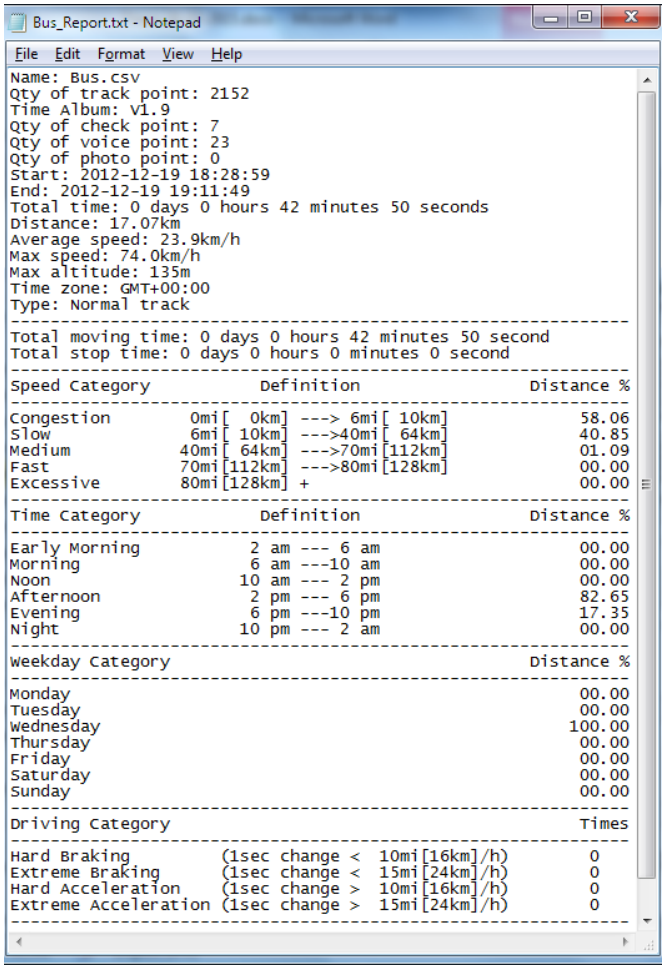


Bus_Report.txt - Notepad

File Edit Format View Help

```
Name: Bus.csv
Qty of track point: 2152
Time Album: V1.9
Qty of check point: 7
Qty of voice point: 23
Qty of photo point: 0
Start: 2012-12-19 18:28:59
End: 2012-12-19 19:11:49
Total time: 0 days 0 hours 42 minutes 50 seconds
Distance: 17.07km
Average speed: 23.9km/h
Max speed: 74.0km/h
Max altitude: 135m
Time zone: GMT+00:00
Type: Normal track
-------------------------------------------------------------
Total moving time: 0 days 0 hours 42 minutes 50 second
Total stop time: 0 days 0 hours 0 minutes 0 second
-------------------------------------------------------------
Speed Category          Definition                  Distance %
-------------------------------------------------------------
Congestion        0mi[  0km] ---> 6mi[ 10km]            58.06
Slow              6mi[ 10km] --->40mi[ 64km]            40.85
Medium           40mi[ 64km] --->70mi[112km]            01.09
Fast             70mi[112km] --->80mi[128km]            00.00
Excessive        80mi[128km] +                          00.00
-------------------------------------------------------------
Time Category           Definition                  Distance %
-------------------------------------------------------------
Early Morning          2 am --- 6 am                    00.00
Morning                6 am ---10 am                    00.00
Noon                  10 am --- 2 pm                    00.00
Afternoon              2 pm --- 6 pm                    82.65
Evening                6 pm ---10 pm                    17.35
Night                 10 pm --- 2 am                    00.00
-------------------------------------------------------------
Weekday Category                                        Distance %
-------------------------------------------------------------
Monday                                                    00.00
Tuesday                                                   00.00
Wednesday                                                100.00
Thursday                                                  00.00
Friday                                                    00.00
Saturday                                                  00.00
Sunday                                                    00.00
-------------------------------------------------------------
Driving Category                                        Times
-------------------------------------------------------------
Hard Braking          (1sec change <  10mi[16km]/h)        0
Extreme Braking       (1sec change <  15mi[24km]/h)        0
Hard Acceleration     (1sec change >  10mi[16km]/h)        0
Extreme Acceleration  (1sec change >  15mi[24km]/h)        0
-------------------------------------------------------------
```

Figure 3.10 Time Album Report.

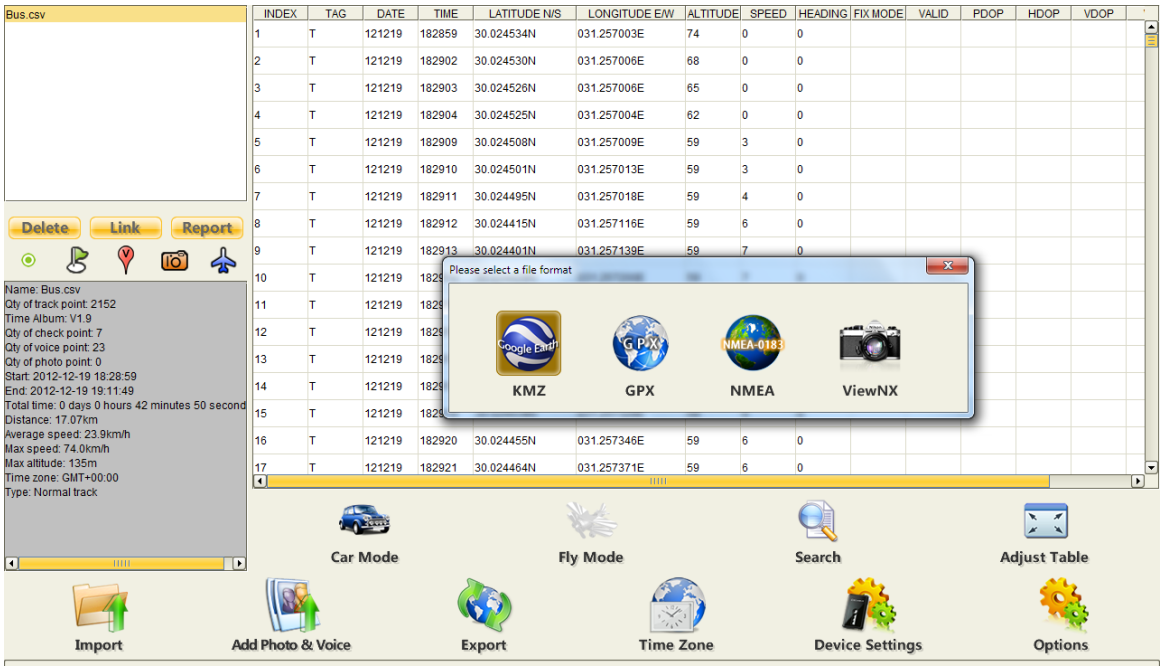


Figure 3.11 Generate track file with an extension KMZ.

3.5.2 Google Earth

Google Earth allows the users to travel the world through a virtual globe and view satellite imagery, maps, terrain, 3D buildings, and much more. With Google Earth rich, geographical content, a user is able to experience a more realistic view of the world, can fly to their favorite place, search for businesses and even navigate through directions. In this research, Google Earth was used to project the track of journey as shown before in (Figure 3.1 through Figure 3.6).

3.6 Data Preparation

In general, the travel times of transit vehicles and the automobiles have to be measured for the same travel route at the same time. Hence, the two vehicle types were equipped with GPS devices and the test vehicle was launched within 30 minutes of the start time of a bus trip. The GPS was programmed to log the vehicle's speed and position every second. The collected GPS data were later on used to develop a model which estimates average travel time of the automobiles using bus travel times as an input.

The GPS data logger collects the following information: date, time, geodetic coordinates, altitude, speed, and heading angle. The data acquisition interval was set to 1 second. The geodetic coordinates (latitude and longitude), represent the angles that uniquely define points on a sphere. These coordinates should be converted to the Universal Transverse Mercator (UTM) grid coordinate system which uses the distance in meters to the east, as the "easting (E)", and a distance in meters to the north, as the "northing (N)". Hence, the distance (d) between any two GPS data points at any second can be easily calculated by the Pythagoras equation, $d = \sqrt{\Delta E^2 + \Delta N^2}$

3.6.1 Global Mapper

Global Mapper is an affordable and easy-to-use Geographic Information System (GIS) application that offers access to an unparalleled variety of spatial data sets and provides just the right level of GIS functionality to satisfy both mapping beginners and experienced GIS professionals as shown in Figure 3.12.

This program is more than just a utility; it has a built in functionality for distance and area calculations, raster blending, spectral analysis, elevation querying, cut-and-fill volume calculations, as well as advanced capabilities like image rectification, contour generation from surface data, sea level rise modeling and triangulation and gridding of 3D point data.

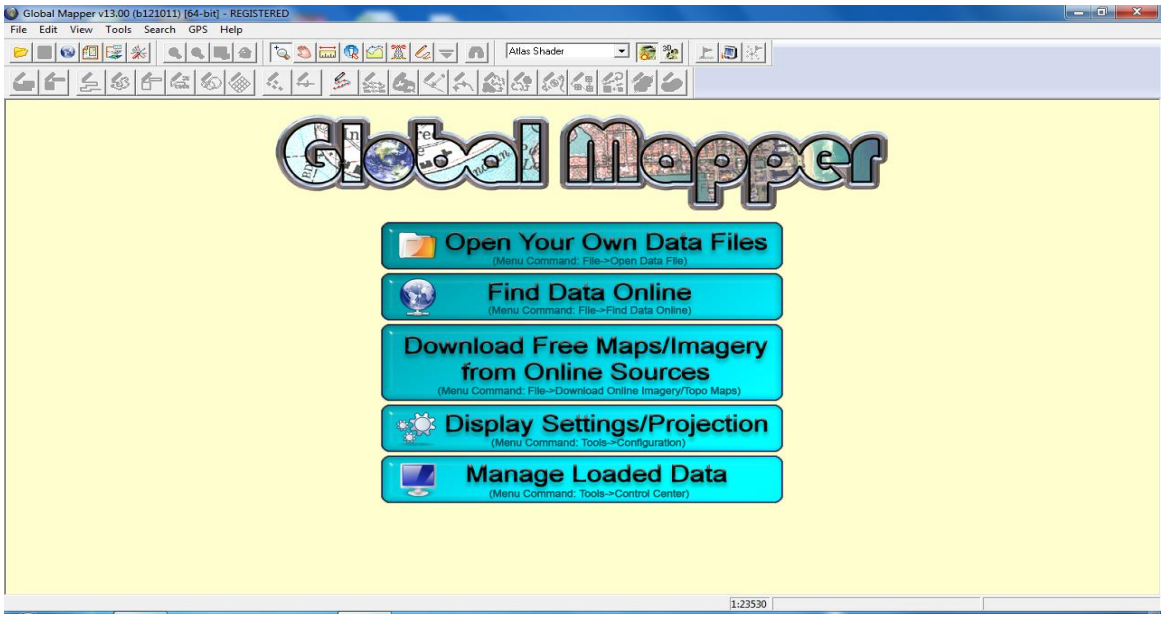


Figure 3.12 Global Mapper Software.

In this research, Global Mapper was used to transform the longitude and latitude co-ordinates into easting and northing. The output (N, E) was consequently used to calculate the distance between each two GPS points every second using spread sheets (Figure 3.13).

INDEX	TAG	DATE	Hour	Min.	Sec.	LATITUDE N/S	LONGITUDE E/W	HEIGHT	SPEED	HEADING	N	E	Distance	Time	Diff. Time	Comm.Distance	Comm.Time
1	T	121219	18	28	59	30.024534N	031.257003E	74	0	0	3322783.411	331920.3	0	66539	0	0	0
2	T	121219	18	29	2	30.024530N	031.257006E	68	0	0	3322782.963	331920.582	0.529365658	66542	3	0.529365658	3
3	T	121219	18	29	3	30.024526N	031.257006E	65	0	0	3322782.519	331920.576	0.444040539	66543	1	0.973406197	4
4	T	121219	18	29	4	30.024525N	031.257004E	62	0	0	3322782.412	331920.381	0.222427516	66544	1	1.195833713	5
5	T	121219	18	29	9	30.024508N	031.257009E	59	3	0	3322780.52	331920.834	1.945475006	66549	5	3.141308719	10
6	T	121219	18	29	10	30.024501N	031.257013E	59	3	0	3322779.738	331921.208	0.866833317	66550	1	4.008142037	11
7	T	121219	18	29	11	30.024495N	031.257018E	59	4	0	3322779.066	331921.681	0.8217743	66551	1	4.829916336	12
8	T	121219	18	29	12	30.024415N	031.257116E	59	6	0	3322770.055	331930.997	12.96094044	66552	1	17.79085677	13
9	T	121219	18	29	13	30.024401N	031.257139E	59	7	0	3322768.47	331933.192	2.707443444	66553	1	20.49830022	14
10	T	121219	18	29	14	30.024428N	031.257200E	59	7	0	3322771.373	331939.121	6.601549061	66554	1	27.09984928	15
11	T	121219	18	29	15	30.024399N	031.257236E	59	8	0	3322768.106	331942.544	4.731830301	66555	1	31.83167958	16
12	T	121219	18	29	16	30.024399N	031.257260E	59	8	0	3322768.07	331944.859	2.315279897	66556	1	34.14695948	17
13	T	121219	18	29	17	30.024411N	031.257278E	59	7	0	3322769.374	331946.615	2.187224726	66557	1	36.3341842	18
14	T	121219	18	29	18	30.024423N	031.257305E	59	7	0	3322770.664	331949.239	2.9239487	66558	1	39.2581329	19
15	T	121219	18	29	19	30.024434N	031.257328E	59	6	0	3322771.85	331951.476	2.531948854	66559	1	41.79008175	20
16	T	121219	18	29	20	30.024455N	031.257346E	59	6	0	3322774.151	331953.248	2.9042357	66560	1	44.69431745	21
17	T	121219	18	29	21	30.024464N	031.257371E	59	6	0	3322775.112	331955.674	2.609405488	66561	1	47.30372294	22
18	T	121219	18	29	22	30.024473N	031.257388E	59	5	0	3322776.084	331957.329	1.919325142	66562	1	49.22304808	23
19	T	121219	18	29	23	30.024473N	031.257390E	59	4	0	3322776.081	331957.522	0.193023315	66563	1	49.4160714	24
20	T	121219	18	29	24	30.024471N	031.257419E	59	5	0	3322775.817	331960.315	2.805449162	66564	1	52.22152056	25
21	T	121219	18	29	25	30.024489N	031.257436E	59	6	0	3322777.787	331961.985	2.582595594	66565	1	54.80411615	26
22	T	121219	18	29	26	30.024495N	031.257471E	59	8	0	3322778.401	331965.371	3.441219551	66566	1	58.24533571	27
23	T	121219	18	29	27	30.024500N	031.257494E	59	7	0	3322778.921	331967.598	2.286903802	66567	1	60.53223951	28
24	T	121219	18	29	28	30.024508N	031.257511E	59	7	0	3322779.783	331969.251	1.864256688	66568	1	62.3964962	29
25	T	121219	18	29	29	30.024514N	031.257534E	59	9	0	3322780.414	331971.479	2.315630584	66569	1	64.71212678	30
26	T	121219	18	29	30	30.024523N	031.257570E	59	12	72	3322781.359	331974.966	3.612782031	66570	1	68.32490881	31
27	T	121219	18	29	31	30.024528N	031.257613E	58	13	77	3322781.85	331979.122	4.184903464	66571	1	72.50981227	32
28	T	121219	18	29	32	30.024546N	031.257648E	58	14	81	3322783.793	331982.528	3.921235137	66572	1	76.43104741	33
29	T	121219	18	29	33	30.024546N	031.257698E	58	15	82	3322783.72	331987.35	4.82255254	66573	1	81.25359995	34
30	T	121219	18	29	34	30.024551N	031.257758E	58	16	82	3322784.186	331993.145	5.813706305	66574	1	87.06730626	35
31	T	121219	18	29	35	30.024556N	031.257819E	58	18	80	3322784.651	331999.037	5.91032055	66575	1	92.97762681	36
32	T	121219	18	29	36	30.024568N	031.257883E	57	20	79	3322785.887	332005.23	6.315136182	66576	1	99.29276299	37
33	T	121219	18	29	37	30.024561N	031.257966E	57	20	79	3322784.989	332013.223	8.043286207	66577	1	107.3360492	38
34	T	121219	18	29	38	30.024568N	031.258036E	57	21	79	3322785.662	332019.986	6.796403313	66578	1	114.1324525	39
35	T	121219	18	29	39	30.024561N	031.258100E	56	19	83	3322784.793	332026.147	6.221983767	66579	1	120.3544363	40
36	T	121219	18	29	40	30.024568N	031.258154E	56	18	84	3322785.489	332031.367	5.266195591	66580	1	125.6206319	41
37	T	121219	18	29	41	30.024579N	031.258210E	55	20	84	3322786.626	332036.786	5.536996478	66581	1	131.1576283	42
38	T	121219	18	29	42	30.024583N	031.258273E	55	22	83	3322786.977	332042.869	6.093118249	66582	1	137.2507466	43
39	T	121219	18	29	43	30.024586N	031.258345E	54	25	82	3322787.204	332049.818	6.952706667	66583	1	144.2034533	44

Figure 3.13 The output of Global Mapper.

3.6.2 Data Analysis

The data obtained from the GPS data loggers which were installed on buses and automobiles were processed for each of the thirty data collection trips. The raw position and time stamp information was used to estimate the average speed, total trip length, total travel time, time delay, free flow travel time, and total number of stops (Figure 3.14). The time-space diagram was consequently plotted for each trip by bus or car. Time-space diagrams are strong tools that enable visualizing the trip trajectories of each vehicle and identifying the main characteristics of this trip. For example, Figure 3.15 can be used to identify the location and time for stoppage, accelerating, and decelerating. These data were then used for developing a relationship between automobile travel times and bus travel times. All tables and charts for all trips are shown in appendix (A).

GPS DATA						OUTPUT DATA			
SPEED	N	E	Hour	Min.	Sec.	Speed Classification	Route Length (meter)	16413	Meter
0	3322783.411	331920.3	18	28	59	Start Trip	Total Travel Time (by GPS),(Second)	2527	Second
0	3322782.963	331920.582	18	29	2	Stoppage	Stop. Delay (Second)	34	Second
0	3322782.519	331920.576	18	29	3	Stoppage	Total Acc. Delay (Second)	499	Second
0	3322782.412	331920.381	18	29	4	Stoppage	Total Dec. Delay (Second)	482	Second
3	3322780.52	331920.834	18	29	9	Stoppage	Illegal Stops (Second)	297	Second
3	3322779.738	331921.208	18	29	10	Stoppage	Travel Time without Delay (by GPS), (Second)	1215	Second
4	3322779.066	331921.681	18	29	11	End Stoppage & Start Acc.	Free Flow Travel Time (Velocity=60 Kph.), (Second)	985	Second
6	3322770.055	331930.997	18	29	12	Acc.	Delay due to hardly reach Free Flow Time(Second)	230	Second
7	3322768.47	331933.192	18	29	13	End Acc. & Start Constant	Total Delay (Second)	1542	Second
7	3322771.373	331939.121	18	29	14	Constant	Number of Total Stops	31	
8	3322768.106	331942.544	18	29	15	Constant	Number of Stops at Station	7	
8	3322768.07	331944.859	18	29	16	Constant			
7	3322769.374	331946.615	18	29	17	Constant			
7	3322770.664	331949.239	18	29	18	Constant			
6	3322771.85	331951.476	18	29	19	Constant			
6	3322774.151	331953.248	18	29	20	Constant			
6	3322775.112	331955.674	18	29	21	Constant			
5	3322776.084	331957.329	18	29	22	End Constant & Start Stoppage			
4	3322776.081	331957.522	18	29	23	Stoppage			
5	3322775.817	331960.315	18	29	24	End Stoppage & Start Acc.			
6	3322777.787	331961.985	18	29	25	Acc.			
8	3322778.401	331965.371	18	29	26	End Acc. & Start Constant			
7	3322778.921	331967.598	18	29	27	Constant			
7	3322779.783	331969.251	18	29	28	End Constant & Start Acc.			
9	3322780.414	331971.479	18	29	29	Acc.			
12	3322781.359	331974.966	18	29	30	Acc.			
13	3322781.85	331979.122	18	29	31	Acc.			
14	3322783.793	331982.528	18	29	32	Acc.			

Figure 3.14 Sample of Data Analysis.

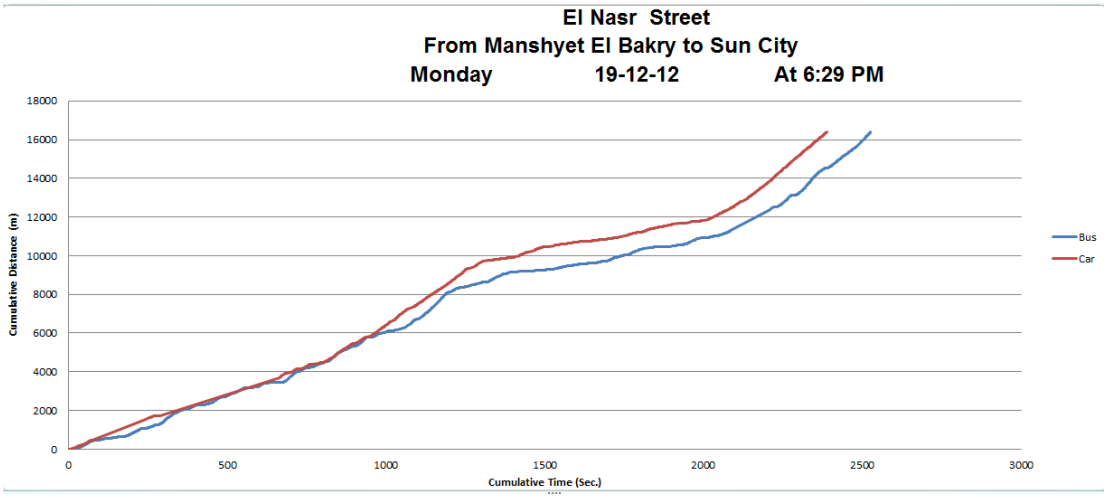


Figure 3.15 Sample of chart for a trip.

CHAPTER FOUR

TRAVEL TIME ESTIMATION MODELS

4.1 Introduction

In using the bus travel time as the source of data for estimating automobile travel time, one needs to realize of the unique aspect of bus travel time. It is important to recognize that there is a difference between automobile travel time and bus travel time for the same route because of the following reasons:

1. Buses stop at bus stations. They leave and join the traffic stream a number of times during their travel; therefore they incur additional time for merging and diverging as well as deceleration and acceleration to/from a station. Buses also stand at bus stations for loading/unloading passengers for a certain period of time.

2. Illegal stops of buses. The bus drivers were not committed to stop at stations only, but they stop anywhere to load/unload passengers.

3. Usually, buses travel on the rightmost lane of an urban route. The average speeds are different among the lanes. The fact that buses travel on the rightmost lane introduces a bias in the travel time of buses.

Despite this difference between the automobile travel time and the bus travel time, what makes buses attractive candidates as probe vehicles is that buses typically run on heavily traveled urban roads, which are locations where the travel time data is in high demand. Also, buses follow the same traffic regulations and speed limits. Further, information on automobile travel time is most needed during the peak hours; it is during these hours that buses also have a higher frequency and therefore a greater sampling rate.

The objective of this research is to investigate the strength of the relationship between automobile travel times and bus travel times. As described earlier, GPS data were collected for buses and automobiles on six main urban roads in Greater Cairo. The collected GPS data were used to calculate different types of effectiveness measures including average travel time and speed, deceleration delay, acceleration delay, stoppage delay, and total delay as in Table 4.1. These variables were tested as potential input

variables in the models that were developed to relate bus travel times/speeds with automobile travel times/speeds.

High variability was found in the route length where the minimum and maximum lengths were 2 and 16 km, respectively. Such high variability in section length is not recommended by most researchers. Therefore, it was decided to divide the routes into one hundred and twenty-one sections, which each section represents one kilometer as shown in Table 4.2. Details of the methodology are presented in the following sections.

4.2 The Modeling Method: Regression Models

Regression analysis is a statistical technique that tries to explain the linear relation between a set of independent variables (x) and a dependent response variable (y). The ultimate goal is to derive the regression equation which describes the output variable as a linear function of the input variables. The linear regression relation can be described as:

$$y = a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_n x_n$$

In this research, "Minitab", a statistical software package was used to test and develop different combinations of functional forms and input variables that can be used to describe the relationship between bus and automobile travel times.

Table 4.1 Data Collection.

No.	Street Name	Direction		W.D. (dd/mm/year)	Bus Data														Car Data	
					Time	Route Length (meter)	Avg. Speed (Km/h)	TT (GPS) (sec.)	Illegal Stops (Sec.)	Stop Delay (sec.)	Total Stopping Time (sec.)	Acc. delay (sec.)	Dec. delay (sec.)	Stop./ Acc./ Dec. delay (sec.)	FF TT (sec.)	Total delay (sec.)	No. of stops	No. of stations	TT (GPS) (sec.)	Avg. Speed (Km/h)
1	Gesr El-Suez Street	Forward	G1	26-11-12	9:54 AM	7632	19.16	1434	111	101	212	197	420	829	458	976	23	4	1183	21.23
2			G2	26-11-12	10:28 AM	7797	20.61	1362	92	1	93	302	368	762	468	894	12	2	1300	23.79
3		Backward	G1	26-11-12	11:42 AM	10348	21.95	1697	333	141	474	244	258	976	621	1076	21	12	1440	24.27
4			G2	26-11-12	12:19 PM	10638	18.66	2052	297	103	400	325	480	1205	638	1414	17	5	1753	20.85
5	El-Harm Street	Forward	G1	26-11-12	3:15 PM	3472	20.53	609	22	41	63	134	119	316	208	401	11	0	616	18.29
6			G2	26-11-12	3:54 PM	3474	24.82	504	65	5	70	97	77	244	208	296	6	0	512	22.43
7		Backward	G1	26-11-12	4:00 PM	3499	14.25	884	54	130	184	185	201	571	210	674	17	0	858	13.88
8			G2	26-11-12	4:30 PM	3500	16.22	777	41	139	180	154	156	490	210	567	14	0	695	18.13
9	El-Nasr Street	Forward	G1	27-11-12	3:38 PM	9633	25.24	1374	152	237	389	182	124	695	578	796	18	17	1229	28.22
10			G2	27-11-12	4:09 PM	9636	21.43	1619	150	312	462	230	297	988	578	1041	16	0	1579	24.97
11		Backward	G1	27-11-12	5:35 PM	5818	39.16	535	0	38	38	90	51	179	349	186	1	3	542	41.65
12			G2	27-11-12	6:10 PM	5821	25.91	809	89	63	152	152	122	425	349	460	8	7	720	29.11
13	Fesal Street	Backward	G1	28-11-12	6:16 PM	5675	7.43	2751	484	769	1253	274	655	2183	341	2410	62	8	2449	8.84
14			G2	28-11-12	6:44 PM	5673	8.34	2448	230	1104	1334	163	437	1934	340	2108	29	4	2258	9.05
15	Salah Salem	Forward	G1	29-11-12	4:18 PM	7016	21.77	1160	116	23	139	241	189	569	421	739	13	3	1048	24.10

16	Street		G2	29-11-12	4:54 PM	7005	19.25	1310	64	58	122	311	256	689	420	890	19	0	1284	17.64
17	El-Harm Street	Backward	G1	02-12-12	8:42 AM	6717	13.28	1821	189	322	511	259	440	1210	403	1418	49	14	1764	13.11
18			G2	02-12-12	9:19 AM	6950	17.28	1448	216	184	400	216	316	932	417	1031	20	3	1425	16.16
19	Gameet El-Dewl El-Arabyia Street	Backward	G1	03-12-12	6:43 PM	2078	11.12	673	24	160	184	106	180	469	125	548	9	3	552	13.55
20			G2	03-12-12	7:15 PM	1995	16.94	424	60	63	123	75	61	258	120	304	10	0	363	18.49
21	Salah Salem Street	Backward	G1	17-12-12	5:45 PM	8444	11.99	2535	249	826	1075	308	335	1718	507	2028	30	0	2450	12.41
22			G2	17-12-12	6:16 PM	8162	8.86	3318	908	362	1270	313	958	2541	490	2828	73	35	2270	12.94
23	El-Nasr Street	Forward	G1	19-12-12	3:30 PM	15808	17.66	3222	430	443	873	497	632	2001	948	2273	50	10	3143	16.11
24			G2	19-12-12	4:22 PM	15808	14.45	3939	598	1135	1733	360	614	2707	948	2990	46	18	3100	17.16
25		Backward	G1	19-12-12	5:41 PM	16411	11.03	5358	377	2418	2795	565	700	4060	985	4373	64	21	5105	11.57
26			G2	19-12-12	6:29 PM	16412	23.38	2527	297	34	331	499	482	1312	985	1542	31	7	2390	26.32
27	Gameet El-Dewl El-Arabyia Street	Forward	G1	10-01-13	10:15 AM	1935	21.50	324	46	15	61	55	43	159	116	208	6	5	280	22.38
28			G2		10:45 AM	1969	24.11	294	28	0	28	72	52	152	118	176	3	2	305	21.64
29		Backward	G1	10-01-13	11:13 AM	1997	20.03	359	66	0	66	92	57	216	120	239	6	1	343	22.26
30			G2		11:47 AM	1970	20.98	338	81	0	81	72	48	201	118	220	4	0	350	19.26

Table 4.2 Data for each section.

No.	Bus Data								Car Data	
	V (km/h)	**TT (sec.)**	**Illegal Stops (sec.)**	**Stop Delay (sec.)**	**Total stopping time (sec.)**	**Acc. Delay (sec.)**	**Dec. Delay (sec.)**	**FF TT (sec.)**	**TT (sec.)**	**V (Km/h)**
1	23.2	156	31	0	31	10	25	60	110	32.9
2	21.4	168	6	25	31	25	31	60	130	27.7
3	23.0	156	0	4	4	20	56	60	174	20.6
4	14.2	255	17	2	19	17	147	60	274	13.2
5	22.7	159	12	23	35	23	17	60	262	13.8
6	24.5	147	0	15	15	18	44	60	121	29.7
7	15.6	232	14	0	14	50	73	60	356	10.1
8	23.2	122	0	27	27	24	13	47	99	28.6
9	35.0	103	9	0	9	16	10	60	90	40.1
10	22.3	162	19	8	27	38	31	60	135	26.7
11	34.1	105	0	0	0	27	15	60	88	40.7
12	7.4	484	39	60	99	76	231	60	383	9.4
13	22.1	163	11	0	11	16	66	60	152	23.7
14	19.0	189	34	1	35	29	41	60	144	25.0
15	32.2	111	16	1	17	12	20	60	129	27.7
16	25.8	140	31	6	37	21	19	60	104	34.7
17	19.4	185	0	19	19	32	43	60	184	19.5
18	21.9	165	40	3	43	23	24	60	188	19.2
19	25.0	144	25	0	25	26	16	60	219	16.4
20	20.1	84	0	3	3	17	24	28	79	21.4
21	16.5	219	18	13	31	72	30	60	232	15.5
22	12.9	278	13	30	43	49	79	60	265	13.6
23	13.1	275	8	95	103	36	58	60	288	12.5
24	16.0	112	15	1	16	28	34	30	73	24.5
25	22.2	162	0	19	19	40	25	60	126	28.5
26	12.1	297	14	81	95	49	61	60	260	13.8
27	15.8	227	27	39	66	36	44	60	208	17.2
28	20.2	91	0	0	0	29	25	31	101	18.2
29	19.1	188	9	52	61	24	28	60	343	10.5
30	9.9	362	83	140	223	30	21	60	210	17.1
31	20.0	180	11	45	56	30	22	60	150	24.0
32	17.5	205	26	56	82	23	26	60	210	17.1
33	30.9	116	27	1	28	28	12	60	131	27.4
34	24.8	146	0	11	11	37	29	60	108	33.5
35	19.1	190	0	29	29	30	52	61	143	25.4
36	30.0	66	0	0	0	17	12	33	101	19.6
37	35.1	102	0	0	0	24	11	60	98	36.6
38	24.3	121	0	38	38	13	18	49	166	17.7
39	25.6	140	14	3	17	27	18	60	196	18.3
40	26.3	138	20	1	21	36	16	60	129	28.1
41	33.0	90	0	37	37	7	10	49	139	21.3
42	9.2	394	68	39	107	55	91	60	356	10.1
43	8.4	432	28	134	162	68	104	60	586	6.2
44	5.3	674	118	243	361	45	180	60	562	6.4
45	9.3	388	0	121	121	42	105	60	710	5.1
46	11.4	211	72	57	129	18	33	40	147	16.4

47	7.7	470	72	188	260	34	74	60	337	10.7
48	13.6	265	19	26	45	38	102	60	301	12.0
49	7.2	504	52	367	419	22	26	61	1011	3.6
50	5.6	641	49	385	434	20	122	60	198	18.2
51	5.8	400	38	138	176	23	84	38	165	14.0
52	13.4	270	24	18	42	59	54	60	172	21.0
53	12.1	299	58	6	64	67	61	60	218	16.5
54	23.7	152	0	0	0	41	20	60	175	20.6
55	27.3	132	15	1	16	26	17	60	108	33.3
56	20.4	178	19	0	19	13	9	61	151	24.1
57	14.2	254	10	15	25	68	50	60	299	12.1
58	12.6	286	7	30	37	90	60	60	342	10.6
59	34.0	106	0	0	0	19	19	60	100	36.0
60	11.0	327	40	1	41	69	88	60	279	12.9
61	18.0	200	0	0	0	5	3	60	260	13.8
62	15.3	235	29	81	110	26	27	60	463	7.8
63	19.5	185	14	41	55	29	23	60	135	26.7
64	26.6	135	20	4	24	27	14	60	114	31.5
65	7.3	491	28	77	105	59	178	60	288	12.5
66	4.2	614	42	104	146	33	121	43	1036	2.5
67	8.2	449	88	95	183	17	62	61	197	18.6
68	32.6	111	0	1	1	33	7	60	114	31.7
69	15.5	232	55	1	56	25	39	60	259	13.9
70	16.5	220	64	45	109	42	26	60	136	26.7
71	21.0	171	0	22	22	44	37	60	170	21.2
72	27.3	132	0	9	9	30	20	60	146	24.7
73	5.7	582	9	11	20	25	21	55	610	5.4
74	9.3	403	0	0	0	50	112	62	414	9.0
75	15.3	233	28	36	64	41	44	59	278	12.8
76	6.7	538	16	304	320	49	44	60	681	5.3
77	10.1	356	80	100	180	33	65	60	523	6.9
78	5.0	726	153	400	553	37	39	60	616	5.8
79	10.8	332	0	10	10	64	59	60	388	9.2
80	2.3	1625	525	266	791	52	651	61	456	8.0
81	5.9	620	248	51	299	71	89	61	539	6.8
82	11.4	320	65	7	72	65	76	61	262	13.9
83	13.8	267	38	16	54	52	71	61	280	13.2
84	16.4	223	32	22	54	40	48	61	368	10.0
85	37.3	98	0	0	0	21	6	61	110	33.3
86	36.8	98	0	0	0	25	6	60	109	33.1
87	31.1	116	0	2	2	32	14	60	168	21.5
88	13.1	276	31	14	45	70	57	60	191	19.0
89	6.9	519	83	168	251	56	117	60	785	4.6
90	8.0	453	26	122	148	54	142	60	354	10.2
91	14.8	244	47	29	76	34	61	60	243	14.9
92	8.9	408	95	68	163	57	70	60	274	13.2
93	14.1	255	39	10	49	51	76	60	180	20.0
94	30.0	120	0	4	4	24	20	60	117	30.8
95	14.1	256	90	25	115	33	40	60	280	12.9
96	20.0	126	19	1	20	31	19	42	160	15.8
97	13.3	270	24	89	113	41	42	60	304	11.8
98	9.7	383	103	29	132	66	64	62	221	16.9

99	22.9	156	30	11	41	28	17	60	113	31.6
100	1.9	1896	6	1648	1654	70	64	62	2426	1.5
101	24.3	152	0	13	13	34	21	62	193	19.2
102	26.6	139	0	15	15	29	26	62	235	15.7
103	31.6	119	0	3	3	29	4	63	111	33.9
104	16.3	225	22	16	38	50	31	61	163	22.6
105	26.8	138	12	3	15	29	22	62	193	19.1
106	20.5	180	35	0	35	47	30	61	193	19.1
107	19.0	194	25	24	49	19	30	61	175	21.1
108	27.8	133	10	1	11	28	27	62	130	28.5
109	23.2	159	16	9	25	29	26	62	111	33.2
110	14.7	251	7	42	49	57	44	62	150	24.6
111	11.5	332	68	0	68	64	110	64	268	14.3
112	12.4	290	53	0	53	44	122	60	298	12.1
113	31.9	126	0	0	0	97	0	67	185	21.7
114	35.7	104	0	10	10	80	9	62	120	30.9
115	20.7	174	29	16	45	34	29	60	118	30.6
116	23.9	150	14	1	15	35	33	60	203	17.6
117	24.4	144	14	1	15	37	19	58	112	31.3
118	18.6	194	50	1	51	49	21	60	127	28.3
119	21.8	165	10	1	11	44	36	60	216	16.6
120	26.8	133	12	1	13	28	23	59	116	30.7
121	17.2	205	69	0	69	44	25	59	234	15.1

4.3 Choice of Functional Form

Determining the functional form that estimates automobile travel time from bus travel time is a fundamental step in model's development. In doing so, some general requirements were considered; first, the form should be as simple as possible; second, the function should not provide negative outcomes under any circumstances, and thirdly, the function has to lead to logical meanings. A multi-linear model form was selected to relate the output variable with the input variables. The linear form is generally acceptable in most similar previous studies and it also provides high flexibility in terms of variables inclusion. Furthermore, the model parameters will be easy to interpret and the model itself will be easy to apply.

4.3.1 Choice of Input Variables

There are two conditions that should generally exist to include a variable in a functional form. Firstly, the variable is believed to naturally affect automobile travel time. Secondly, the variable should have a statistically significant coefficient in the developed model. The statistical significance of the model can be evaluated through the use of the coefficient p-

value; where a predictor that has a p-value of less than 0.05 is likely to be a meaningful addition to the model because changes in the predictor's value are related to changes in the response variable. Also, The t-statistic is also used for evaluating the significance of an input variable where a t-statistic is calculated as the ratio between the coefficient estimate and its standard error. The coefficient is considered statistically significant at a 95% significance level when its t-statistic exceeds a critical value of 1.96.

The backward elimination procedure was adopted in the variable selection process for the final model. Initially, all variables were included in the regression model and their parameters were estimated. The variable that was not significant at a 95% significance level was removed from the model. The parameters of the new model were re-estimated and their p-values and t-statistics re-calculated. The procedure continued until the p-values and t-statistics of all parameters in the model were significant. Linear models were shown to provide more robust models and hence Based on these requirements, the initial model had the form:

$$TT_{Automobile} = a_0 + a_1.TT + a_2.A + a_3.D + a_4.S + a_5.IS$$

Where:

$TT_{Automobile}$	=	Automobile Travel Time	(sec.)
TT	=	Bus Travel Time	(sec.)
A	=	Acceleration Delay for Bus	(sec.)
D	=	Deceleration Delay for Bus	(sec.)
S	=	Stoppage Delay for Bus	(sec.)
IS	=	Illegal Stops for Bus	(sec.)

a_0, a_1, a_2, a_3, a_4, and a_5 = Model parameters to be estimated.

4.3.2 Model Evaluation

The developed models were evaluated using several goodness of fit criteria. First, the model coefficients had to appear with the positive signs, which indicating an increase in the automobile travel time with any increase of these variables. Second, the coefficient of determination (R^2) was used a statistical measure that shows how much variability the model could interpret. The (R^2) static ranges between 0% and 100% where the higher the

value, the better the fit. Also, mean square of errors (MSE), sum of squares due to errors (SSE), and F-test were used to evaluate the model.

4.3.3 Model Results

The modeling process started with all variables (bus travel time, acceleration delay, deceleration delay, stoppage delay, and illegal stops delay to estimate automobile travel time. All variables except average bus travel time were shown to be insignificant regardless to the model form used as shown in Figure 4.1 and therefore were removed. A second round of modeling was carried out and the models showed better statistics where all the parameters had low p-values and high t-statistics of more than 1.96. Figure 4.2 and Figure 4.3 show the model results and their goodness of fit.

Two models were finally developed, one that related average automobile travel time to average bus travel time while the second model used automobile and bus speeds instead of the travel times such that:

- *Average Bus Speed vs. Average Automobile Speed*

$$V_{Automobile}\,(km/hr.) \;=\; 3.42 \;+\; 0.8569\,V_{Bus}\,(km/hr.)$$

- *Bus Travel Time vs. Automobile Travel Time*

$$TT_{Automobile}(sec.) \;=\; 23.40 \;+\; 0.7978\,TT_{Bus}\,(sec.)$$

As shown in Figure 4.2 and Figure 4.3, the R^2 is 65.9%, and 69.3% for the two functional forms, respectively, which means there is a strong correlation between the term and the response variable. All parameters appear with positive sign, which is the fundamental condition for not rejecting any of the two models. Other models statistics are shown in Figure 4.2 and Figure 4.3. The fitted line plots are shown in Figure 4.4 and Figure 4.5 in addition to three residual plots that can be used to examine the goodness of model fit which will discussed below.

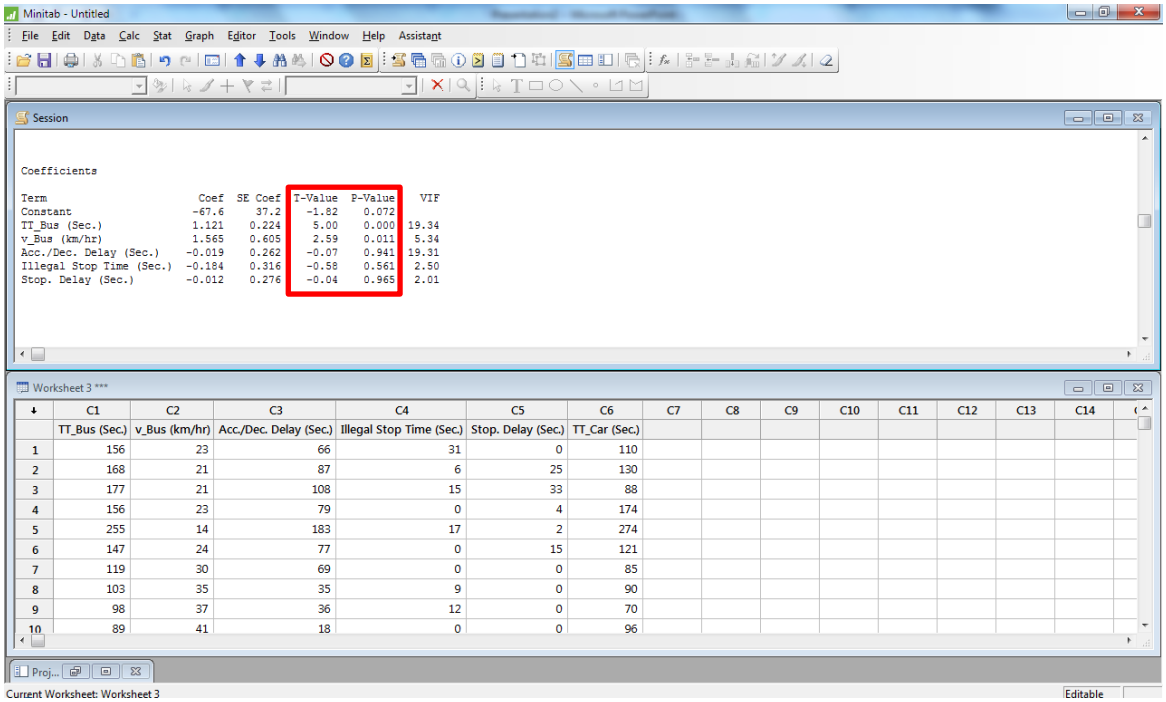


Figure 4.1 Model Summary.

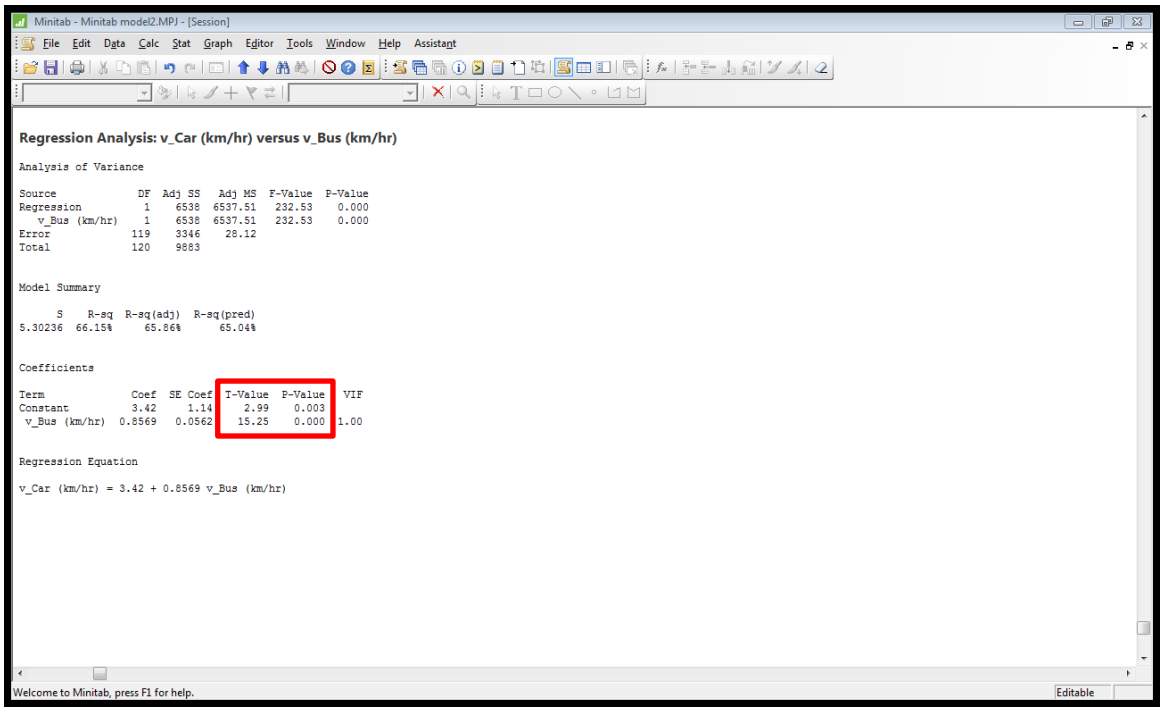


Figure 4.2 Model Summary for First Functional Form.

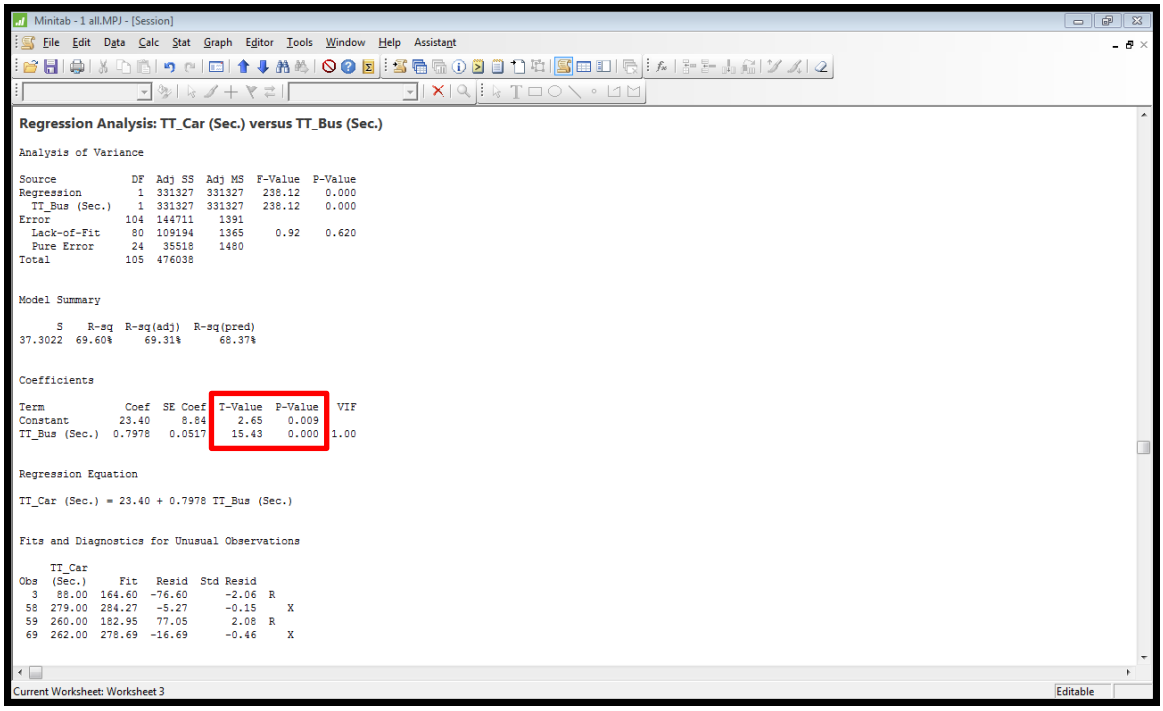
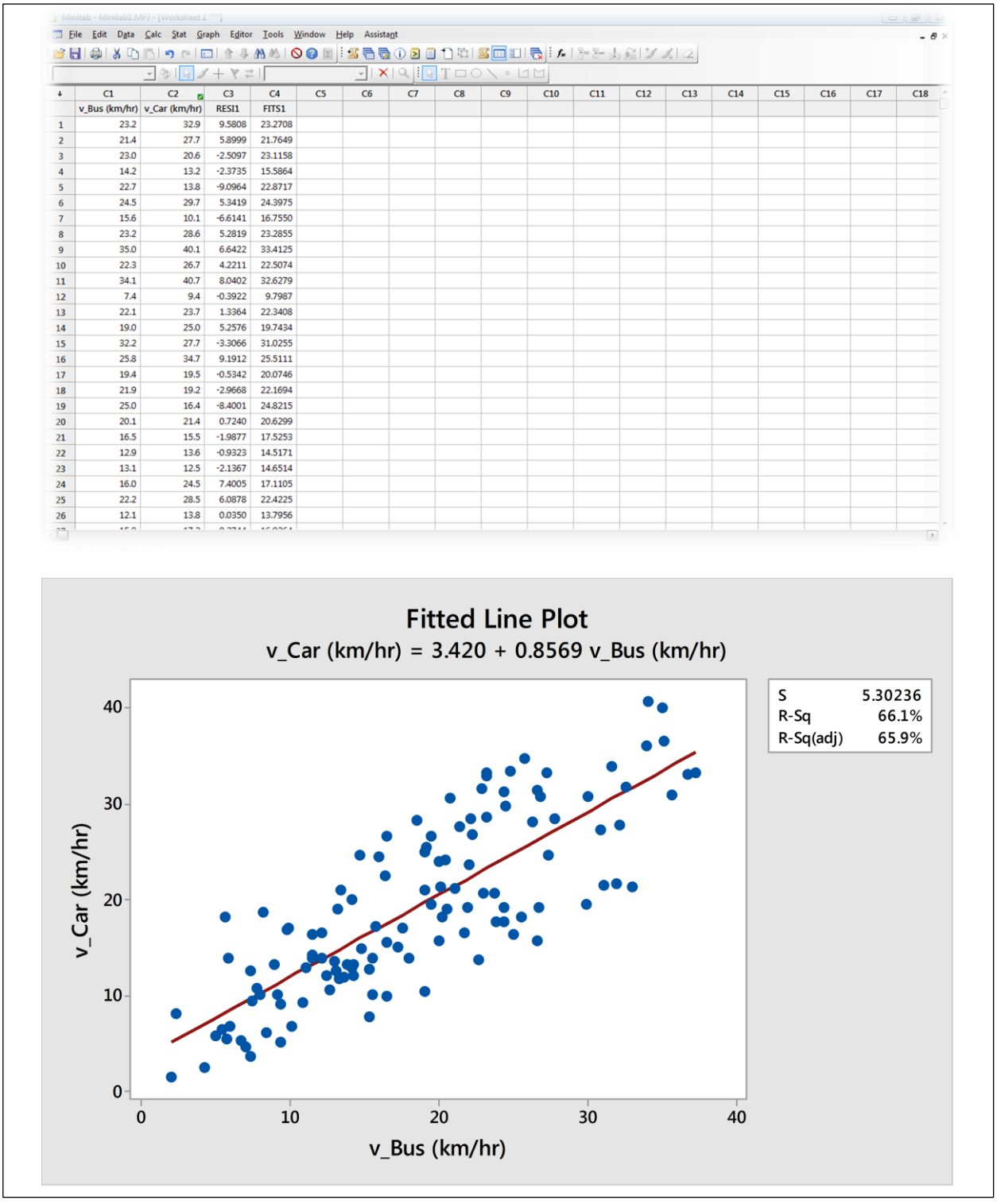
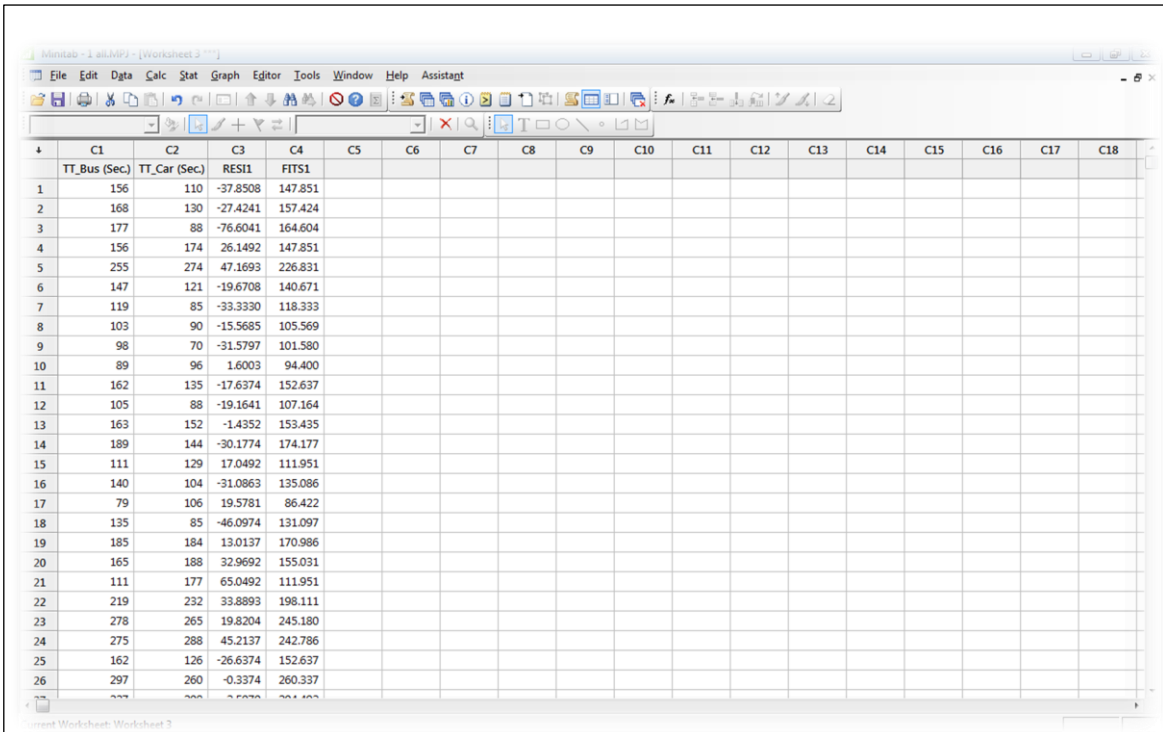


Figure 4.3 Model Summary for Second Functional Form.



	C1	C2	C3	C4
	v_Bus (km/hr)	v_Car (km/hr)	RESI1	FITS1
1	23.2	32.9	9.5808	23.2708
2	21.4	27.7	5.8999	21.7649
3	23.0	20.6	-2.5097	23.1158
4	14.2	13.2	-2.3735	15.5864
5	22.7	13.8	-9.0964	22.8717
6	24.5	29.7	5.3419	24.3975
7	15.6	10.1	-6.6141	16.7550
8	23.2	28.6	5.2819	23.2855
9	35.0	40.1	6.6422	33.4125
10	22.3	26.7	4.2211	22.5074
11	34.1	40.7	8.0402	32.6279
12	7.4	9.4	-0.3922	9.7987
13	22.1	23.7	1.3364	22.3408
14	19.0	25.0	5.2576	19.7434
15	32.2	27.7	-3.3066	31.0255
16	25.8	34.7	9.1912	25.5111
17	19.4	19.5	-0.5342	20.0746
18	21.9	19.2	-2.9668	22.1694
19	25.0	16.4	-8.4001	24.8215
20	20.1	21.4	0.7240	20.6299
21	16.5	15.5	-1.9877	17.5253
22	12.9	13.6	-0.9323	14.5171
23	13.1	12.5	-2.1367	14.6514
24	16.0	24.5	7.4005	17.1105
25	22.2	28.5	6.0878	22.4225
26	12.1	13.8	0.0350	13.7956

Figure 4.4 V_Car versus V_Bus.



	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
	TT_Bus (Sec.)	TT_Car (Sec.)	RESI1	FITS1														
1	156	110	-37.8508	147.851														
2	168	130	-27.4241	157.424														
3	177	88	-76.6041	164.604														
4	156	174	26.1492	147.851														
5	255	274	47.1693	226.831														
6	147	121	-19.6708	140.671														
7	119	85	-33.3330	118.333														
8	103	90	-15.5685	105.569														
9	98	70	-31.5797	101.580														
10	89	96	1.6003	94.400														
11	162	135	-17.6374	152.637														
12	105	88	-19.1641	107.164														
13	163	152	-1.4352	153.435														
14	189	144	-30.1774	174.177														
15	111	129	17.0492	111.951														
16	140	104	-31.0863	135.086														
17	79	106	19.5781	86.422														
18	135	85	-46.0974	131.097														
19	185	184	13.0137	170.986														
20	165	188	32.9692	155.031														
21	111	177	65.0492	111.951														
22	219	232	33.8893	198.111														
23	278	265	19.8204	245.180														
24	275	288	45.2137	242.786														
25	162	126	-26.6374	152.637														
26	297	260	-0.3374	260.337														

Figure 4.5 TT_Car versus TT_Bus.

- Histogram of residuals: an exploratory tool to show general characteristics of the data, including: typical values, spread or variation, shape and unusual values in the data (Figure 4.6 and Figure 4.7).

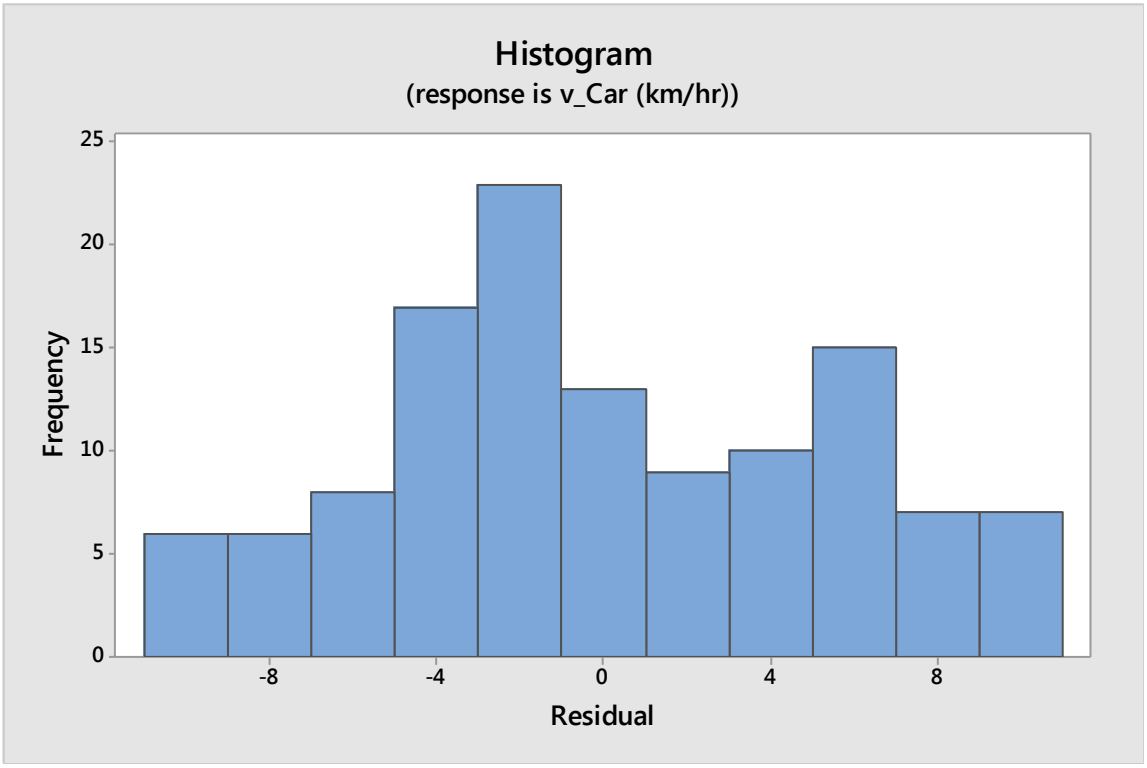


Figure 4.6 Residual Histogram for V_Car.

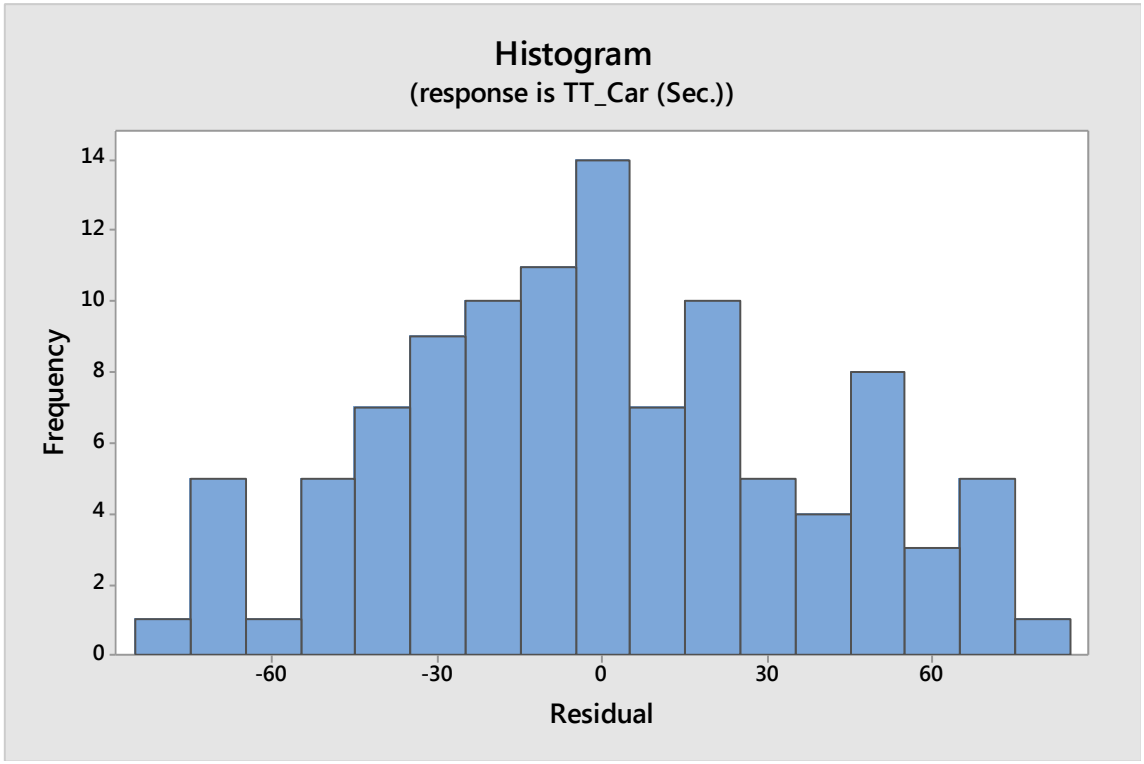


Figure 4.7 Residual Histogram for TT_Car.

- Normal probability plot of residuals: the points in this plot should generally form a straight line if the residuals are normally distributed (Figure 4.8 and Figure 4.9).

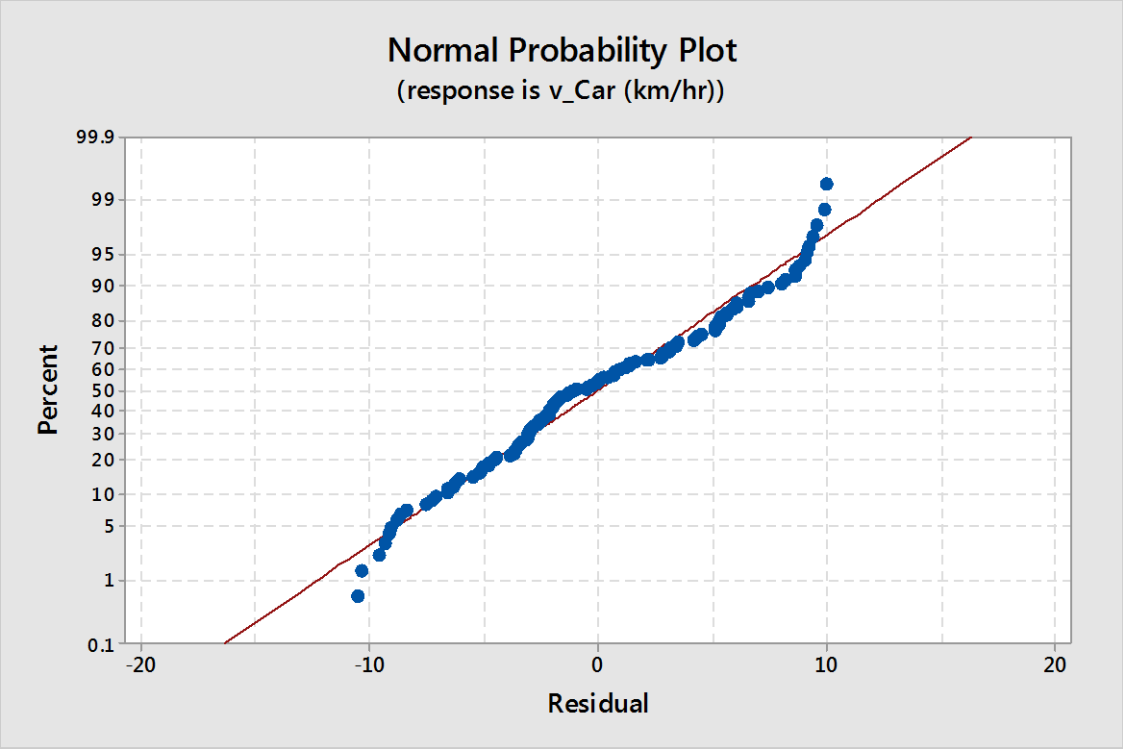


Figure 4.8 Normplot of Residuals for V_Car.

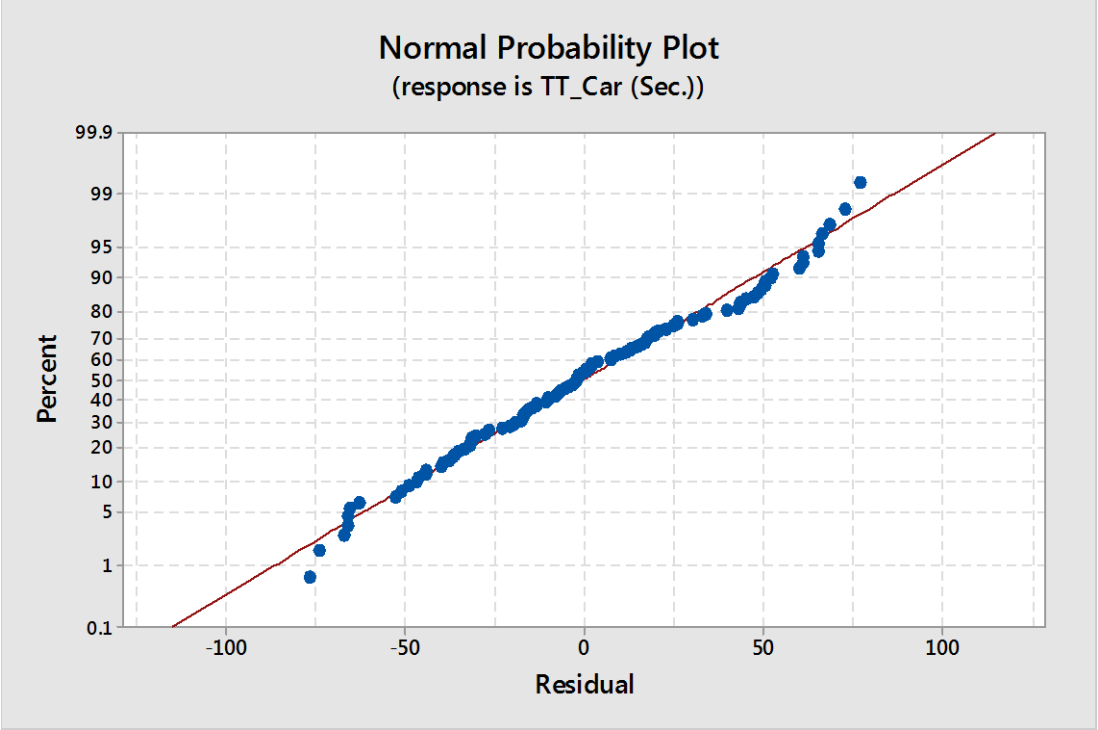


Figure 4.9 Normplot of Residuals for TT_Car.

- Residuals versus fits: this plot should show a random pattern residuals on both sides of zero (Figure 4.10 and Figure 4.11).

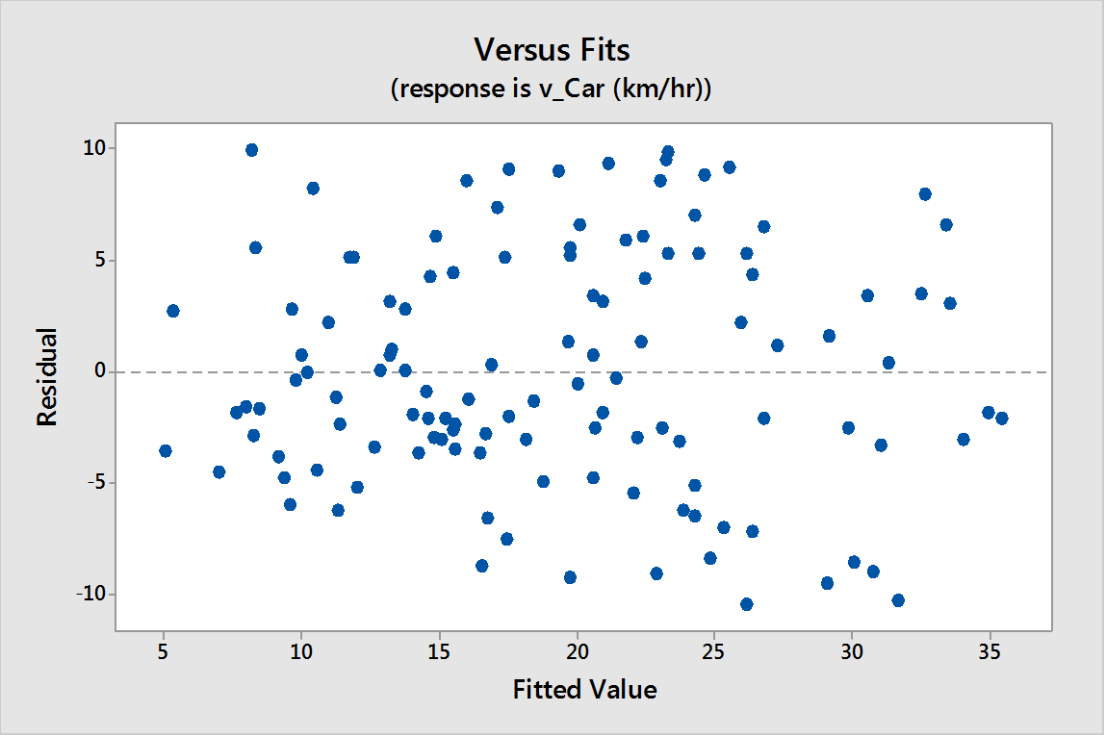


Figure 4.10 Residuals versus Fits for V_Car.

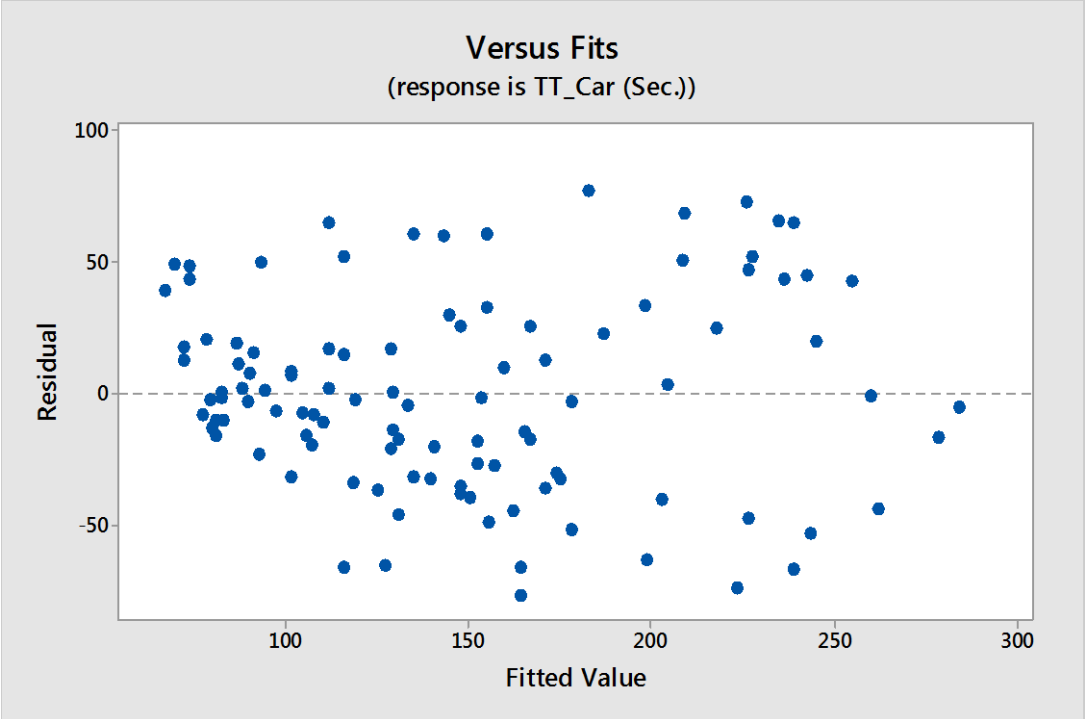


Figure 4.11 Residuals versus Fits for TT_Car.

The two models were tested on the development data of the thirty trips and the estimation errors were calculated by comparing the actual values with the estimated values, as shown in Table 4.3. According to the error estimates, it can be concluded that average automobile speed and travel times were estimated with reasonable accuracy. For the speed mode, the average errors of ten out of thirty trips did not exceed ±10% and the remaining were less than ± 17%. For the travel time model, however, thirteen out of thirty trips had an error of ±10% and the remaining trips had an average error of ±18%. These accuracy levels are considered generally acceptable and indicate a good potential for using transit vehicles as probes.

4.4 Validation

To verify the feasibility and suitability of the developed two models, another set of data was collected on some roads in different days as shown in Table 4.4. The main content to be verified is to compare both the actual average speed and the actual travel time of the automobile with the estimated one. It was found that the error does not exceed 17.6% when using any of the two models. These findings further supported the hypothesis that buses can be used as probes to estimate automobile travel time on urban roads in Greater Cairo.

Table 4.3 Model Application on the Calibration Data.

No.	Street Name	Direction		W.D. (dd/mm/year)	Time	Route Length (meter)	Bus Data		Car Data		First Functional Form				Second Functional Form			
							Avg. Speed (Km/h)	TT (GPS) (sec.)	TT (GPS) (sec.)	Avg. Speed (Km/h)	Calc. Avg. Car Speed (Km/h)	Residual	Abs. Residual	% Error	Calc. Car TT (sec.)	Residual	Abs. Residual	% Error
1	Gesr El-Suez Street	Forward	G1	26-11-12	9:54 AM	7632	19.16	1434	1183	21.23	19.84	1.39	1.39	6.56	1167	16	16	1.31
2			G2	26-11-12	10:28 AM	7797	20.61	1362	1300	23.79	21.08	2.71	2.71	11.39	1110	190	190	14.62
3		Backward	G1	26-11-12	11:42 AM	10348	21.95	1697	1440	24.27	22.23	2.04	2.04	8.41	1377	63	63	4.36
4			G2	26-11-12	12:19 PM	10638	18.66	2052	1753	20.85	19.41	1.44	1.44	6.91	1660	93	93	5.28
5	El-Harm Street	Forward	G1	26-11-12	3:15 PM	3472	20.53	609	616	18.29	21.01	-2.72	2.72	-14.88	509	107	107	17.33
6			G2	26-11-12	3:54 PM	3474	24.82	504	512	22.43	24.69	-2.26	2.26	-10.07	425	87	87	16.90
7		Backward	G1	26-11-12	4:00 PM	3499	14.25	884	858	13.88	15.63	-1.75	1.75	-12.61	729	129	129	15.08
8			G2	26-11-12	4:30 PM	3500	16.22	777	695	18.13	17.32	0.81	0.81	4.47	643	52	52	7.44
9	El-Nasr Street	Forward	G1	27-11-12	3:38 PM	9633	25.24	1374	1229	28.22	25.05	3.17	3.17	11.23	1120	109	109	8.90
10			G2	27-11-12	4:09 PM	9636	21.43	1619	1579	24.97	21.78	3.19	3.19	12.76	1315	264	264	16.72
11		Backward	G1	27-11-12	5:35 PM	5818	39.16	535	542	41.65	36.97	4.67	4.67	11.22	450	92	92	16.93
12			G2	27-11-12	6:10 PM	5821	25.91	809	720	29.11	25.62	3.49	3.49	11.99	669	51	51	7.11
13	Fesal Street	Backward	G1	28-11-12	6:16 PM	5675	7.43	2751	2449	8.84	9.79	-0.95	0.95	-10.71	2218	231	231	9.43
14			G2	28-11-12	6:44 PM	5673	8.34	2448	2258	9.05	10.57	-1.52	1.52	-16.85	1976	282	282	12.47
15	Salah Salem	Forward	G1	29-11-12	4:18 PM	7016	21.77	1160	1048	24.10	22.08	2.02	2.02	8.39	949	99	99	9.46

16	Street		G2	29-11-12	4:54 PM	7005	19.25	1310	1284	17.64	19.92	-2.28	2.28	-12.90	1069	215	215	16.78
17	El-Harm Street	Backward	G1	02-12-12	8:42 AM	6717	13.28	1821	1764	13.11	14.80	-1.69	1.69	-12.89	1476	288	288	16.32
18			G2	02-12-12	9:19 AM	6950	17.28	1448	1425	16.16	18.23	-2.07	2.07	-12.79	1179	246	246	17.29
19	Gameet El-Dewl El-Arabyia Street	Backward	G1	03-12-12	6:43 PM	2078	11.12	673	552	13.55	12.95	0.61	0.61	4.48	560	-8	8	-1.51
20			G2	03-12-12	7:15 PM	1995	16.94	424	363	18.49	17.94	0.55	0.55	3.00	362	1	1	0.37
21	Salah Salem Street	Backward	G1	17-12-12	5:45 PM	8444	11.99	2535	2450	12.41	13.70	-1.29	1.29	-10.38	2046	404	404	16.50
22			G2	17-12-12	6:16 PM	8162	8.86	3318	2270	12.94	11.01	1.94	1.94	14.95	2671	-401	401	-17.64
23	El-Nasr Street	Forward	G1	19-12-12	3:30 PM	15808	17.66	3222	3143	16.11	18.56	-2.44	2.44	-15.16	2594	549	549	17.47
24			G2	19-12-12	4:22 PM	15808	14.45	3939	3100	17.16	15.80	1.36	1.36	7.91	3166	-66	66	-2.13
25		Backward	G1	19-12-12	5:41 PM	16411	11.03	5358	5105	11.57	12.87	-1.30	1.30	-11.20	4298	807	807	15.81
26			G2	19-12-12	6:29 PM	16412	23.38	2527	2390	26.32	23.46	2.87	2.87	10.89	2039	351	351	14.67
27	Gameet El-Dewl El-Arabyia Street	Forward	G1	10-01-13	10:15 AM	1935	21.50	324	280	22.38	21.84	0.54	0.54	2.40	282	-2	2	-0.67
28			G2		10:45 AM	1969	24.11	294	305	21.64	24.08	-2.44	2.44	-11.27	258	47	47	15.43
29		Backward	G1	10-01-13	11:13 AM	1997	20.03	359	343	22.26	20.58	1.68	1.68	7.53	310	33	33	9.68
30			G2		11:47 AM	1970	20.98	338	350	19.26	21.40	-2.14	2.14	-11.10	293	57	57	16.27

Table 4.4 Model Validation Results.

Working Day	Street Name	Direction	Route Length (Km)	Bus Data			Car Data			First Functional Form		Second Functional Form	
				Time	Avg. Speed (Km/h)	Actual TT (Sec.)	Time	Avg. Speed (Km/h)	Actual TT (Sec.)	Calc. Avg. Speed (Km/h)	% Error	Calc. TT (Sec.)	% Error
Sunday 06-04-2014	Salah Salem Street	From Military College to El-Abasya Bridge	8.5	16:26	13.3	2114	17:02	12.6	2066	14.8	-17.6	1710	17.2
Tuesday 22-04-2014	Fesal Street	From El-Giza Bridge to Maryotya Bridge	6.8	17:18	8.2	2657	18:05	9.0	2529	10.4	-16.1	2143	15.3
Thursday 22-05-2014	Salah Salem Street	From El-Abasya Bridge to Military College	7.8	17:26	21.1	1304	17:50	18.5	1431	21.5	-16.2	1284	17.2
Thursday 25-02-2015	El-Harm Street	From El-Giza Bridge to El-Maryotya Bridge	6.6	08:32	22.4	1821	09:12	19.9	1632	22.6	-13.6	1476	9.5
Thursday 25-02-2015	Fesal Street	From El-Maryotya Bridge to El- Giza Bridge	5.8	12:43	24	1702	13:10	28	1520	24	14.3	1381	9.1
Saturday 28-02-2015	El-Harm Street	From El-Maryotya Bridge to El- Giza Bridge	7.1	16:30	18.7	2236	17:15	16.8	2194	19.44	-15.7	1807	17.6

Sunday 08-03-2015	Gesr El-Suez Street	From El-Salam Park to Ebn Sendr Square	10	16:55	7.2	4721	18:00	11.1	3442	9.6	13.6	3790	-10.1
Sunday 08-03-2015	Gesr El-Suez Street	From Ebn Sendr Square to El-Salam Park	10.2	20:00	10.1	3945	20:44	13.2	2967	12.1	8.5	3171	-6.9
Tuesday 10-03-2015	El-Nasr Street	From Sun City to Manshyet El-Bakry	16.1	14:05	14.3	5222	15:30	18	4580	15.7	12.9	4190	8.5
Tuesday 10-03-2015	El-Nasr Street	From Manshyet El-Bakry to Sun City	15.8	15:50	7.2	5950	17:08	10.5	5045	9.6	8.7	4770	5.4
Wednesday 11-03-2015	Ramses Street	From Nile Corniche to Abaseya Square	6.2	14:15	6.1	3824	15:22	7.4	3450	8.6	-16.9	3074	10.9
Thursday 19-03-2015	Gameet El-Dewl El-Arabya Street	From El-Mehwar Bridge to El-Sudan Street	2.1	19:30	6	1432	19:54	9.1	1118	8.6	5.9	1166	-4.3
Thursday 19-03-2015	Gameet El-Dewl El-Arabya Street	From El-Sudan Street to El-Mehwar Bridge	2.3	21:05	5.4	1610	21:30	8.7	1209	8.0	7.5	1308	-8.2

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Travel time information is an important element in ITS applications. Historically, inductance loops, cameras and other sensors have been used to obtain travel time data. This research suggests the use of transit vehicles as probes to collect travel time data on urban roads in Greater Cairo.

This objective was achieved by comparing bus travel times with those of automobiles for the same road sections. The data were collected using GPS-equipped vehicles, where a total of 30 trips were completed on the major urban roads in Greater Cairo. The raw GPS data were processed and used to obtain traffic measures such as total travel time, acceleration and deceleration delays, and average trip speeds.

Regression models were used to develop a relationship between bus travel times/speeds and automobile travel times/speeds. Different combinations of functional forms and explanatory variables were used to select the best models for application. Finally two linear regression models were developed and were found to be the most successful models in terms of their goodness of fit and predictive ability. In the first model, average bus speed was used as the dependent variable while average automobile speed was used as the explanatory variable. In the second model, however, travel times were used instead of speeds as in the following equations are suggested for the conversion.

- *Average Bus Speed vs. Average Automobile Speed*

$$V_{Automobile}\,(km/hr.) \;=\; 3.42 \;+\; 0.8569\,V_{Bus}\,(km/hr.)$$

- *Bus Travel Time vs. Automobile Travel Time*

$$TT_{Automobile}(sec.) \;=\; 23.40 \;+\; 0.7978\,TT_{Bus}\,(sec.)$$

A part of the collected data was reserved for models validation. The validations results showed that the mean error of any of the two models did not exceed 17.6%. This accuracy level was considered acceptable taking into account the high variability of urban travel time in general and the chaotic traffic environment of Greater Cairo in specific. Hence, it can be concluded that transit vehicles travel times and speeds can be used, generally, to

estimate the average speed and travel times of the general traffic on the urban roads of Greater Cairo.

Overall, the findings of this research demonstrate the potential for using transit vehicles as probes in Greater Cairo.

5.2 Future Work

This research proposed models for estimating automobile travel time by using transit buses as probes on some urban roads in Greater Cairo. It paves the way towards the development of a continuous system for collecting and disseminating traffic information to travelers using transit probes data.

Therefore, further work is necessary for improving the developed models and validating their generality . This can be done by collecting a large set of travel time data for more urban roads, doing many runs on each route and considering more traffic parameters that affect travel time such as: number of intersections per road segment, traffic volumes, pedestrians' activity density, time of the day, incidents history and so on.

Other extensions of the current work should focus on employing other modeling techniques such as non-parametric models and Artificial Intelligence (AI) models to relate bus and automobile travel times and speeds. It is also important to test the applicability of the developed models on a dynamic basis where the travel times should be update every small time interval; 10-30 minutes.

5.3 Recommendations

The models presented in this research can be a corner stone in solving some traffic problems in Greater Cairo. The idea is to initiate a traffic management. Hence, travelers can effectively select their daily routes based on exact information presented in minutes if not seconds rather than rough estimates of historical travel time. Traffic authorities can quickly detect the locations of congestions and take the necessary actions to alleviate the situation. It is recommended to install onboard tracking GPS devices in all buses so that

the data collection system becomes readily available at no major cost. It is also recommended to establish a transportation management center that uses the tracks of buses for the calculation of the network indicators such as travel time and speed. The automation of the entire process is necessary to enable data collection, processing, and information dissemination in a timely manner.

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APPENDIX (A)

DATA ANALYSIS FOR EACH TRIP

1st Trip

BUS DATA

GPS DATA						OUTPUT DATA			
SPEED	N	E	Hour	Min.	Sec.	Speed Classification	Route Length (meter)	7632	Meter
0	3335182.332	344862.722	9	53	54	Start Trip	Total Travel Time (by GPS),(Second)	1434	Second
0	3335182.112	344862.623	9	53	55	Stoppage	Total Stoppage Delay (Second)	212	Second
0	3335179.27	344859.788	9	53	56	Stoppage	Total Acc. Delay (Second)	197	Second
5	3335165.164	344846.003	9	53	57	End Stoppage & Start Constant	Total Dec. Delay (Second)	420	Second
8	3335158.516	344837.912	9	54	1	Constant	Delay due to stoppage/Acc./Dec. Delay (Second)	829	Second
8	3335156.443	344835.571	9	54	2	Constant	Travel Time without Delay (by GPS), (Second)	605	Second
8	3335153.71	344832.834	9	54	3	Constant	Free Flow Travel Time (Velocity=60 Kph.), (Second)	458	Second
7	3335152.08	344830.499	9	54	4	Constant	Delay due to hardly reach Free Flow Time(Second)	147	Second
7	3335151.012	344827.689	9	54	5	End Constant & Start Dec.	Total Delay (Second)	976	Second
8	3335150.513	344823.732	9	54	6	Dec.	Number of Total Stops	23	
7	3335148.767	344821.78	9	54	7	Dec.	Number of Stops at Station	4	
6	3335147.579	344819.547	9	54	8	Dec.			
5	3335146.491	344818.087	9	54	9	End Dec. & Start Stoppage			
4	3335146.383	344817.892	9	54	10	Stoppage			
5	3335144.54	344814.976	9	54	11	Stoppage			
5	3335143.68	344813.037	9	54	12	Stoppage			
4	3335143.682	344812.94	9	54	13	Stoppage			
5	3335142.848	344809.171	9	54	14	Start Dec.			
6	3335141.54	344807.611	9	54	15	Dec.			
0	3335141.543	344807.418	9	54	16	End Dec. & Start Stoppage			
4	3335141.545	344807.225	9	54	17	Stoppage			
0	3335141.331	344806.74	9	54	18	Stoppage			
0	3335141.224	344806.45	9	54	19	Stoppage			
0	3335141.006	344806.158	9	54	20	Stoppage			
3	3335140.57	344805.67	9	54	21	Stoppage			
0	3335140.244	344805.184	9	54	22	Stoppage			

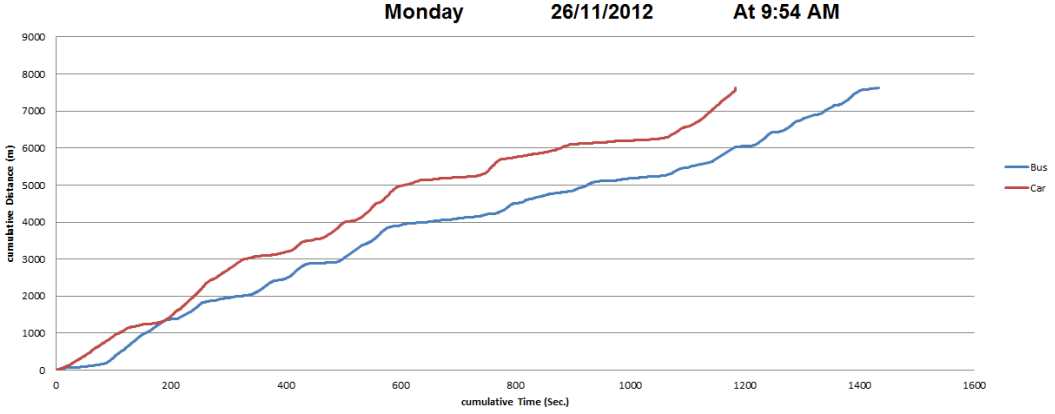
CAR DATA

GPS DATA						OUTPUT DATA			
SPEED	N	E	Hour	Min.	Sec.	Speed Classification	Route Length (meter)	7632	Meter
0	3335599.456	345864.562	9	56	16	Start Trip	Total Travel Time (by GPS),(Second)	1183	Second
3	3335599.241	345864.077	9	56	17	Stoppage	Total Stoppage Delay (Second)	199	Second
4	3335598.916	345863.494	9	56	18	Stoppage	Total Acc. Delay (Second)	199	Second
5	3335596.571	345856.813	9	56	19	Stoppage	Total Dec. Delay (Second)	207	Second
5	3335596.037	345855.361	9	56	20	End Stoppage & Start Acc.	Delay due to stoppage/Acc./Dec. Delay (Second)	604	Second
10	3335594.964	345852.841	9	56	21	Acc.	Travel Time without Delay (by GPS), (Second)	579	Second
12	3335594.121	345849.746	9	56	22	Acc.	Free Flow Travel Time (Velocity=60 Kph.), (Second)	458	Second
13	3335592.842	345846.067	9	56	23	Acc.	Delay due to hardly reach Free Flow Time(Second)	121	Second
16	3335590.694	345841.123	9	56	24	Acc.	Total Delay (Second)	725	Second
18	3335589.106	345835.801	9	56	25	Acc.	Number of Total Stops	13	
20	3335587.519	345830.384	9	56	26	Acc.			
22	3335584.832	345824.372	9	56	27	Acc.			
24	3335581.617	345816.523	9	56	28	Acc.			
28	3335578.403	345808.577	9	56	29	Acc.			
29	3335574.652	345799.372	9	56	30	Acc.			
30	3335571.895	345790.469	9	56	31	End Acc. & Start dec.			
27	3335569.125	345782.433	9	56	32	Dec.			
26	3335566.895	345775.465	9	56	33	End Dec. & Start Acc.			
22	3335565.086	345770.14	9	56	34	Acc.			
23	3335562.837	345764.52	9	56	35	End Acc. & Start Constant			
23	3335560.033	345758.893	9	56	36	End Constant & Start Acc.			
25	3335558.007	345753.18	9	56	37	Acc.			
27	3335554.885	345746.584	9	56	38	End Acc. & Start Constant			
27	3335552.435	345739.517	9	56	39	End Constant & Start Acc.			
31	3335549.55	345731.768	9	56	40	Acc.			
34	3335546.574	345722.67	9	56	41	Acc.			

Gesr El-Suez Street

From El Salam Park to Ebn Sendr Square

Monday 26/11/2012 At 9:54 AM



2nd Trip

BUS DATA

GPS DATA							OUTPUT DATA		
SPEED	N	E	Hour	Min.	Sec.	Speed Classification	Route Length (meter)	7798	Meter
0	3335131.09	344770.464	10	27	38	Start Trip	Total Travel Time (by GPS),(Second)	1362	Second
4	3335131.098	344769.886	10	27	39	Stoppage	Total Stoppage Delay (Second)	93	Second
5	3335129.97	344763.414	10	27	40	End Stoppage & Start Acc.	Total Acc. Delay (Second)	303	Second
6	3335128.097	344762.617	10	27	41	Acc.	Total Dec. Delay (Second)	368	Second
12	3335125.794	344760.85	10	27	42	End Acc. & Start Stoppage	Delay due to stoppage/Acc./Dec. Delay (Second)	764	Second
0	3335107.849	344744.216	10	27	54	Stoppage	Travel Time without Delay (by GPS), (Second)	598	Second
0	3335107.741	344744.022	10	27	55	Stoppage	Free Flow Travel Time (Velocity=60 Kph.), (Second)	468	Second
0	3335107.302	344743.727	10	27	56	Stoppage	Delay due to hardly reach Free Flow Time(Second)	130	Second
4	3335104.893	344741.573	10	28	3	End Stoppage & Start Acc.	Total Delay (Second)	894	Second
6	3335099.967	344737.168	10	28	4	Acc.	Number of Total Stops	12	
8	3335098.547	344735.702	10	28	5	End Acc. & Start Constant	Number of Stops at Station	2	
8	3335096.016	344734.318	10	28	6	End Constant & Start Acc.			
10	3335093.039	344733.216	10	28	7	Acc.			
11	3335090.862	344730.391	10	28	8	End Acc. & Start dec.			
9	3335088.902	344727.858	10	28	9	Dec.			
5	3335087.593	344726.394	10	28	10	Dec.			
5	3335086.498	344725.415	10	28	11	End Dec. & Start Acc.			
10	3335084.637	344723.751	10	28	12	Acc.			
14	3335082.119	344721.499	10	28	13	Acc.			
17	3335079.623	344717.706	10	28	14	Acc.			
21	3335075.909	344713.799	10	28	15	Acc.			
25	3335071.202	344709.59	10	28	16	Acc.			
28	3335066.525	344703.261	10	28	17	Acc.			
31	3335060.625	344697.107	10	28	18	Acc.			
34	3335054.184	344690.079	10	28	19	Acc.			
35	3335047.412	344682.949	10	28	20	Acc.			

CAR DATA

GPS DATA							OUTPUT DATA		
SPEED	N	E	Hour	Min.	Sec.	Speed Classification	Route Length (meter)	7798	Meter
0	3334228.145	342783.946	10	35	0	Start Trip	Total Travel Time (by GPS),(Second)	1419	Second
36	3334221.405	342751.375	10	35	3	Dec.	Total Stoppage Delay (Second)	387	Second
28	3334218.774	342741.605	10	35	4	Dec.	Total Acc. Delay (Second)	221	Second
26	3334217.427	342735.033	10	35	5	Dec.	Total Dec. Delay (Second)	257	Second
22	3334211.688	342709.993	10	35	9	Dec.	Delay due to stoppage/Acc./Dec. Delay (Second)	865	Second
20	3334210.657	342704.582	10	35	10	Dec.	Travel Time without Delay (by GPS), (Second)	554	Second
18	3334209.073	342699.067	10	35	11	Dec.	Free Flow Travel Time (Velocity=60 Kph.), (Second)	468	Second
16	3334207.801	342695.002	10	35	12	Dec.	Delay due to hardly reach Free Flow Time(Second)	86	Second
16	3334206.63	342691.612	10	35	13	End Dec. & Start Acc.	Total Delay (Second)	951	Second
17	3334206.472	342687.177	10	35	14	Acc.	Number of Total Stops	14	
18	3334205.992	342681.967	10	35	15	End Acc. & Start dec.			
17	3334205.739	342676.374	10	35	16	Dec.			
11	3334206.015	342672.62	10	35	17	Dec.			
10	3334206.39	342669.638	10	35	18	End Dec. & Start Constant			
10	3334206.212	342666.552	10	35	19	Constant			
11	3334206.143	342663.66	10	35	20	Constant			
11	3334206.295	342660.772	10	35	21	Constant			
10	3334206.659	342658.56	10	35	22	Constant			
10	3334207.366	342655.68	10	35	23	Constant			
8	3334208.279	342653.862	10	35	24	Constant			
8	3334208.421	342651.648	10	35	25	End Constant & Start Dec.			
6	3334208.443	342650.106	10	35	26	Dec.			
0	3334208.443	342650.106	10	35	34	End Dec. & Start Stoppage			
0	3334208.443	342650.106	10	35	35	Stoppage			
0	3334208.443	342650.106	10	35	36	Stoppage			
0	3334208.443	342650.106	10	35	37	Stoppage			

Gesr El-Suez Street

From El Salam Park to Ebn Sendr Square

Monday 26/11/2012 At 10:28 AM