Seas, respectively. Thus, there were no road exits or entries at north and south borders except navy piers along the Marmara shore. Ferry exit points are not considered in this study but international Ro-Ro ports (data for the ports are not analyzed though). For the data collection at each study location, two trained persons were employed counting the same traffic flows continuously but having 10-minute breaks after every 30 minutes during their 12-hour shifts a day. Thus, they counted only 30 or 40 minutes during one hour recording period, and only 20-minutes of their counts were matched to measure the differences or errors between the two count sets. Shift changes were twice a day at midnight and noon times.

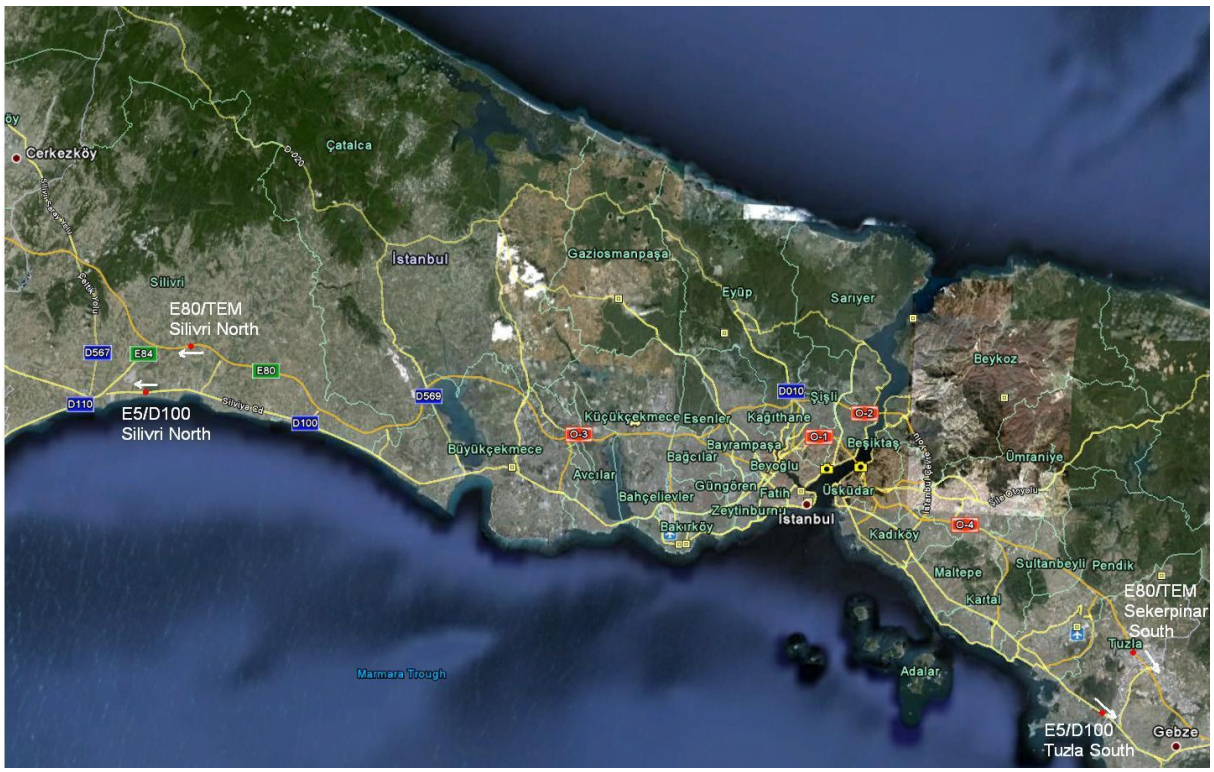

Figure 5 – Count locations (1. E80/TEM Sekerpinar South, 2. E5/D100 Tuzla South, 3. E80/TEM Silivri/North, and 4. E5/D100 Silivri North)

Analysis of Data

Distribution of the errors in the two data sets by flow rate, day of week, location, and time of day were analyzed and it was seen that the differences or errors during the first day counts

were usually higher than those of the second day counts either in both absolute and percent differences in averages as seen in Table 2. Hourly volume or traffic flow is to be 419 veh. in average and does not vary very much between the two days. It should be noted that average hourly traffic flow is higher on Friday, but the errors between the two sets of the count data on Friday are lower than those on Thursday. Thus, a negative correlation is observed between the flow rate (veh/hr) and the difference between the two counts with respect to day of week. Average percent difference or error of the total count during the two days is considered to be reasonable as to be 2.24%. Per vehicle error is calculated to be 2.92%. This is lower than 5% and the 95% significant level is valid in the validation of these counts.

Table 2 – Averages of the absolute and percent differences or errors by day of week

Day	Average Flow Rate (veh/hr)	Avg. Absolute difference	Avg. Percent Difference	Absolute diff. per 100 vehicle	Percent diff. per 100 vehicle
Thursday	407.60	49.14	14.47	12.05	3.55
Friday	430.67	41.97	10.03	9.75	2.33
Total	419.07	45.55	12.24	10.87	2.92

Table 3 presents absolute and percent differences or errors between the two count sets by location. It is seen that counts at high volume locations (east sections) include lower errors (1.32 and 1.92) per 100 vehicles than those (3.67 and 10.93)at low volume sections (west sections).

Table 3 – Averages of the absolute and percent differences or errors by location

Location		Average Flow Rate (veh/hr)	Avg. Absolute difference	Avg. Percent Difference	Absolute diff. per 100 vehicles	Percent diff. per 100 vehicles
1 East	E5/D100 - Tuzla - South	561,32	39,56	7,41	7,05	1,32
2 East	E80/TEM – Şekerpinar- South	693,82	91,40	13,35	13,17	1,92
3 West	E80/TEM - Silivri – North	239,41	22,98	8,80	9,60	3,67
4 West	E5/D100 - Silivri - North	176,69	28,27	19,32	16,00	10,93
Total	Total	419,07	45,55	12,24	10,87	2,92

Table 4 shows averages of the absolute differences per 100 vehicles between the counts by location, day of week and transport mode. The highest differences per 100 vehicles associated with the auto mode (20.25-20.81) are seen at east as well as at west locations, and the lowest value (6.32) is seen at an east section. Usually regarding the auto mode, higher errors in counting are seen during the first day (Thursday, Jan. 8th). For mode of truck-trailer, the highest differences were 119.66 and 119.81 seen at E5/D100 Silivri North section on the first and second days, respectively. Truck and minibuses are also associated with high errors at the same location on both days. The highest errors are associated with motorbikes and the modes classified as others due to low count values. The lowest errors associated with day of week are seen in the second day of the counting. At the second day of the survey, counters were more experienced and felt more comfortable with their assignment with respect to the day before. The lowest two errors are associated with the two

sections, one at the west and the other at east borders of the city. Thus, the effect of the amount of flow had no apparent effect on the magnitude of errors.

Table 4 – Averages of the absolute differences or errors between the counts by location and day of week

Location		**Day**	**Averages of the absolute difference or error between the counts per 100 vehicles**									
			auto	truck-trailer	truck	small truck	bus	minibus	motorbike	others	Total	
1 East	E5/D100 - Tuzla - South	Thur.	11.62	20.57	12.82	24.57	15.44	24.70	66.67	58.33	9.78	7.05
		Friday	6.32	13.46	24.67	31.95	17.94	6.92	20.29	17.39	4.32	
2 East	E80/TEM – Şekerpinar-South	Thur.	20.39	25.78	22.16	64.67	37.80	70.59	137.14	137.50	13.74	13.17
		Friday	20.25	22.82	25.58	31.17	30.88	46.75	61.82	116.28	12.69	
3 West	E80/TEM - Silivri – North	Thur.	11.30	8.25	13.68	29.39	26.45	14.30	200.00	54.55	8.67	9.60
		Friday	15.45	8.59	17.06	31.09	26.51	13.13	142.86	41.38	10.51	
4 West	E5/D100 - Silivri - North	Thur.	20.81	119.81	31.80	46.32	63.11	34.06	85.71	94.74	17.12	16.00
		Friday	17.84	119.66	26.76	98.98	34.41	23.71	200.00	81.82	14.65	
Total			15.16	23.62	21.63	39.89	30.87	28.61	77.46	72.58		10.87

Table 5 presents the count errors in absolute and percent terms associated with the time of day. The highest error is observed during the midnight to 7:00 period probably due to the snow blizzard effective from midnight to around 7:00, followed by the evening-peak (from 17:00 to 20:00) and the afternoon-peak (17:00-20:00). On the contrary to expectations, errors during the morning-peak were the lowest. The average error observed during the noon-peak was higher than that of the morning-peak.

Table 5 – Averages of the absolute and percent differences or errors by time period

Time Period			**Average Flow Rate (veh/hr)**	**Avg. Absolute difference**	**Avg. Percent Difference**	**Absolute diff. per 100 vehicles**	**Percent diff. per 100 vehicles**
1	Early morning	00:00-07:00	121,50	10,46	12,02	8,61	9,89
2	Morning-peak	07:00-10:00	730,48	69,21	9,95	9,47	1,36
3	Morning-off peak	10:00-12:00	620,69	51,88	10,23	8,36	1,65
4	Noon-peak	12:00-14:00	581,44	70,88	12,81	12,19	2,20
5	Afternoon-off peak	14:00-17:00	618,42	63,67	10,20	10,30	1,65
6	Afternoon-peak	17:00-20:00	488,08	61,83	14,90	12,67	3,05
7	Evening-peak	20:00-00:00	319,92	47,59	14,57	14,88	4,55
Total			419,07	45,55	12,24	10,87	2,92

Figure 6 presents the relationship between the flow and error or absolute difference between the counts by mode of travel. All the models are significant at $\alpha=0.05$ level ($p\leq0.05$) and start at the origin. That means the models include no constant. The coefficient of the independent variable is significant at $\alpha=0.05$ level ($p\leq0.05$). By these models, the errors associated with manual counts can be estimated. The higher the flow, the higher is the error is.

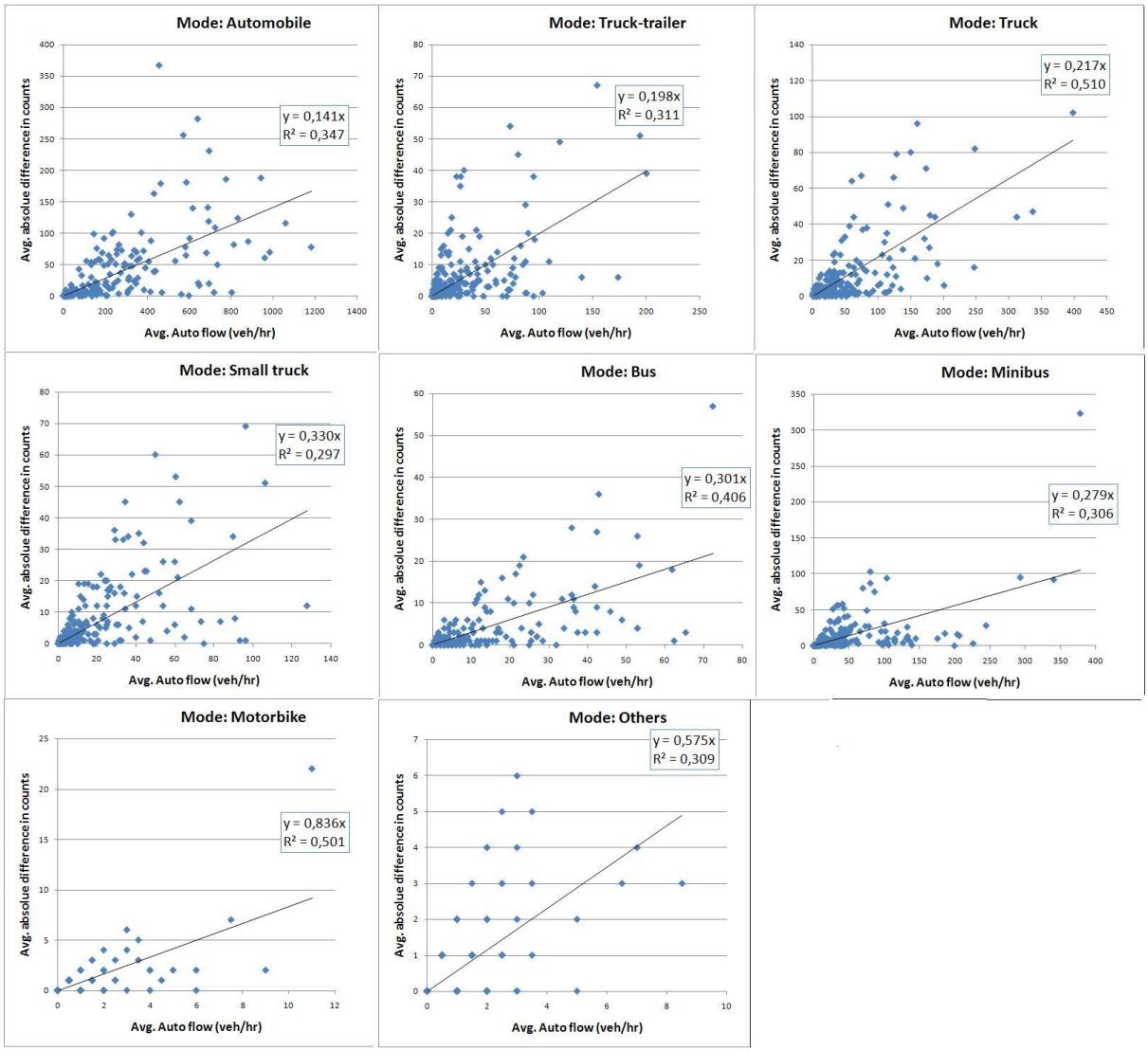

Figure 6 – Relationship between the traffic flow and observed errors or absolute differences between counts by mode of travel

Figure 7 shows the differences between the two counters for the two day counts at two different locations (west sections). High errors or peaks between the two count sets during the first day are seen after 5, 9 and 10 hours since the start of the shifts. The second shift during the first day (Jan. 8th) at the location of E80/TEM shows almost no peak at the second shift (from noon to midnight). On the other hand, during the second day (Jan 9th) at E5/D100 there is almost no peak during the first shift (from midnight to noon) except at the end of the shift, but during the same shift at E80/TEM section the errors between the two counts are quite significant. It should be noted that during the second day (Jan 9th) from midnight to around 7 am, the snow blizzard was effective and since E80/TEM was towards the north of E5/D100 section.

Regarding the errors associated with the mode of transport, the highest errors are observed with the counts of automobile, followed by truck-trailers, trucks and minibuses. It should also be noted that the overall differences or errors between the counts are higher during the first day than those in the second day.

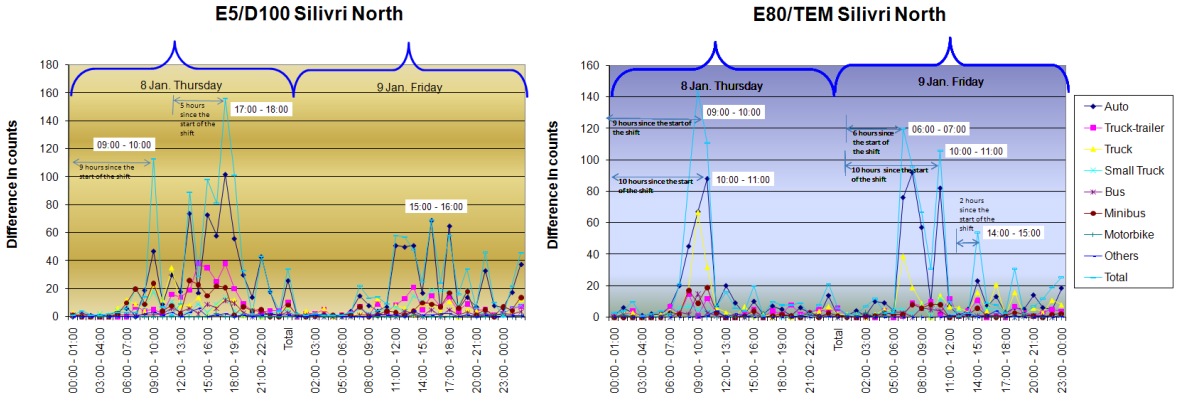

Figure 7 – Difference in manual counts between two counters during two consecutive days at E5/D100 and E80/TEM Silivri North sections

Figure 8 shows the errors between the two counters for the two day counts at the two east sections. It is seen that during the first day (Jan. 8th) counts at E5/D100 Tuzla South section, differences between the counts are minimal in the first shift (from midnight to noon) compared to those in the second shift (from noon to midnight). Actually the first-day variations in the second shift are significantly higher than those for the second day.

Regarding the errors associated with the mode of transport, the highest errors are observed with the counts of automobile, followed by truck-trailers, trucks and minibuses. Regarding the count errors associated with the mode of transport, errors in auto counts can be associated to the readiness or alertness of counters since auto flow is the highest of all and some entities can be easily missed. The count errors with respect to other modes like, truck, minibus or small truck, however, can be associated with the quality of training. It should also be noted that the overall differences between the counts are higher during the first day than those in the second day. This means that counters get used to with the counting process and get experienced more after the first day.

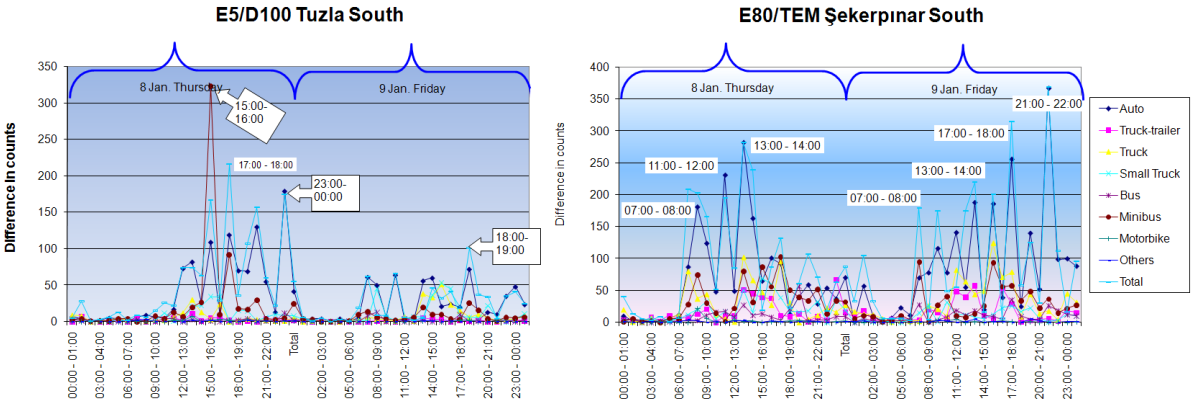

Figure 8 – Difference in manual counts between two counters during two consecutive days at E5/D100 Tuzla and E80/TEM Sekerpinar South sections

Peak (morning-noon-afternoon and evening) period counts had the highest errors in percent (equal and over 100%). Night-time counts (between 12-7 am) were the least problematic

ones regarding the percent of errors (equal and less than 100%) except at one location on E80/TEM highway at the west exit on Friday night, probably due to a blizzard effective from midnight to around 7 am. On the contrary to the expectations, at high-speed and high volume locations no significantly high errors were observed between the counts, probably due to controlled lane drops for the purpose of pulling vehicles from continues traffic flow onto interview locations to conduct roadside interviews at the count locations. Although some big count errors observed regarding types of vehicles (some small- or mid-size vehicles were sometimes confused with their larger sizes, and some motorcycles were ignored or missed), differences between total vehicle counts varied about between 5 and 26%. Except those two limit values, the other ones were about 10%, which is pretty much inside the acceptable limits. The lowest one was on E5/D100 highway at the east exit on Friday (Jan. 9th) and the highest one was on E5/D100 highway at the west exit on Thursday (Jan. 8th).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions of the Current Research

In this paper, errors associated with manual vehicle counts by trained counters are analyzed in a traffic survey study in order to determine the movements of goods as well as passenger traffic through the metropolitan city of Istanbul, Turkey, at four locations selected, two of which were at the east and the other two were at the west borders of the city. When the differences in the two data sets by day of week, time of day, location and flow rate were analyzed, it is concluded that there is no explainable trend observed in differences between the counts based on day of week, time of day, location or flow rate other than the tiredness and/or weak integrity of the count personnel and their supervisors in the field. As a result, some of the errors can be attributable to the experience or integrity of counters and supervisors, the quality of training provided by project managers and other factors such environmental conditions during the survey.

Recommendations for Future Research

For a future research study, it is recommended to compare manual counts with automated counts in order to see whether differences are due to some external factors such as weather conditions, time of day, survey location or the magnitude of flow rate.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Department Transportation Planning at the Directorate of Transportation of the Metropolitan Municipality of Istanbul (IMM), for creating this opportunity to conduct this study, and the financial support for the survey from BIMTAS, a public corporation of the IMM was also acknowledged.

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