PARATRANSIT SYSTEMS OPERATIONS MODELS

FINAL REPORT

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ABSTRACT

The Paratransit Systems Operations Models project was proposed in the Fall of 2002 and funded May 10, 2002. The project focused on developing models for use in evaluating routing, scheduling and dispatch alternatives for paratransit system management. Development relied on historical data available from Galavan, the Bozeman, MT area paratransit system operators, and the Gallatin County Geographical Information Systems (GIS) group.

As a result of this work, a general routing database architecture has been specified and travel, load and unload time estimation models have been developed. Basic testing has demonstrated the viability of the database design, and the estimation models have been validated under conditions similar to those present during development.

This work will support development of improved computer-aided routing, scheduling and dispatch systems for small urban and rural paratransit operators. Other uses will be found in paratransit system fleet configuration and operational systems design.

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INTRODUCTION

There is a significant and increasing number of disabled, elderly, very young or poor Americans that do not own or cannot use an automobile for personal transportation. According to the Community Transportation Association, "nearly 40 percent of the country's transit dependent population – primarily senior citizens, persons with disabilities and low-income individuals – resides in rural areas" (Community Transportation Association, 2002).

In most urban areas there is some sort of public transit system, usually conventional fixed route transportation such as buses, streetcars, subways etc. In addition, Federal law mandates equal access to public transportation for disabled individuals who are unable to use conventional, fixed route systems where such systems exist. Alternative, *demand responsive*, or *paratransit*, systems are provided for disabled individuals. In contrast, alternative transportation in non-urban communities is often limited to taxi services, if it exists at all.

More than one-third of America's population currently lives in suburban, small town and rural communities. With these communities aging faster than the general population, and increasing expectations for elderly and disabled independent living, demand for public transportation services can be expected to increase dramatically. Paratransit systems will likely play a major role in satisfying this demand.

PARATRANSIT BACKGROUND

In early 70's alternate transportation services started to get implemented for filling the gap left by the existing public transportation methods. Most of these systems were implemented through Federal funds mainly as demonstration programs. These forms of transportation came to be known as *paratransit*. The word *para* means "closely related to" and *transit* stands for "conventional transportation(Levinson-Weant, 1982). Paratransit systems can be loosely defined as a transportation services falling some where between a private automobile and fixed route systems. Paratransit has grown to include:

- Special service for the elderly and handicapped.
- Feeder services to line haul operations.
- Exploratory service in low-density suburbs to promote new ridership and to build the transit habit.
- Possible peak hour service to relieve pressure on often overtaxed vehicles and labor
- Possible late night service on certain routes where the capacity of conventional fixed route service is not required.

There are many forms of paratransit offering a wide range of service to different elements of society, but all can be broadly classified into two major categories. They are:

- Demand responsive paratransit – mainly includes Dial-a-ride or Dial-a-bus.
- Prearranged ride sharing – mainly includes Carpools, Vanpools, Subscription buses.

There are many organizations that provide paratransit services in many parts of the country and with differing objectives. According to Levinson (Levinson-Weant, 1982), these organizations are either public or private. There are two main types of public sector providers:

- Local governments.

- Regional transit authorities

Similarly, most private sector providers can be classified as:

- Non-profit social service agencies.
- Profit-making, nonsubsidized organizations.
- Profit-making transportation providers that have local government contracts and subsidies.
- Employers and employee organizations.

Whether public or private, all paratransit systems have similar management, routing and scheduling problems.

PARATRANSIT OPERATIONS MANAGEMENT AND VEHICLE ROUTING

Paratransit transportation system managers must assign *vehicles* and *drivers* to point-to-point *trips* corresponding to *ride requests* from elderly and disabled *passengers*. While operational details may vary, most small systems operate similar to the Galavan system documented in Appendix I.

Requests for rides must usually be made in advance by making a reservation. Some reservations can be made for a fixed *time window* while others are "will-call," meaning that the passenger will call for a return ride sometime after arriving at their destination. For example, a passenger may request a ride to a doctor appointment the next day, but must call when done for the return trip.

Hence, from a management point of view some vehicle trips can be planned at the beginning of the day while others are known but cannot be scheduled until a "will-call" event occurs. Paratransit vehicle routing thus involves three principle activities:

1. Reservation management.
2. Vehicle loading and routing (vehicle trip planning).
3. Real-time dispatching in response to will-call, breakdown, and other events.

This project focused on identifying computerized support opportunities for the second activity – vehicle trip planning – for small paratransit systems.

Figure 1 illustrates the architecture for a computerized decision support system for paratransit vehicle routing. The system will ultimately consist of two components:

- A database with map and trip reservation information
- Trip planning software including vehicle loading and routing and trip time estimation models.

While this project initially focused on routing software, it quickly became apparent that data issues would occupy most of the time. Planning algorithm development was therefore limited, while solutions to map and trip information acquisition and their integration and trip time estimation were devised.

A prototype database was designed and tested using Gallatin County Geographical Information System (GIS) map data and historical trip data from the Galavan reservation database. Data for developing trip time estimation models was collected by observing the Galavan vehicles.

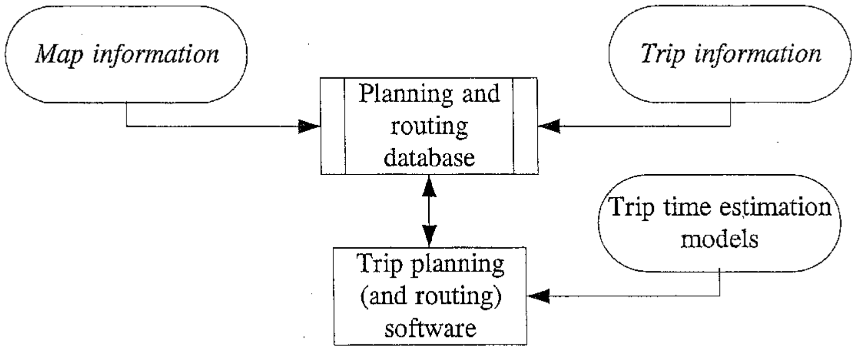

Figure 1 - Paratransit Routing System Architecture

This report is divided into two major sections, followed by conclusions and recommendations for future work. The first section summarizes the map and trip information database portion of the study and the time estimation models are described in the second section.

VEHICLE TRIP PLANNING DATABASE

Vehicle trips must be planned from reservations for paratransit vehicles daily. Planning involves identifying trips and assigning them to and sequencing them on the available vehicles. Unfortunately, because travel times are dependent on the *route* followed between trip "start" and "end" *stops*, assumptions must be made about the *routes* followed. Therefore, trip planning requires detailed vehicle routing between stops.

Vehicle routing begins by identifying *stops* from reservations. Each stop involves loading and/or unloading one or more passengers at the start and/or end of a trip. These stops are assigned to and sequenced for each vehicle by routing the vehicle through a network of streets and roads. Routes must be developed to allow all trips to be made in the available time with the vehicles in the fleet as efficiently as possible.

Good estimates for load, unload and travel times are essential for effective routing. As shown in the next section, load and unload times are a function of the number and type of passengers loaded and vehicle characteristics. Similarly, travel times may be affected by vehicle characteristics, driver experience, and distance. Other factors that may be important for estimation include road condition, speed limits, weather, traffic levels, etc.

Clearly, computerized trip planning requires a significant amount of data organized in a database for use by planning software. This project identified four general categories of data:

1. Reservation data: passenger(s), pickup/dropoff location and times requested
2. Passenger data: elderly, wheel chair, disability information, etc.
3. Vehicle data: capacity, ramp type, door opening mechanism, etc.
4. Map data: x-y coordinates, speed limits, intersections, road condition, etc.

Other information such as the weather, etc. would likely be input as part of the daily planning activity. All of the information necessary for planning may be available in existing databases, although coding for vehicle and passenger characteristics, addresses, etc. has not been standardized, in general.

Data obtained from Galavan and the Gallatin County Geographical Information System (GIS) project was used for this project. A significant amount of time was required to convert the Galavan reservation addresses to the GIS format. Unfortunately, the GIS and Galavan address data format incompatibility may be typical.

This project combined the Gallatin County map data (represented as street segments) with the Galavan reservation data in a common database. Address lookup was demonstrated using the combined datasets. Street networks were also constructed from the map data for routing.

The remainder of this section provides details about the map data analysis and programs written to construct street networks for routing. As a result of this work, the groundwork has been laid for developing computer-aided trip planning tools.

MAP DATA

Map data, or more specifically, street information, must be accessible for computer-aided trip planning. This information is needed for vehicle trip planning and routing. These days, such information is often stored in a Geographical Information System (GIS).

A GIS is defined in many ways. The Environmental Systems Research Institute (ESRI) states that "Simply put, a GIS combines layers of information about a place to give you a better understanding of that place" (GIS, 2000) . A more detailed definition is given by the United States Geological Survey (USGS): "In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations," (USGS, 2001).

As is common in the computer industry, several competing formats and standards exist for GIS. ESRI is one of the major players, with its "shapefile" format and programs like Arcview, ArcExplorer, and ArcInfo etc. The shapefile formatting standards are documented in a white paper, making it one of the more "open" and widely used formats(ESRI, 1998).

The TIGER/ Line files format is promoted by the USGS and the details can be obtained from their website, included in references as (USCB, 2000). Yet other format used is by MapInfo and the details can be obtained from their corporate website (MapInfo, 2002). Data and software availability both depend on the format chosen for the map data.

The shapefile format was chosen for this project due to it's ubiquity, relatively open standards, and the available software. As a bonus, the Gallatin County GIS coordination and planning center had the test information available in shapefile format.

By identifying that Shapefile has a lot of information that could be used to create the network model that is necessary for the routing and scheduling package, the next attempt was to figure out how to obtain that network. To understand that there should be some technical details to be known about the Shapefile. This information was obtained from the ESRI white paper on Shapefile that can be obtained from their corporate website as in reference as (ESRI, 1998).

MAP DATA APPLICATIONS PROTOTYPES

Shapefiles actually store special information for graphical display as well as other "attributes" of the shapes stored in the files. Several shapefiles may be overlaid to produce a display, with each shapefile restricted to a particular shape "type." Shapefiles are somewhat analogous to the layers in common drawing programs when building a display.

The street map data obtained from Gallatin County is stored as "polylines" in a shape file, where each polyline is a street segment. Attributes of each street segment, including x-y locations for the end points, distance of the segment, left and right address ranges, speed limits, condition etc. are stored in a separate DBASE III formatted file with a .dbf extension. These two files are linked for display by application programs like ARCVIEW.

The contents of the attributes file were sufficient for constructing a routing database, since detailed display was not needed to construct a street network. The .dbf file was therefore read into an ACCESS database for verification and testing with the Galavan reservation data. C++ programs were written to construct the street network for routing.

While the basic organization of the shapefiles is straight-forward, the internal format in which the data is stored is not compatible with the Intel formats and the conversion can be quite complex. Fortunately, a library of conversion routines was found, and a program to convert the data to an internal format was written using this library.

The ShapeLib library is available from Frank Warmerdam (Warmerdam, 1998). While functions are available for reading and writing both .dbf and .shp files, only the .dbf files were needed for this project.

The library was tested and assumptions regarding the shapefile format were verified by running the programs distributed with the library on a small "map" created for testing.. The link between the .shp and .dbf files Gallatin County GIS files was confirmed to be a unique identifier for each polyline. (Polylines represent street segments in the Gallatin Count GIS). The same results were observed with a "map" including an intersection generated using ArcView. The details are in Appendix IIto those who are interested in the technicalities of the work.

The main goal for accessing the shapefiles is to construct a street network in a routing program. A prototype program to do this using the ShapeLib functions was also written and verified. The program uses the Gallatin County GIS .dbf file. The fields in the dbf file contain the attributes of each street segment and are defined in Table 1. The source code and technical details are included in Appendix II.

Table 1 - Gallatin County GIS Field Definitions

SNO	FIELD NAME	DESCRIPTION OF CONTENT
1	FNODE	From Node
2	TNODE	To Node
3	LPOLY	Left Polygon
4	RPOLY	Right Polygon
5	LENGTH	Length of the Road Segment between nodes (Meters)
6	JUNK_	Created by ArcView (function of directory name to export is done)
7	JUNK_ID	Created by ArcView (function of directory name to export is done)
8	UNIQUE_ID	Identification used to identify each road uniquely.
9	DIRPRE	Directional Prefix (N, E, W, S)
10	ROADNAME	Road Name itself excluding prefix
11	ROADTYPE	Road Type; details like Street, Avenue, Alley etc
12	DIRSUF	Directional Suffix (N, E, W, S)
13	ROADCLA	Road Class (not used will be removed)
14	FRADDL	From Address Left
15	TOADDL	To Address Left
16	FRADDR	From Address Right
17	TOADDR	To Address Right
18	SPEEDLIM	Speed Limit designated to that segment

19	LANES	Total number of lanes in the road
20	CONDITION	Road Condition – Excellent/Good/Fair/Bad
21	DIRECTION	The field is not used, will be removed
22	SURFACE	Type of Road Surface - Asphalt, Concrete etc
23	COMMUNITY	Who responds to 911 – Emergency Response
24	MUNL	Municipality Left
25	MUNR	Municipality Right
26	COMMENT	Unwanted field will be removed from database in final cleaning
27	COUNTY	County to which the road belongs
28	UPDATE	When the information about the road was last entered to the database
29	ADRMETE	The length of the road in feet
30	ROUTE	Not used; will be removed from database at the time of cleaning
31	O_DIRPRE	Old Directional Prefix
32	O_ROADNAME	Old Road Name
33	O_ROADTYPE	Old Road Type
34	O_DIRSUF	Old Directional Suffix

2 shows the directional convention used in the construction of the digital spatial data. This is important if the optimal routes are to be displayed on the screen.

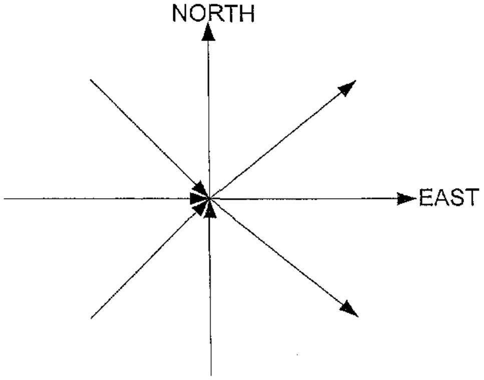

Figure 2 - Gallatin County GIS Direction Convention

The output from the prototype to construct a network model from the dbf file is given in Figure 3. The final matrices are the adjacency matrix and the distance matrix.

```
  FNODE_      TNODE_      LPOLY_      RPOLY_         LENGTH
     1           2           0           0          97.91825
     3           2           0           0          72.32528
     2           4           0           0         101.46682
     2           5           0           0          59.09170

The results after scanning the dbf files are:
From Node Array :
1 3 2 2
To Node Array :
2 2 4 5
Distance Array :
97.9183 72.3253 101.4668 59.0917
From-To Matrix :
0 1 0 0 0
0 0 0 1 1
0 1 0 0 0

 Distance Matrix :
 0.0000 97.9183  0.0000   0.0000   0.0000
 0.0000  0.0000  0.0000 101.4668  59.0917
 0.0000 72.3253  0.0000   0.0000   0.0000
```

Figure 3 - Output listings for the prototype of the program

TRIP TIME ESTIMATION

Scheduling vehicle trips can be done efficiently if the times taken to complete all the assigned trips are known. In a real world transit system the trips times are not deterministic. So various models are necessary to estimate the trip times to a considerable accuracy. In this project the method of multiple regression was used to develop these estimation models.

The development of multiple regression estimation models was based on the actual operational data collected from the transit system. Time study was conducted to collect the data to obtain the time necessary for loading, travel and unloading events along with independent variables that control these times. The estimation models were developed from this data by conducting regression analysis.

All models developed were validated with the system under study to test its viability. In this project the model validation was done with the help of a new set of data collected. If the model gave a good fit for the validation data, it could be concluded that the time estimates from the model is dependable for the routing software.

DATA COLLECTION

The trip time estimation models were based on the real time operational data for load, unload and travel time. These times were collected with the associated factors. The accuracy maintained during the data collection affected the modeling based on the collected data.

Before operation times were collected, the load-travel-unload process was analyzed and documented. The detailed process charting of the activities is included in the Appendix I for reference.

Time study was then used to obtain times and values for related factors that affect the daily operations of a paratransit system. One of the major achievements of this project was a methodology developed for conducting time study on door-to-door paratransit system in small urban and rural areas. Specifically the time study resulted in development of forms that could capture various influencing factors against time for analysis purpose .

Standard equipment was used in the study. According to Niebel & Freivalds (Niebel-Freivalds, 1999) "the minimum equipment required to conduct a time study program includes a stopwatch, time study board, time study form and a pocket calculator." Keeping this in mind the following equipment was used:

- Stopwatch – Make: Spalding, Model: Digital, Method of Timing: Continuous, Accuracy: 1/100th of a second.
- Time Study Board – Make: A&W, Model: Plywood lightweight, with strong clip for holding the forms.
- Time Study form – Properly and specially designed forms for the time study. .
- Pocket Calculator – Make: CASIO, Model: fx115W, has time conversion facility.
- Pencil
- Eraser

Meetings with Galavan drivers and the dispatcher were conducted to identify the factors that seem to influence their daily operations. In later portions of the report where load, unload and travel times are discussed these factors are tabulated for easy reference. Information obtained from the interviews helped in designing data collection forms. The forms and some sample time study data are included in Appendix III.

The start and end point of the operations to be timed is quite important and was determined from the process analysis. By defining the start and end points as some clearly observable and a must activity of the procedure, the timing process won't get skewed by personal differences. Table 2 explains the start and end points of each activity considered for time study.

Table 2 - Start and End points of Events in Time Study

SN.	Activity	Start Point	End Point
1	Load Passenger	Vehicle in Parking Gear	Vehicle in Drive Gear
2	Unload Passenger	Vehicle in Parking Gear	Vehicle in Drive Gear

With the data collection study designed, the project moved to data collection and model construction. The challenge in model construction was to identify relevant factors and relations and validate the models with reall data.

MODEL CONSTRUCTION METHODOLOGY

Models are needed that accurately predict load, unload and travel times for use in paratransit routing and scheduling. Multiple regression analysis was used to develop the models. The analysis was conducted using Microsoft Excel and Jumpin statistics software. Developing each of the three models involved several steps:

- Initially simple regression analysis was done to individual factors to identify their significance. .
- Then factors that were determined to be interacting were examined together. .
- After completing the simple regression analysis on all factors unimportant ones were filtered out.
- A multiple regression analysis was conducted with the filtered out factors, by adding one by one to the model.
- Every time a new factor or interaction factor was added to the model, the resulting R^2 and t-statistics values for each factor were examined. Factors that became insignificant were eliminated.

The final load, travel, and unload time prediction model were found by iterating through many combinations of factors. Details for each model follow.

LOAD TIME MODEL

Before the regression analysis a rough estimation was done to find the percentage of time spent in loading and unloading of passengers in a day in Galavan. This was found out to vary from 28% to 39% - a significant amount of the total cycle time for a trip in a door-to-door type paratransit operation. So, an accurate model for predicting load and unload times is necessary for meaningful scheduling and routing.

Initially a large set of parameters was identified from the discussion with drivers and similar studies. Table 3 Lists them all. The fields marked with asterix (*) appear in the proposed multiple regression model. The details of individual analysis are available in Appendix IV.

Table 3 - List of parameters considered for Load Time Estimation Model

Class	Variable	Description of variables	Values
Passenger Attributes	EL *	No of Elderly Passengers	0,1,2...
	WC *	No of Wheel Chair Passengers	0,1,2...
	DB *	No of Disabled Passengers	0,1,2...
	OT	No of Other Category Passengers	0,1,2...
	SP *	No of Special Category Passengers	0,1,2...
Driver Attributes	DRIVER	Code of driver operating the vehicle	1,2,3,4
Vehicle Attributes	VEHCAT *	Category upon Passenger Loading Mechanism	1,2
	VEHICLE	Vehicle Number associated with each one	4,5,6,7,8
Interactions	WVEH *	W. C passenger and Vehicle Category	0,1,2...
Combinations	VEH-DRIV	Different Vehicle Driver Combinations	4-1,4-2...
	DRIV-VEH	Different Driver Vehicle Combinations	1-4,1-5...

Some of the observations collected did have some characteristic that was not considered during the study. These data items had the potential to skew the results. So they were removed from the collected data. The details of the removed data are included in Appendix V.

While analyzing the data collected, it was found that loading mechanism on vehicles was affecting the load times. There are two types of vehicle body construction, one with lever-operated door and electrical wheel chair lifts and other with sliding door and manual folding ramp. Table 4 shows the classification of available vehicles in Galavan into two sets.

Table 4 - Classification of available vehicles in Galavan into categories

Category No	Classification Characteristics	Included Vehicles
1	Electrical W. C lift, Lever Operated Door	U4, U5, U8
2	Manual Folding Ramp, Sliding Doors	U6, U7

More details about the categories are available in Appendix VI. A time study was conducted to verify the effect of loading mechanism on the predicted load times. Table 5 summarizes the result of analysis on the effect of category 1combination on load times of wheel chair passengers.

Table 5 - Average times on each step for wheel chair loading on Category 1

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	17.00
2	Open sliding door	5.33
3	Unfold Ramp	16.67
4	Move wheel chair to ramp	18.33

5	Load wheel chair into vehicle	35.67
6	Strap the wheel chair securely	124.00
7	Fold the ramp back	16.33
8	Close sliding door	4.33
9	Walk back and go	22.00
Grand Total =		259.66

Similarly Table 6 gives the summary of analysis of category 2 configuration on wheel chair passengers. The considerable difference in the load times on both configurations substantiates the claim.

Table 6 - Average times on each step for wheel chair loading on Category 2

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	6.333
2	Open sliding door	4.000
3	Unfold Ramp	4.667
4	Move wheel chair to ramp	30.333
5	Load wheel chair into vehicle	26.333
6	Strap the wheel chair securely	12.000
7	Fold the ramp back	4.333
8	Close sliding door	5.000
9	Walk back and go	9.000
Grand Total =		101.999

The details of the steps along with their start and end points are detailed in Appendix IV. Sample time study form for wheel chair load time dependency on vehicle configuration is included in Appendix III.

The summary of average load time for various category passengers on available vehicles are summarized in Table 7. The details of analysis with graphs, statistical calculations, box plots etc are included in Appendix IV for technical accuracy.

Table 7 - Summary of load times for passenger types and vehicles

Vehicle ID	Average Load Time For Elderly Person (Seconds)	Average Load Time For Wheel Chair (Seconds)	Average Load Time For Disabled (Seconds)	Average Load Time For Special Category (Seconds)
U4	78.6	Not Working	46.0	NA
U5	62.25	Not Working	72.67	112.0
U6	76.28	68.0	61.0	87.37
U7	84.08	59.5	91.25	93.0
U8	65.78	222.67	43.75	85.25
Group	73.695	159.10	66.14	93.0

After completing all these analysis,, the final multiple regression models were constructed to estimate load times. The factors for constructing multiple regression equation were assigned synonymical notations. . Table 8 summarizes these notations for easy reference with equation.

Table 8 - List of independent variables and their coefficients for Multiple Regression Equation

Sl. No	Variable Description	Notation	Symbol	Coefficients
1	No of Elderly Passengers	#EL	Y_1	α_1
2	No of Wheel Chair Passengers	#WC	Y_2	α_2
3	No of Disabled Passengers	#DB	Y_3	α_3
4	No of Other Category Passengers	#OT	Y_4	α_4
5	No of Special Category Passengers	#SP	Y_5	α_5
6	Vehicle Type	VEHCAT	Y_6	α_6
7	Driver	DRIVER	Y_7	α_7
8	Wheel Chair Passenger X Vehicle Type	WVEH	Y_{26}	α_{26}
9	Vehicle	VEH	Y_8	α_8

These variables were added one by one to form the multiple regression equation. The RSquare value of the model was constantly monitored while adding each new variable. This indicated how well the addition of the variable explained the variability in the system. A t-ratio test was conducted for each newly added variable to establish its significance. The step-by-step details of analysis are available in Appendix IV.

After removing all insignificant terms and other physically nonsense variables, the final multiple regression model was arrived with a good value for RSquare fit as given in Equation 1 for L_{est}, the estimated load lime

$$L_{est} = \alpha_0 + \alpha_1.Y_1 + \alpha_2.Y_2 + \alpha_3.Y_3 + \alpha_5.Y_5 + \alpha_{26}.Y_{26},$$

or

$$\mathbf{L_{est} = 17.65 + 59.88\ Y_1 + 289.65\ Y_2 + 43.99\ Y_3 + 62.92\ Y_5 - 106.89\ Y_{26}}$$

Equation 1 - Multiple Regression Equation for load time estimation

The R-Squared fit for the model was 0.6563. This means the model explained around 66% of the variability of the system. The terms in the model made sense too. As seen in the preliminary analysis the wheel chair loading took most time. All the load time coefficients are positive except the wheel chair vehicle interaction. This is because the vehicle coded as 1 are those with electrical wheel chair lift. They took more time to load compared to the vehicles coded as 2, which had the manual-folding ramp. So the negative coefficient was due to the convention used in coding.

The evaluation of t-ratio was conducted to find the modified significance of each parameters. The null and alternative hypothesis was stated as in Equation 2.

H_0: $\alpha_0 = 0; \alpha_1 = 0; \alpha_2 = 0; \alpha_3 = 0; \alpha_5 = 0; \alpha_{26} = 0$. (Insignificance).
H_1: $\alpha_0 \neq 0; \alpha_1 \neq 0; \alpha_2 \neq 0; \alpha_3 \neq 0; \alpha_5 \neq 0; \alpha_{26} \neq 0$. (Significance).

Equation 2 - Null and Alternate hypothesis for Load time estimation model

Table 9 gives the final t-ratio estimates for each of the variables in the final multiple regression model..

Table 9 - Details of t-statistics for each factor in the load time estimation model

Sl. No	Coefficients	Values	t-ratio	Prob > | t |	Conclusion
1	α_0	17.65	1.40	0.1663	Significant; Accept H_1
2	α_1	59.88	7.43	< 0.0001	Significant; Accept H_1
3	α_2	289.65	5.28	< 0.0001	Significant; Accept H_1
4	α_3	43.99	2.24	0.0277	Significant; Accept H_1
5	α_5	62.92	5.13	< 0.0001	Significant; Accept H_1
6	α_{26}	- 106.89	-2.41	0.0186	Significant; Accept H_1

The details of the statistical analysis, model plots, significance verification, residuals etc are included in Appendix IV. The final regression model for predicting passenger Load Times was stated with the mnemonic terms in Equation 3.

$$L_{est} = 17.65 + 59.88\ \#EL + 289.65\ \#WC + 43.99\ \#DB + 62.92\ \#SP - 106.89\ WCVEH$$

Equation 3 - Load Time Estimation Model

UNLOAD TIME MODEL

All passengers loaded into the vehicle should get unloaded at some specified destination. The factors considered for the unload time estimation model are summarized in Table 10. The fields marked with asterix (*) denote the factors appeared in final estimation model proposed.

Table 10 - List of parameters considered for Unload Time Estimation Model

Class	Variables	Description of variables	Values
Passenger Attributes	EL *	No of Elderly Passengers	0,1,2...
	WC *	No of Wheel Chair Passengers	0,1,2...
	DB *	No of Disabled Passengers	0,1,2...
	OT	No of Other Category Passengers	0,1,2...
	SP *	No of Special Category Passengers	0,1,2...
Driver Attributes	DRIVER *	Code of driver operating the vehicle	1,2,3,4
Vehicle Attributes	VEHCAT	Category upon Passenger Loading Mechanism	1,2

	VEHICLE	Vehicle Number associated with each one	4,5,6,7,8
Interactions	WVEH	W. C passenger and Vehicle Category	0,1,2...
Combinations	VEH-DRIV	Different Vehicle Driver Combinations	4-1,4-2...
	DRIV-VEH	Different Driver Vehicle Combinations	1-4,1-5...

The details of the simple regression analysis on these parameters, calculation of mean and other statistical parameters, box plot etc are included in Appendix VII.. The unload times were dependent on vehicle configuration too. Classification of the vehicles based on their load/unload mechanism is available in Table 4. Table 11 summarizes the average times for performing each step in category 1 configuration.

Table 11 - Average times on each step for wheel chair unloading on Category 1

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	8.33
2	Open sliding door	3.33
3	Unfold Ramp	19.00
4	Unstrap the wheel chair.	59.33
5	Unload wheel chair from vehicle	33.64
6	Move wheel chair to drop off	45.00
7	Fold the ramp back	20.33
8	Close sliding door	7.00
9	Walk back and go	25.33
	Grand Total =	221.29

Table 12 summarizes the average time taken to perform each step in category 2 configuration.. The details of the time study, data analysis and explanations for the observations are included in Appendix VII for further reference and clarification.

Table 12 - Average times on each step for wheel chair unloading on Category 2

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	5.667
2	Open sliding door	3.333
3	Unfold Ramp	4.333
4	Unstrap the wheel chair.	25.333
5	Unload wheel chair from vehicle	7.667
6	Move wheel chair to drop off	30.000
7	Fold the ramp back	5.667
8	Close sliding door	5.000
9	Walk back and go	16.000
	Grand Total =	103.000

Table 13 summarizes the unload times for each category of passengers on available vehicles. Details of statistical analysis are included in Appendix VII.

Table 13 - Summary of unload times for passenger types and vehicles

Veh. ID	Aver. Unload Time For Elderly Person (Seconds)	Aver. Unload Time For Wheel Chair (Seconds)	Aver. Unload Time For Disabled People (Seconds)	Aver. Unload Time For Special Category (Seconds)
U4	54.0	Not Working	42	NA
U5	45.8	Not Working	27.5	60.5
U6	50.46	96.5	109	62.5
U7	52.11	127.0	65	93.0
U8	33.71	131.67	23.67	30.75
Tot.	48.06	119.17	45.54	58.39

As in the case of load time analysis some data points were containing error values. Those data were removed to get a proper unload time estimation model. The details of the removed data is available in Appendix VIII.

After the completion of simple regression analysis, multiple regression models for unload time estimation was formulated. Iterating through the steps detailed in model construction methodology resulted in the final model. Table 14 summarizes the variable names and coefficient notation used for generating the equation.

Table 14 - List of independent variables and their coefficients for Multiple Regression Equation

Sl. No	Variable Description	Symbol	Coefficients
1	No of Elderly Passengers	Y_1	γ_1
2	No of Wheel Chair Passengers	Y_2	γ_2
3	No of Disabled Passengers	Y_3	γ_3
4	No of Other Category Passengers	Y_4	γ_4
5	No of Special Category Passengers	Y_5	γ_5
6	Vehicle Type	Y_6	γ_6
7	Driver	Y_7	γ_7
8	Wheel Chair Passenger X Vehicle Type	Y_{26}	γ_{26}
9	Vehicle	Y_8	γ_8

After removing the insignificant terms, final multiple regression model that predicted the unload times to a good extent was found.. Equation 4 defines the model for U_{est}, the estimated unload time.

The R-Squared value for the model was 0.5592. This mean the model explained around 56% of the variability in the system. Also the coefficients made physical sense. If the number of passengers in any category increase, the unload time increased. The magnitude of the

$$U_{est} = \gamma_0 + \gamma_1.Y_1 + \gamma_2.Y_2 + \gamma_3.Y_3 + \gamma_5.Y_5 + \gamma_7.Y_7,$$

or,

$$\mathbf{U_{est} = 2.9 + 26.01\ Y_1 + 86.20\ Y_2 + 18.92\ Y_3 + 24.74\ Y_5 + 8.49\ Y_7}$$

Equation 4 - Multiple Regression Equation for unload time estimation

coefficients showed that the maximum increase in unload times were in the case of wheel chair passengers, followed by elderly, special and then disabled. This was in conjunction with the values obtained in preliminary analysis. The drivers were coded based on their experience; lowest value for most experienced driver and highest value for the least experienced one. This explained the positive coefficient for the term in the model.

Evaluations of t-ratio were conducted to find the significance of each parameter. The null and alternative hypothesis was stated as in **Equation 5**.

$$H_0: \gamma_0 = 0; \gamma_1 = 0; \gamma_2 = 0; \gamma_3 = 0; \gamma_5 = 0; \gamma_7 = 0. \text{ (Insignificance).}$$
$$H_1: \gamma_0 \neq 0; \gamma_1 \neq 0; \gamma_2 \neq 0; \gamma_3 \neq 0; \gamma_5 \neq 0; \gamma_7 \neq 0. \text{ (Significance).}$$

Equation 5 - Null and Alternate hypothesis for Unload time estimation model

Table 15 summarizes the results of t ratio test.

Table 15 - Details of t-statistics for each factor in the unload time estimation model

Sl. No	Coefficients	Values	t-ratio	Prob > | t |	Conclusion
1	γ_0	2.9	0.28	0.7811	Insignificant; Accept H_0
2	γ_1	26.01	6.51	< 0.0001	Significant; Accept H_1
3	γ_2	86.20	8.83	< 0.0001	Significant; Accept H_1
4	γ_3	18.92	2.24	0.0277	Significant; Accept H_1
5	γ_5	24.74	3.85	0.0002	Significant; Accept H_1
6	γ_7	8.49	2.97	0.004	Significant; Accept H_1

The step-by-step details of model generation procedure are included in Appendix VII. The final regression model for predicting passenger unload times were stated in mnemonic terms as in Equation 6 for U_{est}, the estimated unloading time.

$$\mathbf{U_{est} = 2.9 + 26.01 \#EL + 86.20 \#WC + 18.92 \#DB + 24.74 \#SP + 8.49\ DRIV}$$

Equation 6 - Unload Time Estimation Model

TRAVEL TIME MODEL

As a general notion the travel times usually depend on the distance traveled. This is because of the relation Time = (Distance / Speed). But there are other factors that could affect the travel time. Table 16 summarizes the initial set of factors considered after discussing with driving crew. Fields with an asterix (*) denotes the ones that were kept in the final model.

Table 16 - List of parameters considered for Travel Time Estimation Model

Class	Variables	Description of variables	Values
Driver Attributes	DRIV	Code of driver operating the vehicle	1,2,3,4
Vehicle Attributes	VEH	Vehicle Number associated with each one	4,5,6,7,8
	CAP	Timeliness: Ahead to behind the schedule	1,2,3
Road Attributes	DIST *	Distance between consecutive stops	0…n
	TRAF *	Traffic on the road segment at the instance	1,2,3,4,5
	COND *	Road Condition: Poor to Excellent	1,2,3,4,5
General Attributes	WEAT	Weather at the particular time	1,2,3
	TOD	Time of Day	Not Coded
	TOY	Time of Year	Not Coded
Interactions	DISTRAF *	Interaction of Distance and Traffic	0,0.1,0.2…
	TRAFCOND	Interaction of Traffic and Road Condition	0,0.5,1.0…
	DISTCOND	Interaction of Distance and Road Condition	0,0.1,0.2…
	DSTRCD	Distance, Traffic and Condition interaction	0,0.1,0.2…

The details about coding of all these variables are available in Appendix IX for further reference. The variables that appear with out a code were not studied during the time study phase.

Simple regression was performed on all independent variables to ascertain their significance. The statistical analysis details like mean, median and plots like scatter plot, box plot etc are included in Appendix IX for technical reference and accuracy. After completing the simple regression analysis, multiple regression models were constructed by following the steps in model construction methodology..

The data collected for travel time estimation modeling did have some outliers. They were a set of observations that captured some features that were not studied. Those observations were removed from the analysis for getting an unbiased estimation model. The details of the removed observations are included in Appendix X.

Table 17 summarizes the variable names and coefficients assigned to them. These variables were added one by one into the equation monitoring the changes and impacts made on other factors.

Table 17 - List of independent variables and their coefficients for Multiple Regression Equation

Sl. No	Variable Description	Symbol	Coefficients
1	Distance	X_1	β_1
2	Traffic	X_2	β_2
3	Distance-Traffic Interaction	X_{12}	β_{12}
4	Capacity	X_3	β_3
5	Condition	X_4	β_4
6	Traffic-Condition Interaction	X_{24}	β_{24}
7	Distance-Condition Interaction	X_{14}	β_{14}
8	Distance-Traffic-Condition Interaction	X_{124}	β_{124}

Iterating through the steps, the final multiple regression model for travel time estimation was obtained, as shown in Equation 7 for T_{est} , the estimated travel time. The finer details of the analysis are available in Appendix IX.

$$\mathbf{T_{est} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_{12} + \beta_4 X_4,}$$

or,

$$\mathbf{T_{est} = 95.52 + 68.65 X_1 + 31.67 X_2 + 22.39 X_{12} - 58.07 X_4;}$$

Equation 7 - Multiple Regression Equation for Travel Time estimation

The evaluation of t-ratio was conducted to find the significance of the involved parameters. The null and alternative hypothesis was stated as in Equation 8.

H_0: $\beta_0 = 0$; $\beta_1 = 0$; $\beta_2 = 0$; $\beta_{12} = 0$; $\beta_4 = 0$. (Insignificance).
H_1: $\beta_0 \neq 0$; $\beta_1 \neq 0$; $\beta_2 \neq 0$; $\beta_{12} \neq 0$; $\beta_4 \neq 0$. (Significance).

Equation 8 - Null and Alternate hypothesis for Travel time estimation model

The final t-ratio estimates for each of the variables involved in the multiple regression equation for travel time estimation is summarized in Table 18.

Table 18 - Details of t-statistics for each factor in the travel time estimation model

Sl. No	Coefficients	Values	t-ratio	Prob > | t |	Conclusion
1	β_0	95.52	1.40	0.1669	Significant; Accept H_1
2	β_1	68.65	2.37	0.0214	Significant; Accept H_1
3	β_2	31.67	1.50	0.1391	Significant; Accept H_1
4	β_{12}	22.39	2.05	0.0451	Significant; Accept H_1
5	β_4	-58.07	-3.45	0.0010	Significant; Accept H_1

The R-Squared value for the model was 0.7125. This means that the model explained about 71.25% of variability in travel times. This was taken as a good estimate considering the amount of data and the real life complexities. The equation became more readable when the corresponding variables are substituted by their mnemonic representation. The final representation of the travel time estimation model based on multiple regression is given in

$$\mathbf{T_{est} = 95.52 + 68.65\ DIST + 31.67\ TRAF + 22.39\ DISTRAF - 58.07\ COND;}$$

Equation 9 – Final Travel Time Estimation Model

Equation 9.

MODEL VALIDATION

The final result of the time study conducted was a set of multiple regression models that predicted the Load, Unload and Travel times. These models were a set of equations containing the significant independent and interaction terms that affected the operational times. After having a working model for each activity the next major step in modeling was to validate the model. Validation of the model answers whether the output measured by the model match up with the system in reality.

To validate the model there is a methodology. In this case where the multiple regression models were used, verification analysis were done on freshly collected data. The data collection procedure for the verification analysis was the same as in the case of initial time study. Two days where chosen to do the time study, a busy day (Tuesday) and a slow day (Wednesday). The verification data collection did capture all the information that was used in building the model. Vehicles and drivers were randomly chosen to obtain the data. Vehicles in both categories (electrical wheel chair lift and manual folding ramp) were used for the data collection.

The model was validated on the freshly collected data with the help of statistical packages like Excel and Jumpin. The error plot and the other details of the analysis are included in Appendix XI.

To verify how good the developed model fits with the freshly collected data, R^2 for the model with the new data was calculated. R^2 gave how much of the variabilitywas explained by the model. The governing equation of R^2 is given in Equation 10 as per (Spiegel, 1975), (Johnson, 2000).

$$\mathbf{R^2 = (\Sigma\ (Y_{est} - \tilde{Y})^2) / (\Sigma\ (Y - \tilde{Y})^2);}$$

Where:

R^2 is Explained variation / Total variation,
Y_{est} is the predicted travel time,
$\tilde{Y}$ is the mean of the actual sample, and
Y is the observed times from time study

Equation 10 - Estimation of R^2

The details of the statistical analysis are included in the Appendix XI as a technical reference. The final time study verification results are summarized in Table 19.

Table 19 - Comparison of Validation and Estimation Model R^2

Sl. No	Event Type	Model Validation - R^2	Developed Model - R^2
1	Load Times	0.77124	0.6563
2	Unload Times	0.41370	0.5592
3	Travel Times	0.81093	0.7125

From the table the following were concluded.

- The model fits much better in the case of Load times and Travel times. The R^2 fit for the proposed models were lower when compared to the new R^2.
- The new R^2 in the case of Unload times was worse compared to the old value of R^2.
- The model for Unload times might need further detailed study to nail down the reasons for the current behavior.
- The factors that were considered in building the initial model are significant enough in the daily operation of the transit system.
- The unexplained variation might be due to the factors that were not obtainable like the weather, time of year etc.

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APPENDIX – I

GALAVAN PROCESS STUDY DOCUMENTATION

GALAVAN – AN OVERVIEW

Galavan is a transportation facility for elderly, disabled and low-income category citizens in Bozeman. This is a non-profit organization, which mainly depends on the Federal Government grants for meeting its operational costs. The funding is provided by HRDC (Human resource Development Center) at Bozeman. The vehicles are purchased on an 80-20 basis, where 80% of the fund is provided by HRDC and 20% has to be amassed by Galavan. There does a director board exist and functional which is instrumental in the policy making of Galavan. The riders are not charged with any fare for their rides, but usually the passengers provide a donation or something to help in raising some funds. The following definitions are used to define the spectrum of people to whom the service is meant for.

Elderly: People who are currently 60 years or older are considered to be in the elderly category. They are also called as senior citizens as a synonym to the elderly term.

Disabled: A person with any physical limitations that inhibit him/her from doing all tasks a normal person would do or needs a special device to accomplish the normal person's task will come under this category. Here age is not a limit. It can be a child of 5 years old as well as a person of 80 years old.

Low-Income Category: Persons who cannot afford a conventional method of ride from one place to another due to their financial constraints (e.g. from home to work place) falls in this category.

The following are the main highlights of Galavan Service.

- The service is essentially from door-to-door facility.
- The operational period is from 8.00 am in the morning to 5.00 pm in the evening.
- There are no rides scheduled at noon. This way 11.30 is the last pickup for morning slot. Similarly 1.00 pm is the first pickup for the evening slot. The last pickup for the evening slot (or of the day) is at 4.30 pm.
- Operates on Saturdays and Sundays. But the rides should be notified by at the end of that week's Friday (before 4.00 pm).
- The drivers will assist a person if needed from front door and back.
- There is a necessity for 24 hours advanced notice to schedule a ride. This assumes that all phone calls on or before 4.00 pm the previous days will be assured of a ride.
- Galavan does not attend to emergencies that need medical attentions like Ambulance or other special vehicles.
- There is a 30-minute window for pick up and drop off. If the ride is scheduled for 9.00 am then the pick up can be any time between 8.45 am to 9.15 am. The person will be dropped at the destination before the appointment (as early as possible). There were some very few exceptions at certain circumstances by getting little late.
- The people are permitted to use the option of Will Call (W/C) for the ride back when they are done with their appointment. This call will initiate a vehicle being sent to pick them up from the place where they are supposed to be.

Unless specified Galavan assumes that the pick up location for the return trip is the same as the drop off point. If the passenger has moved to another location, it is their duty to inform the dispatcher about their relocation.

GALAVAN – ACTIVITIES

The operational process of Galavan is a harmony between the drivers and the dispatcher at the office. The dispatcher assigns rides to the vehicles and drivers to the vehicles, but the drivers select the routes and order of pickups according to their instincts and experience. Any changes in between in notified to the drivers by the dispatcher (office staff) by the help of a two-way radio. The following are the list of major activities accomplished by the Galavan Crew. The description associated with each activity explains what is being done in short.

1. Open the office – Usually the manager (Mr. Steve) does this.
2. Switch on the Computer and Printer
3. Check for any messages in the answering machine – here the messages that came in the night are checked. Usually there are some cancellation messages. They are noted down. Some people ask for a ride, which was supposed to be done by 4.30 pm the previous day. But as far as possible these requests are accommodated.
4. Note down the messages.
5. Update the list of rides entered in the previous day with the cancellations and new rides.
6. Print out the manifest for the day. – This consists of the name of the person, from address, destination address, time, whether elderly, disabled etc. are contained in this manifest.
7. Dispatching - Here the manager decides whom all (passengers) are to be picked up by which all vehicles. This is usually done by hand. The criterion for doing this job is experience as well as knowledge of locality. Then the drivers are assigned with a vehicle (here also the personal knowledge about the driver comes ahead of all for the assignment).
8. Driver Briefing – The drivers are briefed about their routes as well as passengers. Each driver gets a copy of the manifest in which he/she highlights his or her rides alone with a different color.
9. Distribution of keys – The drivers are handed out with the keys of their assigned vehicles. Then the drivers get the vehicles going according to the best way they feel so that they could get all passengers to their appointments before the scheduled time.
10. Attending Phone Calls – This activity occurs whole through out the day. The phone rings and the person currently sitting in the office attend the phone. The calls can be of the following types:
    a. A Will Call – person who is dropped at a particular place for an appointment is calling back to let the office know that he/she is done and ready to travel back. This information is passed on to the driver who is assigned to pick up that passenger from the office (base).
    b. Schedule a Ride – these are the calls for scheduling a ride the next day. They are usually written down in a piece of paper in the order – Name, From Address, Destination Address, Time of Pickup, expected time for Pick up for the ride back.

   c. Cancellations – these calls inform the office that they are calling to cancel a ride for the current day or the next day that is already scheduled.

11. Check Messages – Many people keeps their message in the answering machine. This occurs when two calls come simultaneously. So the person in the office has to check the answering machine frequently for all the three types of call stated in item 10.
12. Calling Customers in Case of Unclear Message – Since the old aged people forget some times to specify the time of their ride or some other essential details. This will result in initiating a call to that person for conforming and clarifying their ride.
13. Count Rides – The counting process is to determine how many elderly people took ride the previous day and who all are they. This is the part of a cumulative job that ends up in generating a monthly report for the Department of public health and human services showing all these details. This process happens between the phone calls.
14. Communicating with Drivers – This is also an ongoing process, in which the person at the office (base) contacts the driver out there to inform any changes to schedule, any cancellations, any additions etc. The base is also responsible for getting the spare vehicle to the point if any of the vehicles running gets broken down.
15. Entering Rides for the Next Day – It occurs to the end of the day, usually after 4.30 pm when almost all calls have arrived. The person at the office will sit in front of the computer to enter the rides into the current available software. This is used to schedule the rides for the next day.
16. Filling out the Vehicle Inspection Form – The drivers when they complete a day's work has to inspect the vehicles for any malfunctions, odometer reading etc. These details are written down in a specified form and turned in at the end of the day.

OCCASIONAL ACTIVITIES

The above stated are the activities that happen in Galavan on an every day basis. There are some specific activities that happen only on specific days. They are as follows.

- Preparation of Time Sheets – This is done on the first working day after15th of a month as well as the end of the month. They are to be written down in the specified form and to be turned in the same day before 5 o'clock to the HRDC (Human Resource Development Center, Bozeman) office.
- Claim Forms – Galavan does not pay its bills directly. The manager has to fill in a form called Claim Form and submit the original bill along with this to HRDC, from where the service providers get paid. This has to be done on every Tuesday before 5 o'clock (if there are any bills).
- Counting of Donations – Every Thursday evening the donation box kept in each vehicle is opened and counted. Then the collections are noted down in a separate form and kept in the safe for deposit on the next day.
- Deposit of the Donations – Every Friday the donations counted on the previous Thursday is deposited in the HRDC office in Bozeman.
- Quarterly Report for Montana DOT – This report is to be submitted to Montana Department of Transportation regarding the total number of rides, vehicle mileage, elderly rides, disabled rides and others.
- Presentations for Board Meetings – This occurs at least once in every month. This consists of preparing a report about the revenue, number of rides, major locations to

which transportation is done etc. Since there is no computer facility available the preparation of such reports will take some time (on an average 2 days per report).

- Vehicle Maintenance – The normal service required for a vehicle is done after every 3000 miles. This also consists of generating a claim form, submitting to HRDC and then the service provider gets paid.
- Special Presentations – This happens two to three times in a year. These special presentations can be for a federal agency, promoters etc. This usually requires some preparations of documents. Totally he spends a total time of 5-6 working days in a year doing these presentations.

GALAVAN – PROCESS STUDY

There are two important processes going on in Galavan to accomplish their basic responsibilities. They are Dispatching and Routing. These terms are used by the people of Galavan in a different meaning compared to the normal IE context. The "dispatching" in Galavan means the assigning of rides to buses and then buses to drivers. Similarly "routing" means the selection of routes to pick up and drop off people by the drivers in Galavan. Since it is necessary from the IE stand point to study in detail the associated process happening in a system, a detailed study of these processes were done.

The initial process to be studied was the "Dispatching". To do this the aim of the study was described in detail to Mr. Steve Potuzack, who is the manager and dispatcher at Galavan. Then a time and date was fixed. The aim of the study was not only to observe what are the activities, but also to find out what are the criteria taken into account by the person who does the dispatching. The following section summarizes how the necessary details were obtained.

This is the summary of thoughts that were noted down on 06/18/2002 by observing the "dispatching" process being done by Steve. The detailed description of the dispatching process is done with the help of process charts. The process charts are included at the end of this summary. The Gantt Bar Chart depicting the daily activities of the dispatcher on a time scale is included after the process charts in this section. Here Steve assigns passengers to different buses based on his experience, intuitions and knowledge. To obtain the procedure Steve follows in doing the 'dispatching', he promised to think loud as he is doing the process. The person who took the notes just listened to these stated loud thoughts as well as observed his actions to formulate this document. This would help to analyze the parameters he considers in assigning the passengers to different buses.

This observation was carried out on Tuesday, the day when 4 buses are in service. This is a day when Galavan does the Belgrade trip. The following summarizes the conditions that day.

No of Rides to be assigned: 136
No of Buses in Operation: 4
Details of Buses:
    U4 – Big Ford Bus, 12 seated, but the lift for wheel chair is not working.
    U6 – Dodge Grand Caravan, 6 seated, fully operational.
    U7 – Dodge Grand Caravan, 6 seated, fully operational.

U8 – Chevrolet Big Bus, 16 seated, fully operational, dedicated to Belgrade trips on Tuesdays.
Time at which the 'dispatching' started: 6.47 am.
Time at which the 'dispatching' finished: 7.37 am.

DISPATCHING CRITERIA

The following are the important points that were noted down during the observation of the process.

- Since U8 goes to Belgrade, all Belgrade rides are assigned to it initially. When this is done the left out rides are only in Bozeman.
- Since U4 does not have an operational wheel chair lift, no passenger on wheel chair is assigned to that bus.
- Also he decides to keep U4 as a stress reliever for U7 and U8 at busy times.
- Also he decides to assign unique and difficult pickups that are not in a wheel chair to U4.
- U6 and U7 are supposed to pick up majority of the rides.
- Decides that U6 should do the Hospital Appointments (majority of them)
- Decides that U7 should do the others (Western Portion of the town).
- Looks at the destination addresses and assign the Hospital Appointments to U6.
- Reviews the assigned ones to see any Origin (from) address is largely deviated from the others (Grouped ones). If so they are considered as Unique. If these unique addresses are not on a wheel chair, U4 is assigned to pick it up. If it is on a wheel chair, U6 has to pick it up, then some of the people in the grouped ones that are not on a wheel chair gets assigned to U4.
- Looks up at the Appointment Times to find out any clashes. If noted he assigns the clashing one to U4. If the clashing one is on a wheel chair, it is assigned to U6 and some other ride that is not on a wheel chair is assigned to U4 to take pressure off from U6.
- Similarly considers people living together for U7 that will make the pickup easy.
- Considers people traveling together for U7 so the Drop off will be easy.
- As the assignment progresses, he checks back to see that U7 is not assigned to pickup more people than its capacity.
- When he feels the U7 is closing in capacity, he brings in U4 to pick up the people that are not in a wheel chair.
- Checks to see whether there is any time clashes for pick up and drop off for U7 as it is running across the town pretty much.
- If any such clashes are noted they are assigned to U4 unless it is not on a wheel chair. If it is on a wheel chair, then U7 is asked to pick it up and U4 is assigned some of the previous assigned rides of U7 to relieve the pressure from U7.
- If U7 picks up a wheel chair ride the passenger capacity reduces by 4. So when a wheel chair is assigned to U7, a check is done to ensure that not more than 4 people are riding at that time.
- Other than medical appointments, others are not given much importance for dropping early at the destination.

- If there are any data entering mistakes committed yesterday that are noted during this assigning process, they are corrected. But after the correction, it is necessary to exit to the main menu to get the data refreshed. This breaks his line of thoughts and sometimes has to go few steps back to continue what he was doing.
- Any interruption by phone calls also diverts attention (this happened 3 times during the process) hence more time is necessary to coupe up the thoughts, thus taking more time.
- There is a situation that Steve has an appointment at 4.00 pm. So the office will be deserted after that. To avoid this he plans to bring Richard into the office. For that he make sure that U7 (driven by Richard) finishes its ride by 4.00 pm and Richard will be free, so that he can be in office.

During this assigning process if any doubts regarding the pick up or drop off occurs he refers to the piece of papers where the rides are entered. This also results in diversions, which forces him to spend more time on the process.

The next process to be studied in Galavan was the "Routing" process. For this study the most experienced driver of Galavan Mr. Richard volunteered to help. He was briefed with the aim of the study and agreed on times for doing the study. Upon conducting a pilot study for the driver activities, it was evident that the major tasks are loading, unloading, vehicle inspection and driving around.

This section summarizes what are the factors the drivers take into account to decide how and when to pick up his assigned passengers and how and when to drop them off at various destinations. This has been documented with the help of Mr. Richard, with whom the observer traveled around. He also helped by 'thinking out loud' so that the salient points could be noted down.

- Usually Medical Appointments are given the highest priority. If there is any medical appointment to be done, then the immediate goal is to get the passengers there before the appointed time.
- If there were no medical appointments, the farthest one would be the first pickup.
- If the farthest rider is at other end of town and the rest of riders (at least some of them) are traveling to that direction, then those people who travel to that direction is picked up first, dropped off on the way to pick up the farthest rider.
- Always tries to find out any riders living together so that they could be picked up in a single phase.
- Uses the personal information of passengers (like the people who are ready usually early) to decide the pickups.
- Some riders don't like to be picked up before the 30-minute window. Those riders are picked up only in that window; meanwhile the people who are ready to ride around for some time are picked up accordingly to keep up time.
- If there is a wheel chair pick up there is a constraint on the number of passengers that could be ride along. So if there is a wheel chair pickup the driver sees to it that he is not going to pick up more people that he can carry along. So some are dropped off at destinations to make room.
- From his experience the driver knows that which routes are busy at what point of time in a day. So if there is a pickup coming in that portion, he tries to use other parallel roads. In

the mean time if there are some people living in that parallel roads and there is availability of seat they are picked up.

- In most occasions he waits for the will call unless the conformation form base is obtained that the person is ready for pickup. But he knows in some cases that could be ready in a span of time. So if he happens to reach there in middle of a trip, he just stops to see whether he can pick them up.
- When he has a wheel chair, then he uses "Good Roads" to make the ride safer. So that might deviate from a normal route. So pickups may also vary.
- Tries to avoid the distance traveled as much as possible, thus expecting to minimize time lost in travel to keep up to the scheduled times.
- If there is any passenger who is assigned for the other driver, which is living close to some of his pickups or drop offs are found, the driver communicates with other bus and offers to pick that rider. This is done between the drivers to help them to keep up time.
- Similarly if any of his assigned passengers are offered to be picked up by other drivers, he removes them from his "route" and tries to pickup the remaining ones efficiently.

PROCESS CHARTS

Process charts are powerful Industrial Engineering tools that could be used to study, document and analyze any process. The type of process chart used for documentation was a flow process chart. The flow process chart depicts the operation in step-by-step maintaining the continuity between activities. The flow process chart has five symbols. They are given in Figure 1.

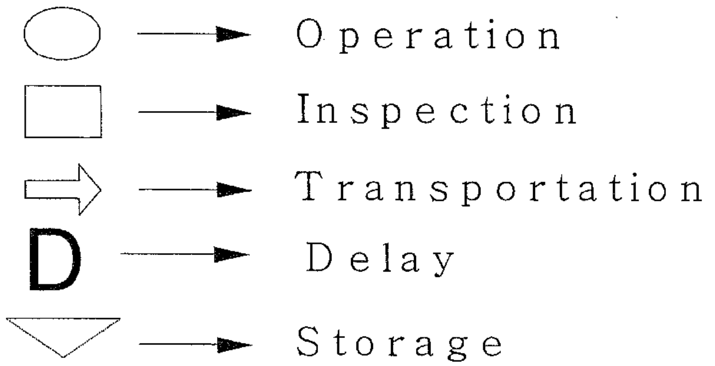


Figure 1 - Flow Process Chart Symbols

The following pages depict the process charts for each activity in Galavan.

Flow Process Chart

Operation: Unloading a passenger who is on a wheel chair from Big buses (U4 & U8)
Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ______ Present X
Material ______ Proposed ______
Sheet # 1 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Put the vehicle into parking gear	● ⇨ ☐ D ▽			
2	Pick up the writing pad with manifest from dashboard tray	● ⇨ ☐ D ▽			
3	Pick up the pencil from pocket	● ⇨ ☐ D ▽			
4	Write down the arrival time at the destination	● ⇨ ☐ D ▽			
5	Keep the writing pad back in dash board tray	○ [✓ ⇨] ☐ D ▽			
6	Keep the pencil back in pocket	○ [✓ ⇨] ☐ D ▽			
7	Unbuckle the seat belt	● ⇨ ☐ D ▽			
8	Open the passenger side door of the bus.	● ⇨ ☐ D ▽			
9	Bent down to engage the emergency brake.	● ⇨ ☐ D ▽			
10	Reach up the overhead switch board for hazard light switch and wheel chair switch	● ⇨ ☐ D ▽			
11	Open the driver side door.	● ⇨ ☐ D ▽			
12	Disembark from the bus.	● ⇨ ☐ D ▽			
13	Move to the passenger side door of the bus.	○ [✓ ⇨] ☐ D ▽			
14	Grip the handle of the elevator door of the bus.	● ⇨ ☐ D ▽			
15	Pull it down to open the door.	● ⇨ ☐ D ▽			
16	Swing open the door panel fully to your right	● ⇨ ☐ D ▽			
17	Grab the left pane of the door.	● ⇨ ☐ D ▽			
18	open it fully to the left side	● ⇨ ☐ D ▽			
19	Grab the electrical control panel for wheel chair	● ⇨ ☐ D ▽			
20	Press unfold switch till the lift unfolds totally to load	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger on a wheel chair from Big buses (U4 & U8)

Date 06/20/2002

Operator Richard

Charted by Deepu

Operator ______ Present X

Material ______ Proposed ______

Sheet # 2 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Move to the passenger side door of the bus	○ ➡ ☐ D ▽			
2	Get into the bus through that door.	● ⇨ ☐ D ▽			
3	Remove the strap that holds the wheel chair from front	● ⇨ ☐ D ▽			
4	Move to the back of the wheel chair	○ ➡ ☐ D ▽			
5	Remove the left hook that holds wheel chair's frontal moti	● ⇨ ☐ D ▽			
6	Remove the right hook that prevents the sideward motion.	● ⇨ ☐ D ▽			
7	unbuckle the seat belt from the belt buckle.	● ⇨ ☐ D ▽			
8	Press the red switch to retrace all extended straps.	● ⇨ ☐ D ▽			
9	Remove the left clamping device from the groove on floor	● ⇨ ☐ D ▽			
10	Move to the box under the back seat of the bus.	○ ➡ ☐ D ▽			
11	Keep the clamping device in the box.	○ ⇨ ☐ D ▼			
12	Move back to the wheel chair's second clamp.	○ ➡ ☐ D ▽			
13	Remove the clamp from groove	● ⇨ ☐ D ▽			
14	Move to the box to put it in the box.	○ ➡ ☐ D ▽			
15	Move to the back of the wheel chair	○ ➡ ☐ D ▽			
16	Unlock the wheel brakes on wheel chair	● ⇨ ☐ D ▽			
17	Push the wheel chair back wards and maneuver into lift	● ⇨ ☐ D ▽			
18	Exit out of the vehicle through passenger door.	○ ➡ ☐ D ▽			
19	Go to the control panel on right pane of the lift's door	○ ➡ ☐ D ▽			
20	Press the down button till the step flap folds in.	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: unloading a passenger in a wheel chair from Big buses (U4 + U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ________
Material ________

Present X
Proposed ____

Sheet # 3 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Hold the wheel chair handle by the free hand.	● ⇨ ☐ D ▽			
2	Press the down button again till the lift reaches ground.	● ⇨ ☐ D ▽			
3	check whether it is Safely grounded.	○ ⇨ ■ D ▽			
4	press down switch to unfold exit flap.	● ⇨ ☐ D ▽			
5	Pull the wheel chair out of ramp.	● ⇨ ☐ D ▽			
6	Transport the passenger to the destination's front door.	○ ➡ ☐ D ▽			
7	Let the passenger in Safely	● ⇨ ☐ D ▽			
8	come back to the lift control panel	○ ➡ ☐ D ▽			
9	Press the 'up' switch till it reaches its maximum up position	● ⇨ ☐ D ▽			
10	Press the 'fold' switch until it folds all way in	● ⇨ ☐ D ▽			
11	Grab the left pane and close it shut.	● ⇨ ☐ D ▽			
12	Grab the right pane and close it shut.	● ⇨ ☐ D ▽			
13	lock the lift door by pushing the handle up.	● ⇨ ☐ D ▽			
14	Move to the driver side of the vehicle	○ ➡ ☐ D ▽			
15	Get into the driver seat	● ⇨ ☐ D ▽			
16	close the passenger side door	● ⇨ ☐ D ▽			
17	close the driver side door	● ⇨ ☐ D ▽			
18	release the emergency brake lever	● ⇨ ☐ D ▽			
19	Switch off the hazard light and wheelchair lift switch.	● ⇨ ☐ D ▽			
20	Pick up the manifest from the dash board tray	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: unloading a passenger on a wheel chair from Big buses (U4 & U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______

Present X
Proposed ______

Sheet # 4 of 4

Operation	Symbol	Dist.	Time	Notes
1 Pick up the pencil from pocket	● ⇨ ☐ D ▽			
2 Note down the departure time from destination	● ⇨ ☐ D ▽			
3 Put the pencil back to the Pocket	○ ➡ ☐ D ▽			
4 Put the manifest back to dash board tray	○ ➡ ☐ D ▽			
5 Put the seat belt and buckle it up.	● ⇨ ☐ D ▽			
6 Engage the vehicle into drive gear	● ⇨ ☐ D ▽			
7 Press the gas pedal.	● ⇨ ☐ D ▽			
8	○ ⇨ ☐ D ▽			
9	○ ⇨ ☐ D ▽			
10	○ ⇨ ☐ D ▽			
11	○ ⇨ ☐ D ▽			
12	○ ⇨ ☐ D ▽			
13	○ ⇨ ☐ D ▽			
14	○ ⇨ ☐ D ▽			
15	○ ⇨ ☐ D ▽			
16	○ ⇨ ☐ D ▽			
17	○ ⇨ ☐ D ▽			
18	○ ⇨ ☐ D ▽			
19	○ ⇨ ☐ D ▽			
20	○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: loading a passenger who is on a wheel chair onto Big buses (U4 + U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ____
Material ____
Present X
Proposed ____

Sheet # 1 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Put the Vehicle into parking brake.	● ⇨ ☐ D ▽			
2	pick up the manifest and writing from dash board tray	● ⇨ ☐ D ▽			
3	Pick up pencil from the pocket	● ⇨ ☐ D ▽			
4	Note down the arrival time at pick up location	● ⇨ ☐ D ▽			
5	Keep the writing pad back onto the dash board tray	○ ➡ ☐ D ▽			
6	keep the pencil back into pocket	○ ➡ ☐ D ▽			
7	Bend down close to driver side door to operate emergency brake.	● ⇨ ☐ D ▽			* with out emergency brake the wheel chair lift won't work
8	Reach up the overhead switch panel to put on hazard and wheel chair switches	● ⇨ ☐ D ▽			
9	open the driver side door and passenger side door by handle.	● ⇨ ☐ D ▽			(opening of passenger door has 3 steps which are not detailed)
10	Disembark from the vehicle. after removing seat belt	● ⇨ ☐ D ▽			
11	Go to the co-driver side of bus.	○ ➡ ☐ D ▽			
12	Grip the handle that locks the door on wheel chair lift	● ⇨ ☐ D ▽			
13	pull the lever down all way to unlock door	● ⇨ ☐ D ▽			
14	Swing open the door portion with handle all way out	● ⇨ ☐ D ▽			
15	Grab the side of the other portion of door.	● ⇨ ☐ D ▽			
16	Swing open the second portion also (lift portion)	● ⇨ ☐ D ▽			
17	Grab the electrical control panel for wheel chair	● ⇨ ☐ D ▽			
18	press the 'unfold' switch till the lift unfolds out totally	● ⇨ ☐ D ▽			
19	Press the 'down' switch till rests totally on ground.	● ⇨ ☐ D ▽			
20	Move to the back of the passenger's wheel chair	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: loading a passenger who is on a wheel chair onto Big buses (U4 U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

Operator _______
Material _______

Present X
Proposed _____

Sheet # 2 of 4

Operation	Symbol	Dist.	Time	Notes
1 Grab the handle bars at the back of wheel chair	● ⇨ ☐ D ▽			
2 push the wheel chair safely into the lift.	● ⇨ ☐ D ▽			
3 Move to the control panel for elevator.	○ ➡ ☐ D ▽			
4 Press the 'up' switch to lift the back stop for wheels.	● ⇨ ☐ D ▽			
5 Hold the wheel chair to prevent shakes As the lift moves up.	● ⇨ ☐ D ▽			
6 Press up switch till the elevator moves all way up	● ⇨ ☐ D ▽			
7 Ensure that the connecting ramp of elevator is safely on busbody	○ ⇨ ■ D ▽			
8 Get into the bus through the passenger side door	○ ➡ ☐ D ▽			
9 Manevor the wheel chair from lift to the locking locations.	○ ➡ ☐ D ▽			
10 Engage the wheel brakes on the passenger's wheel chair	● ⇨ ☐ D ▽			
11 Go to the back side seat below which removable stoppers are kept	○ ➡ ☐ D ▽			
12 Get the wheel chair holders from the box.	● ⇨ ☐ D ▽			
13 Move to the wheel chair	○ ➡ ☐ D ▽			
14 Secure the clamp locks to the grooves into the bus floor	● ⇨ ☐ D ▽			/The locker is placed behi wheels to prevent backward motion/
15 Pull the hook with strap to grip the body of wheel chair	● ⇨ ☐ D ▽			/The straps prevent forward motion/
16 Press the red button to tighten the gripping straps.	● ⇨ ☐ D ▽			
17 Extent the second strap and hook to another location on w/c	● ⇨ ☐ D ▽			
18 Press the red button again to tighten it.	● ⇨ ☐ D ▽			
19 Extent the seat belt lock attached to the holder.	● ⇨ ☐ D ▽			
20 Pull the seat belt attached to the side body of bus.	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: loading a passenger who is on a wheel chair onto Big buses (U4 + U8)

Date 06/20/2002

Operator Richard

Charted by Deepa

Operator ________

Material ________

Present X

Proposed ______

Sheet # 3 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Strap the belt safely around the passenger and lock it	● ⇨ ☐ D ▽			/ In some cases two clamps are used /
2	Ensure the strap is in correct place around body	○ ⇨ ■ D ▽			
3	Tighten the extended strap by turning a knob on holder	● ⇨ ☐ D ▽			/ Reduces the slack in extended seat belt
4	Move to the front of the passenger	● ⇨ ☐ D ▽			buckle's lock /
5	Pick up the front grip strap attached permanently to bus floor	● ⇨ ☐ D ▽			
6	latch it to the body of wheel chair to prevent rolling back.	● ⇨ ☐ D ▽			
7	Tighten the slack by turning the knob on the extender	● ⇨ ☐ D ▽			
8	check again to all things are secured	○ ⇨ ■ D ▽			
9	Disembark from vehicle through the passenger door	● ⇨ ☐ D ▽			
10	Move to the wheel chair's electrical control panel.	○ ➡ ☐ D ▽			
11	Press the fold switch to fold the elevator all way in.	● ⇨ ☐ D ▽			
12	close the left pane of elevator covering door	● ⇨ ☐ D ▽			
13	close the right pane of elevator covering door	● ⇨ ☐ D ▽			
14	grab the locking handle on the right pane	● ⇨ ☐ D ▽			
15	push it up to lock the door securely	● ⇨ ☐ D ▽			
16	Move to the driver side of the vehicle.	○ ➡ ☐ D ▽			
17	Get into the driver seat	● ⇨ ☐ D ▽			
18	Grab the passenger door handle and close it shut	● ⇨ ☐ D ▽			
19	close driver side door	● ⇨ ☐ D ▽			
20	Bend down to release the emergency brakes (Use handle)	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: loading a passenger who is on a wheel chair into Big buses (U4 & U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ____
Material ____

Present X
Proposed ____

Sheet # 4 of 4

	Operation	Symbol	Dist.	Time	Notes
1	Reach up to switch of hazard lights and wheel chair lift switch	● ⇨ ☐ D ▽			
2	Pick up the manifest from the dash board tray	● ⇨ ☐ D ▽			
3	Pick up pencil from the Pocket	● ⇨ ☐ D ▽			
4	note down the departure time from pickup location	● ⇨ ☐ D ▽			
5	Keep the manifest on the dash board tray	○ ➡ ☐ D ▽			
6	Keep the pencil back in the pocket	○ ➡ ☐ D ▽			
7	Put the seat belt back on	● ⇨ ☐ D ▽			
8	Engage the vehicle into drive gear	● ⇨ ☐ D ▽			
9	press gas pedal.	● ⇨ ☐ D ▽			
10		○ ⇨ ☐ D ▽			
11		○ ⇨ ☐ D ▽			
12		○ ⇨ ☐ D ▽			
13		○ ⇨ ☐ D ▽			
14		○ ⇨ ☐ D ▽			
15		○ ⇨ ☐ D ▽			
16		○ ⇨ ☐ D ▽			
17		○ ⇨ ☐ D ▽			
18		○ ⇨ ☐ D ▽			
19		○ ⇨ ☐ D ▽			
20		○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: Vehicle Inspection before the day's work - (U7 - Grand Caravan)
U6 - " "
Date 06/18/2002
Operator Richard
Charted by Deepa

Operator ______
Material ______
Present X
Proposed ______
Sheet # 1 of 2

	Operation	Symbol	Dist.	Time	Notes
1	Pick up the door key from key bunch	● ⇨ ☐ D ▽			
2	Open the door	● ⇨ ☐ D ▽			
3	Get into the vehicle	○ ➡ ☐ D ▽			
4	Put the key into ignition	● ⇨ ☐ D ▽			
5	Adjust seat position	● ⇨ ☐ D ▽			
6	Adjust rear view mirror	● ⇨ ☐ D ▽			
7	Start the vehicle	● ⇨ ☐ D ▽			
8	Unlock the doors from inside	● ⇨ ☐ D ▽			leans across and behind to unlock.
9	Disembark and move to back side of vehicle	○ ➡ ☐ D ▽			
10	Unlock the boot door	● ⇨ ☐ D ▽			
11	Move to the co-driver side of vehicle	○ ➡ ☐ D ▽			
12	Open the sliding door	● ⇨ ☐ D ▽			Check to see the
13	pull down the folding ramp	● ⇨ ☐ D ▽			proper functions of wheel chair ramp.
14	Fold the ramp back.	● ⇨ ☐ D ▽			
15	close the door	● ⇨ ☐ D ▽			
16	Move to the front of the vehicle	○ ➡ ☐ D ▽			
17	Bent down to check any oil puddles.	○ ⇨ ■ D ▽			
18	Move to the driver door.	○ ➡ ☐ D ▽			
19	Pull the hood release handle	● ⇨ ☐ D ▽			
20	Move to front of vehicle	○ ➡ ☐ D ▽			

Flow Process Chart

Operation: Vehicle inspection before a days work. (U6+U7).

Date 06/18/02
Operator Richard
Charted by Deepu

Operator ______
Material ______

Present X
Proposed ______

Sheet # 2 of 2

	Operation	Symbol	Dist.	Time	Notes
1	open the hood	● ⇨ □ D ▽			
2	check engine oil	○ ⇨ ■ D ▽			
3	check coolant level	○ ⇨ ■ D ▽			
4	check transmission fluid	○ ⇨ ■ D ▽			
5	close hood.	● ⇨ □ D ▽			
6	Move to driver side	○ ➡ □ D ▽			
7	Put the left indicators by moving the stalk	● ⇨ □ D ▽			
8	Move back to see both are working	○ ⇨ ■ D ▽			
9	Put the right indicator	● ⇨ □ D ▽			
10	Move to the other side to see them working	○ ⇨ ■ D ▽			
11	Turn the light switch on.	● ⇨ □ D ▽			
12	Move to front to see headlights are working	○ ⇨ ■ D ▽			
13	Move to back to see tail lamps working	○ ⇨ ■ D ▽			
14	Move to get into driver seat	○ ➡ □ D ▽			
15	Get into the vehicle.	● ⇨ □ D ▽			
16	close the door	● ⇨ □ D ▽			
17	Pickup drivers note from Rem tray	● ⇨ □ D ▽			
18	Fill the form and keep it back.	● ⇨ □ D ▽			
19	Put seat belt	● ⇨ □ D ▽			
20	Engage drive gear and proceed.	● ⇨ □ D ▽			

○ → Operation
⇨ → Transport
□ → Inspection
D → Delay
▽ → Storage

Flow Process Chart

Operation: Picking up a normal old person who walks with an aid (U6fU7)

Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______

Present X
Proposed ____

Sheet # 1 of 2

	Operation	Symbol	Dist.	Time	Notes
1	Put the vehicle in park	● ⇨ □ D ▽			* after pulling to desired place (location) *
2	Pick the writing board from dash board (with manifest)	● ⇨ □ D ▽			
3	Get pencil from pocket	● ⇨ □ D ▽			
4	Note down the arrived time on the columns provided	● ⇨ □ D ▽			
5	Keep the writing pad back	○ ➡ □ D ▽			
6	Put pencil back to pocket	○ ➡ □ D ▽			
7	Unbuckle the seat belt	● ⇨ □ D ▽			
8	Open the driver side door	● ⇨ □ D ▽			
9	disembark from vehicle	● ⇨ □ D ▽			
10	Move to the co-passenger side sliding door	○ ➡ □ D ▽			
11	Open the sliding door and push it all back	● ⇨ □ D ▽			
12	grip the handle of folding ramp.	● ⇨ □ D ▽			
13	Pull the ramp down to touch ground securely	● ⇨ □ D ▽			
14	Proceed to the front door of passenger's residence	○ ➡ □ D ▽			
15	open the front door for passenger and keep opened	● ⇨ □ D ▽			
16	Wait for them to pass door	○ ⇨ □ ◗ ▽			
17	Close door	● ⇨ □ D ▽			
18	Assist the passenger by holding his/her hand	○ ➡ □ D ▽			/* To help walking - and this is done during walking /
19	Guide them through ramp	○ ➡ □ D ▽			/again transport /
20	Help to sit in the seat	● ⇨ □ D ▽			

Flow Process Chart

Operation: Picking up a normal old person who walk with an aid (Stick, walkers etc). (U6+U7)

Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ________
Material ________

Present X
Proposed ____

Sheet # 2 of 2

Operation	Symbol	Dist.	Time	Notes
1 Help passenger to put seat belt	● ⇨ □ D ▽			
2 Disembark the vehicle.	● ⇨ □ D ▽			
3 Bend and grab the handle of ramp.	● ⇨ □ D ▽			
4 Fold the ramp to its normal secure position.	● ⇨ □ D ▽			
5 close the sliding door shut	● ⇨ □ D ▽			
6 Walk to the driver side of the vehicle	○ ➡ □ D ▽			
7 Enter the vehicle and sit in the driver seat	● ⇨ □ D ▽			
8 Get the yellow punch card (ride card).	● ⇨ □ D ▽			(There is a delay here sometimes for passenger to get
9 Pick the paper punch from the tray.	● ⇨ □ D ▽			the card. Some has it ready every time).
10 Punch the holes on the card	● ⇨ □ D ▽			
11 Give the card back.	○ ➡ □ D ▽			
12 Keep the punch back into tray	○ ➡ □ D ▽			
13 Pick up the writing pad from dash board	● ⇨ □ D ▽			
14 Get pencil from pocket	● ⇨ □ D ▽			
15 Note down the departure time	● ⇨ □ D ▽			
16 Keep the writing pad back on the dash.	○ ➡ □ D ▽			
17 Put pencil back to pocket	○ ➡ □ D ▽			
18 Put the seat belt	● ⇨ □ D ▽			
19 Engage the gear lever to drive	● ⇨ □ D ▽			
20 Press gas pedal	● ⇨ □ D ▽			

Flow Process Chart

Operation: Picking up a normal old person with no disabilities. (U6+U7)

Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ____
Material ____

Present X
Proposed ____

Sheet # 1 of 2

Operation	Symbol	Dist.	Time	Notes
1 Put the Vehicle in park	● ⇨ ☐ D ▽			*after pulling at the desired place*
2 Pick the writing board with manifest from dashboard	● ⇨ ☐ D ▽			
3 Get pencil from pocket (Shirt)	● ⇨ ☐ D ▽			
4 Note down the arrival time in the provided columns.	● ⇨ ☐ D ▽			
5 keep the writing pad back	○ ➡ ☐ D ▽			
6 Put the pencil back to Pocket	○ ➡ ☐ D ▽			
7 Unbuckle the seat belt	● ⇨ ☐ D ▽			
8 Open the driver side door	● ⇨ ☐ D ▽			
9 Disembark from the vehicle	● ⇨ ☐ D ▽			
10 Move to the driver side sliding door	○ ➡ ☐ D ▽			
11 Open the door for passenger	● ⇨ ☐ D ▽			
12 Wait till he/she reaches there (door)	○ ⇨ ☐ **D** ▽			
13 Help the passenger in (Watch for head knocks)	● ⇨ ☐ D ▽			
14 Help with seat belt	● ⇨ ☐ D ▽			
15 Close the door	● ⇨ ☐ D ▽			
16 Move to driver seat	○ ➡ ☐ D ▽			
17 Enter and Sit in seat	● ⇨ ☐ D ▽			
18 Get The yellow card (ride punching)	● ⇨ ☐ D ▽			(There is a wait sometimes as passenger fumbles for card)
19 Pick The paper punch from dash board tray	● ⇨ ☐ D ▽			
20 Punch The rides on The card.	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: Picking up a normal old person with no disabilities (U6/U7)

Date 06/18/2002

Operator Richard

Charted by Deepu

Operator ______

Material ______

Present X

Proposed ______

Sheet # 2 of 2

Operation	Symbol	Dist.	Time	Notes
1 Give the card back.	● ➡ ☐ D ▽			
2 Keep the clip back in tray.	○ ➡ ☐ D ▽			
3 Pick up the writing pad	● ⇨ ☐ D ▽			
4 Get pencil from pocket	● ⇨ ☐ D ▽			
5 Note down the departure time	● ⇨ ☐ D ▽			
6 Keep the writing pad back on dash	○ ➡ ☐ D ▽			
7 Put pencil in pocket	○ ➡ ☐ D ▽			
8 Put the seat belt	● ⇨ ☐ D ▽			
9 Engage into Drive	● ⇨ ☐ D ▽			
10 Press gas pedal	● ⇨ ☐ D ▽			
11	○ ⇨ ☐ D ▽			
12	○ ⇨ ☐ D ▽			
13	○ ⇨ ☐ D ▽			
14	○ ⇨ ☐ D ▽			
15	○ ⇨ ☐ D ▽			
16	○ ⇨ ☐ D ▽			
17	○ ⇨ ☐ D ▽			
18	○ ⇨ ☐ D ▽			
19	○ ⇨ ☐ D ▽			
20	○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger with no disabilities from small buses (U6447)
Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ____
Material ____

Present X
Proposed ____

Sheet # 1 of 2

Operation	Symbol	Dist.	Time	Notes
1 Put the vehicle into parking gear	● ⇨ ☐ D ▽			
2 Pick up the writing pad with manifest from dash	● ⇨ ☐ D ▽			
3 Pick up pencil from pocket	● ⇨ ☐ D ▽			
4 Note down the arrival time at destination	● ⇨ ☐ D ▽			
5 Keep the writing pad back into dash board	○ ➡ ☐ D ▽			
6 Keep the pencil back into pocket.	○ ➡ ☐ D ▽			
7 Unbuckle the seat belt	● ⇨ ☐ D ▽			
8 Open the driver side door of the vehicle	● ⇨ ☐ D ▽			
9 Disembark from the vehicle	● ⇨ ☐ D ▽			
10 Move to the sliding door in driver's side.	○ ➡ ☐ D ▽			
11 Open the door and push it all way back.	● ⇨ ☐ D ▽			
12 Wait till the passenger gets out.	○ ⇨ ☐ ◗ ▽			
13 Close the sliding door shut.	● ⇨ ☐ D ▽			
14 Get into the driver's seat	● ⇨ ☐ D ▽			
15 Pick up the manifest from dash board	● ⇨ ☐ D ▽			
16 Pick up the pencil from pocket.	● ⇨ ☐ D ▽			
17 Note down the departure time from destination	● ⇨ ☐ D ▽			
18 Put the manifest back into dash	○ ➡ ☐ D ▽			
19 Put pencil back into pocket	○ ➡ ☐ D ▽			
20 Buckle the seat belt	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger with no disabilities from small buses (U6+U7)

Date 06/18/2002

Operator Richard

Charted by Deepu

Operator ______

Material ______

Present X

Proposed ______

Sheet # 2 of 2

	Operation	Symbol	Dist.	Time	Notes
1	Close the driver side door of vehicle	● ⇨ ☐ D ▽			
2	Engage the vehicle to drive gear	● ⇨ ☐ D ▽			
3	press gas pedal.	● ⇨ ☐ D ▽			
4		○ ⇨ ☐ D ▽			
5		○ ⇨ ☐ D ▽			
6		○ ⇨ ☐ D ▽			
7		○ ⇨ ☐ D ▽			
8		○ ⇨ ☐ D ▽			
9		○ ⇨ ☐ D ▽			
10		○ ⇨ ☐ D ▽			
11		○ ⇨ ☐ D ▽			
12		○ ⇨ ☐ D ▽			
13		○ ⇨ ☐ D ▽			
14		○ ⇨ ☐ D ▽			
15		○ ⇨ ☐ D ▽			
16		○ ⇨ ☐ D ▽			
17		○ ⇨ ☐ D ▽			
18		○ ⇨ ☐ D ▽			
19		○ ⇨ ☐ D ▽			
20		○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger with walking aid from small bus (U6847)
Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ____ Present X
Material ____ Proposed ____
Sheet # 1 of 2

	Operation	Symbol	Dist.	Time	Notes
1	put the vehicle into parking gear.	● ⇨ ☐ D ▽			
2	pick up the writing pad from the dash board	● ⇨ ☐ D ▽			
3	pick up the pencil from the pocket	● ⇨ ☐ D ▽			
4	Note down the arrival time at destination	● ⇨ ☐ D ▽			
5	Keep the writing pad back into dash board	○ ➡ ☐ D ▽			
6	keep the pencil back into pocket	○ ➡ ☐ D ▽			
7	Unbuckle the seat belt	● ⇨ ☐ D ▽			
8	open the driver side door of vehicle	● ⇨ ☐ D ▽			
9	Disembark from the vehicle	● ⇨ ☐ D ▽			
10	Move to open the sliding door at driver side	○ ➡ ☐ D ▽			
11	Help rider to unbuckle their seat belt	● ⇨ ☐ D ▽			
12	Assist the passenger to exit out of vehicle	● ⇨ ☐ D ▽			
13	Support the passenger by holding hand.	● ⇨ ☐ D ▽			
14	Walk them to the entrance door.	○ ➡ ☐ D ▽			
15	Open the door for them	● ⇨ ☐ D ▽			
16	Let the rider get in the building	○ ⇨ ☐ ◗ ▽			
17	close the front door of the building	● ⇨ ☐ D ▽			
18	come back to the vehicle.	○ ➡ ☐ D ▽			
19	close the sliding door shut.	● ⇨ ☐ D ▽			
20	Get into the driver's seat.	● ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger with walking aid from small bus (U61U7)

Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______

Present X
Proposed ______

Sheet # 2 of 2

	Operation	Symbol	Dist.	Time	Notes
1	Pick up the writing pad with manifest from dash	● ⇨ ☐ D ▽			
2	pick up the pencil from pocket	● ⇨ ☐ D ▽			
3	Write down the departure time from destination	● ⇨ ☐ D ▽			
4	Keep the manifest back on dash board	○ ➡ ☐ D ▽			
5	keep pencil back into pocket	○ ➡ ☐ D ▽			
6	Buckle seat belt	● ⇨ ☐ D ▽			
7	close the driver side door	● ⇨ ☐ D ▽			
8	Engage vehicle into drive gear	● ⇨ ☐ D ▽			
9	press gas pedal	● ⇨ ☐ D ▽			
10		○ ⇨ ☐ D ▽			
11		○ ⇨ ☐ D ▽			
12		○ ⇨ ☐ D ▽			
13		○ ⇨ ☐ D ▽			
14		○ ⇨ ☐ D ▽			
15		○ ⇨ ☐ D ▽			
16		○ ⇨ ☐ D ▽			
17		○ ⇨ ☐ D ▽			
18		○ ⇨ ☐ D ▽			
19		○ ⇨ ☐ D ▽			
20		○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: Unloading a passenger on wheel chair from small buses (U6, U7)

Date 06/18/2002

Operator Richard

Charted by Deepu

Operator

Material

Present X

Proposed

Sheet # 1 of 2

	Operation	Symbol	Dist.	Time	Notes
1	put the vehicle into parking gear.	● ⇨ ☐ D ▽			
2	pick up the writing pad with manifest from dash	● ⇨ ☐ D ▽			
3	pick up pencil from pocket	● ⇨ ☐ D ▽			
4	Note down the arrival time at destination	● ⇨ ☐ D ▽			
5	Keep the writing pad back on dash board.	○ ➡ ☐ D ▽			
6	keep the pencil back in the pocket.	○ ➡ ☐ D ▽			
7	unbuckle seat belt	● ⇨ ☐ D ▽			
8	open driver's door of vehicle	● ⇨ ☐ D ▽			
9	Disembark from vehicle	● ⇨ ☐ D ▽			
10	Move to the co-driver side sliding doors.	○ ➡ ☐ D ▽			
11	Open the sliding door	● ⇨ ☐ D ▽			
12	Grab the handle on the folding ramp.	● ⇨ ☐ D ▽			
13	open the ramp to extent all way to floor securely	● ⇨ ☐ D ▽			
14	Get into the vehicle	○ ➡ ☐ D ▽			
15	unbuckle the seat belt that holds the rider	● ⇨ ☐ D ▽			
16	Bent down to unbuckle wheel chair holding straps	● ⇨ ☐ D ▽			
17	Grip the handles on wheel chair	● ⇨ ☐ D ▽			
18	Manevour wheel chair towards exit	● ⇨ ☐ D ▽			
19	push the wheel chair out through ramp	● ⇨ ☐ D ▽			
20	Transport the passenger to destination entrance	○ ➡ ☐ D ▽			

Flow Process Chart

Operation: unloading a passenger on wheel chair from small buses - (U6147)
Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______
Present X
Proposed ______
Sheet # 2 of 2

	Operation	Symbol	Dist.	Time	Notes
1	Open the entrance door at destination.	● ⇨ ☐ D ▽			
2	push the wheel chair in securely	● ⇨ ☐ D ▽			
3	close the door	● ⇨ ☐ D ▽			
4	Travel back to the unfoalded ramp	○ ➡ ☐ D ▽			
5	Bent down and grab the handle	● ⇨ ☐ D ▽			
6	Fold the ramp securely to the original position	● ⇨ ☐ D ▽			
7	Close the sliding door securely.	● ⇨ ☐ D ▽			
8	Go to the driver door	○ ➡ ☐ D ▽			
9	Get into the driver's seat	● ⇨ ☐ D ▽			
10	Pick up the writing pad from dash board	● ⇨ ☐ D ▽			
11	Pick up the pencil from pocket	● ⇨ ☐ D ▽			
12	Note down the departure time in manifest.	● ⇨ ☐ D ▽			
13	Keep the pencil back in pocket	○ ➡ ☐ D ▽			
14	Keep the manifest back in the dash board	○ ➡ ☐ D ▽			
15	Put the seat belt	● ⇨ ☐ D ▽			
16	Close the driver side door	● ⇨ ☐ D ▽			
17	Engage vehicle into drive	● ⇨ ☐ D ▽			
18	Press gas pedal	● ⇨ ☐ D ▽			
19		○ ⇨ ☐ D ▽			
20		○ ⇨ ☐ D ▽			

Flow Process Chart

Operation: Picking up a disabled old/young person who is in a wheel chair (464U7)

Date 06/18/2002
Operator Richard
Charted by Deepa

Operator ______ Present X
Material ______ Proposed ______

Sheet # 1 of 3

Operation	Symbol	Dist.	Time	Notes
1 put the vehicle in parking gear	● ⇨ □ D ▽			
2 pick the writing board from dash board (with manifest)	● ⇨ □ D ▽			
3 Get pencil from the pocket	● ⇨ □ D ▽			
4 Note down the arrival time in the column of manifest	● ⇨ □ D ▽			
5 Keep the writing pad back on the dash board	○ ➡ □ D ▽			
6 keep the pencil back into pocket	○ ➡ □ D ▽			
7 unbuckle the seat belt	● ⇨ □ D ▽			
8 Open the driver door of the vehicle	● ⇨ □ D ▽			
9 disembark from vehicle	● ⇨ □ D ▽			
10 Move to the sliding door to the co-driver side	○ ➡ □ D ▽			
11 Open the sliding door, push it all way back to lock hold	● ⇨ □ D ▽			
12 Grab the handle of the folding ramp	● ⇨ □ D ▽			
13 pull the ramp down to all way floor and ground it	● ⇨ □ D ▽			
14 Enter into the vehicle	○ ➡ □ D ▽			
15 Fold the middle seat	● ⇨ □ D ▽			
16 Secure the folded seat in upright position with Safety lock	● ⇨ □ D ▽			
17 Disembark from vehicle	● ⇨ □ D ▽			
18 Go to the front door of the passenger's house	○ ➡ □ D ▽			
19 open the front door	● ⇨ □ D ▽			
20 Hold the door opened for the passenger to pass it	○ ⇨ □ ◗ ▽			

Flow Process Chart

Operation: Picking up a disabled old/young person who is on a wheel chair (U64U7)
Date 06/18/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______
Present X
Proposed ______

Sheet # 2 of 8

Operation	Symbol	Dist.	Time	Notes
1 Grab the hand grip in back of the wheel and push him away from door	● ⇨ ☐ D ▽			
2 close the front door of passengers home	● ⇨ ☐ D ▽			
3 Push the passenger from home to the vehicle through ramp	○ ➡ ☐ D ▽			
4 Maneuvre the wheel chair inside vehicle to accomodate him/her	● ⇨ ☐ D ▽			
5 put the wheel locks for the wheel chair.	● ⇨ ☐ D ▽			
6 Bend down to grab the wheel tie at floor of vehicle.	● ⇨ ☐ D ▽			
7 clip the wheel tie over the wheels to lock lateral motion	● ⇨ ☐ D ▽			
8 pull the wheel chair seat belt from the pillar of vehicle	● ⇨ ☐ D ▽			
9 Clip it to the seat belt hook on wheel chair of passenger	● ⇨ ☐ D ▽			
10 Test to see whether the wheel chair is secured	○ ⇨ ■ D ▽			
11 Disembark the vehicle	● ⇨ ☐ D ▽			
12 Bend down and grab the handle of folding ramp.	● ⇨ ☐ D ▽			
13 Fold the ramp to its secure position.	● ⇨ ☐ D ▽			
14 close the sliding door shut.	● ⇨ ☐ D ▽			
15 Move to the drivers door	○ ➡ ☐ D ▽			
16 Get into the drivers seat	● ⇨ ☐ D ▽			
17 Collect the yellow ride card from passenger	● ⇨ ☐ D ▽			
18 Pick up the paper punch from the tray	● ⇨ ☐ D ▽			
19 Punch the rides	● ⇨ ☐ D ▽			
20 Give the card back to the passenger	○ ➡ ☐ D ▽			

Flow Process Chart

Operation: Picking up a disabled person who is on a wheel chair (U64U7)

Date 06/18/02
Operator Richard
Charted by Deepu

Operator ____
Material ____

Present X
Proposed ____

Sheet # 3 of 3

Operation	Symbol	Dist.	Time	Notes
1 Keep the paper punch back in dash board tray	○ [✓ ⇨] □ D ▽			
2 Pick up the writing board from dash board	[✓ ○] ⇨ □ D ▽			
3 Pick up pencil from pocket	[✓ ○] ⇨ □ D ▽			
4 Note down the departure time	[✓ ○] ⇨ □ D ▽			
5 Keep the writing pad back on dash	○ [✓ ⇨] □ D ▽			
6 Keep pencil back in pocket	○ [✓ ⇨] □ D ▽			
7 Put seat belt	[✓ ○] ⇨ □ D ▽			
8 Engage drive gear	[✓ ○] ⇨ □ D ▽			
9 Press gas pedal	[✓ ○] ⇨ □ D ▽			
10	○ ⇨ □ D ▽			
11	○ ⇨ □ D ▽			
12	○ ⇨ □ D ▽			
13	○ ⇨ □ D ▽			
14	○ ⇨ □ D ▽			
15	○ ⇨ □ D ▽			
16	○ ⇨ □ D ▽			
17	○ ⇨ □ D ▽			
18	○ ⇨ □ D ▽			
19	○ ⇨ □ D ▽			
20	○ ⇨ □ D ▽			

Flow Process Chart

Operation: Loading an old passenger who is not on a wheel chair onto Big buses (U4 & U8)
Date 06/20/2002
Operator Richard
Charted by Deepu

Operator ______
Material ______
Present X
Proposed ______
Sheet # 1 of 2

	Operation	Symbol	Dist.	Time	Notes
1	put the vehicle into parking gear	● ⇨ ☐ D ▽			
2	Pick up writing board with manifest from dash tray	● ⇨ ☐ D ▽			
3	pick up pencil from pocket	● ⇨ ☐ D ▽			
4	Note down the arrival time at pickup location	● ⇨ ☐ D ▽			
5	Put the writing board down onto dashboard tray	○ ➡ ☐ D ▽			
6	put pencil back to pocket	○ ➡ ☐ D ▽			
7	Grab the lock of the door handle	● ⇨ ☐ D ▽			
8	push lock lever up	● ⇨ ☐ D ▽			
9	push driver handle away from body to open bus door	● ⇨ ☐ D ▽			
10	wait until the passenger gets into bus.	○ ⇨ ☐ ◗ ▽			
11	Grab the control handle	● ⇨ ☐ D ▽			
12	pull it towards body to close the door	● ⇨ ☐ D ▽			
13	Ensure the handle lock is on now	○ ⇨ ■ D ▽			
14	Wait till the passenger gets seated.	○ ⇨ ☐ ◗ ▽			
15	Pick up the writing pad from dash board tray	● ⇨ ☐ D ▽			
16	Pick up pencil from pocket	● ⇨ ☐ D ▽			
17	Write down the departure time	● ⇨ ☐ D ▽			
18	Put the writing board back into dashboard tray	○ ➡ ☐ D ▽			
19	put the pencil back to pocket	○ ➡ ☐ D ▽			
20	Check inside view mirror to ensure every one seated	○ ⇨ ■ D ▽			

Flow Process Chart

Operation: Loading an old passenger with
+ MWF) no disabilities into Big buses (U4 & U8)

Date 06/20/2002
Operator Richard
Charted by Deepu

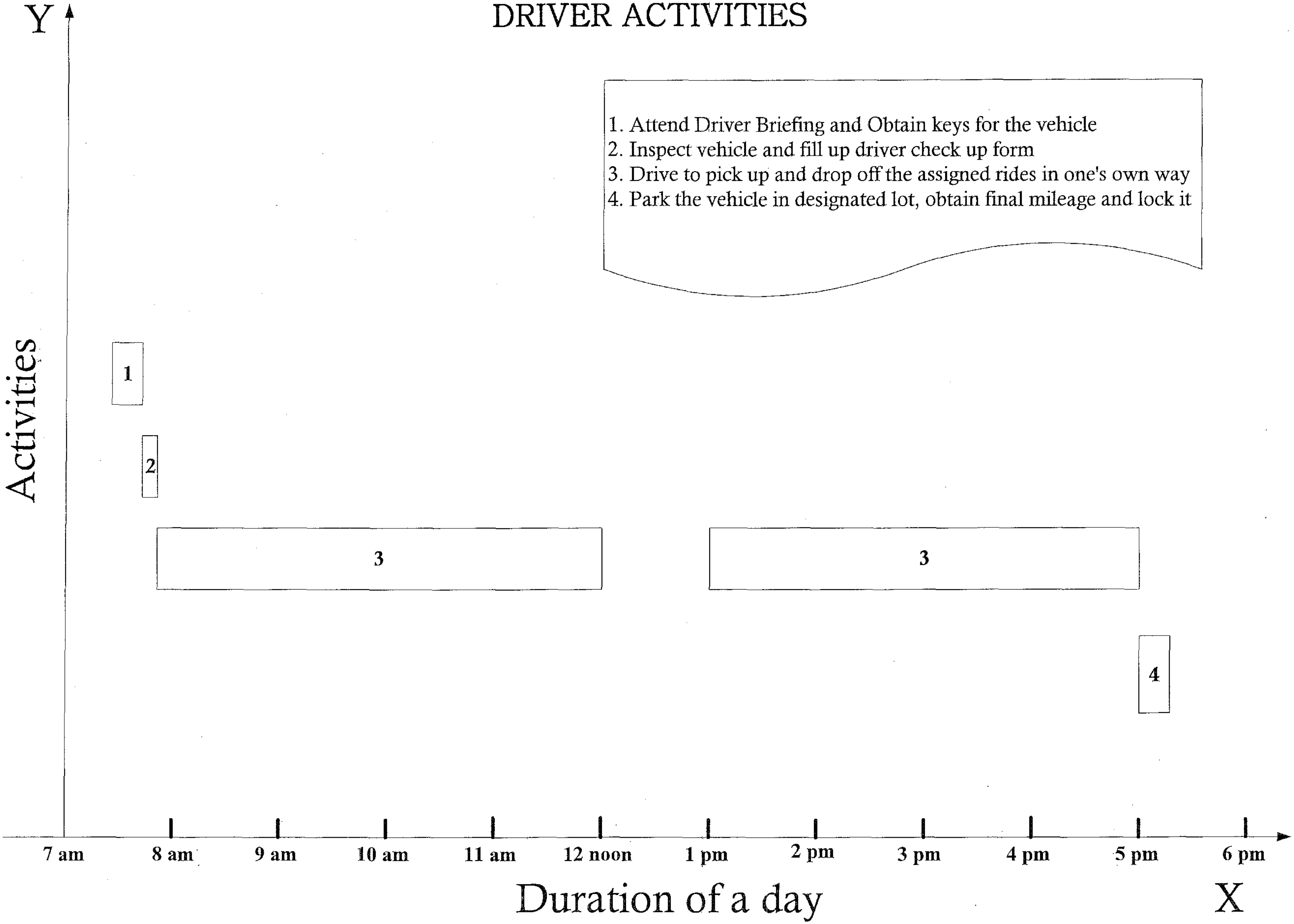
Operator
Material

Present X
Proposed

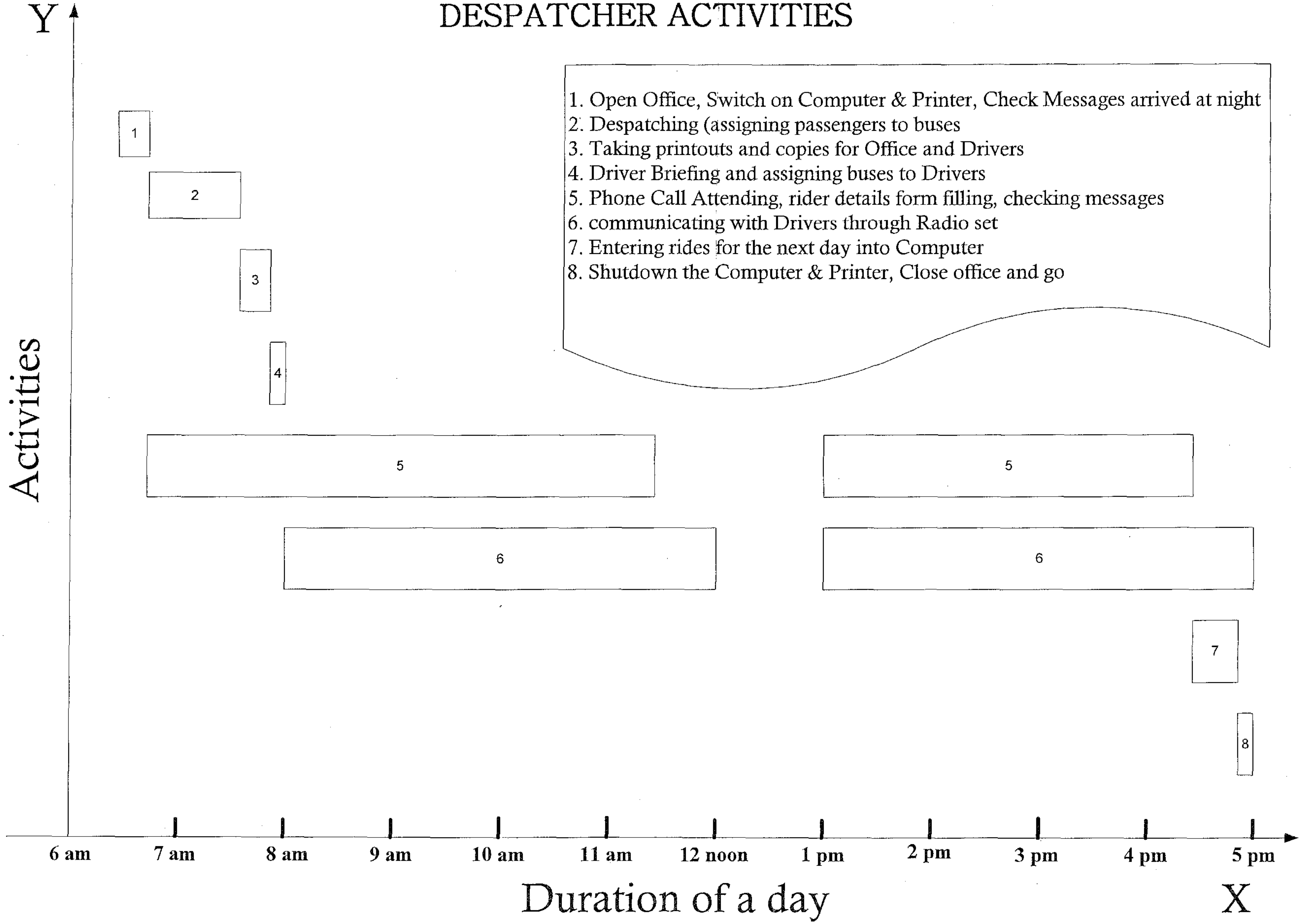
Sheet # 2 of 2

Operation	Symbol	Dist.	Time	Notes
1 Engage into drive gear	● ⇨ ☐ D ▽			
2 press gas pedal	● ⇨ ☐ D ▽			
3	○ ⇨ ☐ D ▽			
4	○ ⇨ ☐ D ▽			
5	○ ⇨ ☐ D ▽			
6	○ ⇨ ☐ D ▽			
7	○ ⇨ ☐ D ▽			
8	○ ⇨ ☐ D ▽			
9	○ ⇨ ☐ D ▽			
10	○ ⇨ ☐ D ▽			
11	○ ⇨ ☐ D ▽			
12	○ ⇨ ☐ D ▽			
13	○ ⇨ ☐ D ▽			
14	○ ⇨ ☐ D ▽			
15	○ ⇨ ☐ D ▽			
16	○ ⇨ ☐ D ▽			
17	○ ⇨ ☐ D ▽			
18	○ ⇨ ☐ D ▽			
19	○ ⇨ ☐ D ▽			
20	○ ⇨ ☐ D ▽			

DRIVER ACTIVITIES



DESPATCHER ACTIVITIES



1. Open Office, Switch on Computer & Printer, Check Messages arrived at night
2. Despatching (assigning passengers to buses
3. Taking printouts and copies for Office and Drivers
4. Driver Briefing and assigning buses to Drivers
5. Phone Call Attending, rider details form filling, checking messages
6. communicating with Drivers through Radio set
7. Entering rides for the next day into Computer
8. Shutdown the Computer & Printer, Close office and go

APPENDIX – II

GIS MAP DATA DETAILS

SHAPEFILE – TECHNICAL DETAILS

ESRI defines Shapefile as "A Shapefile stores nontopological geometry and attribute information for the spatial features in the data set." Shapefile can support point, lines and area features. The attributes of the Shapefile are held in a dBASE format file. The ESRI Shapefile consists of the following; (for details use the reference **Error! Reference source not found.**.).

- A main file – with the extension .shp, which is a direct access variable-record-length file.
- An index file – with the extension .shx, which contains the offset of the corresponding main file record from the beginning of the main file.
- A dBASE table – with the extension .dbf, contains the feature attribute with one record per feature.

All these three files have the same name prefix. In other words programs like ArcView, ArcExplorer etc, need these three files to display the spatial information. Also from the ESRI white paper on Shapefile **Error! Reference source not found.**, it was known that Shapefile stores integer and double precision numbers.. The ArcView program was then used to create a shape file from scratch.

After having ArcView installed the initial experimentation was conducted upon the Shapefile obtained from county GIS office. It was found that the necessary information needed to develop the network model is available in the dbf file. Initially Microsoft Excel was used to view the contents of the dbf file. But to extract the necessary information to construct the model, a c program is necessary. This is because the final model will be coded in c/c++.

ShapeLib and Shapefile verifications

A Shapefile library was obtained from Frank Warmerdam, who has written C programs to read the contents of the Shapefile and dbf file. This library was used as the starting point to experiment with the Shapefile. The ShapeLib contained files like shpdump, dbfdump etc, which dumped the contents of these files onto the terminal. The source code listings of the shpdump and dbfdump are included at the end of this appendix.

The outputs generated by these two important programs confirmed the hypothesis formed initially about the .shp, .shx, .dbf files. The sample outputs are available at the end of this section of appendix. The output is for a sample intersection chosen from the Gallatin County shape file. The shpdump gives the co-ordinates of the vertices and the co-ordinates follow state co-ordinate system.

Street Network construction program details

When the initial c program source code available was modified to obtain a network matrix that is a typical From-To matrix, a lot of information about the source code was needed. Initially the code was compiled and run on a sample dbf file. The output of the program was written to a file. By comparing the output with the same dbf file opened with the help of Excel, it was ascertained that the program is reading all the fields accurately.

While going through the program one can notice that a variable hDBF is used to get the information about the dbf file. This variable is of the type DBFHandle that is defined in the shapefil.h, which is the header file. This header contains the functions to identify the type of field being read like integer, real, string etc. The function used is DBFGetFieldInfo (). Also this function is in conjunction with the specifications of each field declared by ESRI in their white paper about shape files.

Similarly the program to read the contents of Shapefile also has variables defined like this. They are hSHP as the handle for shape file (SHPHandle) and similar functions like SHPGetInfo (), SHPReadObject () etc are used to obtain the data about the shapes included in the Shapefile. This program is useful in the context when the decisions made by the routing and dispatching algorithm has to be visualized in graph or map format.

The logic of the program is depicted in the flow chart included in Figure 2. This explains the basic logic that was used later to obtain the From-To matrix for developing the network model. The program was basically reading all fields and printing on the screen. It is evident from the dbf file that the FNODE field gives the information about from node; TNODE field gives information about to nodes. The information in these fields is read into two different matrices, which stores the number of these nodes. Also field 4 gives the information about the distance in meters about the particular line segment defined by the FNODE and TNODE values. This was read into the distance array.

When all these information were stored in the corresponding arrays, the next step is to convert the information in these arrays to a From-To matrix. The following piece of code in Figure 1 generates the necessary matrix.

```
for(i=0;i<numpairs;i++)
    {
        FrToMx[Fndarr[i]][Tndarr[i]] = 1; /* assign 1 to show the arc is existing
*/
        Distmat[Fndarr[i]][Tndarr[i]] = Distarr[i];
    }
```

Figure 1 - C Program for generating the FROM-TO matrix from dbf file

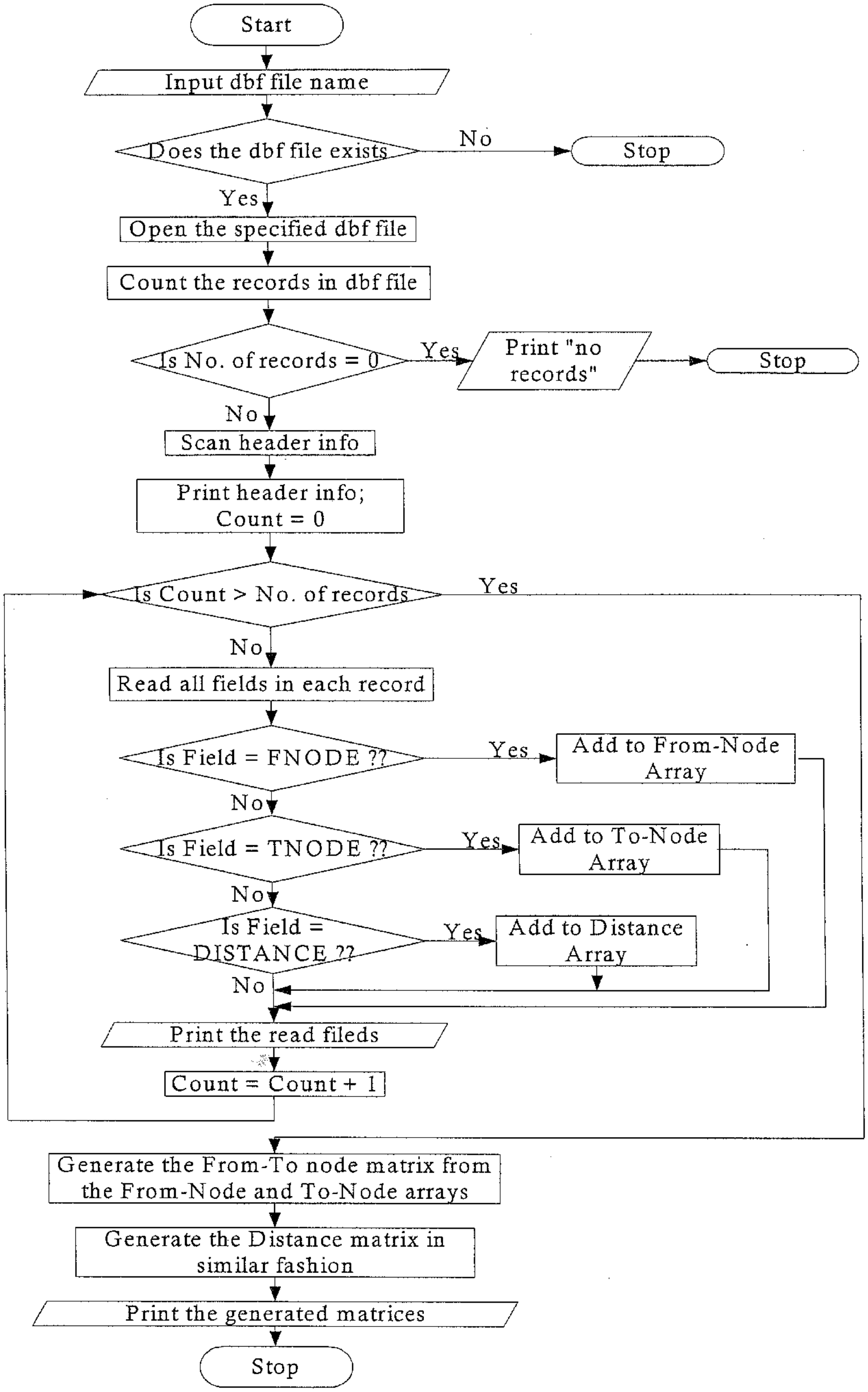


Figure 2 - Flow chart depicting the logic for the generation of network model

```
/******************************************************************************
 * $Id: shpdump.c,v 1.8 2000/07/07 13:39:45 warmerda Exp $
 *
 * Project:  Shapelib
 * Purpose:  Sample application for dumping contents of a shapefile to
 *           the terminal in human readable form.
 * Author:   Frank Warmerdam, warmerda@home.com
 *
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 *
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 ******************************************************************************
 *
 * $Log: shpdump.c,v $
 * Revision 1.9  2002/06/12 21:20:15  Deepu Philip
 * adapted to read the specified portion of a big shape file
 *
 * Revision 1.8  2000/07/07 13:39:45  warmerda
 * removed unused variables, and added system include files
 *
 * Revision 1.7  1999/11/05 14:12:04  warmerda
 * updated license terms
 *
 * Revision 1.6  1998/12/03 15:48:48  warmerda
 * Added report of shapefile type, and total number of shapes.
 *
 * Revision 1.5  1998/11/09 20:57:36  warmerda
 * use SHPObject.
 *
 * Revision 1.4  1995/10/21 03:14:49  warmerda
 * Changed to use binary file access.
 *
 * Revision 1.3  1995/08/23  02:25:25  warmerda
 * Added support for bounds.
 *
 * Revision 1.2  1995/08/04  03:18:11  warmerda
 * Added header.
 *
 */

static char rcsid[] =
  "$Id: shpdump.c,v 1.8 2000/07/07 13:39:45 warmerda Exp $";

#include "shapefil.h"
```

```
int main( int argc, char ** argv )

{
    SHPHandle     hSHP;
    int           nShapeType, nEntities, i, iPart;
    const char    *pszPlus;
    double  adfMinBound[4], adfMaxBound[4];

/* --------------------------------------------------------------------- */
/*      Display a usage message.                                         */
/* --------------------------------------------------------------------- */
    if( argc != 2 )
    {
      printf( "shpdump shp_file\n" );
      exit( 1 );
    }

/* --------------------------------------------------------------------- */
/*      Open the passed shapefile.                                       */
/* --------------------------------------------------------------------- */
    hSHP = SHPOpen( argv[1], "rb" );

    if( hSHP == NULL )
    {
      printf( "Unable to open:%s\n", argv[1] );
      exit( 1 );
    }

/* --------------------------------------------------------------------- */
/*      Print out the file bounds.                                       */
/* --------------------------------------------------------------------- */
    SHPGetInfo( hSHP, &nEntities, &nShapeType, adfMinBound, adfMaxBound );

    printf( "Shapefile Type: %s   # of Shapes: %d\n\n",
            SHPTypeName( nShapeType ), nEntities );

    printf( "File Bounds: (%12.3f,%12.3f,%g,%g)\n"
            "         to  (%12.3f,%12.3f,%g,%g)\n",
            adfMinBound[0],
            adfMinBound[1],
            adfMinBound[2],
            adfMinBound[3],
            adfMaxBound[0],
            adfMaxBound[1],
            adfMaxBound[2],
            adfMaxBound[3] );

/* --------------------------------------------------------------------- */
/*    Skim over the list of shapes, printing all the vertices.    */
/* --------------------------------------------------------------------- */
    for( i = 0; i < nEntities; i++ )
    {
      int         j;
        SHPObject *psShape;

      psShape = SHPReadObject( hSHP, i );

      printf( "\nShape:%d (%s)  nVertices=%d, nParts=%d\n"
                "  Bounds:(%12.3f,%12.3f, %g, %g)\n"
                "      to (%12.3f,%12.3f, %g, %g)\n",
              i, SHPTypeName(psShape->nSHPType),
                psShape->nVertices, psShape->nParts,
                psShape->dfXMin, psShape->dfYMin,
                psShape->dfZMin, psShape->dfMMin,
                psShape->dfXMax, psShape->dfYMax,
                psShape->dfZMax, psShape->dfMMax );

      for( j = 0, iPart = 1; j < psShape->nVertices; j++ )
```

```
        {
              const char  *pszPartType = "";

              if( j == 0 && psShape->nParts > 0 )
                  pszPartType = SHPPartTypeName( psShape->panPartType[0] );

            if( iPart < psShape->nParts
                  && psShape->panPartStart[iPart] == j )
            {
                  pszPartType = SHPPartTypeName( psShape->panPartType[iPart] );
              iPart++;
              pszPlus = "+";
            }
            else
                pszPlus = " ";

            printf("   %s (%12.3f,%12.3f, %g, %g) %s \n",
                     pszPlus,
                     psShape->padfX[j],
                     psShape->padfY[j],
                     psShape->padfZ[j],
                     psShape->padfM[j],
                     pszPartType );
        }

          SHPDestroyObject( psShape );
      }

    SHPClose( hSHP );

#ifdef USE_DBMALLOC
    malloc_dump(2);
#endif

    exit( 0 );
}
```

```
Shapefile Name: lammegrand.shp
Shapefile Type: Arc   # of Shapes: 4

File Bounds: (  496780.467, 5058585.266,0,0)
         to  (  496979.852, 5058716.635,0,0)

Shape:0 (Arc)  nVertices=2, nParts=1
  Bounds:(  496881.934, 5058644.357, 0, 0)
      to (  496979.852, 5058644.423, 0, 0)
     (  496979.852, 5058644.423, 0, 0) Ring
     (  496881.934, 5058644.357, 0, 0)

Shape:1 (Arc)  nVertices=9, nParts=1
  Bounds:(  496880.625, 5058644.357, 0, 0)
      to (  496881.934, 5058716.635, 0, 0)
     (  496880.625, 5058716.635, 0, 0) Ring
     (  496880.632, 5058713.626, 0, 0)
     (  496880.660, 5058710.645, 0, 0)
     (  496881.220, 5058699.583, 0, 0)
     (  496881.355, 5058688.110, 0, 0)
     (  496881.521, 5058668.254, 0, 0)
     (  496881.158, 5058658.489, 0, 0)
     (  496881.906, 5058647.161, 0, 0)
     (  496881.934, 5058644.357, 0, 0)

Shape:2 (Arc)  nVertices=2, nParts=1
  Bounds:(  496780.467, 5058644.289, 0, 0)
      to (  496881.934, 5058644.357, 0, 0)
     (  496881.934, 5058644.357, 0, 0) Ring
     (  496780.467, 5058644.289, 0, 0)

Shape:3 (Arc)  nVertices=2, nParts=1
  Bounds:(  496881.934, 5058585.266, 0, 0)
      to (  496881.945, 5058644.357, 0, 0)
     (  496881.934, 5058644.357, 0, 0) Ring
     (  496881.945, 5058585.266, 0, 0)
```

```
/************************************************************************
*******
 * $Id: dbfdump.c,v 1.8 2001/05/31 18:15:40 warmerda Exp $
 *
 * Project:  Shapelib
 * Purpose:  Sample application for dumping .dbf files to the terminal.
 * Author:   Frank Warmerdam, warmerda@home.com
 *

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*************************************************************************
******
 *
 * $Log: dbfdump.c,v $
 *
 * Revision 1.10 2002/06/04 09:20:15 Deepu Philip
 * Added provision to store distances with From-To matrix
 *
 * Revision 1.9 2002/06/03 16:30:45 Deepu Philip
 * Added code to generate a FROM-TO Matrix from the DBF file
 * contact at: dphilip@montana.edu
 *
 * Revision 1.8  2001/05/31 18:15:40  warmerda
```

```
 * Added support for NULL fields in DBF files
 *
 * Revision 1.7  2000/09/20 13:13:55  warmerda
 * added break after default:
 *
 * Revision 1.6  2000/07/07 13:39:45  warmerda
 * removed unused variables, and added system include files
 *
 * Revision 1.5  1999/11/05 14:12:04  warmerda
 * updated license terms
 *
 * Revision 1.4  1998/12/31 15:30:13  warmerda
 * Added -m, -r, and -h commandline options.
 *
 * Revision 1.3  1995/10/21 03:15:01  warmerda
 * Changed to use binary file access.
 *
 * Revision 1.2  1995/08/04  03:16:22  warmerda
 * Added header.
 *
 */

static char rcsid[] =
  "$Id: dbfdump.c,v 1.8 2001/05/31 18:15:40 warmerda Exp $";

#include <stdlib.h>
#include <string.h>
#include "shapefil.h"

int main( int argc, char ** argv )

{
    DBFHandle     hDBF;
    int           *panWidth, i, iRecord;
    char    szFormat[32], *pszFilename = NULL;
    int           nWidth, nDecimals;
    int           bHeader = 0;
    int           bRaw = 0;
    int           bMultiLine = 0;
    char    szTitle[12];
/* --------------------------------------------------------------------
*/
/* Newly added arrays to hold the from and to nodes - dp
      */
/* --------------------------------------------------------------------
*/
    int Fndarr[35];      /* array to hold the FROM node values */
    int Tndarr[35];      /* array to hold the TO node values */
    int FrToMx[35][35];  /* 2D array to hold the FROM-TO matrix */
    int j;              /* counter variable */
    int numpairs=35;
    int countf=0;       /* counter variable to add numbers to FROM array
*/
    int countt=0;       /* counter variable to add numbers to TO array */
    int countd=0;       /* counter variable to add distances to array */
    float Distarr[35];  /* array to hold the distances of intersection
*/
    float Distmat[35][35];  /* Distanec matrix to hold the distances of
arcs */
    for(i=0;i<numpairs;i++)
    {                   /* initialize elements of arrays to zero */
```

```
      Fndarr[i]=0;
      Tndarr[i]=0;
      Distarr[i]=0.0;
    } /* end for - i*/
    for(i=0;i<=numpairs;i++)
    {                      /* initialize elements of the matrix to zero */
      for(j=0;j<=numpairs;j++)
      {
         FrToMx[i][j] = 0;
         Distmat[i][j] = 0.0;
      }   /* end for - j */
    }   /* end for - i*/       /* end of addition by deepu philip */

/* =================================== DEBUG TRACE
===================================== */
/* added by - Deepu Philip
                */
/*
-------------------------------------------------------------------------
------------ */
    printf("From Node Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%d ", Fndarr[i]);
    printf("\n");
    printf("To Node Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%d ", Tndarr[i]);
    printf("\n");
    printf("Distance Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%7.4f ", Distarr[i]);
    printf("\n");
    printf("From-To Matrix :\n");
    for(i=0;i<numpairs;i++)
    {
      for(j=0;j<numpairs;j++)
        printf("%d ", FrToMx[i][j]);
      printf("\n");
    }
    printf(" Distance Matrix :\n");
    for(i=0;i<numpairs;i++)
    {
      for(j=0;j<numpairs;j++)
        printf("%7.4f ", Distmat[i][j]);
      printf("\n");
    }

/* ====================================================================
End Debug Trace */

/* ---------------------------------------------------------------------
*/
/*      Handle arguments.
*/
/* ---------------------------------------------------------------------
*/
    for( i = 1; i < argc; i++ )
    {
        if( strcmp(argv[i],"-h") == 0 )
            bHeader = 1;
        else if( strcmp(argv[i],"-r") == 0 )
```

```
            bRaw = 1;
        else if( strcmp(argv[i],"-m") == 0 )
            bMultiLine = 1;
        else
            pszFilename = argv[i];
    }

/* --------------------------------------------------------------------
*/
/*      Display a usage message.
*/
/* --------------------------------------------------------------------
*/
    if( pszFilename == NULL )
    {
      printf( "dbfdump [-h] [-r] [-m] xbase_file\n" );
        printf( "        -h: Write header info (field descriptions)
\n" );
        printf( "        -r: Write raw field info, numeric values not
reformatted\n" );
        printf( "        -m: Multiline, one line per field.\n" );
      exit( 1 );
    }

/* --------------------------------------------------------------------
*/
/*      Open the file.
*/
/* --------------------------------------------------------------------
*/
    hDBF = DBFOpen( pszFilename, "rb" );
    if( hDBF == NULL )
    {
      printf( "DBFOpen(%s,\"r\") failed.\n", argv[1] );
      exit( 2 );
    }

/* --------------------------------------------------------------------
*/
/*    If there is no data in this file let the user know.         */
/* --------------------------------------------------------------------
*/
    if( DBFGetFieldCount(hDBF) == 0 )
    {
      printf( "There are no fields in this table!\n" );
      exit( 3 );
    }

/* --------------------------------------------------------------------
*/
/*    Dump header definitions.                                  */
/* --------------------------------------------------------------------
*/
    if( bHeader )
    {
        for( i = 0; i < DBFGetFieldCount(hDBF); i++ )
        {
            DBFFieldType      eType;
            const char        *pszTypeName;

            eType = DBFGetFieldInfo( hDBF, i, szTitle, &nWidth,
```

```
&nDecimals );
            if( eType == FTString )
                pszTypeName = "String";
            else if( eType == FTInteger )
                pszTypeName = "Integer";
            else if( eType == FTDouble )
                pszTypeName = "Double";
            else if( eType == FTInvalid )
                pszTypeName = "Invalid";

            printf( "Field %d: Type=%s, Title=`%s', Width=%d, Decimals=%
d\n",
                    i, pszTypeName, szTitle, nWidth, nDecimals );
        }
    }

/* --------------------------------------------------------------------
*/
/*    Compute offsets to use when printing each of the field
      */
/*    values. We make each field as wide as the field title+1, or
      */
/*    the field value + 1.                                     */
/* --------------------------------------------------------------------
*/
    panWidth = (int *) malloc( DBFGetFieldCount( hDBF ) * sizeof(int) );

    for( i = 0; i < DBFGetFieldCount(hDBF) && !bMultiLine; i++ )
    {
      DBFFieldType      eType;

      eType = DBFGetFieldInfo( hDBF, i, szTitle, &nWidth, &nDecimals );
      if( strlen(szTitle) > nWidth )
          panWidth[i] = strlen(szTitle);
      else
          panWidth[i] = nWidth;

      if( eType == FTString )
          sprintf( szFormat, "%%-%ds ", panWidth[i] );
      else
          sprintf( szFormat, "%%%ds ", panWidth[i] );
      printf( szFormat, szTitle );
    }
    printf( "\n" );

/* --------------------------------------------------------------------
*/
/*    Read all the records                                     */
/* --------------------------------------------------------------------
*/
    for( iRecord = 0; iRecord < DBFGetRecordCount(hDBF); iRecord++ )
    {
        if( bMultiLine )
            printf( "Record: %d\n", iRecord );

      for( i = 0; i < DBFGetFieldCount(hDBF); i++ )
      {
            DBFFieldType      eType;

            eType = DBFGetFieldInfo( hDBF, i, szTitle, &nWidth,
&nDecimals );
```

```
            if( bMultiLine )
            {
                printf( "%s: ", szTitle );
            }

/* --------------------------------------------------------------------
*/
/*      Print the record according to the type and formatting
*/
/*      information implicit in the DBF field description.
*/
/* --------------------------------------------------------------------
*/
            if( !bRaw )
            {
                if( DBFIsAttributeNULL( hDBF, iRecord, i ) )
                {
                    if( eType == FTString )
                        sprintf( szFormat, "%%-%ds", nWidth );
                    else
                        sprintf( szFormat, "%%%ds", nWidth );

                    printf( szFormat, "(NULL)" );
                }
                else
                {
                    switch( eType )
                    {
                      case FTString:
                        sprintf( szFormat, "%%-%ds", nWidth );
                        printf( szFormat,
                                DBFReadStringAttribute( hDBF, iRecord, i
) );
                        break;

                      case FTInteger:
                        sprintf( szFormat, "%%%dd", nWidth );
                        printf( szFormat,
                                DBFReadIntegerAttribute( hDBF, iRecord,
i ) );
                        /* ===========================================
Deepu's addition */
                        if(i==0)
                        {
                          Fndarr[countf] = DBFReadIntegerAttribute(
hDBF, iRecord, i );
                          countf = countf+1;
                        }
                        if(i==1)
                        {
                          Tndarr[countt] = DBFReadIntegerAttribute(
hDBF, iRecord, i );
                          countt = countt+1;
                        }
                        break;

                      case FTDouble:
                        sprintf( szFormat, "%%%d.%dlf", nWidth,
nDecimals );
                        printf( szFormat,
```

```
                                DBFReadDoubleAttribute( hDBF, iRecord, i
) );
                        if(i==4)
                        {
                          Distarr[countd] = DBFReadDoubleAttribute(
hDBF, iRecord, i );
                          countd=countd+1;
                        }
                        break;
                        /* ============================================
End of addition */
                      default:
                        break;
                    }
                }
            }

/* --------------------------------------------------------------------
*/
/*      Just dump in raw form (as formatted in the file).
*/
/* --------------------------------------------------------------------
*/
            else
            {
                sprintf( szFormat, "%%-%ds", nWidth );
                printf( szFormat,
                        DBFReadStringAttribute( hDBF, iRecord, i ) );
            }

/* --------------------------------------------------------------------
*/
/*      Write out any extra spaces required to pad out the field
*/
/*      width.
*/
/* --------------------------------------------------------------------
*/
          if( !bMultiLine )
          {
            sprintf( szFormat, "%%%ds", panWidth[i] - nWidth + 1 );
            printf( szFormat, "" );
          }

            if( bMultiLine )
                printf( "\n" );

          fflush( stdout );
      }
      printf( "\n" );
    }

    DBFClose( hDBF );

/*
======================================================================
DEBUG TRACE */
    printf("\n\nThe results after scanning the dbf files are: \n");
    printf("From Node Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%d ", Fndarr[i]);
```

```
    printf("\n");
    printf("To Node Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%d ", Tndarr[i]);
    printf("\n");
    printf("Distance Array :\n");
    for(i=0;i<numpairs;i++)
      printf("%7.4f ", Distarr[i]);
    printf("\n");

/* ================================================================= End
of Debug Trace */

/*
=========================================================================
============ */
/*   Convert the Obtained data in arrays into a From-To Matrix  - dp
                */
/*
=========================================================================
============ */
   for(i=0;i<numpairs;i++)
   {
      FrToMx[Fndarr[i]][Tndarr[i]] = 1;
      Distmat[Fndarr[i]][Tndarr[i]] = Distarr[i];
   }

/*
=========================================================================
DEBUG TRACE */
   printf("From-To Matrix :\n");
    for(i=1;i<numpairs;i++)
    {
      for(j=1;j<=numpairs;j++)
        printf("%d ", FrToMx[i][j]);
      printf("\n");
    }
   printf(" Distance Matrix :\n");
    for(i=1;i<numpairs;i++)
    {
      for(j=1;j<=numpairs;j++)
        printf("%7.4f ", Distmat[i][j]);
      printf("\n");
    }
/* ================================================================== End
of DEBUG TRACE */

  return( 0 );
}
```

```
#ifndef _SHAPEFILE_H_INCLUDED
#define _SHAPEFILE_H_INCLUDED

/**********************************************************************
*******
 * $Id: shapefil.h,v 1.20 2001/07/20 13:06:02 warmerda Exp $
 *
 * Project:  Shapelib
 * Purpose:  Primary include file for Shapelib.
 * Author:   Frank Warmerdam, warmerda@home.com
 *

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**********************************************************************
******
 *
 * $Log: shapefil.h,v $
 *
 * Revision 1.21  2002/06/15 07:10:00 Deepu Philip
 * included the requirements to have the From-To matrix generated.
 * defined constants nnede for the network model and node-arc incidence
matrix.
 *
```

```
 * Revision 1.20  2001/07/20 13:06:02  warmerda
 * fixed SHPAPI attribute for SHPTreeFindLikelyShapes
 *
 * Revision 1.19  2001/05/31 19:20:13  warmerda
 * added DBFGetFieldIndex()
 *
 * Revision 1.18  2001/05/31 18:15:40  warmerda
 * Added support for NULL fields in DBF files
 *
 * Revision 1.17  2001/05/23 13:36:52  warmerda
 * added use of SHPAPI_CALL
 *
 * Revision 1.16  2000/09/25 14:15:59  warmerda
 * added DBFGetNativeFieldType()
 *
 * Revision 1.15  2000/02/16 16:03:51  warmerda
 * added null shape support
 *
 * Revision 1.14  1999/11/05 14:12:05  warmerda
 * updated license terms
 *
 * Revision 1.13  1999/06/02 18:24:21  warmerda
 * added trimming code
 *
 * Revision 1.12  1999/06/02 17:56:12  warmerda
 * added quad'' subnode support for trees
 *
 * Revision 1.11  1999/05/18 19:11:11  warmerda
 * Added example searching capability
 *
 * Revision 1.10  1999/05/18 17:49:38  warmerda
 * added initial quadtree support
 *
 * Revision 1.9  1999/05/11 03:19:28  warmerda
 * added new Tuple api, and improved extension handling - add from
candrsn
 *
 * Revision 1.8  1999/03/23 17:22:27  warmerda
 * Added extern "C" protection for C++ users of shapefil.h.
 *
 * Revision 1.7  1998/12/31 15:31:07  warmerda
 * Added the TRIM_DBF_WHITESPACE and DISABLE_MULTIPATCH_MEASURE options.
 *
 * Revision 1.6  1998/12/03 15:48:15  warmerda
 * Added SHPCalculateExtents().
 *
 * Revision 1.5  1998/11/09 20:57:16  warmerda
 * Altered SHPGetInfo() call.
 *
 * Revision 1.4  1998/11/09 20:19:33  warmerda
 * Added 3D support, and use of SHPObject.
 *
 * Revision 1.3  1995/08/23 02:24:05  warmerda
 * Added support for reading bounds.
 *
 * Revision 1.2  1995/08/04  03:17:39  warmerda
 * Added header.
 *
 */

#include <stdio.h>
```

```
#ifdef USE_DBMALLOC
#include <dbmalloc.h>
#endif

#ifdef __cplusplus
extern "C" {
#endif

#ifndef SHPAPI_CALL
#define SHPAPI_CALL
#endif

#define SHPAPI_CALL1(x)       * SHPAPI_CALL

/************************************************************************
*/
/*                        Configuration options.
*/
/************************************************************************
*/

/* ---------------------------------------------------------------------
*/
/*      Should the DBFReadStringAttribute() strip leading and
*/
/*      trailing white space?
*/
/* ---------------------------------------------------------------------
*/
#define TRIM_DBF_WHITESPACE

/* ---------------------------------------------------------------------
*/
/*      Should we write measure values to the Multipatch object?
*/
/*      Reportedly ArcView crashes if we do write it, so for now it
*/
/*      is disabled.
*/
/* ---------------------------------------------------------------------
*/
#define DISABLE_MULTIPATCH_MEASURE

/************************************************************************
*/
/*                             SHP Support.
*/
/************************************************************************
*/
typedef     struct
{
    FILE        *fpSHP;
    FILE    *fpSHX;

    int           nShapeType;                 /* SHPT_* */

    int           nFileSize;                  /* SHP file */

    int         nRecords;
    int           nMaxRecords;
```

```
    int             *panRecOffset;
    int             *panRecSize;

    double  adBoundsMin[4];
    double  adBoundsMax[4];

    int             bUpdated;
} SHPInfo;

typedef SHPInfo * SHPHandle;

/* -------------------------------------------------------------------
*/
/*      Shape types (nSHPType)
*/
/* -------------------------------------------------------------------
*/
#define SHPT_NULL 0
#define SHPT_POINT      1
#define SHPT_ARC  3
#define SHPT_POLYGON    5
#define SHPT_MULTIPOINT 8
#define SHPT_POINTZ     11
#define SHPT_ARCZ 13
#define SHPT_POLYGONZ   15
#define SHPT_MULTIPOINTZ 18
#define SHPT_POINTM     21
#define SHPT_ARCM 23
#define SHPT_POLYGONM   25
#define SHPT_MULTIPOINTM 28
#define SHPT_MULTIPATCH 31


/* -------------------------------------------------------------------
*/
/*      Part types - everything but SHPT_MULTIPATCH just uses
*/
/*      SHPP_RING.
*/
/* -------------------------------------------------------------------
*/

#define SHPP_TRISTRIP   0
#define SHPP_TRIFAN     1
#define SHPP_OUTERRING  2
#define SHPP_INNERRING  3
#define SHPP_FIRSTRING  4
#define SHPP_RING 5

/* -------------------------------------------------------------------
*/
/*      SHPObject - represents on shape (without attributes) read
*/
/*      from the .shp file.
*/
/* -------------------------------------------------------------------
*/
typedef struct
{
    int             nSHPType;
```

```
    int             nShapeId; /* -1 is unknown/unassigned */

    int             nParts;
    int             *panPartStart;
    int             *panPartType;

    int             nVertices;
    double  *padfX;
    double  *padfY;
    double  *padfZ;
    double  *padfM;

    double  dfXMin;
    double  dfYMin;
    double  dfZMin;
    double  dfMMin;

    double  dfXMax;
    double  dfYMax;
    double  dfZMax;
    double  dfMMax;
} SHPObject;

/* --------------------------------------------------------------------
*/
/*      SHP API Prototypes
*/
/* --------------------------------------------------------------------
*/
SHPHandle SHPAPI_CALL
      SHPOpen( const char * pszShapeFile, const char * pszAccess );
SHPHandle SHPAPI_CALL
      SHPCreate( const char * pszShapeFile, int nShapeType );
void SHPAPI_CALL
      SHPGetInfo( SHPHandle hSHP, int * pnEntities, int * pnShapeType,
                  double * padfMinBound, double * padfMaxBound );

SHPObject SHPAPI_CALL1(*)
      SHPReadObject( SHPHandle hSHP, int iShape );
int SHPAPI_CALL
      SHPWriteObject( SHPHandle hSHP, int iShape, SHPObject * psObject
);

void SHPAPI_CALL
      SHPDestroyObject( SHPObject * psObject );
void SHPAPI_CALL
      SHPComputeExtents( SHPObject * psObject );
SHPObject SHPAPI_CALL1(*)
      SHPCreateObject( int nSHPType, int nShapeId,
                       int nParts, int * panPartStart, int *
panPartType,
                       int nVertices, double * padfX, double * padfY,
                       double * padfZ, double * padfM );
SHPObject SHPAPI_CALL1(*)
      SHPCreateSimpleObject( int nSHPType, int nVertices,
                             double * padfX, double * padfY, double *
padfZ );

void SHPAPI_CALL
      SHPClose( SHPHandle hSHP );
```

```
const char SHPAPI_CALL1(*)
      SHPTypeName( int nSHPType );
const char SHPAPI_CALL1(*)
      SHPPartTypeName( int nPartType );

/* --------------------------------------------------------------------
*/
/*      Shape quadtree indexing API.
*/
/* --------------------------------------------------------------------
*/

/* this can be two or four for binary or quad tree */
#define MAX_SUBNODE     4

typedef struct shape_tree_node
{
    /* region covered by this node */
    double  adfBoundsMin[4];
    double  adfBoundsMax[4];

    /* list of shapes stored at this node.  The papsShapeObj pointers
       or the whole list can be NULL */
    int           nShapeCount;
    int           *panShapeIds;
    SHPObject   **papsShapeObj;

    int           nSubNodes;
    struct shape_tree_node *apsSubNode[MAX_SUBNODE];

} SHPTreeNode;

typedef struct
{
    SHPHandle   hSHP;

    int           nMaxDepth;
    int           nDimension;

    SHPTreeNode   *psRoot;
} SHPTree;

SHPTree SHPAPI_CALL1(*)
      SHPCreateTree( SHPHandle hSHP, int nDimension, int nMaxDepth,
                     double *padfBoundsMin, double *padfBoundsMax );
void    SHPAPI_CALL
      SHPDestroyTree( SHPTree * hTree );

int   SHPAPI_CALL
      SHPWriteTree( SHPTree *hTree, const char * pszFilename );
SHPTree SHPAPI_CALL
      SHPReadTree( const char * pszFilename );

int   SHPAPI_CALL
      SHPTreeAddObject( SHPTree * hTree, SHPObject * psObject );
int   SHPAPI_CALL
      SHPTreeAddShapeId( SHPTree * hTree, SHPObject * psObject );
int   SHPAPI_CALL
      SHPTreeRemoveShapeId( SHPTree * hTree, int nShapeId );

void  SHPAPI_CALL
```

```
      SHPTreeTrimExtraNodes( SHPTree * hTree );

int    SHPAPI_CALL1(*)
      SHPTreeFindLikelyShapes( SHPTree * hTree,
                               double * padfBoundsMin,
                               double * padfBoundsMax,
                               int * );
int     SHPAPI_CALL
      SHPCheckBoundsOverlap( double *, double *, double *, double *, int
);

/************************************************************************
*/
/*                           DBF Support.
*/
/************************************************************************
*/
typedef     struct
{
    FILE    *fp;

    int         nRecords;

    int           nRecordLength;
    int           nHeaderLength;
    int           nFields;
    int           *panFieldOffset;
    int           *panFieldSize;
    int           *panFieldDecimals;
    char    *pachFieldType;

    char    *pszHeader;

    int           nCurrentRecord;
    int           bCurrentRecordModified;
    char    *pszCurrentRecord;

    int           bNoHeader;
    int           bUpdated;
} DBFInfo;

typedef DBFInfo * DBFHandle;

typedef enum {
  FTString,
  FTInteger,
  FTDouble,
  FTInvalid
} DBFFieldType;

#define XBASE_FLDHDR_SZ       32

DBFHandle SHPAPI_CALL
      DBFOpen( const char * pszDBFFile, const char * pszAccess );
DBFHandle SHPAPI_CALL
      DBFCreate( const char * pszDBFFile );

int   SHPAPI_CALL
      DBFGetFieldCount( DBFHandle psDBF );
int   SHPAPI_CALL
      DBFGetRecordCount( DBFHandle psDBF );
```

```
int   SHPAPI_CALL
      DBFAddField( DBFHandle hDBF, const char * pszFieldName,
                   DBFFieldType eType, int nWidth, int nDecimals );

DBFFieldType SHPAPI_CALL
      DBFGetFieldInfo( DBFHandle psDBF, int iField,
                       char * pszFieldName, int * pnWidth, int *
pnDecimals );

int SHPAPI_CALL
      DBFGetFieldIndex(DBFHandle psDBF, const char *pszFieldName);

int   SHPAPI_CALL
      DBFReadIntegerAttribute( DBFHandle hDBF, int iShape, int iField );
double      SHPAPI_CALL
      DBFReadDoubleAttribute( DBFHandle hDBF, int iShape, int iField );
const char SHPAPI_CALL1(*)
      DBFReadStringAttribute( DBFHandle hDBF, int iShape, int iField );
int     SHPAPI_CALL
      DBFIsAttributeNULL( DBFHandle hDBF, int iShape, int iField );

int SHPAPI_CALL
      DBFWriteIntegerAttribute( DBFHandle hDBF, int iShape, int iField,
                                int nFieldValue );
int SHPAPI_CALL
      DBFWriteDoubleAttribute( DBFHandle hDBF, int iShape, int iField,
                               double dFieldValue );
int SHPAPI_CALL
      DBFWriteStringAttribute( DBFHandle hDBF, int iShape, int iField,
                               const char * pszFieldValue );
int SHPAPI_CALL
     DBFWriteNULLAttribute( DBFHandle hDBF, int iShape, int iField );

const char SHPAPI_CALL1(*)
      DBFReadTuple(DBFHandle psDBF, int hEntity );
int SHPAPI_CALL
      DBFWriteTuple(DBFHandle psDBF, int hEntity, void * pRawTuple );

DBFHandle SHPAPI_CALL
      DBFCloneEmpty(DBFHandle psDBF, const char * pszFilename );

void  SHPAPI_CALL
      DBFClose( DBFHandle hDBF );
char    SHPAPI_CALL
      DBFGetNativeFieldType( DBFHandle hDBF, int iField );

#ifdef __cplusplus
}
#endif

#endif /* ndef _SHAPEFILE_H_INCLUDED */
```

```
============= Debug Trace output for matrix generation ==================
From Node Array :
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
To Node Array :
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Distance Array :
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
From-To Matrix :
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 Distance Matrix :
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

```
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

```
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000

======================== Reading Values form dbf file ================================

     FNODE_      TNODE_      LPOLY_      RPOLY_             LENGTH       JUNK_     JUNK_ID
UNIQUE_ID DIRPRE ROADNAME                       ROADTYPE DIRSUF ROADCLASS FRADDL
TOADDL     FRADDR     TOADDR     SPEEDLIMIT LANES CONDITION  DIRECTION SURFACE
COMMUNITY                        MUNL                             MUNR
COMMENTS                       COUNTY     UPDATE        ADRMETERS ROUTE O_DIRPRE
O_ROADNAME                     O_ROADTYPE O_DIRSUF
          1           2           0           0          194.31268      2006          6688
2010     (NULL)     ALLEY                          (NULL)     (NULL)     (NULL)
(NULL)     (NULL)     (NULL)     (NULL)       25        1    (NULL)     BD        GRAVEL
BOZEMAN                          BOZEMAN                          BOZEMAN
(NULL)                         GALLATIN   01-01-1999      120.740 (NULL)     (NULL)
(NULL)                         (NULL)       (NULL)
          2           3           0           0           99.52686      2008          6687
2012     (NULL)     ALLEY                          (NULL)     (NULL)     (NULL)
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(NULL)      (NULL)      (NULL)      (NULL)        25         1     (NULL)      BD          GRAVEL
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999       61.843 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           3           4            0             0            102.76741        2009          6686
2013       (NULL)      ALLEY                                  (NULL)      (NULL)      (NULL)
(NULL)      (NULL)      (NULL)      (NULL)        25         1     (NULL)      BD          GRAVEL
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999       63.857 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           2           5            0             0            64.43328         5817          1813
5853       N       3RD                                AVE       (NULL)      RESI       20           2
21          1             25           2     GOOD          BD         ASPHALT                 BOZEMAN
BOZEMAN                             BOZEMAN                                (NULL)
GALLATIN    01-01-1999        40.037 (NULL)      (NULL)        (NULL)
(NULL)      (NULL)
           1           6            0             0            50.52213         5844          1818
5880       N       5TH                                AVE       (NULL)      RESI       11          21
12          22            25           2     GOOD          BD         ASPHALT                 BOZEMAN
BOZEMAN                             BOZEMAN                                (NULL)
GALLATIN    01-01-1999        31.393 (NULL)      (NULL)        (NULL)
(NULL)      (NULL)
           7           8            0             0            61.15927        10236          1829
11461      N       5TH                                AVE       (NULL)      RESI        1           9
2           10            25           2     GOOD          BD         ASPHALT                 BOZEMAN
BOZEMAN                             BOZEMAN                                (NULL)
GALLATIN    01-01-1999        38.003 (NULL)      (NULL)        (NULL)
(NULL)      (NULL)
           7           9            0             0            186.49655       10237          1891
11462      W       MAIN                               ST        (NULL)      ARTE       500
636         501         635            25          4     GOOD          BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999      115.884 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           10          11           0             0            212.85074        10238         6667
11463      (NULL)      ALLEY                                  (NULL)      (NULL)      (NULL)
(NULL)      (NULL)      (NULL)      (NULL)        25         1     (NULL)      BD          GRAVEL
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999      132.259 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           12          13           0             0            113.05762       10275          1216
11500      S       GRAND                              AVE       (NULL)      RESI       2
36          1           37             25          2     (NULL)        BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999       70.251 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           14          12           0             0            99.52553        10276          1889
11501      W       MAIN                               ST        (NULL)      ARTE       237
201         236         200            25          4     GOOD          BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999       61.842 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           15          16           0             0            109.83167       10277          1234
11502      S       3RD                                AVE       (NULL)      (NULL)      37
1           36          2              25          2     GOOD          BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999       68.246 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           17          16           0             0            192.13651       10301          1890
11526      W       MAIN                               ST        (NULL)      ARTE       423
301         424         300            25          4     GOOD          BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
(NULL)                            GALLATIN    01-01-1999      119.388 (NULL)      (NULL)
(NULL)                            (NULL)       (NULL)
           17          18           0             0            57.99351        10302          1276
11527      S       5TH                                AVE       (NULL)      (NULL)      2
10          1           11             25          2     (NULL)        BD         ASPHALT
BOZEMAN                             BOZEMAN                                BOZEMAN
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(NULL)                              GALLATIN    01-01-1999       36.035 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          18          19              0           0            48.97864       10305         1277
11530      S       5TH                               AVE       (NULL)      (NULL)      12
22         13          21             25         2    (NULL)      BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       30.434 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          20          21              0           0          106.07825      10383         3948
11608      W       MAIN                              ST        (NULL)      ARTE       175
101        148         100            25         4    GOOD        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       65.914 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          22          23              0           0          119.82407      10392         6685
11617     (NULL)      ALLEY                               (NULL)      (NULL)      (NULL)
(NULL)     (NULL)      (NULL)       (NULL)        25         1     (NULL)     BD          GRAVEL
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       74.455 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          24          22              0           0            55.28443       10393         1788
11618      N       WILLSON                           AVE       (NULL)      RESI       34
20         35          19             25         2    GOOD        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       34.352 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          25          26              0           0          119.88271      10394         6666
11619     (NULL)      ALLEY                               (NULL)      (NULL)      (NULL)
(NULL)     (NULL)      (NULL)       (NULL)        25         1     (NULL)     BD          GRAVEL
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       74.492 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          27          25              0           0            62.96798       10395         1199
11620      S       WILLSON                           AVE       (NULL)      SECO       37
23         36          22             25         2    GOOD        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       39.126 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          28          22              0           0            59.68316       10403         3947
11628      N       WILLSON                           AVE       (NULL)      SECO       1
17         2           18             25         2    FAIR        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       37.085 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          28          29              0           0          117.27729      10407         3949
11632      W       MAIN                              ST        (NULL)      ARTE       47           1
98         2             25           4    GOOD         BD         ASPHALT                BOZEMAN
BOZEMAN                               BOZEMAN                              (NULL)
GALLATIN   01-01-1999         72.873 (NULL)      (NULL)       (NULL)
(NULL)       (NULL)
          30          3               0           0            51.40633       12669         1802
14016      N       GRAND                             AVE       (NULL)      RESI       40
22         43          21             25         2    GOOD        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       31.942 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
          3           12              0           0            62.26053       12670         1803
14017      N       GRAND                             AVE       (NULL)      RESI       20           2
19         1             25           2    GOOD         BD         ASPHALT                BOZEMAN
BOZEMAN                               BOZEMAN                              (NULL)
GALLATIN   01-01-1999         38.687 (NULL)      (NULL)       (NULL)
(NULL)       (NULL)
          31          2               0           0            48.72652       12671         1812
14018      N       3RD                               AVE       (NULL)      RESI       38
22         39          23             25         2    GOOD        BD           ASPHALT
BOZEMAN                               BOZEMAN                              BOZEMAN
(NULL)                              GALLATIN    01-01-1999       30.277 (NULL)      (NULL)
(NULL)                              (NULL)        (NULL)
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        25          21           0           0           50.36122     12676        3950
14023     S      WILLSON                        AVE      (NULL)     SECO      21           1
20        2             25         2    GOOD       BD         ASPHALT                BOZEMAN
BOZEMAN                         BOZEMAN    .                        (NULL)
GALLATIN   01-01-1999       31.293 (NULL)      (NULL)       (NULL)
(NULL)        (NULL)


The results after scanning the dbf files are:
From Node Array :
1 2 3 2 1 7 7 10 12 14 15 17 17 18 20 22 24 25 27 28 28 30 3 31 25 0 0 0 0 0 0 0 0 0 0
To Node Array :
2 3 4 5 6 8 9 11 13 12 16 16 18 19 21 23 22 26 25 22 29 3 12 2 21 0 0 0 0 0 0 0 0 0 0
Distance Array :
194.3127 99.5269 102.7674 64.4333 50.5221 61.1593 186.4966 212.8507 113.0576 99.5255
109.8317 192.1365 57.9935 48.9786 106.0782 119.8241 55.2844 119.8827 62.9680 59.6832
117.2773 51.4063 62.2605 48.7265 50.3612  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000
From-To Matrix :
0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 Distance Matrix :
 0.0000 194.3127  0.0000  0.0000  0.0000 50.5221  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000 99.5269  0.0000 64.4333  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000 102.7674  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
62.2605  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

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0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000  61.1593 186.4966   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000 212.8507
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000 113.0576   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
0.0000   0.0000
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99.5255   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
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119.8241  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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0.0000  0.0000  0.0000 119.8827  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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 0.0000 48.7265  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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APPENDIX – III

TIME STUDY FORMS AND SAMPLE DATA COLLECTION

The forms designed to conduct the time study on the door-to-door paratransit system was a major achievement in this project. These forms are carefully designed to capture the necessary information that was used to build the time estimation models for various activities.

Along with these forms there are some sample data included to portray the collection procedure and the amount of information captured. These forms could be used as a base point from which a complete design could be developed to conduct such a time study in any form of paratransit systems.

The forms designed to conduct the time study on the door-to-door paratransit system was a major achievement in this project. These forms are carefully designed to capture the necessary information that was used to build the time estimation models for various activities.

Along with these forms there are some sample data included to portray the collection procedure and the amount of information captured. These forms could be used as a base point from which a complete design could be developed to conduct such a time study in any form of paratransit systems.

Time Study Observation Form

Study No:
Vehicle:
Operator:
Observer:
Operation:
Climate:
Date:
Page of

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A				
B				
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Route Observation Form

Study No:

Vehicle:

Operator:

Observer:

Operation:

Date:

Page of

Routes Taken to Reach the Destination

Time Study Observation Form

Study No: ISE 102 HN **Vehicle:** #7 **Operator:** Ricard **Observer:** Deepu Philip

Operation: Transport people **Climate:** Sunny + dry **Date:** 07/16/2002 **Page** 1 **of** 4

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
			0.00		–	88293								
2 Betty	L	1	3:16	3:58	0:42	88294	1					M	A	elderly lady; walks slow.
2 Betty	U	1	8:03	8:49	0:46	88295	1					M	A	
8 Penny. ——	L	1	12:23	15:46	– –	88298	——	——	——	——		M	A	Tried; failed
7 Shane	L	1	22:05	23:07	1:02	88298			1			M	A	
7 Shane	UL	1	26:44	27:18	0:34	88299			1			M	A	
9 Marian	L	1	30:40	31:20	0:40	88301	1					L	N	
8 Penny	L	1	35:28	35:45	0:17	88301	1					M	N	
8 Penny	UL	1	41:54	42:13	0:19	88303	1					M	N	
9 Marian	UL	1	47:38	48:04	0:26	88304	1					M	N	
17 Phyllis	L	1	59:09	1:00:18	1:09	88308	1					L	N	walks slow
17 Phyllis	UL	1	1:03:42	1:09:04	0:22	88309	1					L	N	

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A	12:23	15:46	3:23	wait for penny.
B				
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time	11:41 am
Starting Time	8:00 am
Elapsed Time	
TEBS	
TEAF	

Total Check Time		Total Recorded Time	
Effective Time		Unaccounted Time	
Ineffective Time		Recording Error (%)	

Remarks:

Time Study Observation Form

Study No: TS75 TUE VTN **Vehicle:** U7 **Operator:** [illegible] **Observer:** Deepu Philip

Operation: Transport People. **Climate:** Sunny & dry **Date:** 04/16/2004 **Page** 2 **of** 4

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
16. Mike	L	1	1:05:40	1:06:2[illegible]	0:37	88309			/			L	N	
16. Mike	UL	1	1:10:31	1:11:00	0:29	88311			/			L	A	
19. Marie	L	1	1:13:27	1:15:38	2:11	88311	1					L	A	elderly; walks slow
20. Anna	L	1	1:19:04	1:21:08	2:04	88312	/					M	A	elderly - walks slow
19. Marie	UL	1	1:24:14	1:25:06	0:52	88313	/					M	A	
20. Anna	UL	1	1:27:56	1:28:41	0:45	88314	/					M	A	
31 Leo	L	1	1:33:12	1:35:29	—	88315	/	—	—	—	—	L	A	attempt failed
27. Lois	L	1	1:44:31	1:45:21	0:50	88316	/					L	A	
27. Lois	UL	1	1:49:09	1:49:56	0:47	88319	/					M	A	
39. Leonard Surd	L	1	2:28:39	2:29:12	0:34	88322	/					L	A	
32 Marie	L	1	2:33:06	2:34:10	1:04	88325	/					L	A	
41 Catherine	L	1	2:41:26	2:42:01	0:35	88327	/					L	A	

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A	1:49:56	1:53:44		Drive to gas. (88320)
B	1:53:44	1:58:57		Put gas;
C	1:58:57	2:03:36		Drive back (88321)
D	2:03:36	2:19:22		Wait at BSSC
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Time Study Observation Form

Study No: ISE NE MN
Vehicle: V+
Operator: [illegible]
Observer: Deepu Philip
Operation: Transport people
Climate: Sunny & dry
Date: 7/16/2002
Page 3 **of** 4

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
32. Marie	UL	1	2:44:34	2:46:20	1:46	88327	2					M	A	
40. Faye Wandle	L	1	2:44:34	2:46:20	1:46	88327	2					L	A	
40. Faye Wandle	UL	3	2.48.03	2.48.45	0:42	88327	3					L	A	
39. Leo	UL	3	2.48.03	2.48.45	0:42	88322	3					L	A	
41. Cathrine	UL	3	2.48.03	2.48.45	0:42	88327	3					L	A	
38. John.	L	1	2.51.58	2.52.49	0:51	88328			1			M	A	
49. Maria	L	1	2.59.21	3.01.01	0:40	88330	1					M	A	
48. Mike	L	1	3.04.19	3.04.48	0:29	88330			1			L	A	(No get out of driver
48. Mike	UL	1	3.07.25	3.08.58	1:33	88331			2			L	A	
49. Maria	UL	1	3.07.26	3.08.58	1:33	88331	1					L	A	
38. John	UL	1	3.07.26	3.08.58	1:33	88231			2			L	A	
47. Penny	L	1	3:13:38	3.14.30	0:52	88332	1					M	A	

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A				
B				
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Time Study Observation Form

Study No: BE WE MW **Vehicle:** V1 **Operator:** Richard **Observer:** Deepu Philip

Operation: Transport People. **Climate:** Sunny day **Date:** **Page** 4 **of** 4

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
47 · penny	UL	1	3:22:21	3:24:12	1:51	83333	1					H	A	
50: Phyllis	L	1	3:26:27	3:27:12	0:45	83334	1					L	A	
50 · Phyllis	UL	1	3:30:18	3:30:38	0:20	83334	1					H	A	
(Back to BS&C)	—	—	3:30:38	3:40:36		83336								

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A				
B				
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Route Observation Form

Study No: TSII TUE MN **Vehicle:** U7 **Operator:** Richard **Observer:** Deepu Philip

Operation: Transport people **Date:** 07/16/2002 **Page** 1 **of**

Routes Taken to Reach the Destination

Tamarack CT, S, Rouse, Griffin, Edgerly (pick betty), Edgerly, Griffin, S. Rouse (H), Tamarack CT, BSSC (drop betty)

N Tracy, Peach, Durston, (RV), Durston, N 19th (M), W Dickerson (L); (pick shane), W Dickerson (L), N 19th (H), College, Parking lot (L) (drop shane)

College, S 15th, W Koch, S 16th (L), W Olive, S 17th, (pick Marian), W Olive (L), S 19th (H), Durston (H), (LV) (pick penny), Durston (H),

Peach, N Wilson (M), S Wilson, W Olive, W Babcock, S Wallace (M), W Main (H), Highland Blvd (L), (Drop Marian) Kagy Blvd, S 11th (L),

W Koch (L), S 16th (L), W Olive (L), S 18th Ave (L) (pick phyllis), S 19th Ave, W Main (Drop phyllis), N 15th (L), Durston Rd (pick mike),

W. Peach (L), N. Wilson, W Beall, (Drop Mike), W Beall (L), N. Wilson, N. 5th, (pick mary), 5th (L), W. Aspen ST, N 7th (L),

Durston RD, N 15th (L), (pick Anna), N 15th (L), W Main, N 19th, (TQC Drop Marie) (L), N 20th (L), W Main, (Drop Anna)

College, W. Main, Fowler (L), Laredo (L), Prairie (L), Golden valley (L), (pick Leo, hild), Golden valley, Treasure (L), Ravalli (L),

Fowler (L), W Babcock, Western Dr (L), Durston RD, W. Peach, N 5th (L), (pick lois), N 5th (L), W Hemlock, N 7th, OAK ST,

N 5th Ave, (Drop lois), / N 5th, N 7th, Griffin Dr, (put gas), Griffin, S. Rouse (L), E Tamarack, (BSSC) /

N Tracy (L), Peach ST (L), Durston (H), gas trip → micheal grove, (pick up Wond), Micheal grove, Durston, N 21st (L), N 20th (L), ←

(pick up Marie), N 20th (L), Durston, N 7th (L), W Lamme, (pick Cathrine), W Lamme (L), N 7th, Peach ST (L), N 5th (L) (Drop

Marie, pick Fay), N 5th (L), Tamarack CT, (Drop Faye, Leo, Cathrine), Tamarack CT, N 7th, (pick

John), N Birch ST (L), N 7th (H), W Willard ST, N Tracy ST, E Lamme ST, (Alley pick maria) (L), E Lamme ST,

N Tracy ST, E Lamme, N Wilson, W Beall (pick Mike), N Wilson ST, W Peach ST, N Tracy, (Drop all)

N Tracy, Peach, Wilson, W Olive (pick penny), Babcock, N Tracy, Mendenhall St, N 7th (H),

Durston (L), (Drop penny) (L), Durston, N 15th, (pick phyllis), W Main ST, W Olive ST, S 19th Ave (H), S 18th Ave

(Drop phyllis), N 19th Ave (H), Durston, N 7th (H), Tamarack CT, (Stop at BSSC)

Time Study Observation Form

Study No: TSITUAF **Vehicle:** U7 **Operator:** Richard **Observer:** Deepu Philip

Operation: Transport people. **Climate:** Warm Sunny **Date:** 06/17/2002 **Page** 1 **of** 3

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
60. Leonard	L	1	0:00	0.42	0:42	88365	1					L	B	
76. Marjorie	L	1	7:39	8:35	0:	88367	1				1	L	B	walks slow
60. Leonard	UL	1	8:59	9:15		88367	1					M	B	
75. Mary Dunn.	L	1	11:33	12:12		88368	1					M	B	starts to rain.
76. Marjorie	UL	1	20:35	21:09		88372	1					M	B	
84. Sherrie	L	1	26:48	27:53		88374			1			L	B	
75. Mary	UL	1	31:08	31:57		88375						H	B	
80. Tammy.	L	1	36:25	38:26		88376		1				H	B	
80. Tammy, 84. Sherrie	UL	2	43:50	45:24		88377	1	1				M	N	
91. Peggy	L	2	50:01	53:48		88378	1					H	A	
93. Elizabeth	L	2	50:01	53:48		88378	1					H	A	in a walker.
91. Elizabeth	UL	1	56:02	56:51		88379	1					H	A	in a wali

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A				
B				
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time	1:27 pm	Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Time Study Observation Form

Study No: [illegible] **Vehicle:** [illegible] **Operator:** [illegible] **Observer:** Deepu Philip

Operation: **Climate:** Warm Sunny **Date:** 06/07/2002 **Page** 2 **of** 3

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
91. Peggy	UL	1	1:00:04	1:0:39		88379	1					L	A	(Side door)
99. Betty	L	1	1:17:55	1:18:54		88380	1					L	A	
99. Betty	UL	1	1:22:10	1:22:56		88382	1					H	A	
95. Peg	L	1	1:27:32	1:28:12		88383	1					L	A	
95. Peg	UL	1	1:31:36	1:31:59		88384	1					L	A	
* 104 · Tammy	L	1	1:35:24	1:36:26		88385		1				L	A	
104 · Tammy	UL	1	1:42:58	1:44:12		88386		1				H	A	
102 · Faye	L	1	1:48:42	1:49:31		88388	1					L	A	
102 · Faye	UL	1	1:51:09	1:51:56		88388	1					L	N	
97 · Chris Kenyon	L	1	1:53:32	1:55:36		88388		1						1:53:22 1:55:05
98 · Mike Leavitt	L	1	1:53:32	1:55:26		88386			1					
103 · Cathrin [illegible]	L	1	1:53:32	1:55:36		88388	1							

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A	1:00:39	1:05:26		Back to DSSC for Break (88380)
B	1:05:26			
C				
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Time Study Observation Form

Study No: ST-(OAP **Vehicle:** A+ **Operator:** [illegible] **Observer:** Deepu Philip

Operation: **Climate:** Warm dry **Date:** 06/17/2002 **Page** 3 **of** 3

Element & Cycle Details			WATCH TIME			Attributes						Traffic	Capacity	Remarks about the passenger
Number and Name	EVNT	NOP	W1	W2	OT	ODO	E	W	D	O	SP	L/M/H	A/N/B	
103. Cathri	UL	1	1:59:28	1:59:59		88389	1					M	N	
97. Chri Kings	UL	1	2:04:20	2:06:51		88390	1					L	N	
98. Mike	UL	1	2:09:41	2:10:22		88391			1			L	N	
111. Shane Ramy	L	1	2:35:46	2:36:11		88394			1					
111. Shane ramy	UL	1	2:39:01	2:39:40		88395			1					
114. Sherry	L	1	2:51:08	2:53:10		88397			1					
114. Sherry	UL	1	2:57:58	2:58:08		88399			1					
109. Magnik	L	1	3:04:54	3:05:11		88401	1							
109. Magnik	UL	1	3:16:35	3:17:15		88404	1							
115. Janet	L	1	3:22:20	3:22:55		88406	1							
115. Janet	UL	1	3:25:58	3:26:31										

Summary

Total OT (Observed Time)		
Rating		
Total NT (Normal Time)		
No. Of Observations		
Average NT		
Percentage Allowances		
Elemental ST		
No. Of Occurances		
Standard Time		

Foreign Elements

Sym	W1	W2	OT	Description
A	2:10:32	2:14:42		~~Waste~~ at BSSC - Drink
B	2:14:42	2:30:38		Wait at BSSC
C	3:26:31	3:27:45		Back to BSSC
D				
E				
F				
G				

Allowance Summary

Personal Needs	
Basic Fatigue	
Variable Fatigue	
Special	
Total Allowance Percentage (%)	

Time Check

Finishing Time		Total Check Time		Total Recorded Time	
Starting Time		Effective Time		Unaccounted Time	
Elapsed Time		Ineffective Time		Recording Error (%)	
TEBS					
TEAF					

Remarks:

Route Observation Form

Study No: ISU TU AP
Vehicle: V7
Operator: Zicheng
Observer: Deepu Philip
Operation:
Date: 06/17/202
Page 1 **of**

Routes Taken to Reach the Destination

(BSSC) (Pick Leonard) - Tamarack CT, N 7th, Durston Micheal Grove, (Pick Magenta) ; Micheal Grove ;
(L) (L) (L)
(Drop Leo) Micheal Grove ; W Babcock St, Yellowstone Ave, (Pick Mary) Yellowstone Av, W Ravalli CT
(L) (L) (L) (L)
Fowler, (~~Huffine Ln~~) W. Main ST, college st, S 19th Ave, W Kagy Blvd, (Dropped Magenta), W Kagy Blvd,
(L) (↑Plant St) (L)
S 11th Ave, Drive way, college, S 15th Ave, (pickup Shellie) S 15th Ave, W. Koch St, S 11th Ave,
(H) (L) (L) (L) (L) (L)
N. Main ST, N 7th Ave, (Drop Mary) N 7th Ave, Oak St, (driveway) (Load Tany), oak street, N 7th,
(H) (H) (Drop through DC) (H)
W. Peach ST, N Willson ST, ^ N Tracy Ave, W Villard ST, N 7th Ave, Durston Rd, (Pick Peggy, Elizabeth)
(H) (H)
Durston Rd, (Dropped Elizabeth), Durston Rd, N 11th Ave, W Lamme, S 9th Ave, (Alley - drop Peggy)
(H) (H) (L) (L)
| W Main St, S 7th Ave, W Tamarack CT, (Stay at BSSC) |
|→ N Turn ←|

| N Tracy, Peach St, Durston Rd, N 11th Ave, college, Driveway (Pick Shane), Driveway, college,
W Richardson ST, (Drop Shane), W Richardson, S 19th Ave, W Babcock St, S. Willson Ave, W Villard ST,
(L) (L) (H) (H)
(Pick up Sherrie), N Tracy Ave, Mendenhall ST, S Willson Ave, W Olive St, S. 11th, W. Koch St, S. 15th, (Drop She
15th, College, S Willson Dr, W Mason ST, S Tracy St, (Pick Magenta) W Kagy Blvd, S 11th Ave, W Main St
(L) (H)
W Babcock St, Micheal Grove Ave, Durston Rd, (Pick up Janet), Durston Rd, Peach, S 5th Ave, (drop
(L) (L)
Janet) S 5th Ave, Tamarack CT, (Bus at BSSC)

Richard U7

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LICENSE
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MLG @ FUELING 88320
FUEL ADDED 16.8
OIL ADDED

MLG START 88293
MLG END 88407
DRIVER RW4

TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	E L	W H	D S	O T
1	U6	8:00	MIRIAM MATTHEWS DM #302	323 N.CHURCH				Y			
2	U7	8:00	BETTY HEASER 315 E. GRIFFIN #25	BSSC	805	805	810	Y			
3	U6	8:30	KATHERINE REED SPRINGMEADOWS	BSSC/RSVP				Y			
4	U6	8:30	MARIE WYRAUCH DM	BSSC HANDCRAFTERS BSCC HANDCRAFTERS				Y			
5	U6	8:30	JOYE WADDELL SPRINGMEADOWS	BSSC RSVP				Y			
6	U6	8:30	IRENE BENDER SPRINGMEADOWS #128	BSSC/RSVP				Y			
7	U7	8:30	SHANE RAMSEY 2200 W.DICKERSON #21	ASMSU DAYCARE	822	824	828			Y	
8	U7	8:30	PENNY MCCLELLAND LV	5 W OLIVE	814	816	attempt			Y	
					836	836	843				
9	U7	8:30	MARIAN STEPHENS 1712 WEST OLIVE #52	HATHAWAY:HP3,L3	831	832	848	Y			
10	U8	8:30	EDNA MORTENSON 4 MARJORIE LN.	BSSC RSVP				Y			
11	U8	8:30	GREG ANCE 219 N.BROADWAY-MANHA	EAGLE MOUNT					Y		
12	U8	8:30	SKIP CARLSON 804 CHURCH- BELGRADE	POST OFFICE-BOZ						Y	
13	U6	8:50	BARBARA MULKIN+1 4050 W.BABCOCK #55	BORGENICHT:HP3,L2				Y			Y
14	~~U7~~	9:00	CHANTEL TUMBLESON 17 W.LAMME #106	237 W.MAIN	CA	—					Y
15	U6	9:00	HELEN WASHBURN ARTEMUS 202 'A'	1ST INTERSTATE BANK				Y			
16	U7	9:00	MIKE LEAVITT 418 N 15TH	MVCC	906	907	911			Y	
17	U7	9:00	PHYLLIS SCHLECHTEN 220 S 18TH #C	OSCO	900	901	905	Y			
18	U6	9:30	CHANTEL TUMBLESON 237 W.MAIN	SMITH'S							Y
19	U7	9:30	MARIE COLE DM #106	T & C	914	915	925	Y			
20	U7	9:30	ANNA LEE PURDY 508 N.15TH AVE.	SHEER PERFECTION	918	921	929	Y			

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TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	E L	W H	D S	O T
21	U8	9:30	FLORENCE BOLLMAN SPRINGMEADOWS #104	7600 SHEDHORN DR. ONE WAY				Y			
22	U6	10:00	PEG HILEMAN 5 W KOCH	BOZ PUB LIBRARY				Y			
23	U6	10:00	NELLIE BRELSFORD ASPEN POINT #318	THE PERK:HPM				Y			
24	U6	10:00	MARIAN STEPHENS HATHAWAY:HP3,L3	1712 W.OLIVE WILL CALL				Y			
25	U6	10:00	HELEN WASHBURN 1ST INTERSTATE BANK	ARTEMUS				Y			
26	U6	10:00	DOROTHY DERHAM 407 SOUTH TRACY AVE.	LIBRARY				Y			
27	U7	10:00	LOIS PARSONS DM #402	WAL-MART	945	946	950	Y			
28	~~U7~~	10:15	CHANTEL TUMBLESON SMITH'S	217 W.LAMME	CA	—					Y
29	U6	10:30	MYRTLE RAMHORST 505 IVAN DR	ASPEN POINTE				Y			
30	U6	10:30	BARBARA MULKIN+1 BORGENICHT:HP3,L2	4050 W.BABCOCK#55 WILL CALL				Y			Y
31	U7	10:30	LEO VONDALL 3508 GOLDEN VALLEY	BSSC	933	935	attend			Y	
32	U7	10:30	MARIE COLE T & C	DM	1034	1035	1046	Y			
33	U8	10:30	DELORES BENTON DM	SUSIE'S SALON				Y			
34	U8	10:30	JUAN MONSERRATE 1000 N.17TH #170	1103 REEVES ROAD				Y			
35	U6	11:00	CHRIS KAMPS CHEQ #11	BSSC					Y		
36	U6	11:00	EDITH SPENCER 2303 S.3RD AVE.	BSSC				Y			
37	U6	11:00	ROBERT HOWE CHEQ #17	HOLIDAY INN ONE WAY				Y			
38	U7	11:00	JOHN HANLEY BOZEMAN INN	BSSC	1052	1053	1109	Y			
39	U7	11:00	LEONARD SCHWIND 50 MICHAEL GROVE	BSSC	1028	1028	1049	Y			
40	U7	11:00	FAYE WAARALA DM	BSSC	1045	1046	1049	Y			
41	U7	11:00	CATHERINE ENGDAHL 120 N.8TH ALLEY	BSSC	1042	1043	1049	Y			
42	U7	11:00	ANNA LEE PURDY SHEER PERFECTION	508 N.15TH WILL CALL	CA			Y			

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TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	E L	W H	D S	O T
43	U8	11:00	DOROTHY HULTMAN 1100 W CENTRAL	BSSC				Y			
44	U8	11:00	ANNA HENTON 624 MOONBEAM LA.	JOHNNY CARINO'S ONE WAY						Y	
45	U8	11:00	GERALD ANTONOVICH 210 QUINELLA #1	DEIBERT:HP2,L1						Y	
46	U8	11:00	VIRGINIA SCHWARTZ 1006 CARDINAL #210	OSCO DRUG	CA	—		Y			
47	U6	11:15	PENNY MCCLELLAND 5 W. OLIVE	LV	1114	1115	1123			Y	
48	U7	11:15	MIKE LEAVITT MVCC	BSSC	1103	1105	1109			Y	
49	U7	11:15	MARIE DALIO 116 N BOZEMAN	BSSC	1100	1101	1109	Y			
50	U6	11:30	PHYLLIS SCHLECHTEN MCDONALD'S	220 S.18TH	1127	1128	1131	Y			
51	U8	11:30	JUAN MONSERRATE 1103 REEVES ROAD	1000 N.17TH				Y			
52	U6	1:00	KATHERINE REED BSSC/RSVP	SPRINGMEADOWS				Y			
53	U6	1:00	MARIE WYRAUCH BSSC HANDCRAFTERS	A/C				Y			
54	U6	1:00	JOYE WADDELL BSSC RSVP	SPRINGMEADOWS				Y			
55	U6	1:00	IRENE BENDER BSSC/RSVP	SPRING MEADOWS				Y			
56	U6	1:00	GERALD ANTONOVICH DEIBERT:HP2,L1	FOOD BANK WILL CALL						Y	
57	U7	1:00	MARY GROSETH 1 ASPIN POINTE B-206	THE PERK:HPM	1241	1249	1251	Y			
58	U6	1:00	EDITH SPENCER BSSC	2303 S.3RD.				Y			
59	U7	1:00	LEO VONDALL BSSC	3508 GOLDEN VALLEY	CH	—	—			Y	
60	U7	1:00	LEONARD SCHWIND BSSC	50 MICHAEL GROVE	127	128	136	Y			
61	U7	1:00	LOIS PARSONS WAL-MART	DM	117	118	124	Y			
62	U7	1:00	PEARL WHITMAN ASPEN POINTE A-211 2	M/A	1241	1249	1252		Y		
63	U8	1:00	JANE MARSHALL BSSC/RSVP	REACH				Y			
64	U8	1:00	JOHN HANLEY BSSC	REACH				Y			

?

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TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	E L	W H	D S	O T
65	U8	1:00	LIBRARY SHUTTLE BOZEMAN LIBRARY	BELGRADE LIBRARY							Y
66	U8	1:00	EDNA MORTENSON BSSC RSVP	4 MARJORIE LN				Y			
67	U8	1:00	SKIP CARLSON HASTINGS	804 CHURCH						Y	
68	U8	1:00	VIRGINIA SCHWARTZ OSCO DRUG	1006 CARDINAL	CA	—	—	Y			
69	U8	1:00	DOROTHY DERHAM LIBRARY	407 S.TRACY				Y			
70	U7	1:15	ELIZABETH HAWTIN LV	GCRH	103	104	105	Y			
71	U7	1:15	STEPHANIE CONANT ARCADIA 627 'B'	WAL-MART	108	110	118		Y		
72	U6	1:30	MARGARITE CHRISTNSON SPRINGMEADOWS #106	K-MART				Y			
73	U6	1:30	STEPHANIE SODDY 606 N.4TH/BACK	U.S.BANK					Y		
74	U7	1:30	PAM BILLMAN +1 32 MICHAEL GROVE	333 HAGGERTY LN.	CA	—	—			Y	Y
75	U7	1:30	MARY DUNCAN 111 S.YELLOWSTONE #4	REALISTIC DESIGN ONE WAY	138	139	158	Y			
76	U7	1:30	MARGUERITE SMITH 211 MICHAEL GROVE'B'	MONSON:115 W.KAGY	135	136	148	Y			
77	U8	1:30	DELORES BENTON SUSIE'S	AM.FED.DRIVE-THRU				Y			
78	U8	1:30	BILL MACHES 703 OAKWOOD DR.	MALL ONE WAY				Y			
79	U6	1:45	MAE TORSDAHL ASPEN POINTE A-116	M/A				Y			
80	U7	1:45	TAMMY J. WALLING 1062 OAK #12	M/A BACK	204	206	213			Y	
81	U8	1:55	DELORES BENTON AM.FED.DRIVE-THRU	DM				Y			
82	U6	2:00	NELLIE BRELSFORD THE PERK:HPM	ASPEN POINTE				Y			
83	U6	2:00	MYRTLE RAMHORST ASPEN POINTE	505 IVAN DR.				Y			
84	U7	2:00	SHERRIE WELZEL 414 S 15TH	M/A BACK	154	155	213			Y	
85	U8	2:00	LIBRARY SHUTTLE BELGRADE LIBRARY	BZN LIBRARY							Y
86	U8	2:00	WALTER DUTTON 3093 SPRINGHILL RD.	ALTA P/T				Y			

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TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	EL	WH	DS	OT
87	U6	2:15	MARY GROSETH THE PERK:HPM	ASPEN POINTE WILL CALL				Y			
88	U6	2:30	MARGARITE CHRISTNSON K-MART	SPRINGMEADOWS				Y			
89	U6	2:30	GERALDINE CALLAHAN DM #211	201 S.WALLACE				Y			
90	U6	2:30	PEARL WHITMAN M/A	ASPEN POINTE WILL CALL					Y		
91	U7	2:30	PEGGY DUNN GCRH	NYE'S CLOTHESLINE NO RETURN	217	221	224	Y			
92	U7	2:30	MARIE WYRAUCH A/C	DM WILL CALL	CA	—	—	Y			
93	U7	2:30	ELIZABETH HAWTIN GCRH	LV	217	221	227	Y			
94	U8	2:45	GREG ANCE EAGLE MOUNT	219 N.BROADWAY					Y		
95	U6	3:00	PEG HILEMAN BOZ LIBRARY	5 W. KOCH	254	255	259	Y			
96	U6	3:00	PAM BILLMAN +1 333 HAGGERTY LN.	32 MICHAEL GROVE WILL CALL	CA	—	—			Y	Y
97	U7	3:00	CHRIS KAMPS BSSC	CHEQ #11	320	322	334		Y		
98	U7	3:00	MIKE LEAVITT BSSC	418 N 15TH	320	322	331			Y	
99	U7	3:00	BETTY HEASER BSSC	315 E.GRIFFIN#25	244	245	249	Y			
0* 1	U7	3:00	HELEN BROUGHAM BSSC DAYCARE	2400 W.DURSTON #6	CA	—		Y			
0* 2	U7	3:00	FAYE WAARALA BSSC	DM	315	316	318	Y			
0* 3	U7	3:00	CATHERINE ENGDAHL BSSC	120 N.8TH	300	302	307	Y			
0* 4	U7	3:00	TAMMY J. WALLING M/A BACK	1062 OAK #12 WILL CALL	302	304	311			Y	
0* 5	U8	3:00	DOROTHY HULTMAN BSSC	1100 W CENTRAL				Y			
0* 6	U8	3:00	GERALD ANTONOVICH FOOD BANK	210 QUINELLA						Y	
0* 7	U8	3:15	WALTER DUTTON ALTA P/T	3093 SPRINGHILL RD.				Y			
0* 8	U6	3:30	MAE TORSDAHL M/A	ASPEN POINTE WILL CALL				Y			
0* 9	U7	3:30	MARGUERITE SMITH MONSON:115 W.KAGY	211 MICHAEL GR. WILL CALL	421	432	444	Y			

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TR	VH	PCKUP TIME	FROM	DEST	ARRIV TIME	DEPRT TIME	DRPFF TIME	E L	W H	D S	O T
0* 10	U6	4:00	GERALDINE CALLAHAN 201 S.WALLACE	DM WILL CALL				Y			
0* 11	U7	4:00	SHANE RAMSEY ASMSU	2200 W DICKERSON	403	404	406			Y	
0* 12	U8	4:15	STEPHANIE CONANT WAL-MART	ARCADIA					Y		
0* 13	U6	4:30	STEPHANIE SODDY U.S.BANK	606 N.4TH WILL CALL					Y		
0* 14	U7	4:30	SHERRIE WELZEL M/A BACK LOT	414 S.15TH AVE.	416	419	425			Y	
0* 15	U7	4:30	JANET LAIR GCRH	DM	448	449	453			Y	

APPENDIX - IV

LOAD TIME ANALYSIS DETAILS

The aim of this analysis was to identify potential factors that could influence the passenger loading times of Galavan transit system. The factors that are affecting the load times were identified as said in the main report. These factors were then individually analyzed with various statistical methods. The methods included scatter plot, box plot, simple regression, residual analysis etc. The individual analysis accounted for the variability explained by these factors when taken individually.

While conducting the time study itself it was evident that it always took more time to load a passenger in a wheel chair compared to a normal elderly person. This was also observed true for the disabled passengers who are on walking appendages like walker, or blind etc. To statistically verify and substantiate this observation the data was analyzed for those categories of passengers. The results are summarized in time estimation section of the final report. The scatter plot, simple regression and other statistical methods used for the analysis are available at the end of this appendix as graphs.

It was observed that the mean load times for Disabled Passengers is less compared to the elderly people. This was explained by the fact that most of the disabled passengers were young and the disabilities were due to some syndromes rather than severe physical disabilities. The mean load time for the Special Category passengers were more compared to the elderly and disabled. The passengers in special category were those that were partially blind, passengers on walkers, and passengers with small kids. They all move slowly or had special attachments to load like car seat, folding walker etc. That made their loading time more compared to the passengers in Elderly and Disabled category.

The classifications of the passengers were quite important in such a detailed analysis. The transit authority definitions were used for the classification. Classification currently followed in Galavan is based on these guidelines. The main classifications for the passenger types are as given below. The coding approach was the foundation in developing the multiple regression models. The coding approach is also explained along with the passenger type definitions.

- **Passenger Type**
    - EL – Elderly passengers: Above 60 years of age and with no physical disabilities. The permissible values are –
        - 0 – if there is no elderly person loaded from a point.
        - > 0 – depending on the number of elderly passengers loaded from a single point.
    - WC – Wheel chair passengers: Any age unable to walk, so that the use of wheel chair is necessary for movement. The permissible values are –
        - 0 – if there is no wheel chair passenger loaded from a point.
        - > 0 – depends on the number of wheel chair passengers loaded from a single point.
    - DB – Disabled passengers: Any age with an inability to perform normal human activities. In Galavan most disabled people are of younger age and syndromes as disabilities.
        - 0 – if there is no disabled passenger loaded from a point.

    - > 0 – depends on the number of disabled passengers loaded from a single point.
- SP – Special category passengers: They include partially blind passengers, passengers on walkers, and passengers with kids who need kid seat to be fixed. The permissible values are:
    - 0 – if there is no special category passenger loaded from a point.
    - > 0 – depends on the number of special category passengers loaded from a single point.

- **Vehicle Type**

The effect of the vehicle on load times can be significant. To load a normal passenger (elderly), in the big buses the driver can sit in his seat and operate the passenger-loading door with a lever. In the case of smaller vehicle the driver has to get out of the vehicle and open the sliding door to load a normal passenger (elderly).

To study the effect all the vehicles were grouped into two. Category 1 contains the vehicles with electrical wheel chair lift and lever operated door. Category 2 contains the vehicles with manual folding ramp for wheel chair loading and sliding doors.

Load times for each included category of vehicles were plotted as scatter diagram, means, simple regression etc to analyze the impact of vehicle type on passenger loading and unloading. These analyses are included after this appendix for detailed technical reference. The biggest effect was on wheel chair passengers hence they were studied in detail. Table 1give the summary of wheel chair loading procedure on both vehicle categories.

Table 1 - Steps in loading a wheel chair passenger on available vehicle categories

Sl No	Element Description	Start Point	End Point
1	Walk to the Side Door	Vehicle in Parking Gear	Stop in front of Door
2	Open Side Door	Grab Door Handle	Release Door Handle
3	Unfold Ramp	Grab Operating Switch/Handle	Ramp at floor fully extended
4	Move W.C to ramp	Walk to Wheel Chair	W.C just in front of Ramp/Lift
5	Load Wheel Chair	Push W.C to Ramp/Lift	Position W.C at Strapping Bay
6	Strap Wheel Chair	Lock Wheels of W. C	Lock the W. C Seat Belt
7	Fold Ramp	Move to Switch/Handle	Ramp back in folding position
8	Close Side Door	Grab Door Handle	Release Door Handle
9	Walk back and Go	Start from the Side Door	Put vehicle in Drive Gear

Similar procedures were to be completed to unload a passenger on a wheel chair from both vehicle categories. Table 2 explains the unloading procedures on both vehicle categories.

Table 2 - Steps in unloading a wheel chair passenger on available vehicle categories

Sl No	Element Description	Start Point	End Point
1	Walk to the Side Door	Vehicle in Parking Gear	Stop in front of Door
2	Open Side Door	Grab Door Handle	Release Door Handle
3	Unfold Ramp	Grab Operating Switch/Handle	Ramp at floor fully extended
4	Unstrap Wheel Chair	Unlock the W. C Seat Belt	Unlock Wheels of W. C
5	Unload Wheel Chair	Move W.C from Strapping Bay	W.C at ground securely
4	Move W.C away	Move W.C from Ramp/Lift	Return to Ramp/Lift Control
7	Fold Ramp	Move to Switch/Handle	Ramp back in folding position
8	Close Side Door	Grab Door Handle	Release Door Handle
9	Walk back and Go	Start from the Side Door	Put vehicle in Drive Gear

The exact effect of these different types of doors could not be studied in detail presently because there were no vehicles available in categories with Electrical Wheel Chair lift and sliding doors and Manual Folding ramps with Lever Operated Doors. If loading and unloading times were available for these setups, the hypothesis could be verified. This way the best configuration of loading and unloading devices for a vehicle meant for paratransit operation could be found out.

- **Driver Experience**

Since the decision of whom to be picked up and when, was being taken by the drivers. Also the routes to reach the designated locations are decided by them. The experience of the drivers can have an impact on the load and unload times. A new driver with lesser experience could take more time to load/unload passengers of different category in comparison to an experienced driver.

To analyze the effect of driver experience on the loading and unloading times initial analysis were done with load and unload times plotted as scatter diagram to recognize patterns. The details of statistical analysis can be found at the end of this section. The drivers were assigned numbers like 1, 2, 3, 4 etc in the decreasing order of experience. So a driver numbered 4 will have lesser experience compared to a driver labeled 2. This will help in the doing the statistical analysis as the variables should be numerical values rather than alphanumeric like names.

- **Passenger Type X Vehicle**

The vehicle loading mechanism can affect the loading times of certain types of passengers. This was noted most in the case of wheel chair passengers. During the time study itself it was evident that the vehicles with electrical wheel chair lift took more time to load in comparison with the manual-folding ramp. This was considered as an interaction of passenger type and vehicle.

In order to verify the hypothesis that the manual wheel chair loading was faster than the electrical wheel chair loading, a time study was conducted on the event to identify each element. This helped to isolate the factors that are independent of the mechanical configuration that affects the load and unload times. Table 3 gives the elements considered in the time study and its relation to the mechanicals of the wheel chair lift configuration.

Table 3 - Steps in loading a wheel chair passenger on manual folding ramp configuration

Sl No	Element Description	Mech. Relation	Explanation
1	Walk to the side door	Dependent	The W.C facility is at navigator side
2	Open/Close side door	Dependent	Door configuration takes its own time
3	Fold/Unfold ramp	Dependent	Manual/Electrical as per construction
4	Move W.C to/away ramp	Independent	Depends only on location of passenger
5	Load Wheel Chair	Dependent	Push/Lift based on configuration of lift
6	Strap/Unstrap W. C	Dependent	Single/3 straps based on configuration
7	Walk back and Go	Dependent	W.C facility to driver's door

It was evident that the total effective load time was the difference of total load time and time for moving wheel chair to or away from ramp. This was because some passengers usually wait outside the home and hence the driver has to travel lesser distance to push the wheel chair passenger to vehicle.

Though this study was conducted on a small available sample, the times observed in all cases were comparable. The samples of the time study with its forms are included in at the end of this section for further reference.

DETAILED ANALYSIS

Having formed a hypothesis about which all variables will be significant in the final multiple regression model for predicting load times, a step-by-step detailed analysis was conducted. For that the first step was to designate the variables that are to be used in the model with representative names.

To do the multiple regression the variables that were found important during the preliminary analysis were added one by one to the model. By adding a new variable some of the variables become more significant and others loose their significance. The RSquare value of the model is constantly monitored while adding each new variable to see how well the addition of the variable explains the variability in the system. A F-ratio test was conducted for each newly added variable to establish its significance. The analysis started with a multiple regression using the number of elderly and wheel chair passengers as variables. The model thus generated is represented in Equation 1.

$$\mathbf{L_{est} = \alpha_0 + \alpha_1.Y_1 + \alpha_2.Y_2;}$$

Where L_{est} is the predicted Load Time

$$\mathbf{L_{est} = 40.33 + 55.69\ Y_1 + 148.88\ Y_2;}$$

Equation 1 - Initial Multiple regression model for load time estimation

The RSquare value for this model is found to be 0.4868. This means that the model explains 48.68% of the variability in the system. Also the coefficients of the equation make physical sense too. As the number of elderly passengers increase the load time increase. It is the case with wheel chair passengers too. Also the increase of load time is more if the passenger is of wheel chair category, which was established in the preliminary analysis.

The t-ratio evaluation for finding the significance for each of the factors was conducted. The procedure is the same as the hypothesis testing in statistics. In this regard the null hypothesis and the alternative hypothesis were as follows.

H_0: $\alpha_1 = 0$; $\alpha_2 = 0$. (Insignificance).
H_1: $\alpha_1 \neq 0$; $\alpha_2 \neq 0$. (Significance).

The observed values of probability was < 0.0001. This establishes the significance of the factors and thus the null hypothesis gets rejected and the alternative hypothesis gets accepted (significance). The statistical details of all these analysis are available at the end of this appendix.

The analysis continued by adding variables into the system and monitoring the RSquare values. When all the variables were added to the system, a good RSquare fit was obtained. But some coefficients never made sense physically and the F-ratio of some of the parameters were so high that they are pretty insignificant in the system.

The model that contains all the terms was obtained as shown in Equation 2. This model was then subjected to an F-ratio test to find the significance of all terms involved.

$$\mathbf{L_{est} = \alpha_0 + \alpha_1.Y_1 + \alpha_2.Y_2 + \alpha_3.Y_3 + \alpha_4.Y_4 + \alpha_5.Y_5 + \alpha_6.Y_6 + \alpha_7.Y_7 + \alpha_{26}.Y_{26} + \alpha_8.Y_8;}$$

Where L_{est} – estimated Load Time

$$\mathbf{L_{est} = -59.79 + 63.11\ Y_1 + 295.05\ Y_2 + 44.94\ Y_3 + 14.89\ Y_4 + 62.92\ Y_5 - 13.36\ Y_6 + 15.47\ Y_7 - 108.73\ Y_{26} + 8.6\ Y_8;}$$

Equation 2 - Multiple Regression Equation for Load Times including all variables

In this model we can see that there are some terms that do not makes any physical sense. One such term is the interaction between wheelchair and passenger type. We have coded the vehicle 1 as the electrical wheel chair one. This vehicle has more load time. So if the vehicle code increases the load time should get reduced. Also this terms was more like multiplying the wheel chair passenger load time by a constant, because we didn't have vehicles in other configurations as said before. The significance test proved that this factor was insignificant and hence we discarded it from the model. Table 4 given below summarizes the details of the F-test for significance of the factor in the model. The level of significance was 0.05.

The hypothesis set up for this model was as follows. The null hypothesis assumes that all factors are insignificant. The alternate hypothesis assumes that all factors are significant in the model.

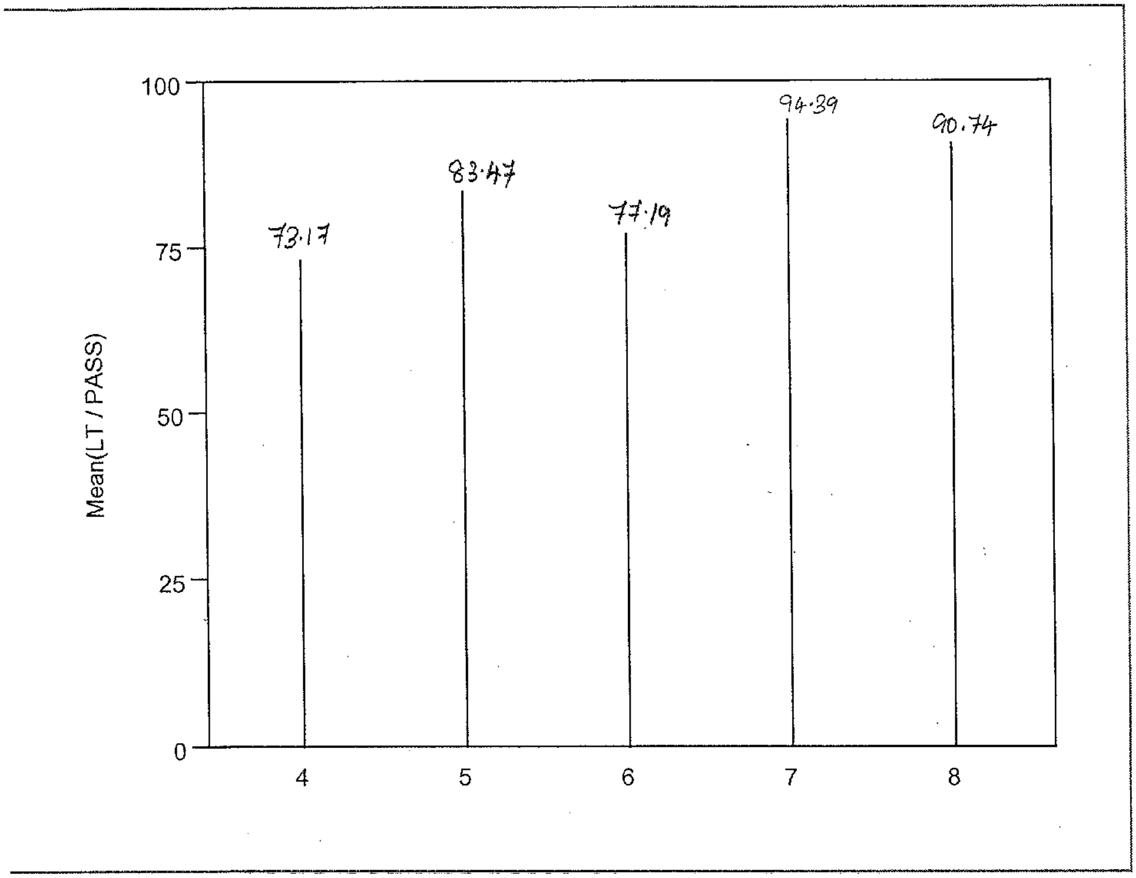
H_0:$\alpha_0 = 0$; $\alpha_1 = 0$; $\alpha_2 = 0$; $\alpha_3 = 0$; $\alpha_4 = 0$; $\alpha_5 = 0$; $\alpha_6 = 0$; $\alpha_7 = 0$; $\alpha_{26} = 0$; $\alpha_8 = 0$. (Insignificance).
H_1:$\alpha_0 \neq 0$; $\alpha_1 \neq 0$; $\alpha_2 \neq 0$; $\alpha_3 \neq 0$; $\alpha_4 \neq 0$; $\alpha_5 \neq 0$; $\alpha_6 \neq 0$; $\alpha_7 \neq 0$; $\alpha_{26} \neq 0$; $\alpha_8 \neq 0$. (Significance).

Table 4 - Details of F-ratio analysis for all factors model for predicting Load Time

Sl. No	Coefficients	Values	F-ratio	Prob > | F |	Conclusion
1	α_0	-59.79	-1.27	0.2094	Significant; Accept H_1
2	α_1	63.11	6.20	< 0.0001	Significant; Accept H_1
3	α_2	295.05	5.12	< 0.0001	Significant; Accept H_1
4	α_3	44.94	2.02	0.0474	Significant; Accept H_1
5	α_4	14.89	0.59	0.5541	Insignificant; Accept H_0
6	α_5	62.92	2.92	< 0.0047	Significant; Accept H_1
7	α_6	-13.36	-0.70	0.4890	Insignificant; Accept H_0
8	α_7	15.47	1.86	0.0666	Insignificant; Accept H_0
9	α_{26}	- 108.73	-2.34	0.0219	Significant; Accept H_1
10	α_8	8.6	1.29	0.2023	Insignificant; Accept H_0

The R-Square fit of this model was 0.677. This means the model explains about 67.7% of the variability. This could be improved by removing the insignificant terms from the model. So the analysis continued and the final model that is stated in the Time Estimation section of this report was obtained. All the statistical details done is available at the end of this section of the report for technical accuracy.

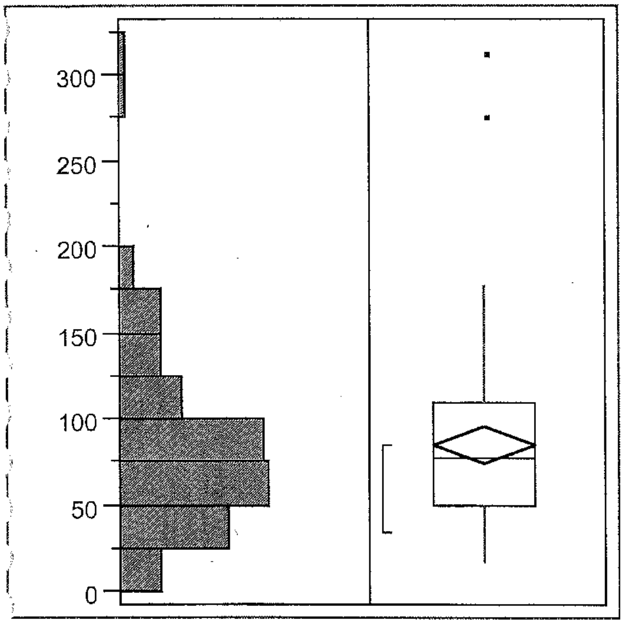
Mean Load Time vs Vehicle Type



Mean Load Time For All Type Of Passengers (Elderly, Wheel Chair, Disabled etc) Based On Vehicle Type
(Load Time per Passenger)
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

LT / PASS



Quantiles

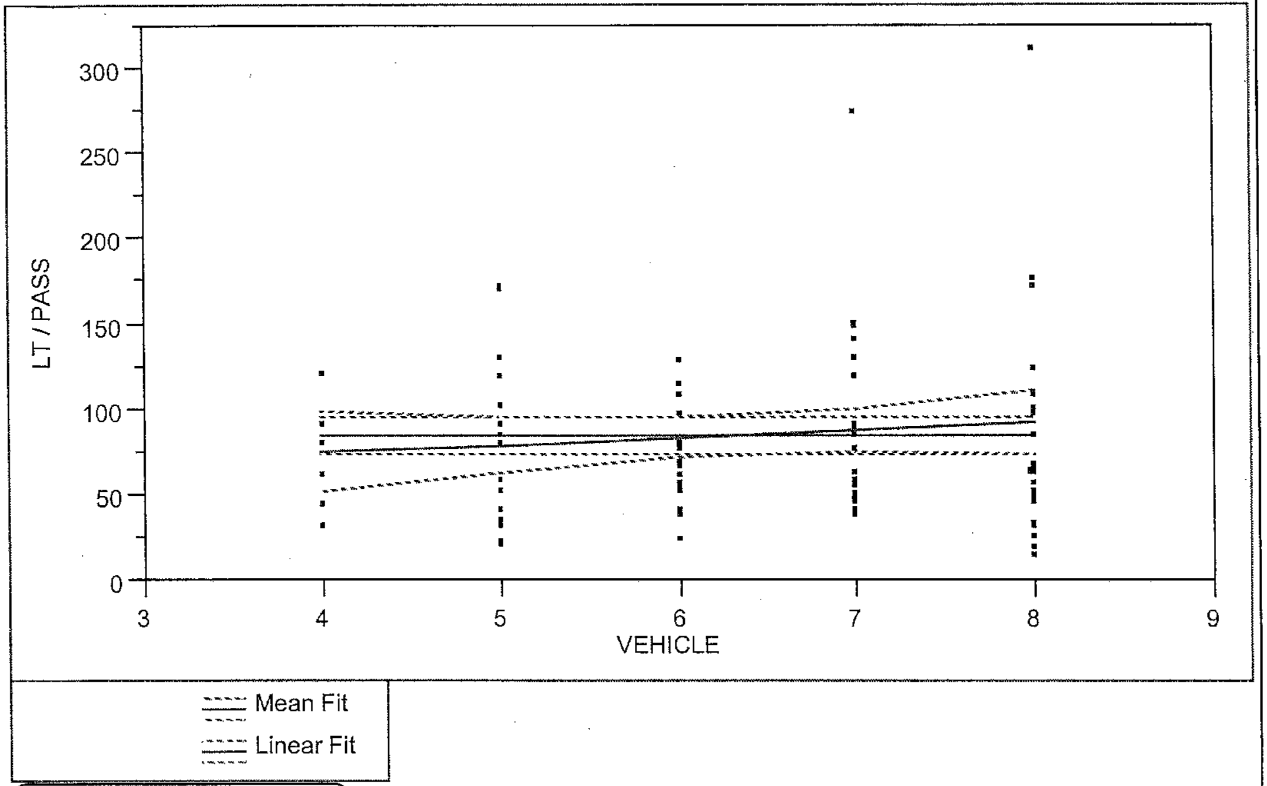
maximum	100.0%	313.00
	99.5%	313.00
	97.5%	248.91
	90.0%	150.90
quartile	75.0%	110.00
median	50.0%	78.50
quartile	25.0%	49.50
	10.0%	34.00
	2.5%	21.55
	0.5%	17.00
minimum	0.0%	17.00

Moments

Mean	85.04256
Std Dev	52.04310
Std Error Mean	5.48582
Upper 95% Mean	95.94282
Lower 95% Mean	74.14229
N	90.00000
Sum Weights	90.00000
Sum	7653.83
Variance	2708.4842
Skewness	1.70414
Kurtosis	4.56297
CV	61.19654

Box Plot For Load Times For All Types Of Passengers For All Type Of Vehicles in Galavan
Date: 07/17/2002

LT / PASS By VEHICLE



Mean Fit

Mean	85.04256
Std Dev [RMSE]	52.0431
Std Error	5.485824
SSE	241055.1

Linear Fit

LT / PASS = 57.6032 + 4.33252 VEHICLE

Summary of Fit

RSquare	0.01059
RSquare Adj	-0.00065
Root Mean Square Error	52.06009
Mean of Response	85.04256
Observations (or Sum Wgts)	90

Analysis of Variance

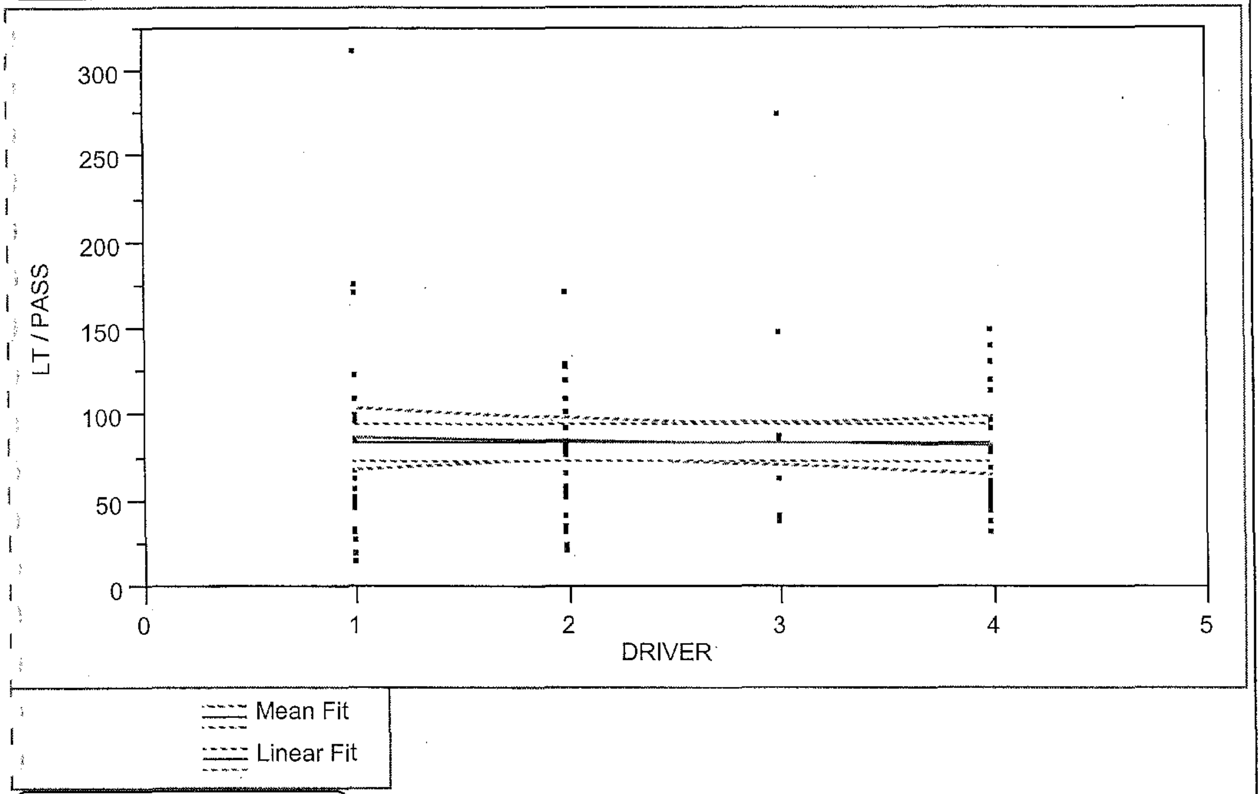
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2552.82	2552.82	0.9419
Error	88	238502.27	2710.25	Prob>F
C Total	89	241055.10		0.3344

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	57.603234	28.80037	2.00	0.0486	0.3682773	114.83819	0
VEHICLE	4.3325245	4.464116	0.97	0.3344	-4.53901	13.204059	0.102909

Scattar Plot Of Load Times Per Passenger For All Type Of Passengers Based On Vehicle Type
Date: 07/27/2002

LT / PASS By DRIVER



Mean Fit

Mean	85.04256
Std Dev [RMSE]	52.0431
Std Error	5.485824
SSE	241055.1

Linear Fit

LT / PASS = 88.8037 – 1.49778 DRIVER

Summary of Fit

RSquare	0.001159
RSquare Adj	-0.01019
Root Mean Square Error	52.30764
Mean of Response	85.04256
Observations (or Sum Wgts)	90

Analysis of Variance

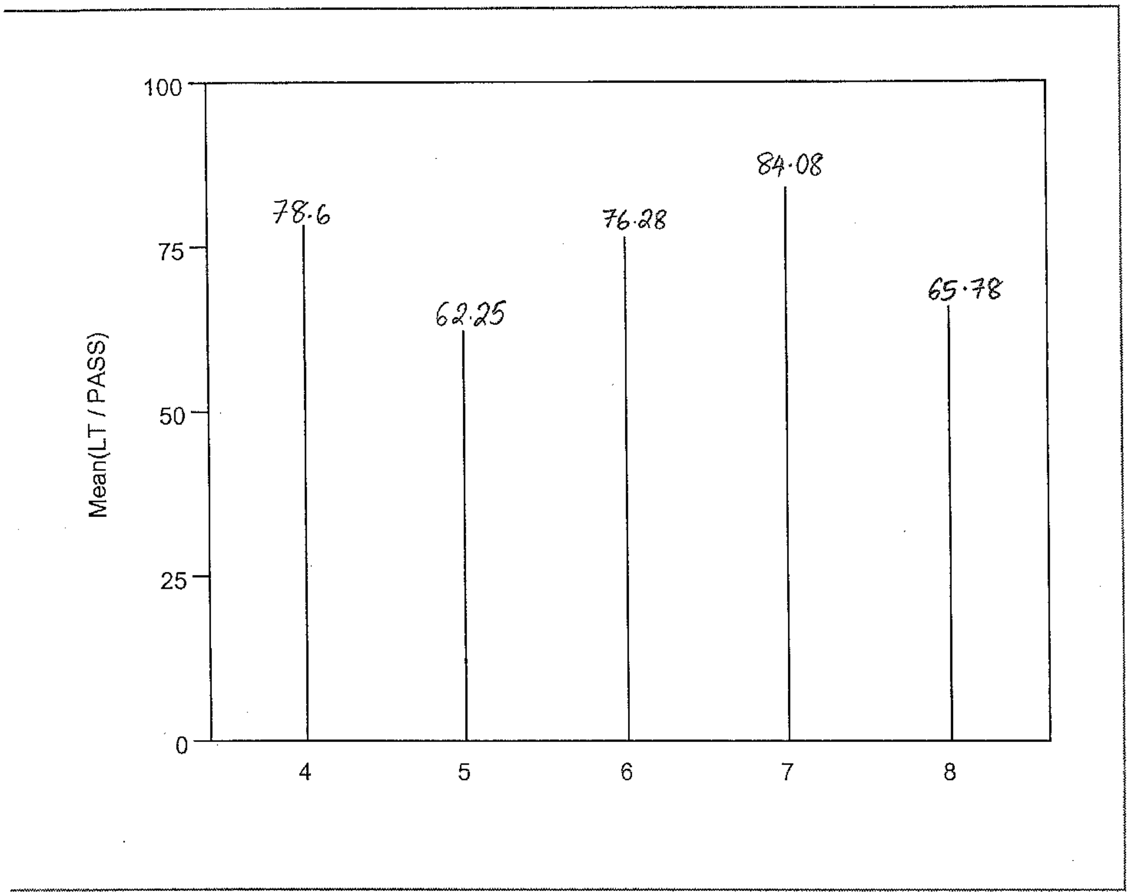
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	279.27	279.27	0.1021
Error	88	240775.82	2736.09	Prob>F
C Total	89	241055.10		0.7501

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	88.803659	12.99965	6.83	<.0001	62.969469	114.63785	0
DRIVER	-1.497785	4.688132	-0.32	0.7501	-10.81451	7.8189356	-0.03404

Scattar Plot Of Load Times Per Passenger For All Type Of Passengers Based On Driver
Date: 07/27/2002

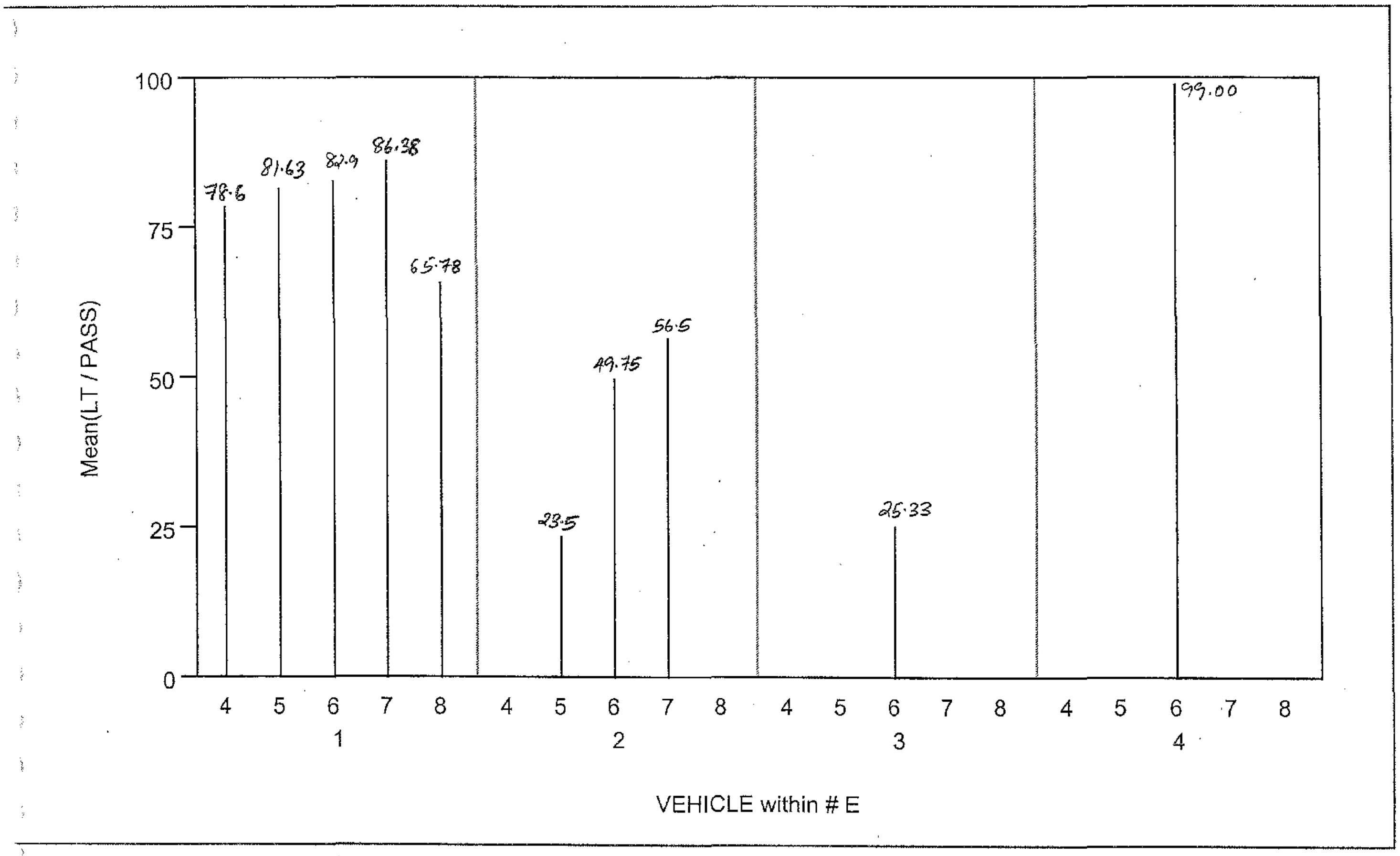
Mean Load Time vs Elderly Passengers by Vehicle



Mean Load Time For Elderly Passengers For Each Vehicle Type
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

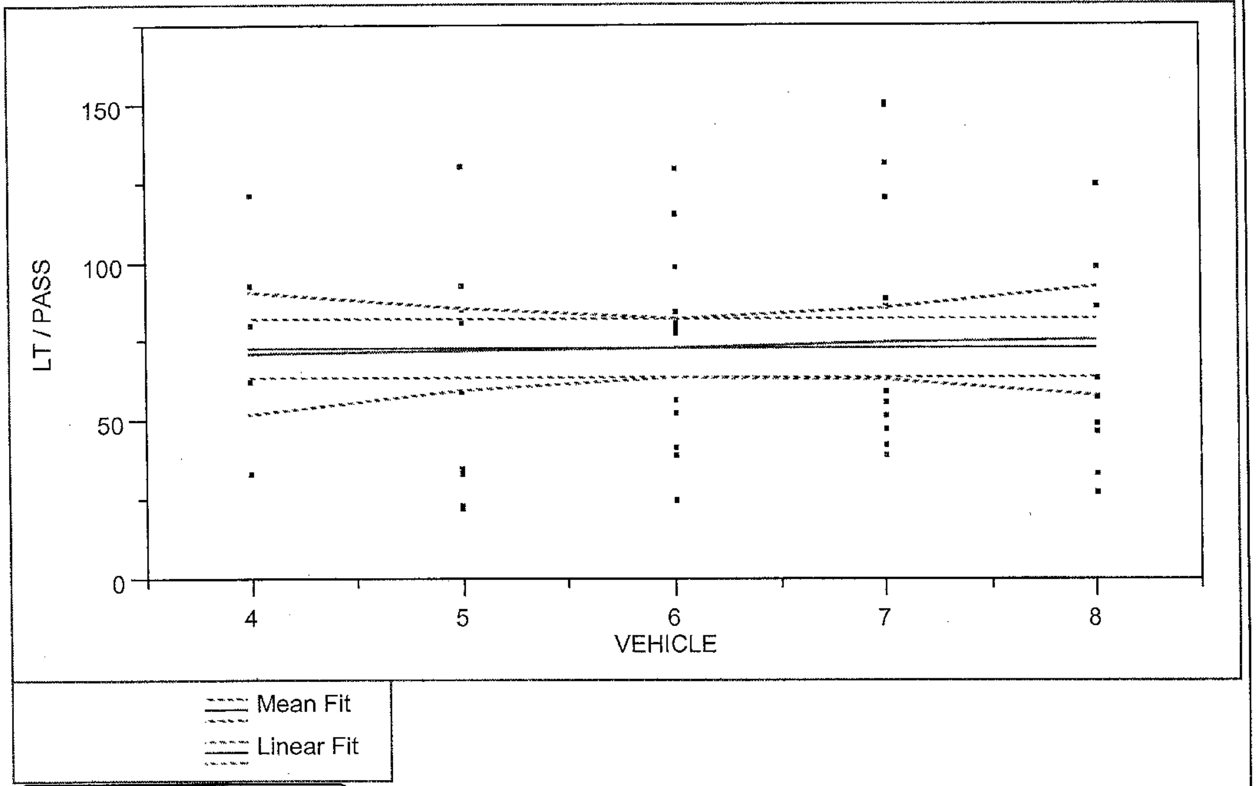
Mean Load Time vs No of Elderly Passengers by Vehicle Type



Mean Load Time For Number of Elderly Passengers For Each Vehicle Type
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

LT / PASS By VEHICLE



Mean Fit

Mean	73.69534
Std Dev [RMSE]	34.94366
Std Error	4.588327
SSE	69600.39

Linear Fit

LT / PASS = 67.4521 + 1.0143 VEHICLE

Summary of Fit

RSquare	0.001177
RSquare Adj	-0.01666
Root Mean Square Error	35.23353
Mean of Response	73.69534
Observations (or Sum Wgts)	58

Analysis of Variance

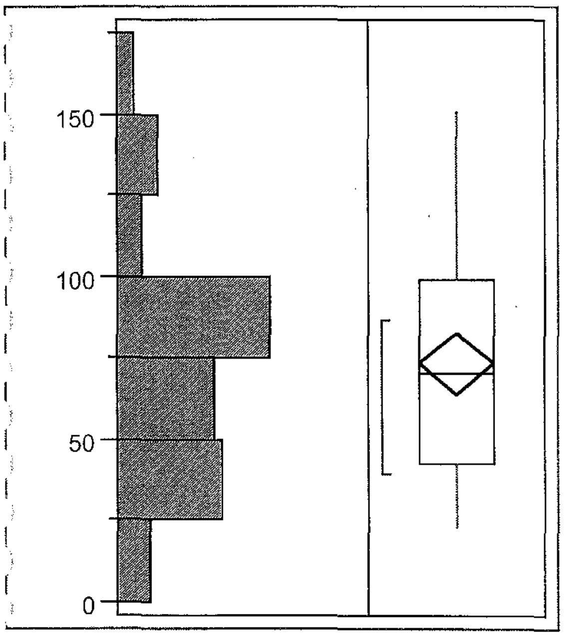
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	81.897	81.90	0.0660
Error	56	69518.489	1241.40	Prob>F
C Total	57	69600.386		0.7982

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	67.452144	24.74331	2.73	0.0085	17.885375	117.01891	0
VEHICLE	1.0143015	3.949028	0.26	0.7982	-6.896548	8.9251505	0.034303

Scattar Plot for Loading Times Per Elderly Passengers Based On Vehicle Types Used in Galavan
Date: 07/17/2002

LT / PASS

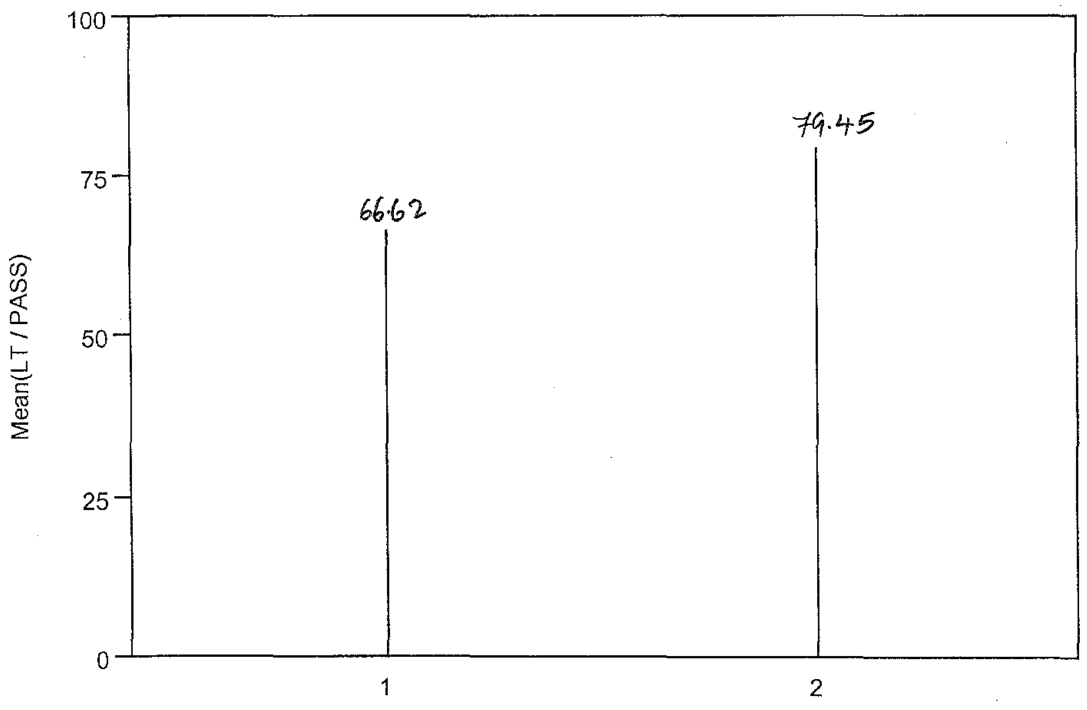


```
Quantiles
 maximum   100.0%    151.00
            99.5%    151.00
            97.5%    150.52
            90.0%    130.10
 quartile   75.0%     99.00
 median     50.0%     71.00
 quartile   25.0%     42.88
            10.0%     27.73
             2.5%     23.00
             0.5%     23.00
 minimum     0.0%     23.00
```

```
Moments
Mean               73.69534
Std Dev            34.94366
Std Error Mean      4.58833
Upper 95% Mean     82.88331
Lower 95% Mean     64.50738
N                  58.00000
Sum Weights        58.00000
Sum                 4274.33
Variance          1221.0594
Skewness            0.41827
Kurtosis           -0.70648
CV                 47.41637
```

Box Plot for the Load Times of Elderly Passengers
ate: 07/17/2002

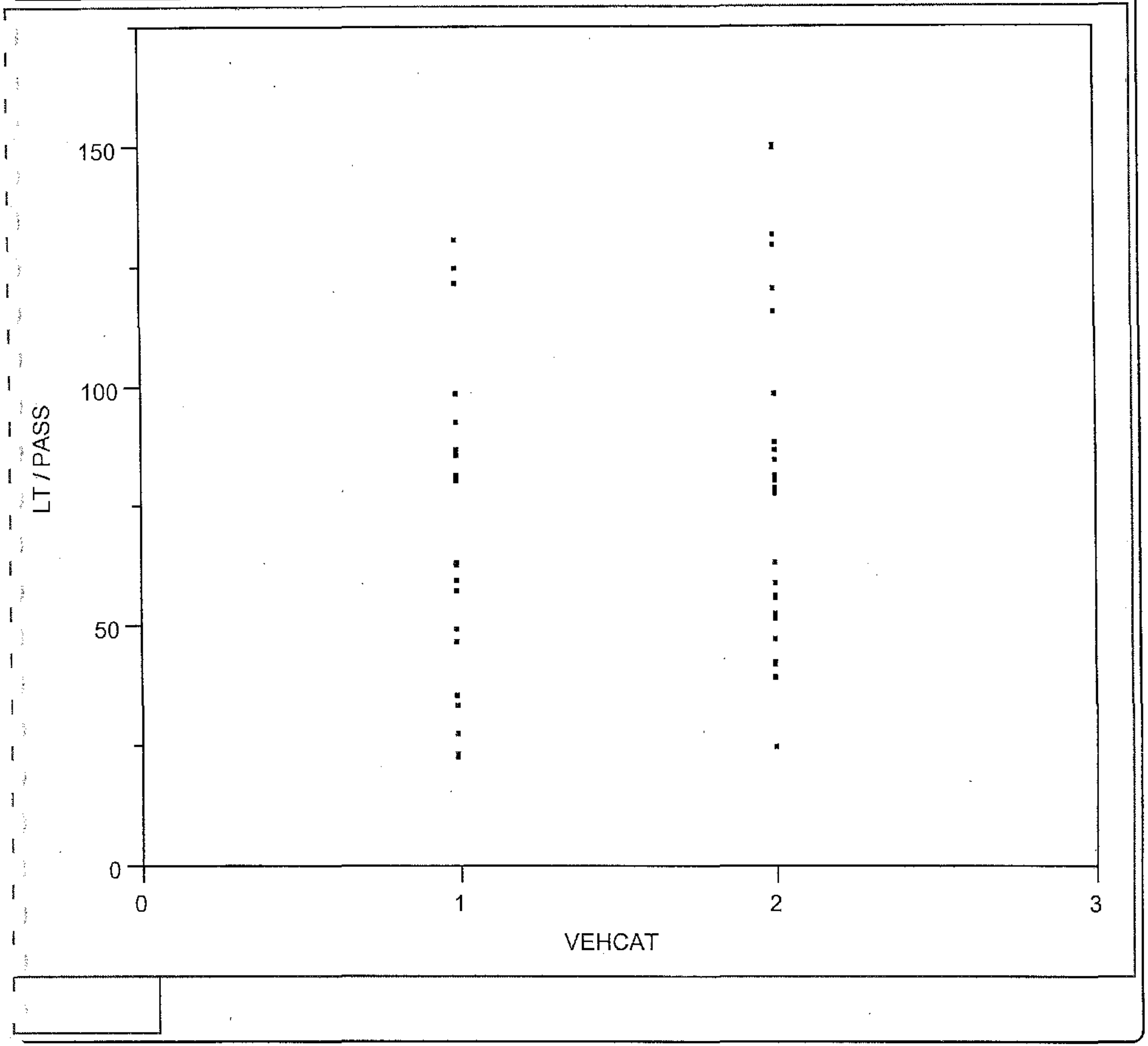
Mean Load Time vs Vehicle Category



Mean Load Time vs Vehicles Grouped Into Categories Based on Characteristics
Date: 07/17/2002

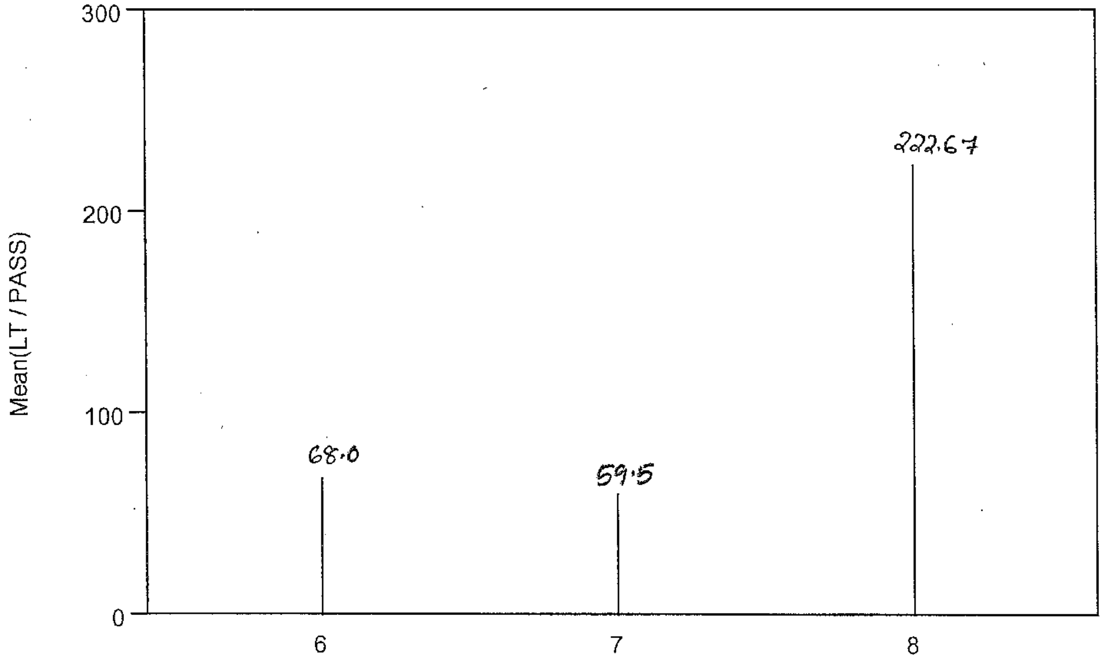
VEHCAT Levels Options
Mean(LT / PASS)

LT / PASS By VEHCAT



Scatter Plot for Load Times of Elderly Passengers Based on Vehicle Categories
ate: 07/17/2002

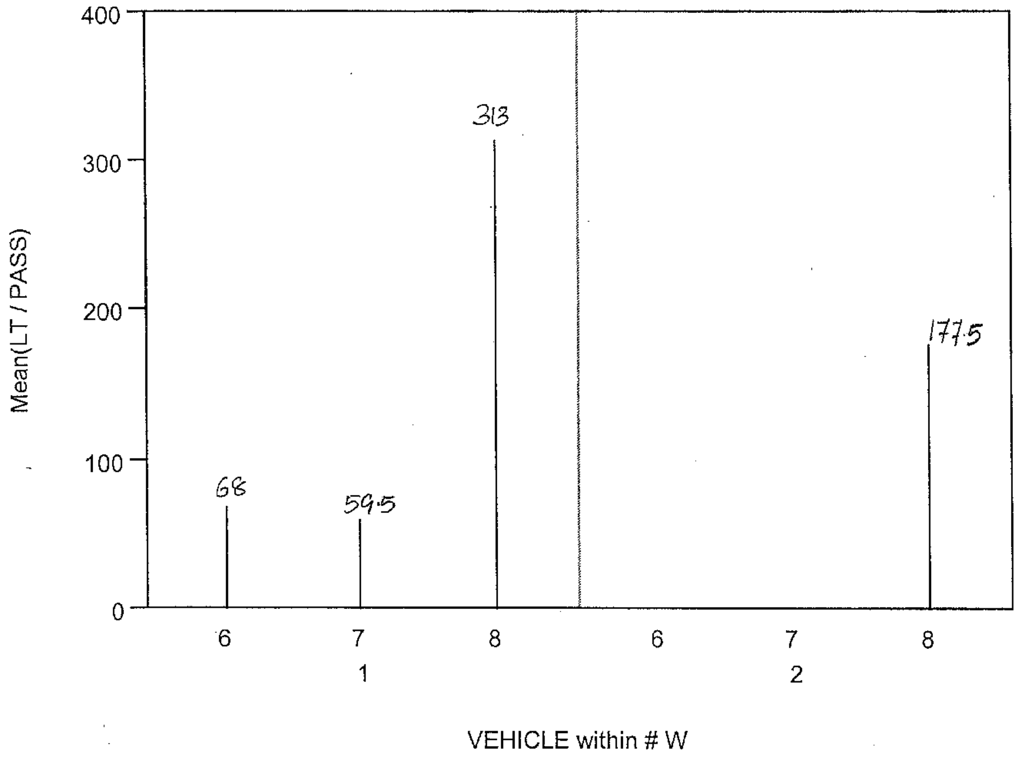
Mean Load Time vs Wheel Chair Passengers by Vehicle



Mean Load Time For Passengers on Wheel Chair by Vehicle (Load Time is Per Passenger)
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

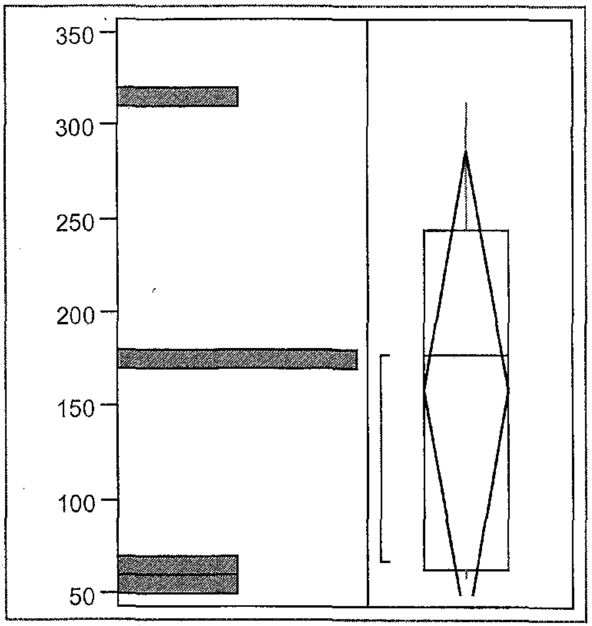
Mean Load Time vs No of Wheel Chair Passengers by Vehicle



Mean Load Time For No Of Wheel Chair Passengers by Vehicle Type
ate: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

LT / PASS



Quantiles

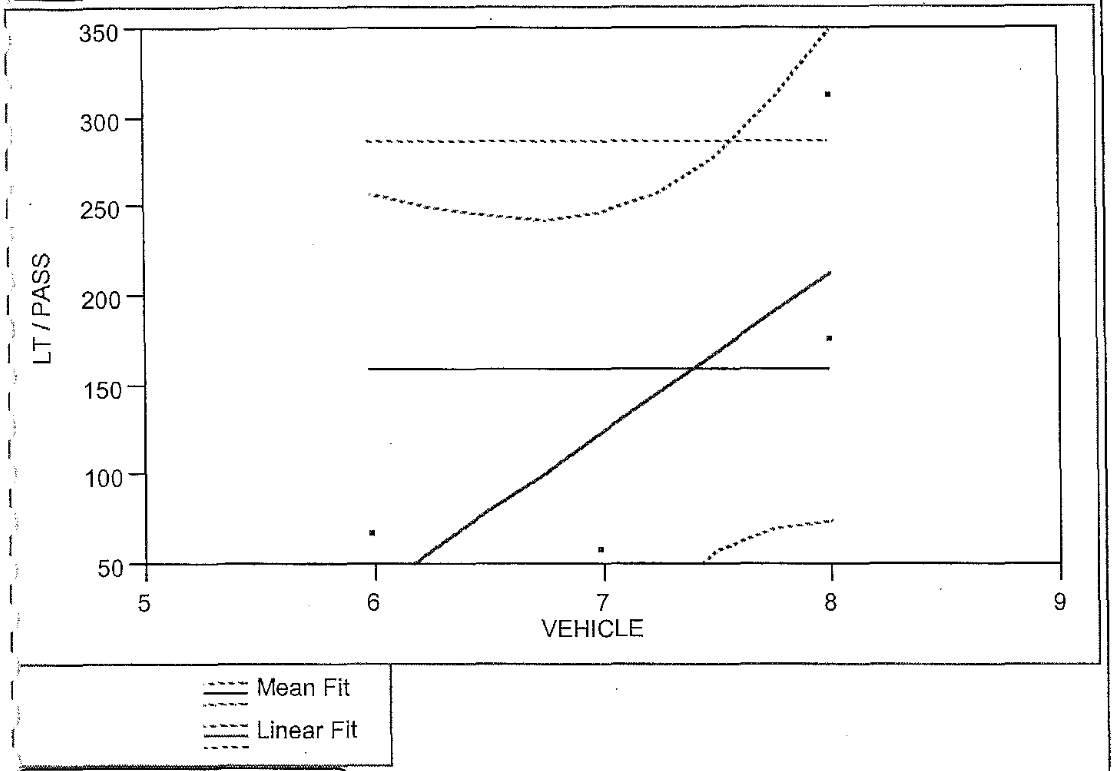
maximum	100.0%	313.00
	99.5%	313.00
	97.5%	313.00
	90.0%	313.00
quartile	75.0%	245.25
median	50.0%	177.50
quartile	25.0%	63.75
	10.0%	59.50
	2.5%	59.50
	0.5%	59.50
minimum	0.0%	59.50

Moments

Mean	159.1000
Std Dev	103.1767
Std Error Mean	46.1420
Upper 95% Mean	287.2090
Lower 95% Mean	30.9910
N	5.0000
Sum Weights	5.0000
Sum	795.5000
Variance	10645.425
Skewness	0.7259
Kurtosis	0.0356
CV	64.8502

Box Plot For The Load Times Per Wheel Chair Passengers For Available Vehicles
Date: 07/17/2002

LT / PASS By VEHICLE



Mean Fit

Mean	159.1
Std Dev [RMSE]	103.1767
Std Error	46.14201
SSE	42581.7

Linear Fit

LT / PASS = -492.56 + 88.0625 VEHICLE

Summary of Fit

RSquare	0.582786
RSquare Adj	0.443714
Root Mean Square Error	76.95386
Mean of Response	159.1
Observations (or Sum Wgts)	5

Analysis of Variance

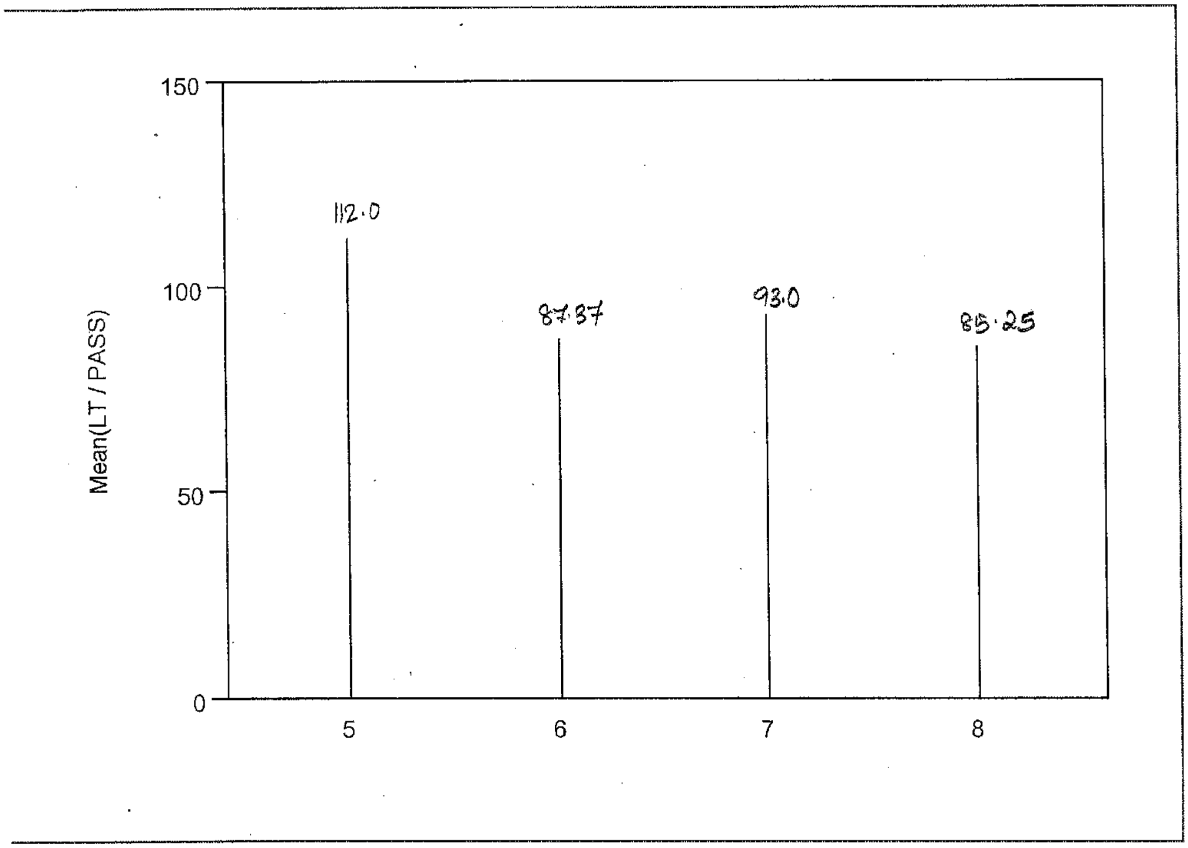
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	24816.012	24816.0	4.1906
Error	3	17765.688	5921.9	Prob>F
C Total	4	42581.700		0.1331

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	-492.5625	320.1919	-1.54	0.2216	-1511.573	526.44807	0
VEHICLE	88.0625	43.01851	2.05	0.1331	-48.84392	224.96892	0.763404

Scattar Plot For Load Times Of Passengers On Wheel Chairs For Available Vehicles in Galavan
Date: 07/17/2002

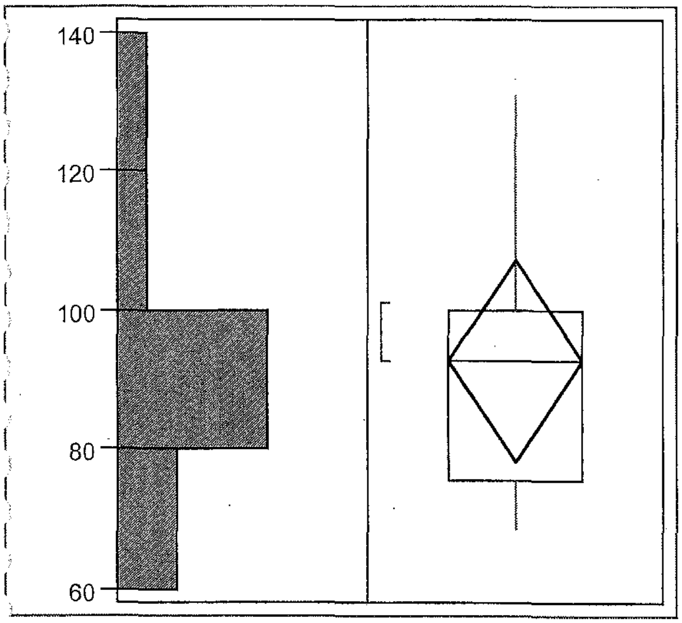
Mean Load Time vs Special Category Passengers by Vehicle



Mean Load Times For Special Category Passengers Based On Vehicle Type
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

LT / PASS



Quantiles

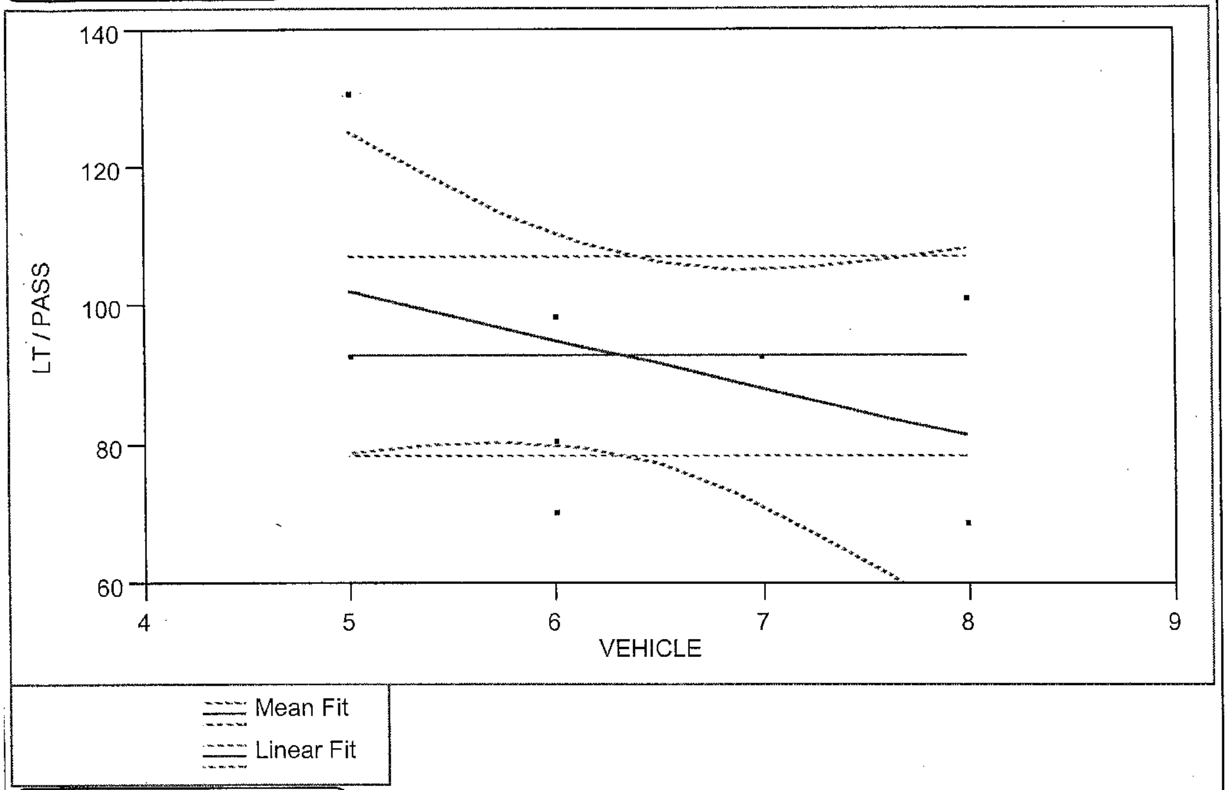
maximum	100.0%	131.00
	99.5%	131.00
	97.5%	131.00
	90.0%	131.00
quartile	75.0%	100.25
median	50.0%	93.00
quartile	25.0%	75.75
	10.0%	69.00
	2.5%	69.00
	0.5%	69.00
minimum	0.0%	69.00

Moments

Mean	93.0000
Std Dev	18.7567
Std Error Mean	6.2522
Upper 95% Mean	107.4178
Lower 95% Mean	78.5822
N	9.0000
Sum Weights	9.0000
Sum	837.0000
Variance	351.8125
Skewness	0.7057
Kurtosis	1.2755
CV	20.1685

ox Plot For The Load Times Of Special Category Passengers For All Types Of Vehicle in alavan
Date: 07/17/2002

LT / PASS By VEHICLE



Mean Fit

Mean	93
Std Dev [RMSE]	18.75667
Std Error	6.252222
SSE	2814.5

Linear Fit

LT / PASS = 136.7 – 6.9 VEHICLE

Summary of Fit

RSquare	0.16916
RSquare Adj	0.050468
Root Mean Square Error	18.27723
Mean of Response	93
Observations (or Sum Wgts)	9

Analysis of Variance

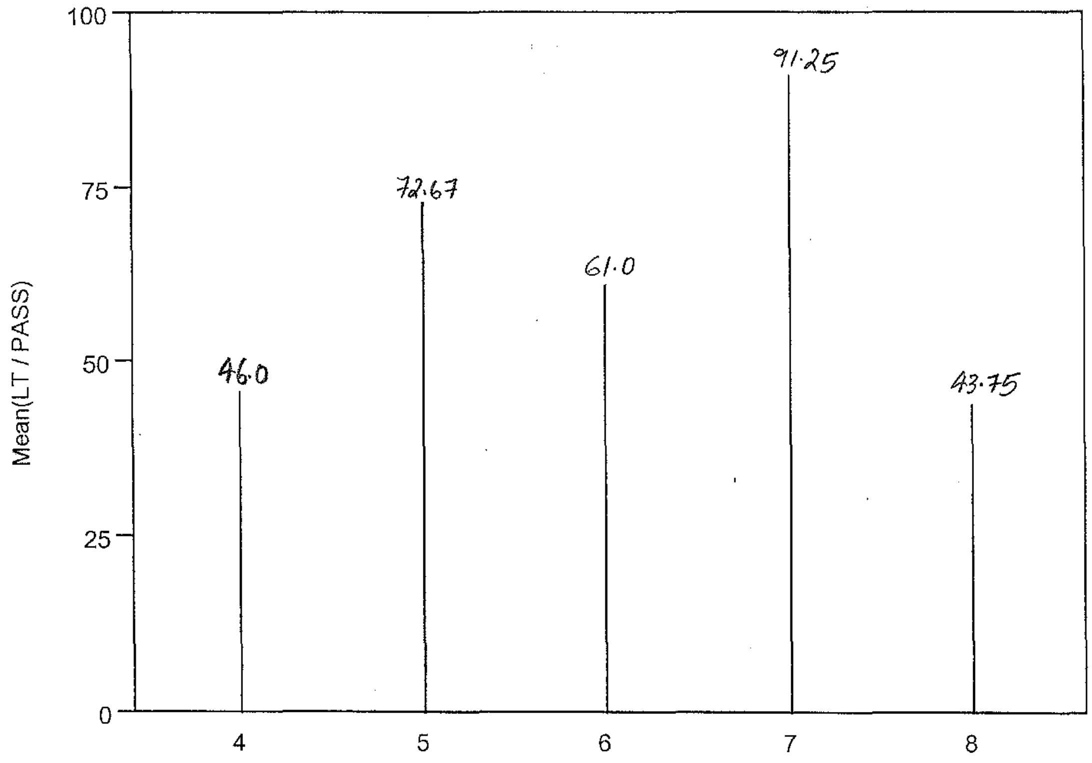
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	476.1000	476.100	1.4252
Error	7	2338.4000	334.057	Prob>F
C Total	8	2814.5000		0.2714

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	136.7	37.10873	3.68	0.0078	48.951095	224.44891	0
VEHICLE	-6.9	5.779768	-1.19	0.2714	-20.56709	6.7670885	-0.41129

Scattar Plot of Load Times For Special Category Passengers Based on Vehicle Type in Galavan
Date: 07/17/2002

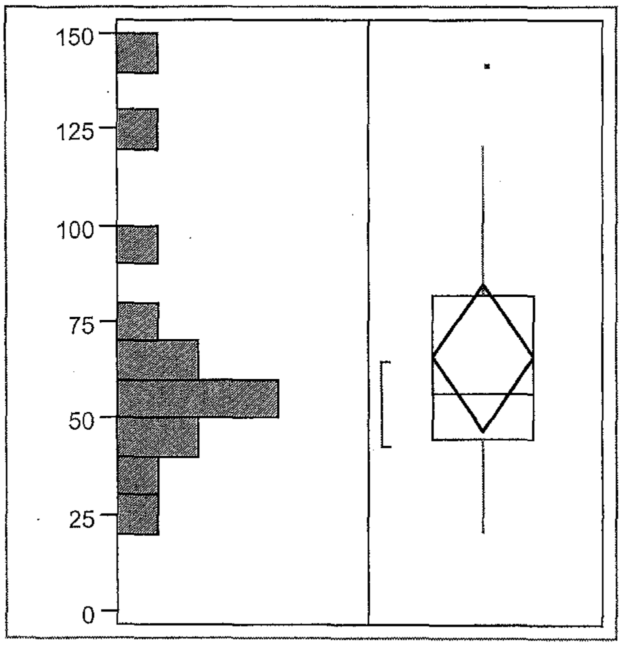
Mean Load Time vs Disabled Passengers by Vehicle



ean Load Times For Disabled Passengers by Vehicles Used in Galavan
Date: 07/17/2002

VEHICLE Levels Options
Mean(LT / PASS)

LT / PASS

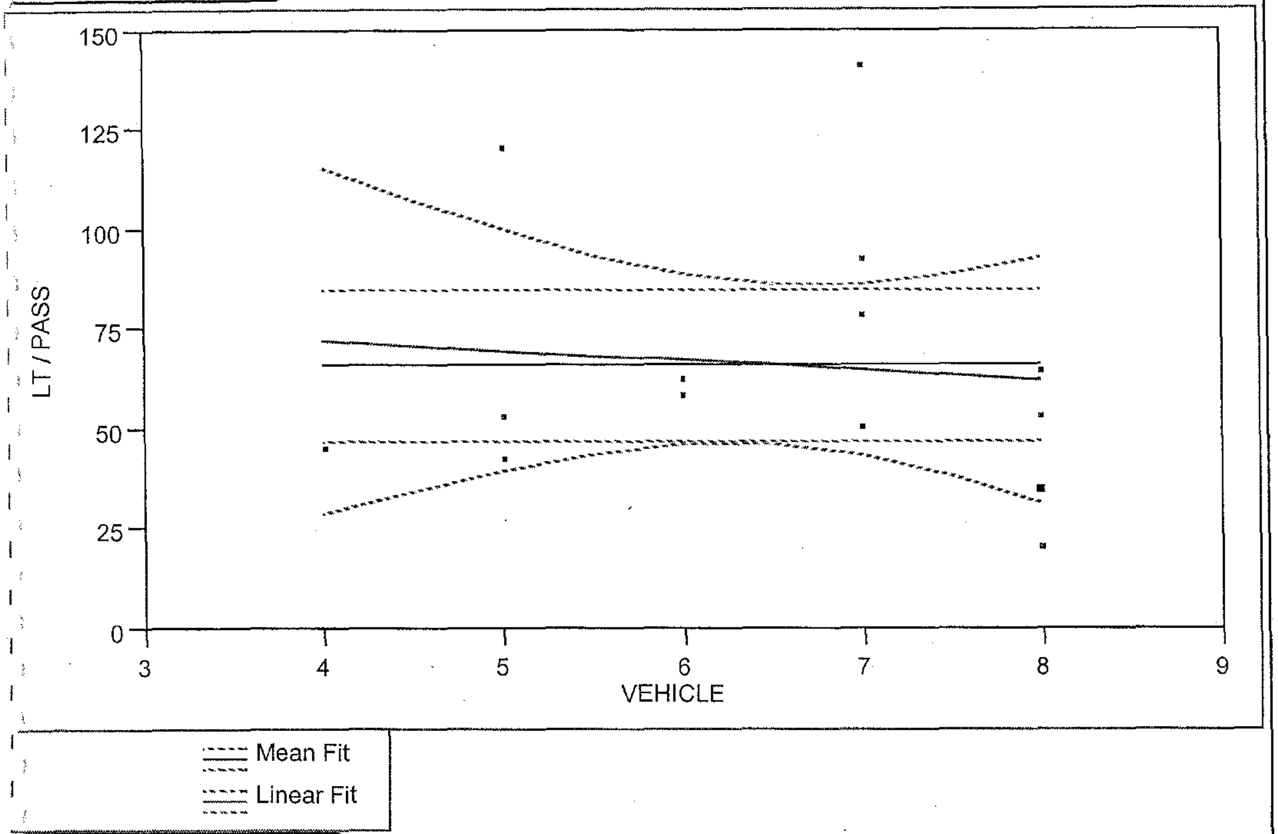


```
Quantiles
maximum   100.0%   142.00
           99.5%   142.00
           97.5%   142.00
           90.0%   131.50
quartile   75.0%    82.50
median     50.0%    56.50
quartile   25.0%    45.25
           10.0%    28.00
            2.5%    21.00
            0.5%    21.00
minimum     0.0%    21.00
```

```
Moments
Mean              66.14286
Std Dev           33.03345
Std Error Mean     8.82856
Upper 95% Mean    85.21579
Lower 95% Mean    47.06992
N                 14.00000
Sum Weights       14.00000
Sum              926.00000
Variance         1091.2088
Skewness           1.17728
Kurtosis           1.12922
CV                49.94258
```

Box Plot for Load Times of Disbaled Passengers
Date: 07/17/2002

LT / PASS By VEHICLE



Mean Fit

Mean	66.14286
Std Dev [RMSE]	33.03345
Std Error	8.828561
SSE	14185.71

Linear Fit

LT / PASS = 82.1854 – 2.46809 VEHICLE

Summary of Fit

RSquare	0.010091
RSquare Adj	-0.0724
Root Mean Square Error	34.20839
Mean of Response	66.14286
Observations (or Sum Wgts)	14

Analysis of Variance

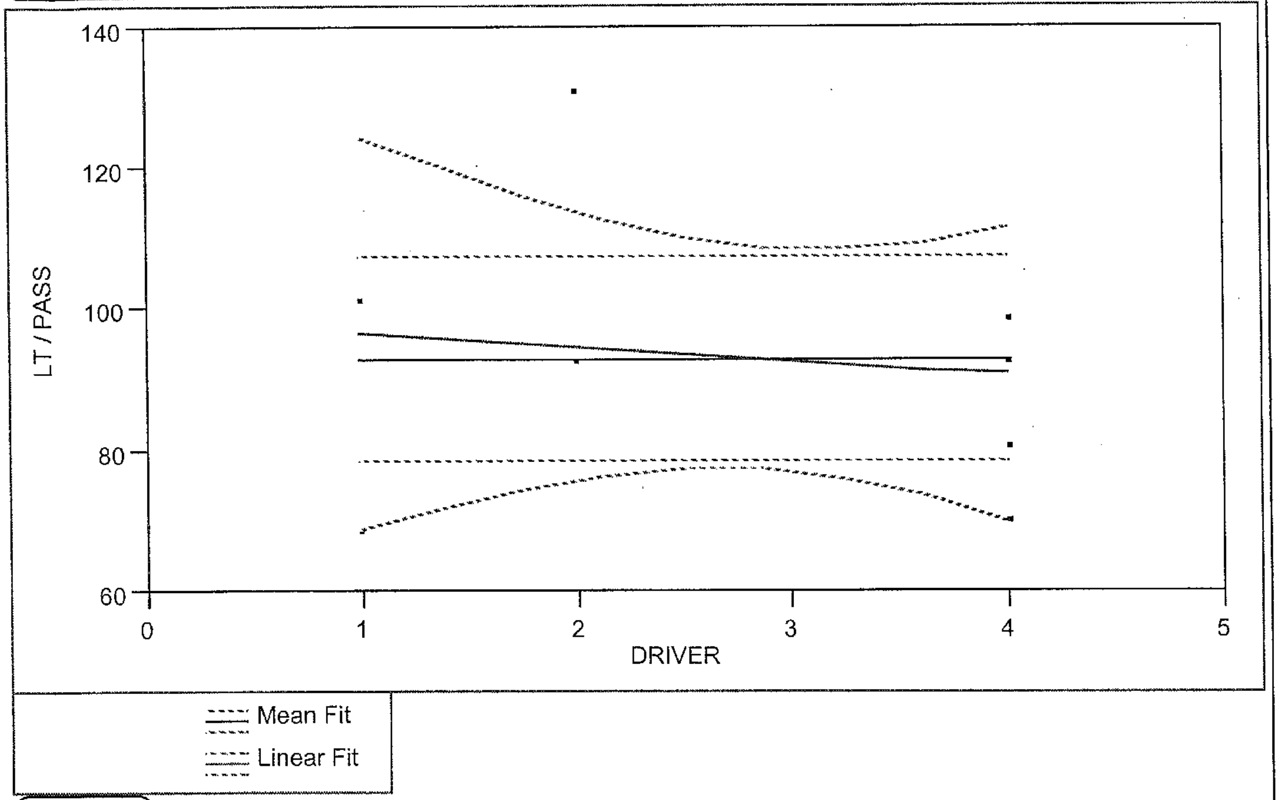
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	143.149	143.15	0.1223
Error	12	14042.565	1170.21	Prob>F
C Total	13	14185.714		0.7326

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	82.18541	46.77052	1.76	0.1043	-19.71895	184.08977	0
VEHICLE	-2.468085	7.056652	-0.35	0.7326	-17.84323	12.90706	-0.10045

Scatter Plot for Load Times of Disabled Passengers by Vehicles Used in Galavan
ate: 07/17/2002

LT / PASS By DRIVER



Mean Fit

Linear Fit

LT / PASS = 98.7239 – 1.98134 DRIVER

Summary of Fit

RSquare	0.020767
RSquare Adj	-0.11912
Root Mean Square Error	19.84242
Mean of Response	93
Observations (or Sum Wgts)	9

Analysis of Variance

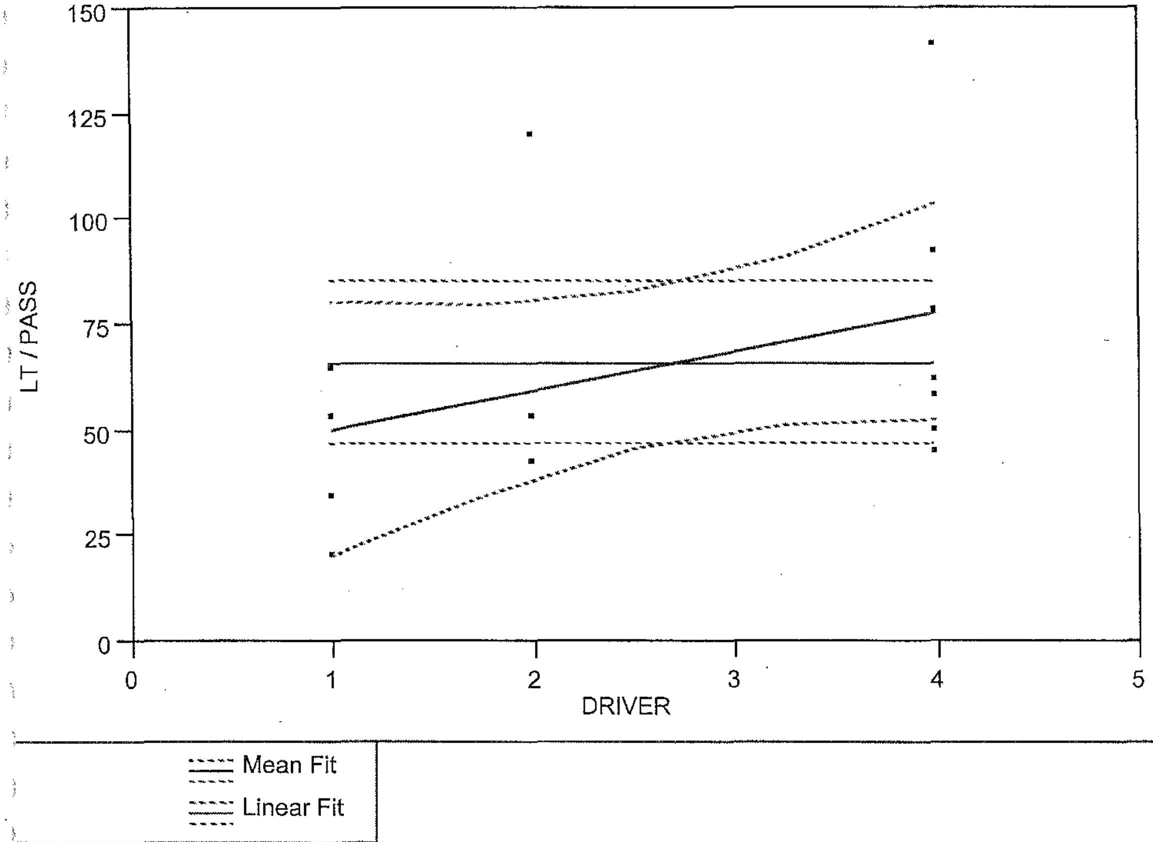
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	58.4496	58.450	0.1485
Error	7	2756.0504	393.721	Prob>F
C Total	8	2814.5000		0.7115

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	98.723881	16.26161	6.07	0.0005	60.270986	137.17678	0
DRIVER	-1.981343	5.142371	-0.39	0.7115	-14.14122	10.17853	-0.14411

Scattar Plot For Load Times of Special Category Passengers Based On Drivers in Galavan
Date: 07/17/2002

T / PASS By DRIVER

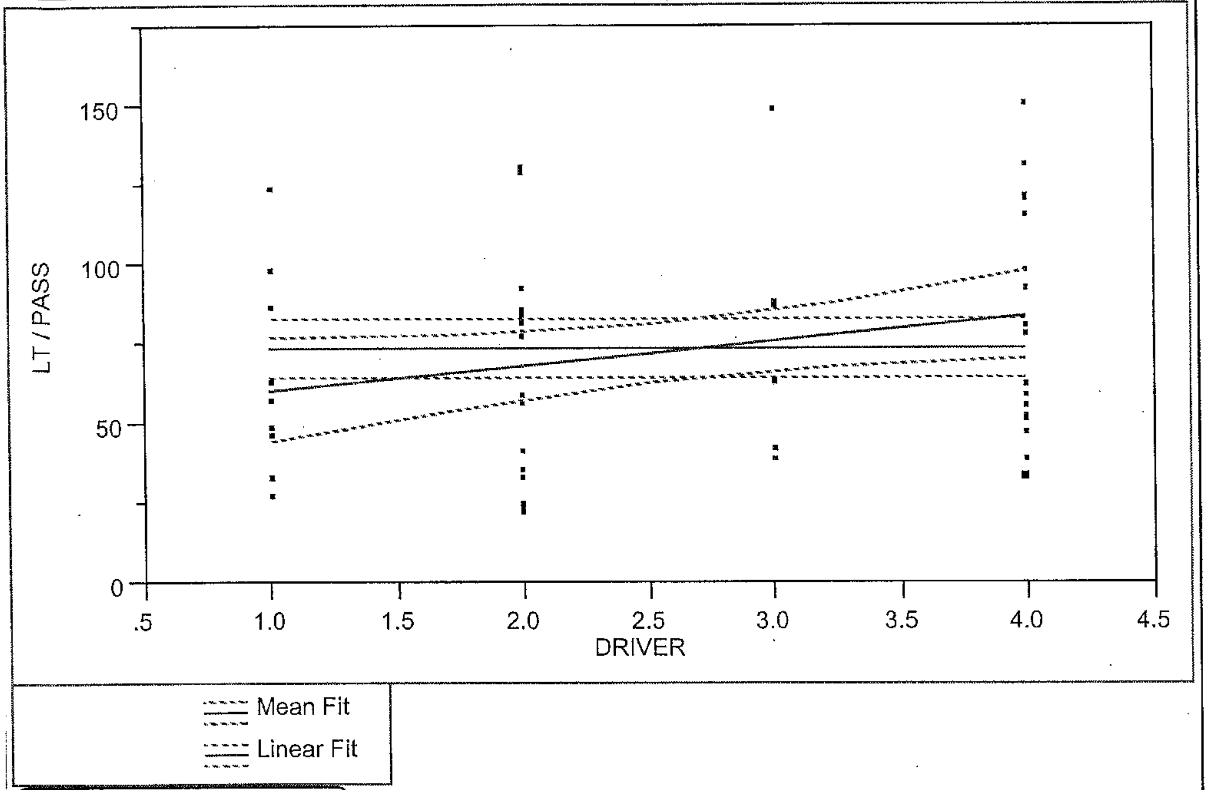


```
Mean Fit
Mean                 66.14286
Std Dev [RMSE]       33.03345
Std Error            8.828561
SSE                  14185.71
```

```
Linear Fit
T / PASS = 41.0747 + 9.23563 DRIVER
Summary of Fit
RSquare                          0.149463
RSquare Adj                      0.078585
Root Mean Square Error           31.70893
Mean of Response                 66.14286
Observations (or Sum Wgts)             14
Analysis of Variance
Source     DF   Sum of Squares   Mean Square    F Ratio
Model       1         2120.237       2120.24     2.1087
Error      12        12065.477       1005.46     Prob>F
C Total    13        14185.714                   0.1721
Parameter Estimates
Term          Estimate   Std Error   t Ratio   Prob>|t|   Lower 95%   Upper 95%   Std Beta
Intercept    41.074713    19.23078      2.14     0.0540   -0.825628   82.975053          0
DRIVER       9.2356322    6.359984      1.45     0.1721   -4.621603   23.092867   0.386604
```

catter Plot For Load Times per Disabled Passengers by Drivers Employed in Galavan
ate: 07/17/2002

LT / PASS By DRIVER



Mean Fit

Mean	73.69534
Std Dev [RMSE]	34.94366
Std Error	4.588327
SSE	69600.39

Linear Fit

LT / PASS = 53.0257 + 7.73445 DRIVER

Summary of Fit

RSquare	0.062551
RSquare Adj	0.045811
Root Mean Square Error	34.13388
Mean of Response	73.69534
Observations (or Sum Wgts)	58

Analysis of Variance

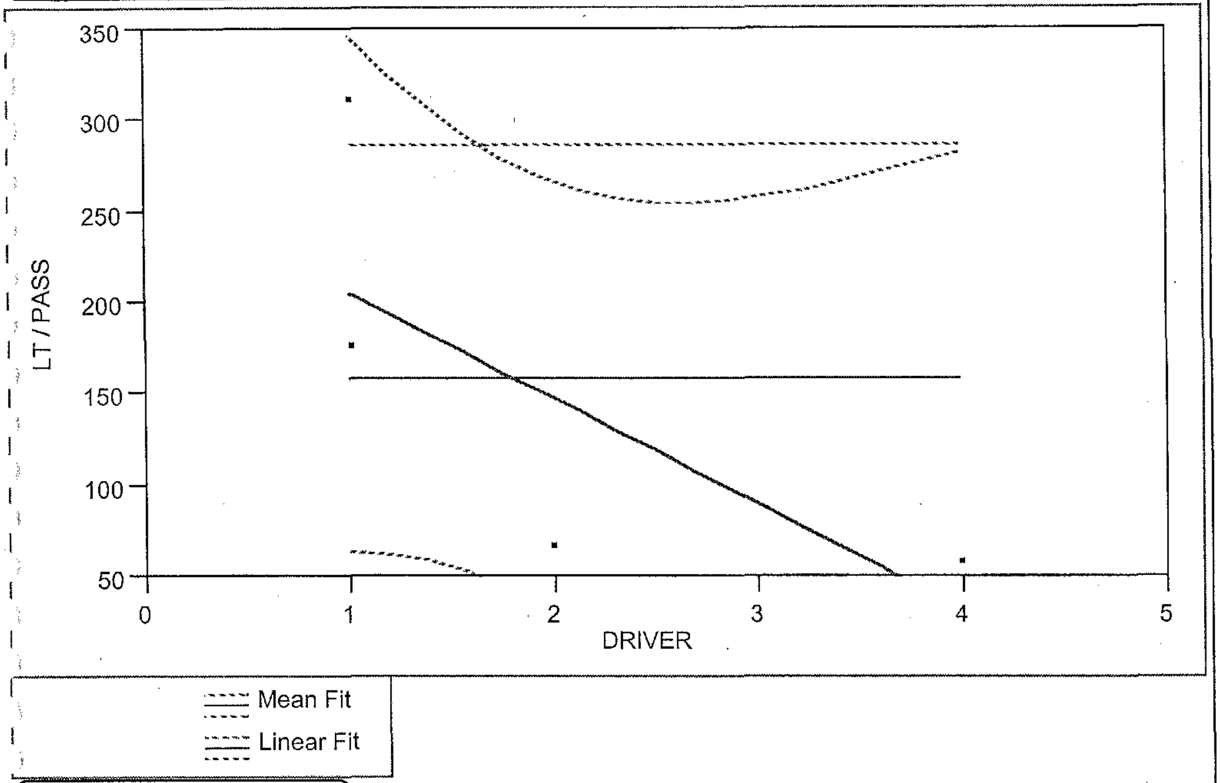
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4353.581	4353.58	3.7366
Error	56	65246.804	1165.12	Prob>F
C Total	57	69600.386		0.0583

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	53.025683	11.59424	4.57	<.0001	29.799636	76.251731	0
DRIVER	7.7344539	4.001215	1.93	0.0583	-0.280939	15.749847	0.250102

Scattar Plot For Loading Times Per Elderly Passenger Based on Drivers Employed in Galavan
Date: 07/17/2002

LT / PASS By DRIVER



Mean Fit

Mean	159.1
Std Dev [RMSE]	103.1767
Std Error	46.14201
SSE	42581.7

Linear Fit

LT / PASS = 262.309 – 57.3382 DRIVER

Summary of Fit

RSquare	0.525018
RSquare Adj	0.366691
Root Mean Square Error	82.10871
Mean of Response	159.1
Observations (or Sum Wgts)	5

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	22356.178	22356.2	3.3160
Error	3	20225.522	6741.8	Prob>F
C Total	4	42581.700		0.1662

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	262.30882	67.53264	3.88	0.0302	47.386209	477.23144	0
DRIVER	-57.33824	31.48725	-1.82	0.1662	-157.5464	42.86995	-0.72458

Scattar Plot For Load Times Of Passengers On Wheel Chairs For Available Drivers in Galavan
Date: 07/17/2002

Response: L/U SECS

Summary of Fit

RSquare	0.486798
RSquare Adj	0.473805
Root Mean Square Error	67.58251
Mean of Response	108.0488
Observations (or Sum Wgts)	82

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	4	168768.24	42192.1	16.4765
Pure Error	75	192055.99	2560.7	Prob>F
Total Error	79	360824.22		<.0001
				Max RSq
				0.7268

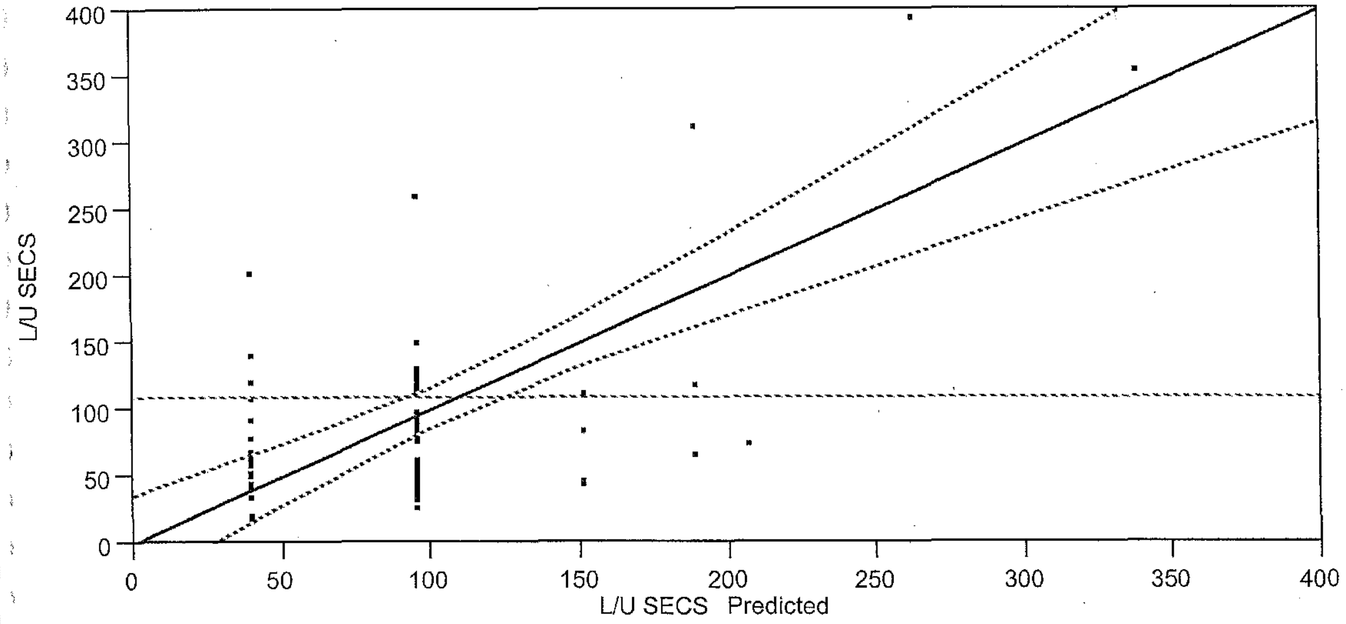
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	40.331225	11.47891	3.51	0.0007	17.482949	63.1795	0
# E	55.687391	8.172088	6.81	<.0001	39.421199	71.953582	0.567386
# W	148.88013	21.64665	6.88	<.0001	105.79341	191.96685	0.572665

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
# E	1	1	212088.07	46.4352	<.0001
# W	1	1	216053.28	47.3034	<.0001

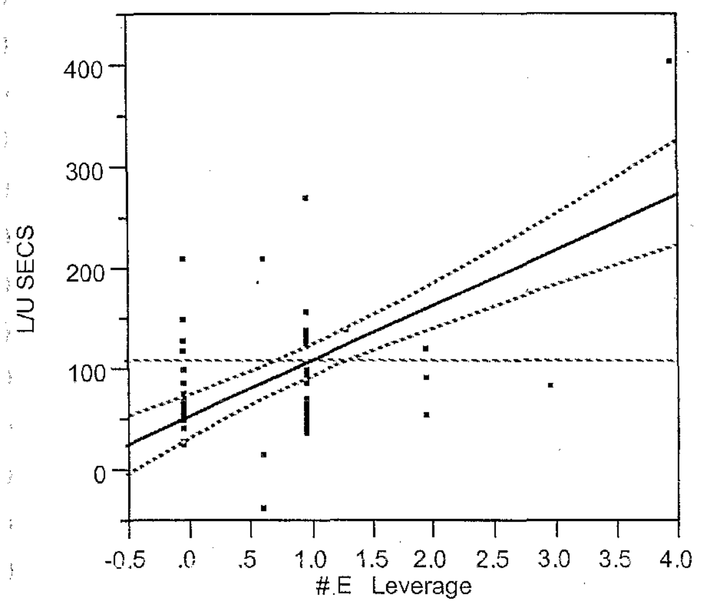
Whole-Model Test



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	342259.58	171130	37.4677
Error	79	360824.22	4567	Prob>F
C Total	81	703083.80		<.0001

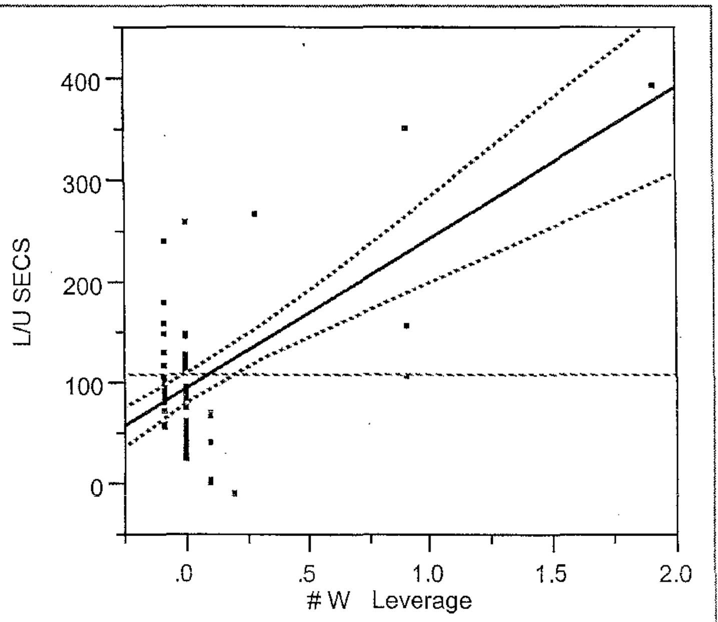
E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
212088.07	46.4352	1	<.0001

W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
216053.28	47.3034	1	<.0001

ultiple regression Analysis of Load Times
Equation: Lest = a0 + a1.Y1+ a1.Y2;
ate: 07/17/2002

Response: L/U SECS

Summary of Fit

RSquare	0.677034
RSquare Adj	0.636663
Root Mean Square Error	56.15853
Mean of Response	108.0488
Observations (or Sum Wgts)	82

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	18	117732.37	6540.69	3.2303
Pure Error	54	109339.84	2024.81	Prob>F
Total Error	72	227072.21		0.0004
				Max RSq
				0.8445

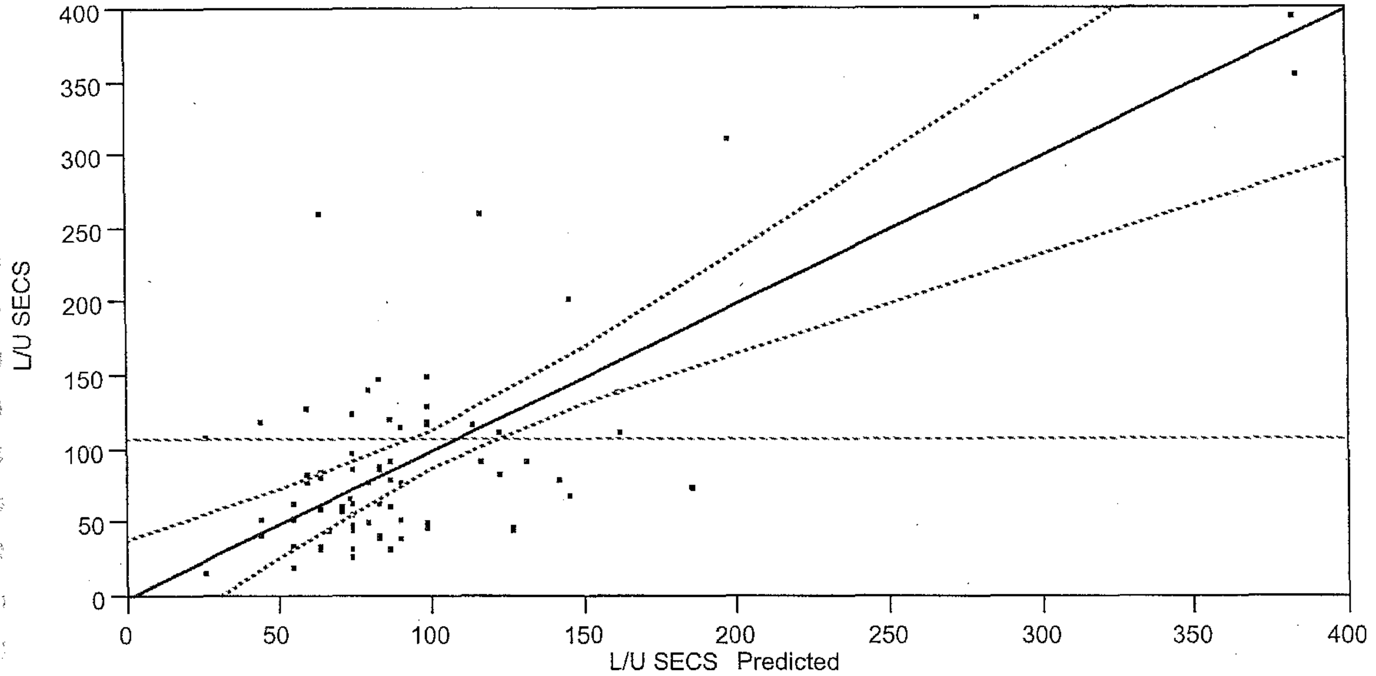
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta	
Intercept	-59.78584	47.2035	-1.27	0.2094	-153.8845	34.312841	0	
VEHICLE	8.6094944	6.690661	1.29	0.2023	-4.728128	21.947117	0.114925	insignificant
VEHCAT	-13.33587	19.17623	-0.70	0.4890	-51.56308	24.891339	-0.07201	insignificant
DRIVER	15.471505	8.306532	1.86	0.0666	-1.087304	32.030314	0.202289	
# E	63.109073	10.1849	6.20	<.0001	42.805788	83.412358	0.643004	
# W	295.05671	57.63649	5.12	<.0001	180.16018	409.95323	1.134931	
#WVEH	-108.7377	46.40535	-2.34	0.0219	-201.2453	-16.23007	-0.51892	
# D	43.315885	21.47782	2.02	0.0474	0.5005269	86.131243	0.176017	
# O	14.891934	25.05376	0.59	0.5541	-35.05195	64.835818	0.064574	insignificant
# SP	51.915636	17.80078	2.92	0.0047	16.430345	87.400928	0.287819	

Effect Test

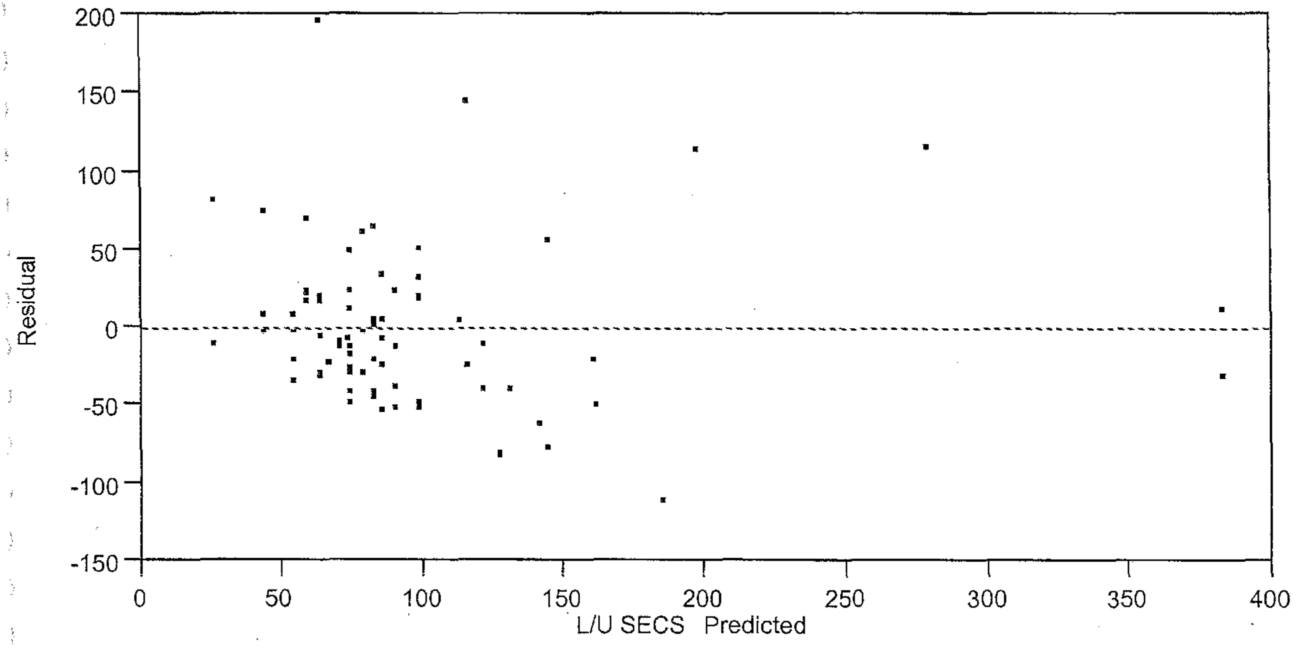
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
VEHICLE	1	1	5222.14	1.6558	0.2023
VEHCAT	1	1	1525.27	0.4836	0.4890
DRIVER	1	1	10941.00	3.4692	0.0666
# E	1	1	121088.03	38.3946	<.0001
# W	1	1	82650.87	26.2069	<.0001
#WVEH	1	1	17316.31	5.4907	0.0219
# D	1	1	12827.60	4.0674	0.0474
# O	1	1	1114.26	0.3533	0.5541
# SP	1	1	26825.62	8.5059	0.0047

Whole-Model Test

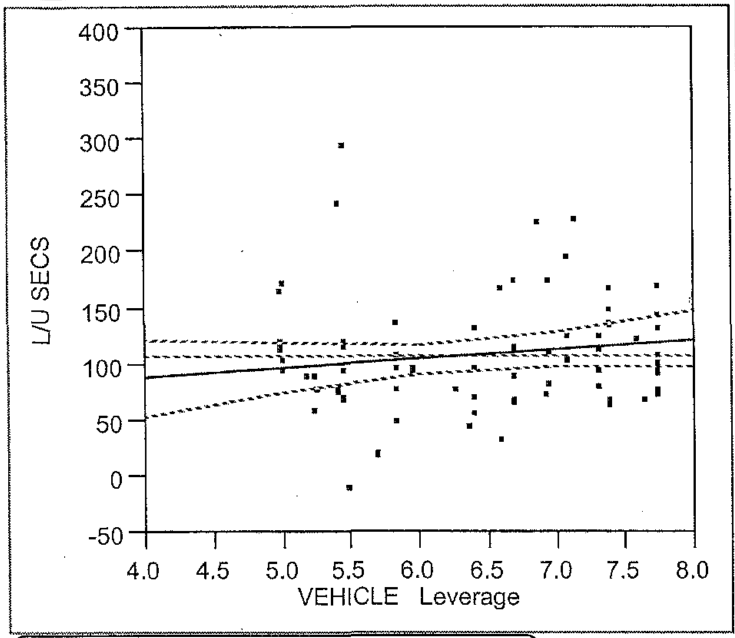


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	476011.60	52890.2	16.7704
Error	72	227072.21	3153.8	Prob>F
C Total	81	703083.80		<.0001



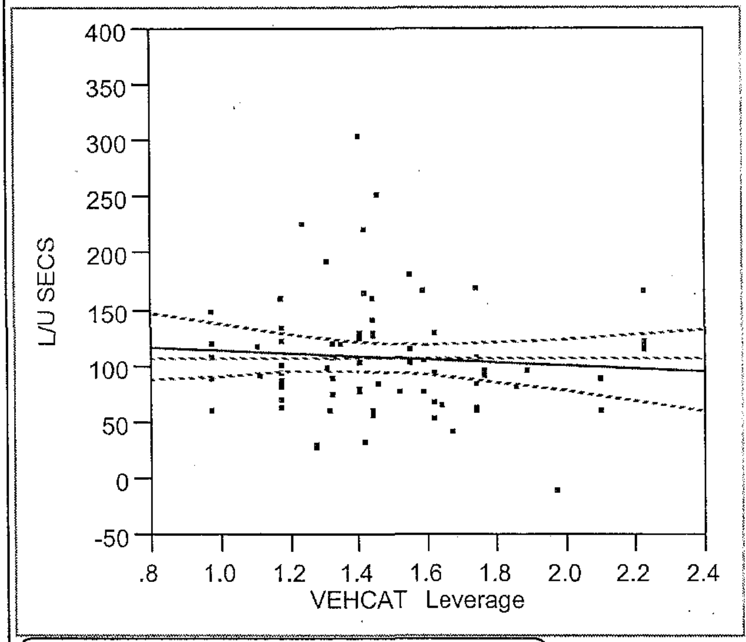
VEHICLE



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
5222.1420	1.6558	1	0.2023

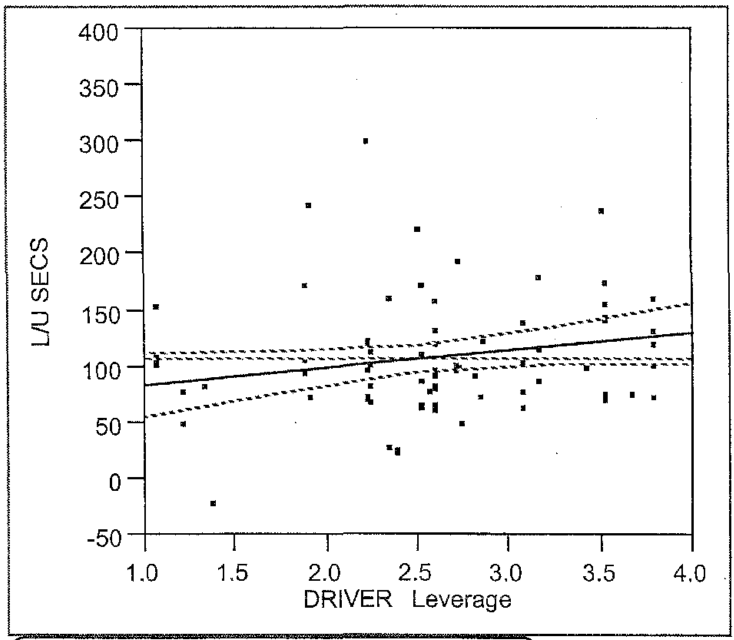
VEHCAT



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
1525.2735	0.4836	1	0.4890

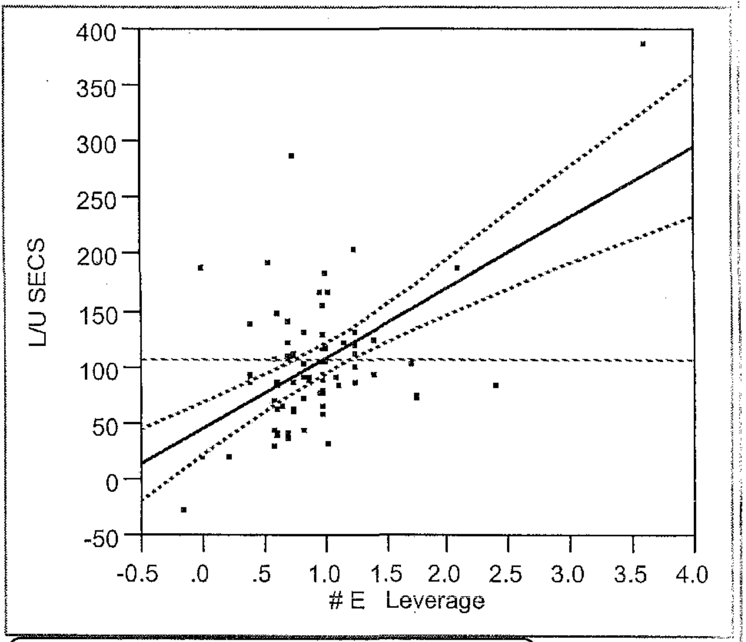
DRIVER



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
10941.004	3.4692	1	0.0666

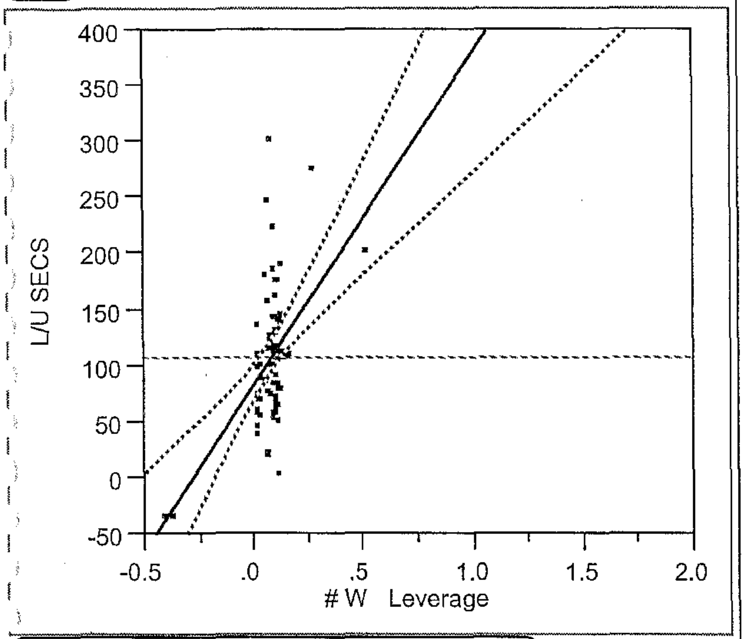
 # E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
121088.03	38.3946	1	<.0001

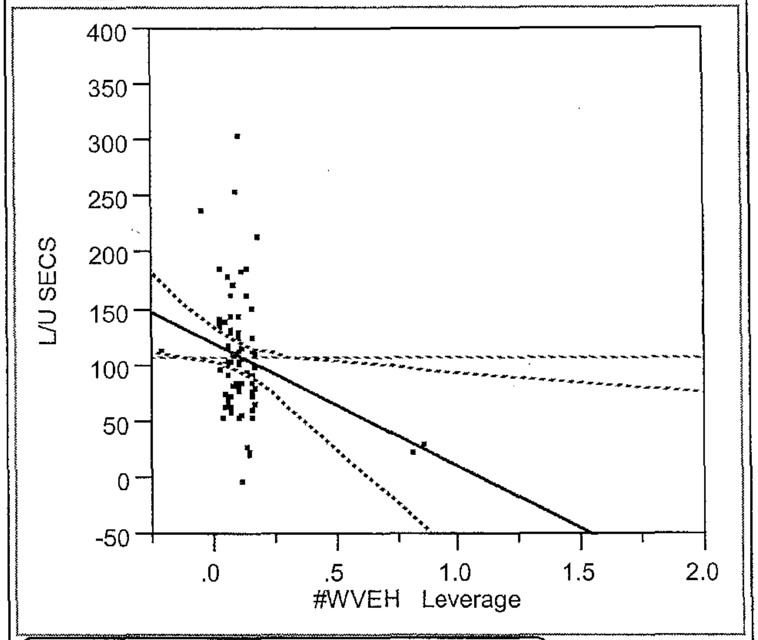
W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
82650.868	26.2069	1	<.0001

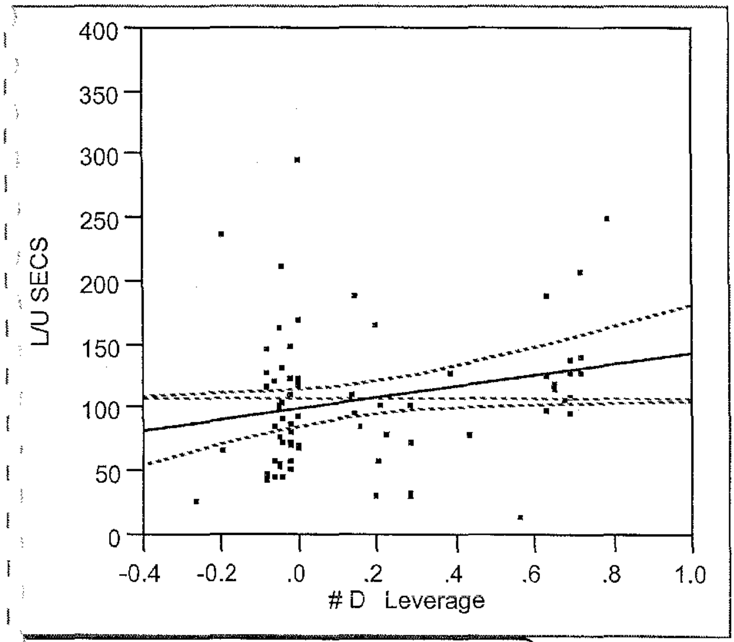
#WVEH



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
17316.312	5.4907	1	0.0219

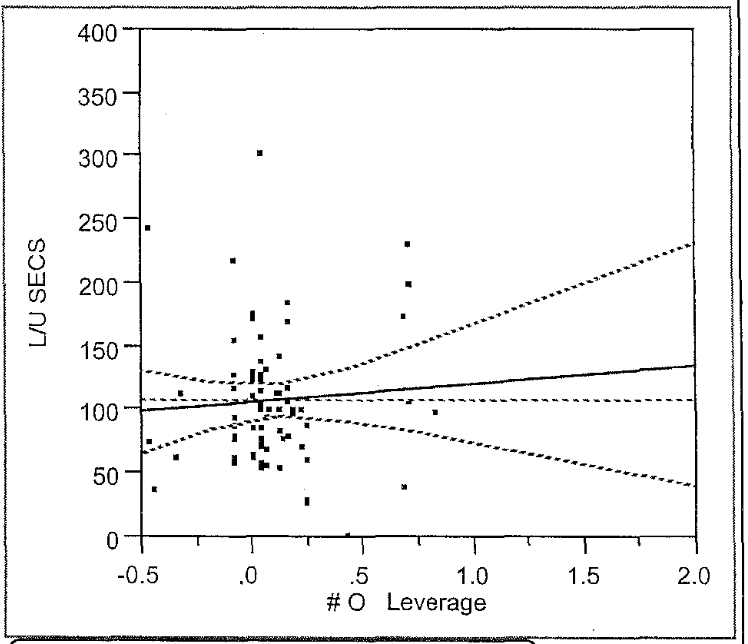
D



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
12827.601	4.0674	1	0.0474

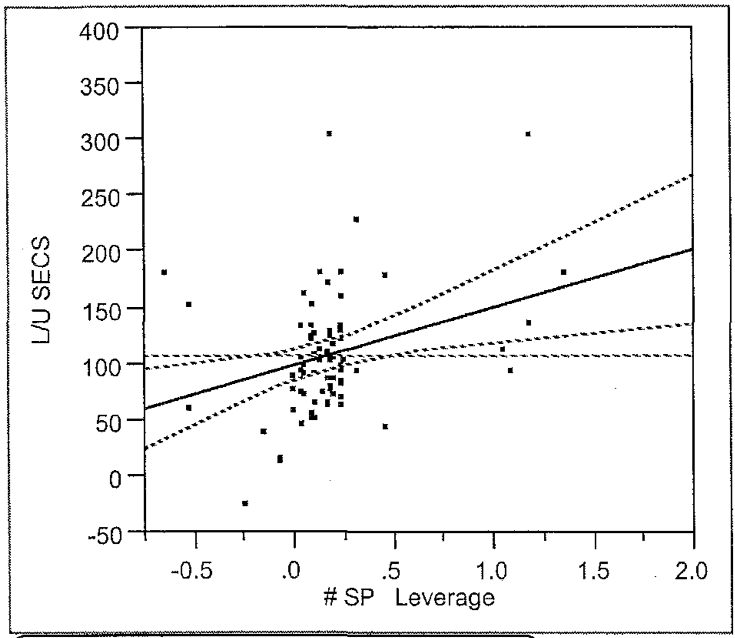
O



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
1114.2633	0.3533	1	0.5541

SP



Effect Test

```
Sum of Squares   F Ratio   DF   Prob>F
     26825.623    8.5059    1   0.0047
```

Intermediate Model in Multiple Regression Containing All Terms.
Date: 07/17/2002
Equation: $\alpha_0 + \alpha_8 Y_8 + \alpha_6 Y_6 + \alpha_7 Y_7 + \alpha_1 Y_1 + \alpha_2 Y_2 + \alpha_{26} Y_{26} + \alpha_5 Y_3 + \alpha_4 Y_4 + \alpha_5 Y_5$

esponse:

Summary of Fit

RSquare	0.667133
RSquare Adj	0.640504
Root Mean Square Error	55.86092
Mean of Response	108.0488
Observations (or Sum Wgts)	82

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	15	114270.40	7618.03	3.8166
Pure Error	60	119762.75	1996.05	Prob>F
Total Error	75	234033.16		0.0001
				Max RSq
				0.8297

Parameter Estimates

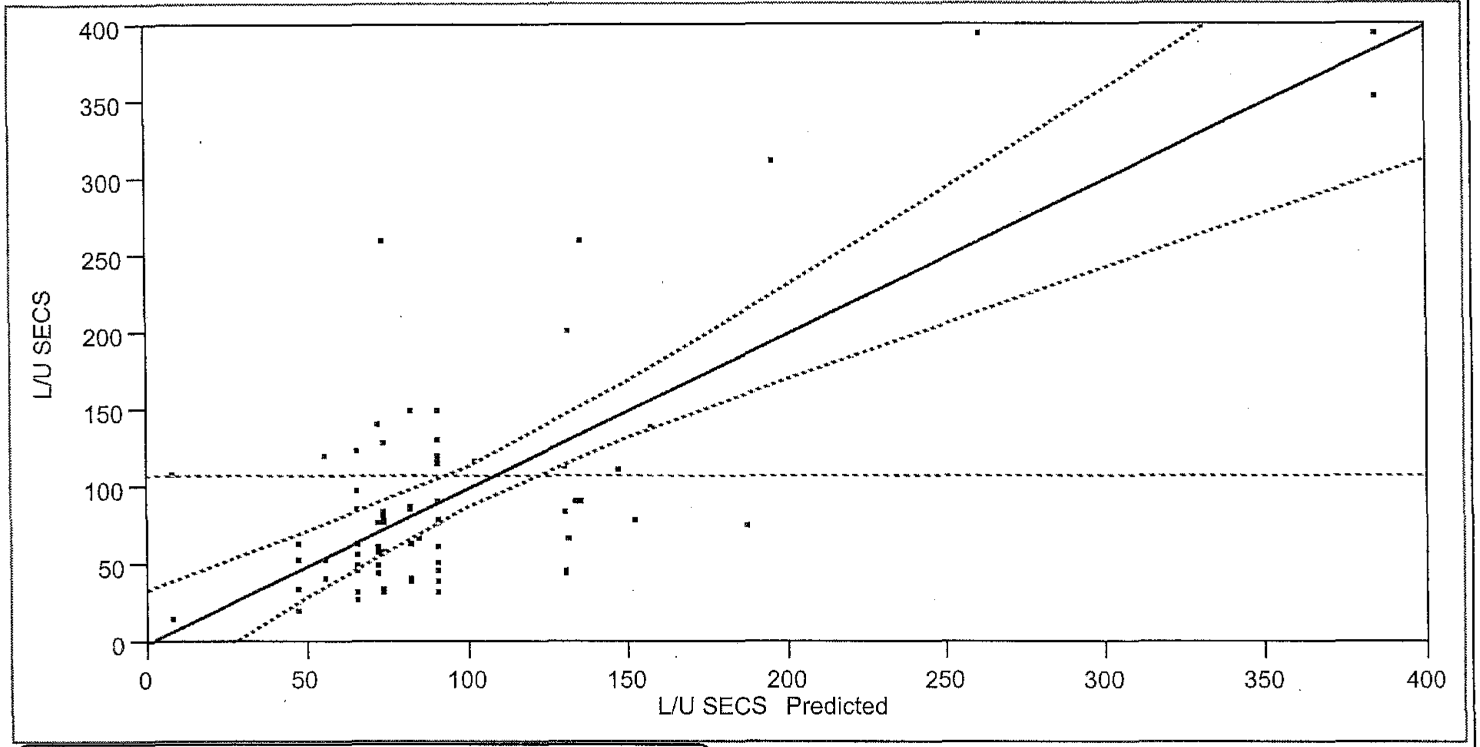
Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	-0.123761	16.91622	-0.01	0.9942	-33.82269	33.575173	0
DRIVER	8.4765599	5.430824	1.56	0.1228	-2.342229	19.295349	0.110831
# E	56.857336	8.214801	6.92	<.0001	40.492567	73.222106	0.579306
# W	307.63614	55.51401	5.54	<.0001	197.04624	418.22605	1.183318
#WVEH	-119.721	44.78091	-2.67	0.0092	-208.9294	-30.51262	-0.57134
# D	38.846508	19.69754	1.97	0.0523	-0.393124	78.086139	0.157856
# SP	61.772265	12.1707	5.08	<.0001	37.526913	86.017616	0.342464

insignificant

Effect Test

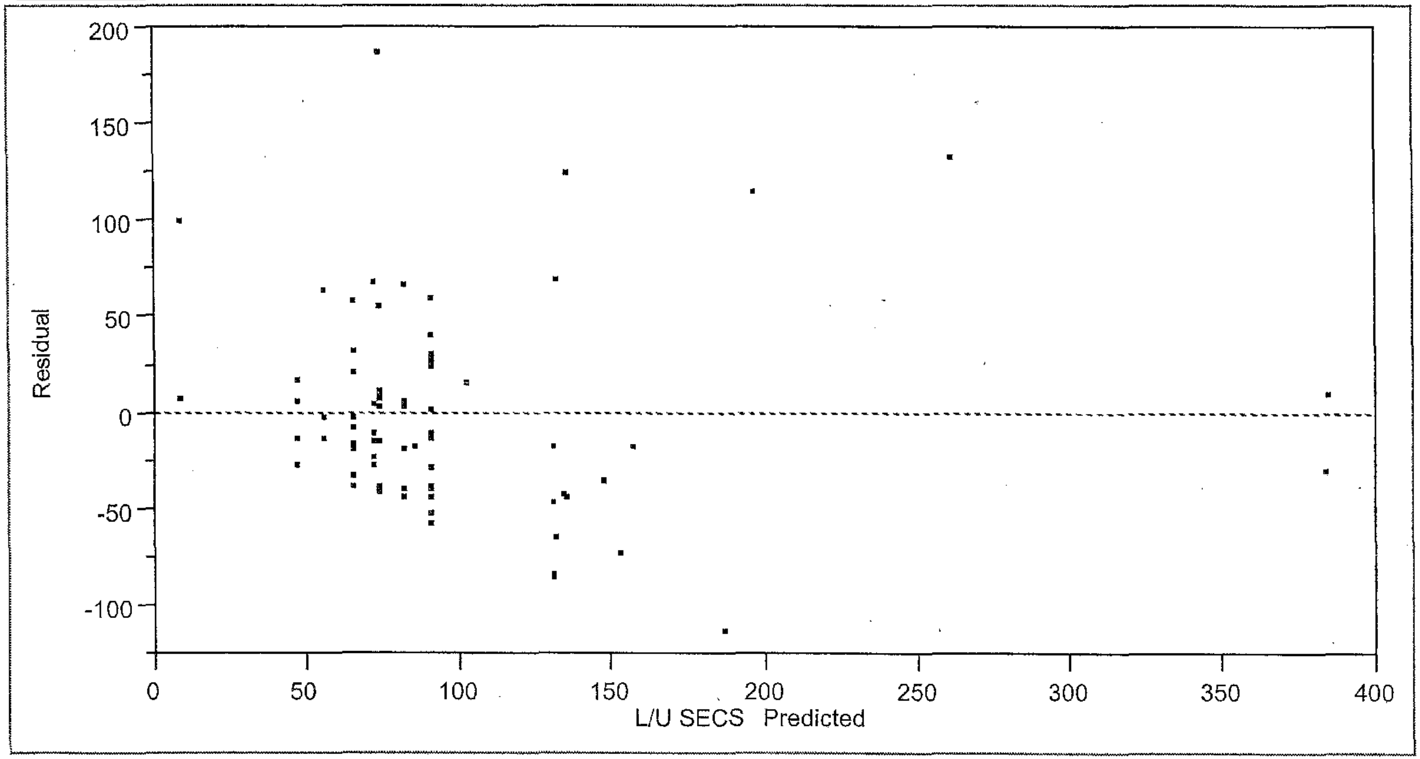
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
DRIVER	1	1	7601.93	2.4362	0.1228
# E	1	1	149484.13	47.9048	<.0001
# W	1	1	95826.50	30.7093	<.0001
#WVEH	1	1	22303.41	7.1475	0.0092
# D	1	1	12136.57	3.8894	0.0523
# SP	1	1	80384.43	25.7606	<.0001

Whole-Model Test

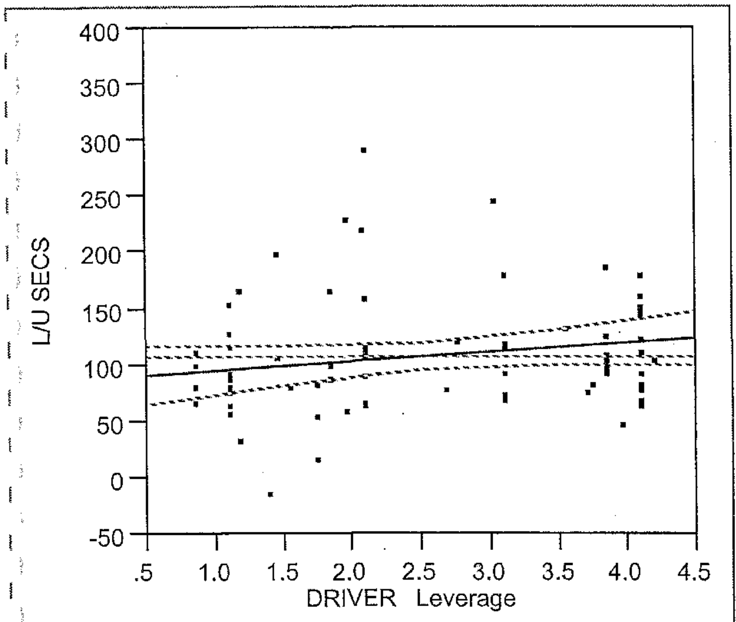


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	469050.65	78175.1	25.0526
Error	75	234033.16	3120.4	Prob>F
C Total	81	703083.80		<.0001



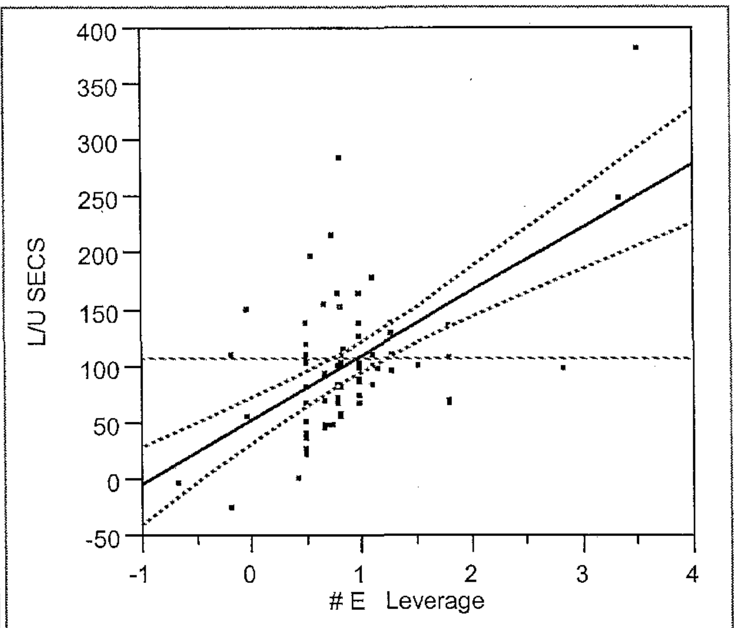
DRIVER



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
7601.9299	2.4362	1	0.1228

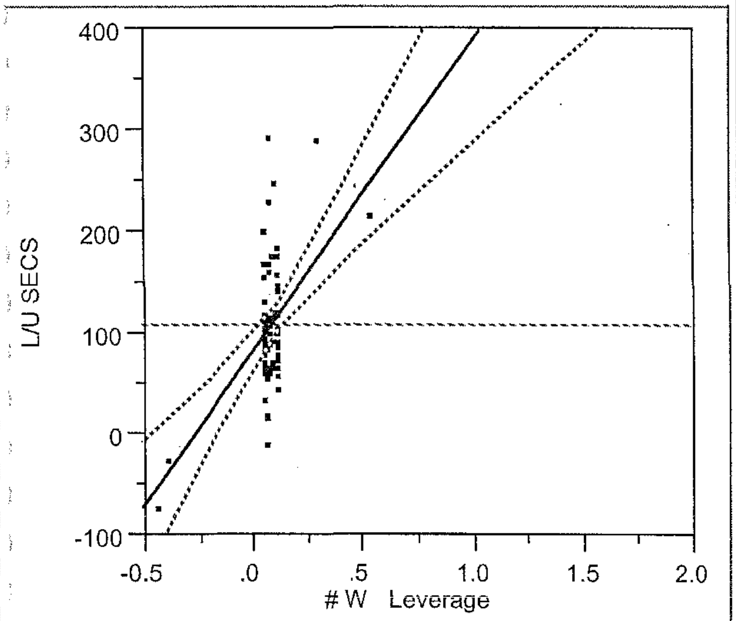
E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
149484.13	47.9048	1	<.0001

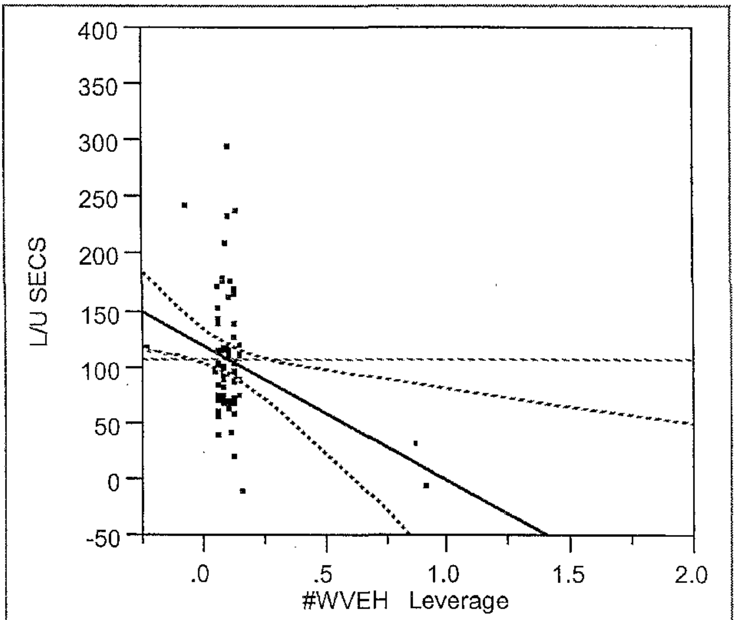
W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
95826.500	30.7093	1	<.0001

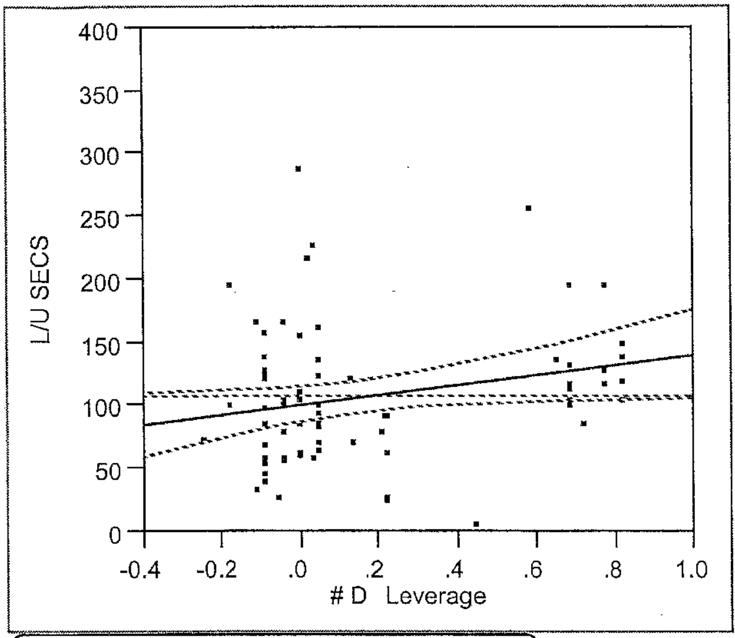
#WVEH



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
22303.406	7.1475	1	0.0092

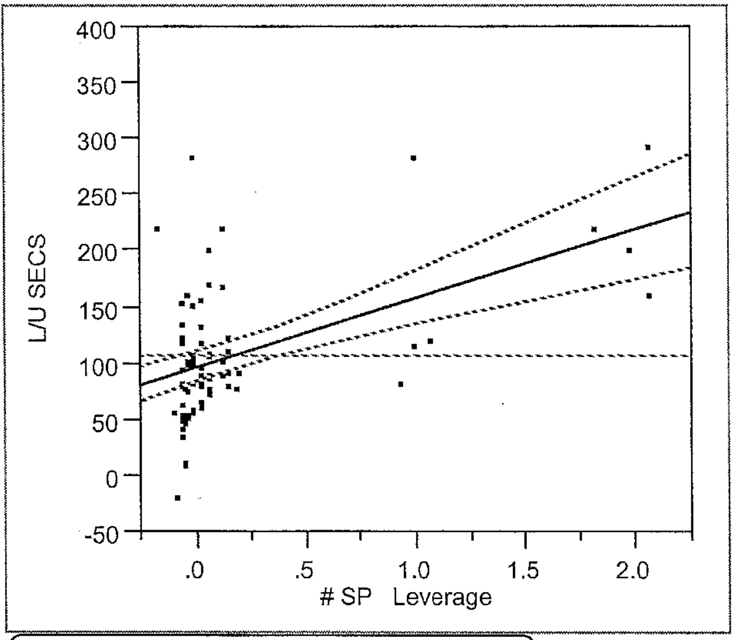
D



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
12136.570	3.8894	1	0.0523

SP



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
80384.431	25.7606	1	<.0001

Intermediate Multiple Regression Model After Removing Insignificant Parameters
Date: 07/17/2002
Equation: $\alpha_0 + \alpha_7 \cdot Y_7 + \alpha_1 \cdot Y_1 + \alpha_2 \cdot Y_2 + \alpha_{26} Y_{26} + \alpha_3 Y_3 + \alpha_5 Y_5$ ·

Summary of Fit

RSquare	0.656321
RSquare Adj	0.633711
Root Mean Square Error	56.38625
Mean of Response	108.0488
Observations (or Sum Wgts)	82

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	7	106512.61	15216.1	7.7701
Pure Error	69	135122.48	1958.3	Prob>F
Total Error	76	241635.09		<.0001
				Max RSq
				0.8078

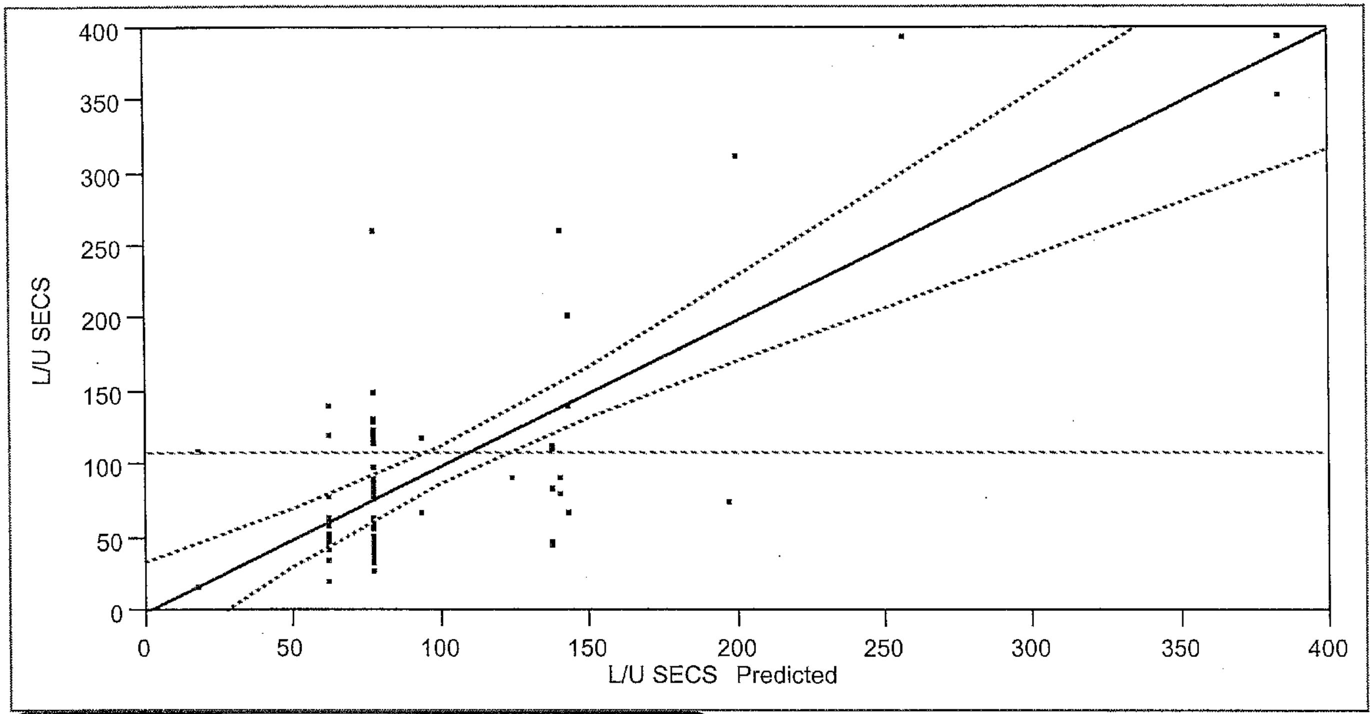
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	17.648912	12.62768	1.40	0.1663	-7.501372	42.799195	0
# E	59.881642	8.058089	7.43	<.0001	43.832517	75.930766	0.61012
# W	289.65012	54.81554	5.28	<.0001	180.47517	398.82507	1.114135
# D	43.999408	19.60153	2.24	0.0277	4.9594615	83.039354	0.178795
# SP	62.923527	12.26258	5.13	<.0001	38.500414	87.346639	0.348847
#WVEH	-106.8995	44.43501	-2.41	0.0186	-195.3998	-18.39925	-0.51015

Effect Test

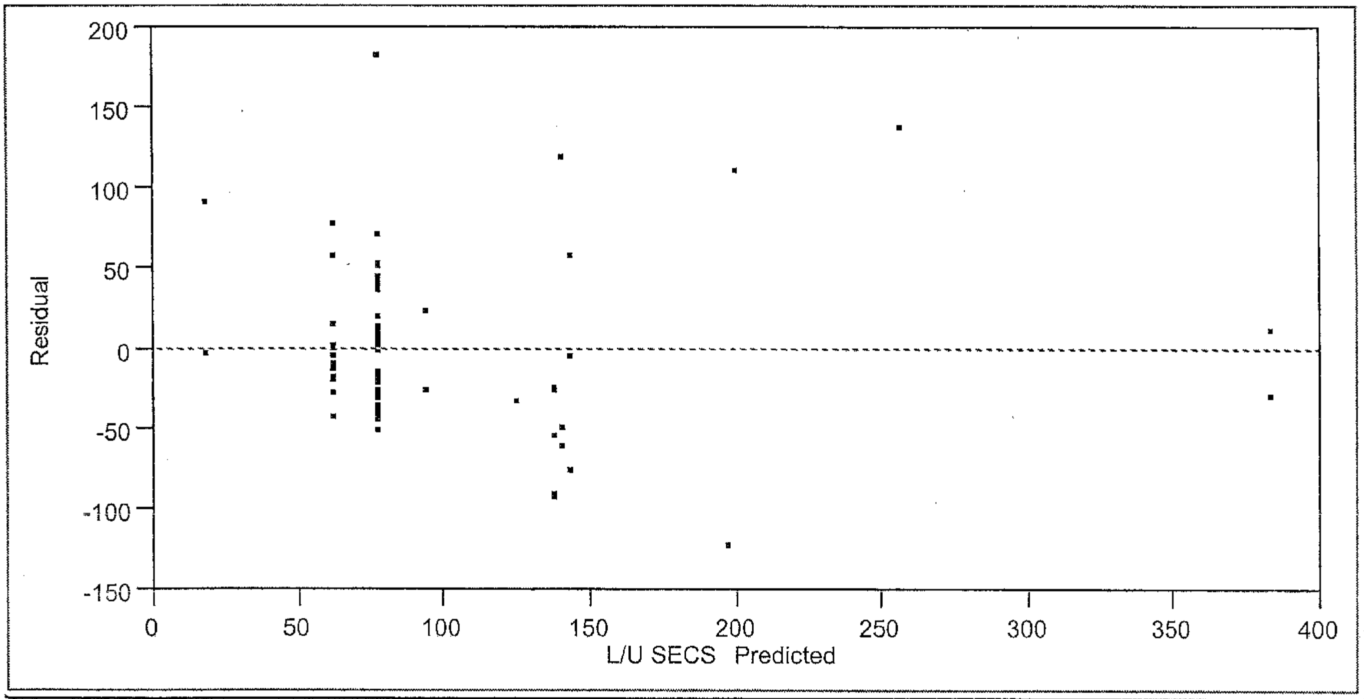
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
# E	1	1	175577.82	55.2234	<.0001
# W	1	1	88774.12	27.9216	<.0001
# D	1	1	16019.91	5.0386	0.0277
# SP	1	1	83716.11	26.3307	<.0001
#WVEH	1	1	18401.25	5.7876	0.0186

Whole-Model Test

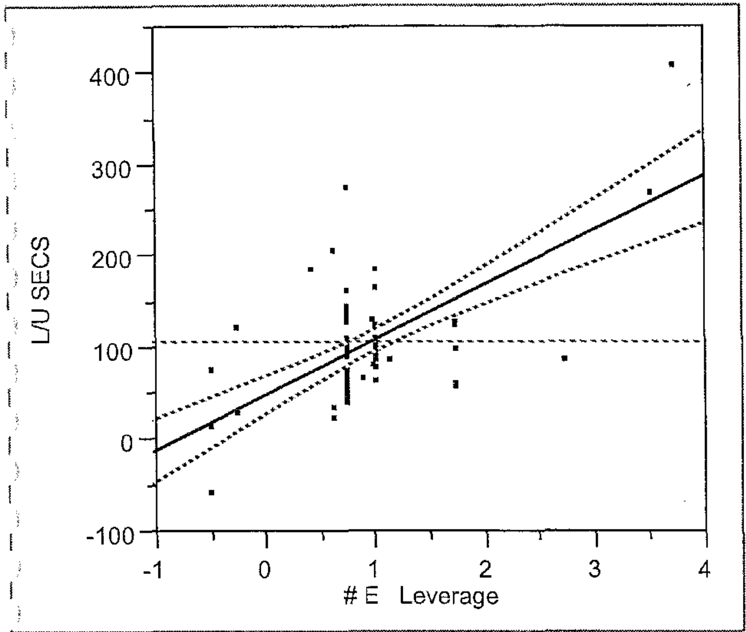


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	461448.72	92289.7	29.0273
Error	76	241635.09	3179.4	Prob>F
C Total	81	703083.80		<.0001



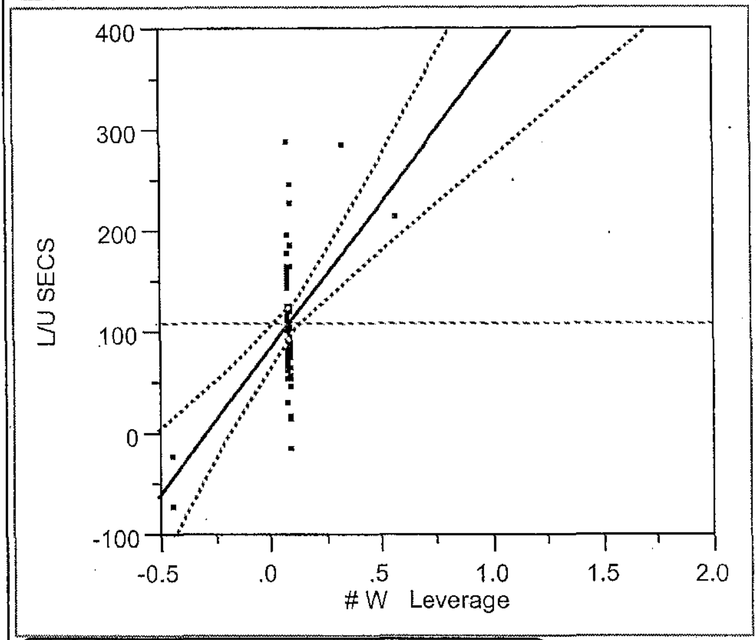
 # E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
175577.82	55.2234	1	<.0001

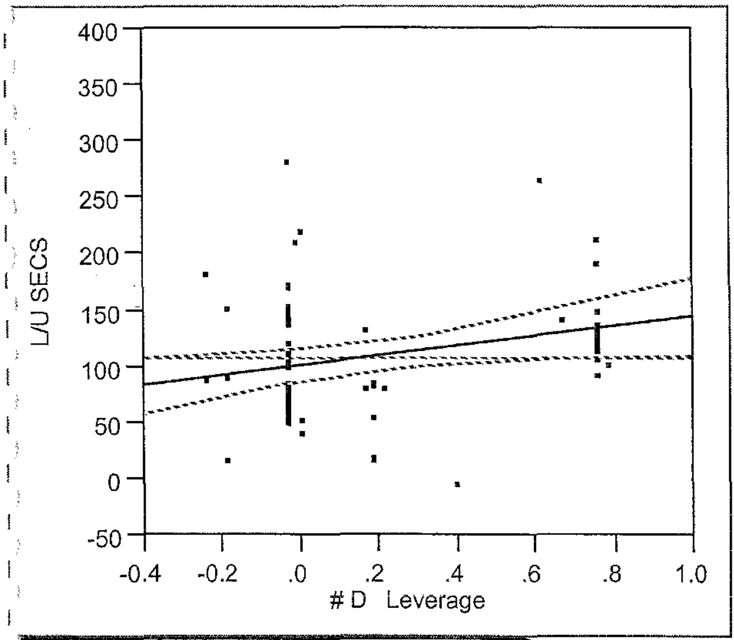
 # W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
88774.121	27.9216	1	<.0001

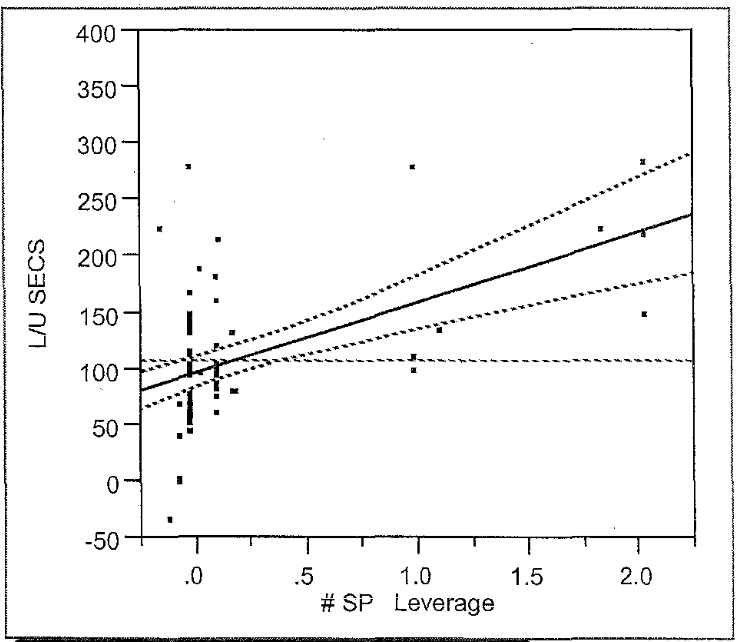
 # D



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
16019.915	5.0386	1	0.0277

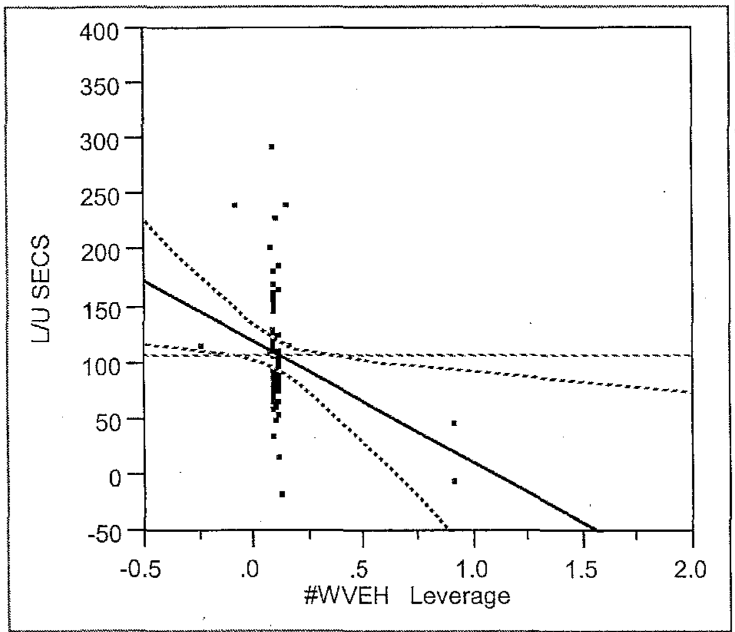
 # SP



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
83716.115	26.3307	1	<.0001

#WVEH



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
18401.250	5.7876	1	0.0186

Final Multiple Regression Model to Predict Load Times
Equation: Lest = a0 + a1.Y1+ a2.Y2 + a3.Y3 + a5.Y5 + a26.Y26;
Date: 07/17/2002

APPENDIX - V

OBSERVATIONS DROPPED FROM LOAD TIME DATA

Observations dropped from the time study data to normalize load times. This was done because they were detected as outliers due to reasons that are not considered in this analysis. The reasons are explained after each observation

1. Passenger No: 23, on 06/24/2002 in U6 and Driver was Becky (Id – 2). The pick up was in front of MSU field house, and there was a wait for about 14 minutes, which the driver is not supposed to do. This is the dropped information for all the load times.
2. Passenger No: 17, on 07/01/2002 on U7 and Driver was Tom (Id – 3). The pick up was in front of the Perk entrance of Highland Park, and the driver arrived there early and simply waited for around 8 minutes. This drop is to normalize the data for Vehicle-Driver combinations.
3. Passenger No: 40, on 06/26/2002 on U5 and Driver was Becky (Id – 2). The two elderly ladies were loaded with extra times because the driver has to go in search for them as she arrived early.
4. Passenger No: 42, on 06/26/2002 on U5 and Driver was Becky (Id – 2). The two elderly ladies were loaded with extra times because the driver has to go in search for them as she arrived early.
5. Passenger No: 69, on 06/26/2002 on U5 and Driver was Becky (Id – 2). The elderly lady was loaded with extra times because the lady was on phone when the driver arrived to pick her up. That wait is not accounted for loading times.
6. Passenger No: 62, on 06/26/2002 on U5 and Driver was Becky (Id – 2). The disabled person was dropped at American federal bank. He has to be picked up from there. So the driver waited there for the passenger there till he finished the business. The wait time is not a normal loading time.
7. Passenger No: 20, on 06/24/2002 on U6 and Driver was Becky (Id – 2). The driver had to wait for the shift of the passenger to get over at REACH Inc. This forced waiting time cannot be counted as loading time.
8. Passenger No: 21, on 06/24/2002 on U6 and Driver was Becky (Id – 2). The driver had to wait for the shift of the passenger to get over at REACH Inc. This forced waiting time cannot be counted as loading time.
9. Passenger No: 11, on 07/01/2002 on U7 and Driver was Tom (Id – 3). Since there were not much rides that day and the driver had to drop a passenger 5 minutes before the pick up at the same location, he just waited for his next ride to come out of hospital.
10. Passenger No: 24, on 06/27/2002 on U8 and Driver was Richard (Id – 1). The lady took extra time in doing some personal thing when the driver arrived. This forced the driver to wait, which cannot be considered as load times.

APPENDIX - VI

VEHICLE CATEGORY INFORMATION

This appendix presents an overview of the resources (vehicles) used in Galavan. Many features (attributes) of the resources have been converted to numerical values for doing statistical analysis. These attributes can be significant in assigning the vehicle to pick up a certain category passenger. Table 1 represents the details of resources (vehicles) used in Galavan.

Table 1 - Configuration Details of Vehicles used in Galavan

VH. NM	CD	MANUFACTR	MODEL	W.C. LFT	COND	MANUAL FLD RMP	SLD DRS	LEV DR	DR SD	CAP
U4	4	FORD		YES	NW	NO	NO	YES	R	12
U5	5	FORD		YES	NW	NO	NO	YES	R	8
U6	6	DODGE	CARAVAN	NO	-	YES	YES	NO	B	6
U7	7	DODGE	CARAVAN	NO	-	YES	YES	NO	B	6
U8	8	CHEVROLET		YES	W	NO	NO	YES	R	12

The abbreviations used in Table 1 are explained in the Figure 1 below. These abbreviations are kept the same as that of the industrial circle. Other abbreviations are provided by the analyzer based on his concept of features and the set up of the time study data.

VH. NM – VEHICLE NAME USED BY GALAVAN
CD – CODE USED IN STATISTICAL DATA ANALYSIS
MANUFACTR – MANUFACTURER: WHICH AUTOMOBILE COMPANY MADE IT
MODEL – SPECIFIC MODEL OR MAKE DETAIL
W.C LFT – ELECTRICALLY OPERATED WHEEL CHAIR LIFT
COND – CONDITION: WORKING OR NOT
MANUAL FLD RAMP – MANULA FOLDING RAMP FOR WHEEL CHAIR LOADING
SLD DRS – SLIDING DOORS
LEV DR – LEVER OPERATED DOOR
DR SD – DOOR SIDE: WHICH SIDE OF THE VEHICLE THE PASSENGER LOADING DOOR
CAP - CAPACITY

NW – NOT WORKING
R – RIGHT SIDE
B – BOTH SIDE
W – WORKING

Figure 1 - Details of abbreviations used in vehicle configuration table

APPENDIX - VII

UNLOAD TIME ANALYSIS APPENDIX

The analyses of unload times were done in the same way as it was done for the load times. Since any passenger who was loaded has to be unloaded at certain point to complete his/her journey, both the activities were interdependent under normal circumstances. By looking at the process study of loading and unloading procedure followed in Galavan attached in Appendix - I, the steps were generally the same. In other words all the factors that were applicable for predicting load times came handy for unload times too.

The factors that were considered in the unload times were the same as that of the load times. So they are not explained in detail, just a mention of them would suffice.

- **Passenger Type**

The classification was the same as that of load times. The detailed statistical analyses of the unloading times for each type of passengers are included at the end of this section. These include the scatter plot of the load and unload times with various contributing factors. The main classifications in passenger types are as follows:

- EL – Elderly passengers:
    - 0 – no elderly person unloaded at a point.
    - > 0 – the number of elderly passengers unloaded at destinations.
- WC – Wheel chair passengers:
    - 0 – no wheel chair passenger unloaded.
    - > 0 – number of wheel chair passengers unloaded at destinations.
- DB – Disabled passengers:
    - 0 – no disabled passenger unloaded at a point.
    - > 0 – number of disabled passengers unloaded at a single point.
- SP – Special category passengers:
    - 0 – no special category passenger unloaded at a point.
    - > 0 – the number of special category passengers unloaded at a single point.

The times show that unload times also follow the general trend as in the case of load times. The unload times are lesser compared to load times because the element of wait for the passenger to come out of his/her home is not present.

The following were the conclusions that were made from the times observed after analysis.. These conclusions were important as they form the basis of analysis in the multiple regression models.

- The mean unload time for the Special Category passengers were more compared to the elderly and disabled. The passengers in special category were those that are partially blind, passengers on walkers, and passengers with small kids. They all move slowly or have special attachments to unload like car seat, folding walker etc. That makes their unloading time more compared to the passengers in Elderly and Disabled category.
- Wheel Chair Passengers need more time to get unloaded (almost twice) because of the undoing of extra strapping mechanisms that hold the passenger and wheel chair safe when the vehicle is in motion. It is a must to use the ramp or lift to unload them.

- **Vehicle Type**

The effect of the vehicle on unload times can be significant as in the case of load times. To verify the hypothesis that the loading/unloading mechanism of the vehicles have an impact on the associated times the same classification of vehicles were followed here. All the available vehicles were grouped into two. Category 1 contains the vehicles with electrical wheel chair lift and lever operated door. Category 2 contains the vehicles with manual folding ramp for wheel chair loading and sliding doors.

The detailed statistical analysis of the effect of vehicle type on unload times was done by scatter plots, box plot, and by using other statistical computations. Those details could be found at the end of this section.

- **Driver Experience**

It was the driver who decides who to be dropped off first after picking up. Also the experience of the driver in the associated steps of unloading can lead to better performance. The hypothesis was that a new driver would take more time to unload a passenger than an experienced one.

The difficulty in the current studies was that there was a factor that cannot be controlled. Some of the passengers need driver assistance to move to the front door of their destination. In this time study that times also got entangled with the unload times. So for verifying the initial observation or hypothesis those times were to be filtered out and a finer time study needs to be conducted.

It can be seen that in some cases the RSquare fit of the regression model for unload times gives a better value. This needs further investigation to prove the driver effect.

- **Passenger Type X Vehicle**

As observed in the case of Load times it was necessary to verify the effect of load/unload mechanism on the unload times of passenger types. Since it is being predominant in the case of wheel chair passengers, the same analysis was conducted for the unload times of vehicles with electrical wheel chair lift and the manual folding ramp mechanisms.

In the load time analysis appendix (Appendix – IV), the elements of time study and its relation to the mechanicals of the wheel chair lift are given. The same procedure of isolating the passenger dependent times from the unloading times was done. This was because in most of the wheel chairs the driver needs to move the passenger to his/her front door after unloading from the vehicle. This time needs to be removed to study the effect of loading/unloading mechanism. The time study was conducted for the manual folding ramp type unloading mechanism. Table 1 gives the average times for each element of time study.

Table 1 - Unloading times for wheel chair at each step for a Category 2 vehicle

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	5.667
2	Open sliding door	3.333

3	Unfold Ramp	4.333
4	Unstrap the wheel chair.	25.333
5	Unload wheel chair from vehicle	7.667
6	Move wheel chair to drop off	30.000
7	Fold the ramp back	5.667
8	Close sliding door	5.000
9	Walk back and go	16.000
Grand Total =		103.000

The effective time for unloading a wheel chair on a manual folding ramp mechanism then became 103.000 – 30.000 = 73 seconds. This was very close to the load times for the same configuration.

The study was also conducted for the unloading times of a passenger based on the electrical wheel chair lift mechanism. The event-by-event times are given in Table 2 and the effective unload time is calculated from the values.

Table 2 - Unloading times for wheel chair at each step for a Category 1 vehicle

Sl. No	Element Description	Average Time (Secs)
1	Walk to the sliding door	8.33
2	Open sliding door	3.33
3	Unfold Ramp	19.00
4	Unstrap the wheel chair.	59.33
5	Unload wheel chair from vehicle	33.64
6	Move wheel chair to drop off	45.00
7	Fold the ramp back	20.33
8	Close sliding door	7.00
9	Walk back and go	25.33
Grand Total =		221.29

The effective time for unloading a wheel chair on an electrically operated wheel chair lift mechanism then became 221.29 – 45.00 = 176.29 seconds. Thus the final comparisons of unload times for both of the wheel chair loading mechanisms is given in Table 3.

Table 3 - Summary of Unload times for wheel chair passengers on available vehicle configurations

Wheel Chair Loading Mechanism Type	Unload Times
Manual Folding Ramp	73.00
Electrical Wheel Chair Lift	176.29

The reduction in average unload times for the electrical wheel chair lift mechanism can be attributed to its unstrapping times that were much less compared to the strappage times.

DETAILED ANALYSIS

Considering all the above stated factors the detailed analysis of unload times was conducted by the method of multiple regressions. The variables used in the model have the same name as that of the load times but only the coefficients (slope terms) vary.

The procedure to obtain the final multiple regression model was the same as that in the load time analysis. Each variable was added to the equation, noting its effect on the RSquare value as well as the t-ratio to estimate the change of significance. The initial model was formulated with the first two independent variables; number of elderly passengers and number of wheel chair passengers. The model thus generated is represented in Equation 1.

$$\mathbf{U_{est} = \gamma_0 + \gamma_1.Y_1 + \gamma_2.Y_2;}$$

Where U_{est} is the predicted Unload Time

$$\mathbf{U_{est} = 40.37 + 19.36\ Y_1 + 70.42\ Y_2;}$$

Equation 1 - Initial multiple regression equation for Unload time estimation

The RSquare value for this model was found to be 0.4113. This means that the model explains 41.13% of the variability in the system. Also the coefficients of the equation make physical sense too. Positive coefficients ensure that as the number of passengers of the category increases the unload time also increases. Also the increase of unload time was more if the passenger is of wheel chair category. This was a statistical verification of the hypothesis made in the preliminary analysis.

The t-ratio evaluation for finding the significance for each of the independent variables was conducted. The procedure was the same as the hypothesis testing in statistics. In this regard the null hypothesis and the alternative hypothesis were as follows.

H_0: $\gamma_1 = 0$; $\gamma_2 = 0$. (Insignificance).
H_1: $\gamma_1 \neq 0$; $\gamma_2 \neq 0$. (Significance).

The observed values of probability was < 0.0001. This establishes the significance of the factors and thus the null hypothesis gets rejected and the alternative hypothesis gets accepted (this means that the factors are of high significance). The statistical details of all these analysis are included at the end of this section.

The analysis continued by adding all variables one by one into the multiple regression model. When all the variables were added the final equation gave a good RSquare value. Yet some of the terms gave a very low significance value when done with the t-ratio analysis. The model was then refined with the help of removing the insignificant terms and still be able to get a good RSquare value. The regression model with all terms added in it is given in Equation 2 below.

$\mathbf{U_{est} = \gamma_0 + \gamma_1.Y_1 + \gamma_2.Y_2 + \gamma_3.Y_3 + \gamma_4.Y_4 + \gamma_5.Y_5 + \gamma_6.Y_6 + \gamma_7.Y_7 + \gamma_{26}.Y_{26} + \gamma_8.Y_8;}$
Where U_{est} – estimated Unload Time

$\mathbf{U_{est} = -19.48 + 26.2\ Y_1 + 95.91\ Y_2 + 19.37\ Y_3 + 8.87\ Y_4 + 19.66\ Y_5 + 4.21\ Y_6 + 9.08\ Y_7 - 8.51\ Y_{26} + 2.31\ Y_8;}$

Equation 2 - Multiple Regression Model with all parameters for Unload time prediction

It was noted that some of the terms never made any physical sense. For example the interaction between the wheel chair passenger and the vehicle type shows a negative coefficient due to the coding values used to categorize the vehicle types. Also a significance test was conducted on the parameters of the selected model and the results were used to decide the terms to be kept and the ones to be left out.

The hypotheses for the testing were stated as follows. The null hypothesis implies the insignificance of all factors, where as the alternative hypothesis says that at least one of the factors are significant.

H_0: $\gamma_0 = 0$; $\gamma_1 = 0$; $\gamma_2 = 0$; $\gamma_3 = 0$; $\gamma_4 = 0$; $\gamma_5 = 0$; $\gamma_6 = 0$; $\gamma_7 = 0$; $\gamma_{26} = 0$; $\gamma_8 = 0$. (Insignificance).
H_1: $\gamma_0 \neq 0$; $\gamma_1 \neq 0$; $\gamma_2 \neq 0$; $\gamma_3 \neq 0$; $\gamma_4 \neq 0$; $\gamma_5 \neq 0$; $\gamma_6 \neq 0$; $\gamma_7 \neq 0$; $\gamma_{26} \neq 0$; $\gamma_8 \neq 0$. (Significance).

The Table 4 summarizes the values for the significance test for each of these coefficients. At a level of significance of 0.05 the factors marked significant stayed in the final model whereas others were found insignificant and hence removed from this model to obtain the final model.

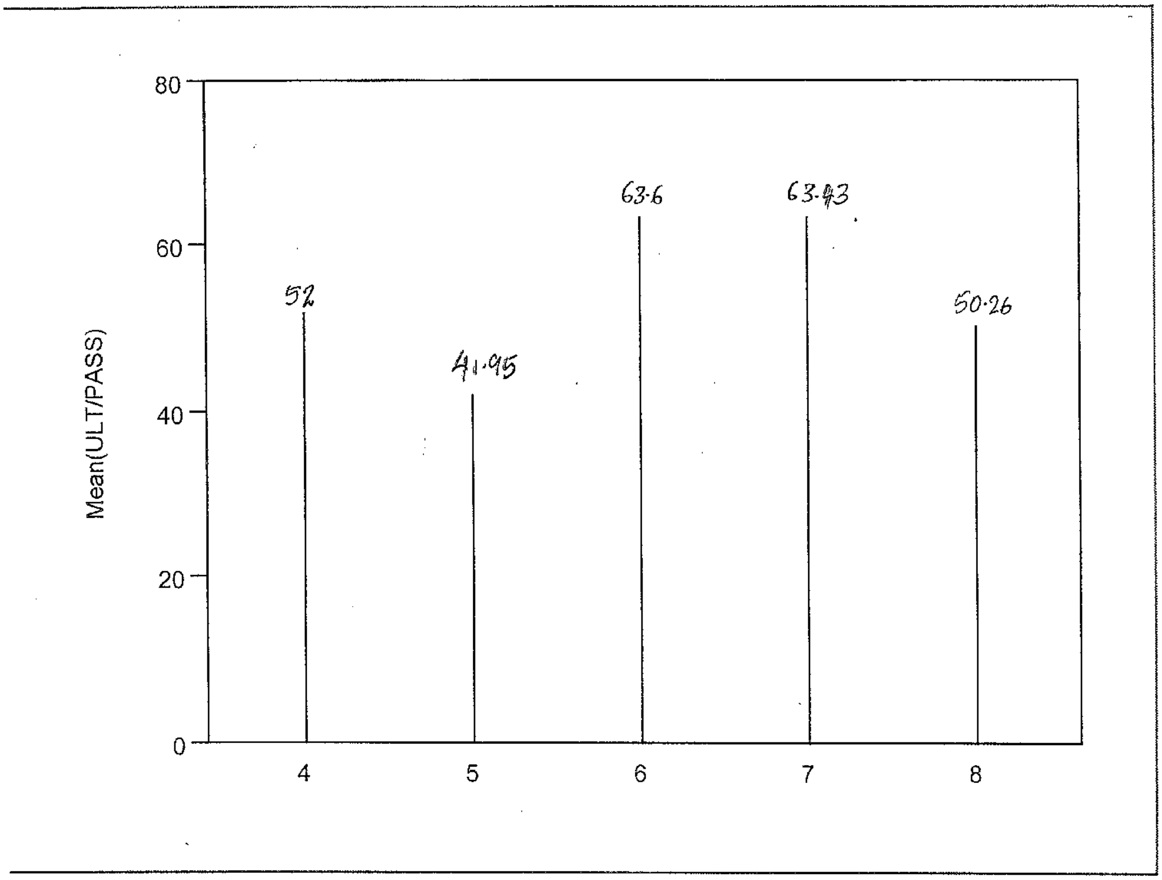
Table 4 - Details of F-ratio analysis for all factors model for predicting Unload Time

Sl. No	Coefficients	Values	F-ratio	Prob > | F |	Conclusion
1	γ_0	-19.47	-0.81	0.42	Insignificant; Accept H_0
2	γ_1	26.2	5.09	< 0.0001	Significant; Accept H_1
3	γ_2	95.91	3.38	0.0012	Significant; Accept H_1
4	γ_3	19.37	2.13	0.0368	Significant; Accept H_1
5	γ_4	8.87	0.72	0.4767	Insignificant; Accept H_0
6	γ_5	19.66	2.30	0.0242	Significant; Accept H_1
7	γ_6	4.21	0.38	0.7059	Insignificant; Accept H_0
8	γ_7	9.08	1.89	0.0624	Significant; Accept H_1
9	γ_{26}	- 8.51	-0.39	0.6965	Insignificant; Accept H_0
10	γ_8	2.31	0.64	0.5234	Insignificant; Accept H_0

The RSquare fit for this model was found out to be around 0.573. This implied that around 57.3% of the variability in the system is explained by the proposed model. This model was considered as parsimonious (over populated with insignificant terms) and hence some of the insignificant terms were removed for a better model with comparable RSquare value of fit. The model is depicted in the body of the report and the Jumpin analysis details are included at the end of this section of the report.

All these analysis were conducted with the help of Jumpin statistical package and hence the graphs and analysis print outs were required for completeness. The multiple regression analysis with all these three models gave a lot of information, which is available in the next pages of this section of appendix. The residual plots, predicted value versus the originals, effect test of each factor, ANOVA (Analysis of variance) etc are available in this sections. This was included for the completeness in technical reference for this report.

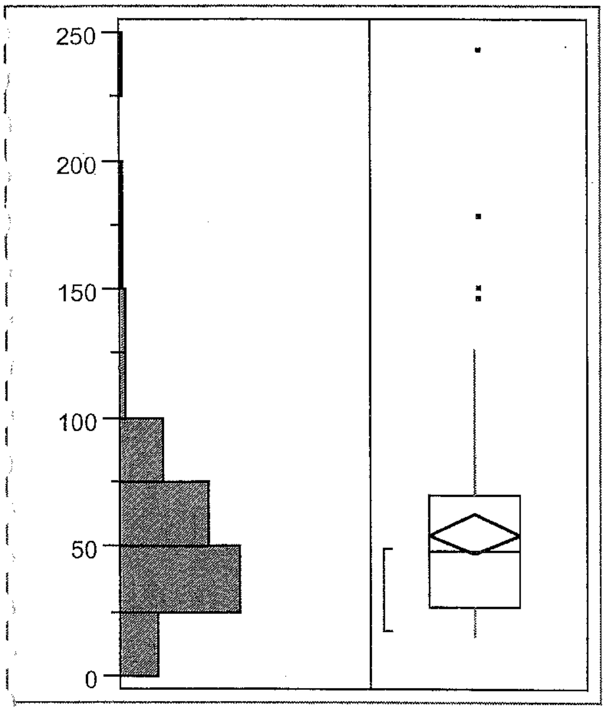
Mean Unload Time vs Vehicle Type



Mean unload Time For All Passenger Type on Available Vehicles in Galavan
Date: 07/18/2002

VEHICLE Levels Options
Mean(ULT/PASS)

ULT/PASS



Quantiles

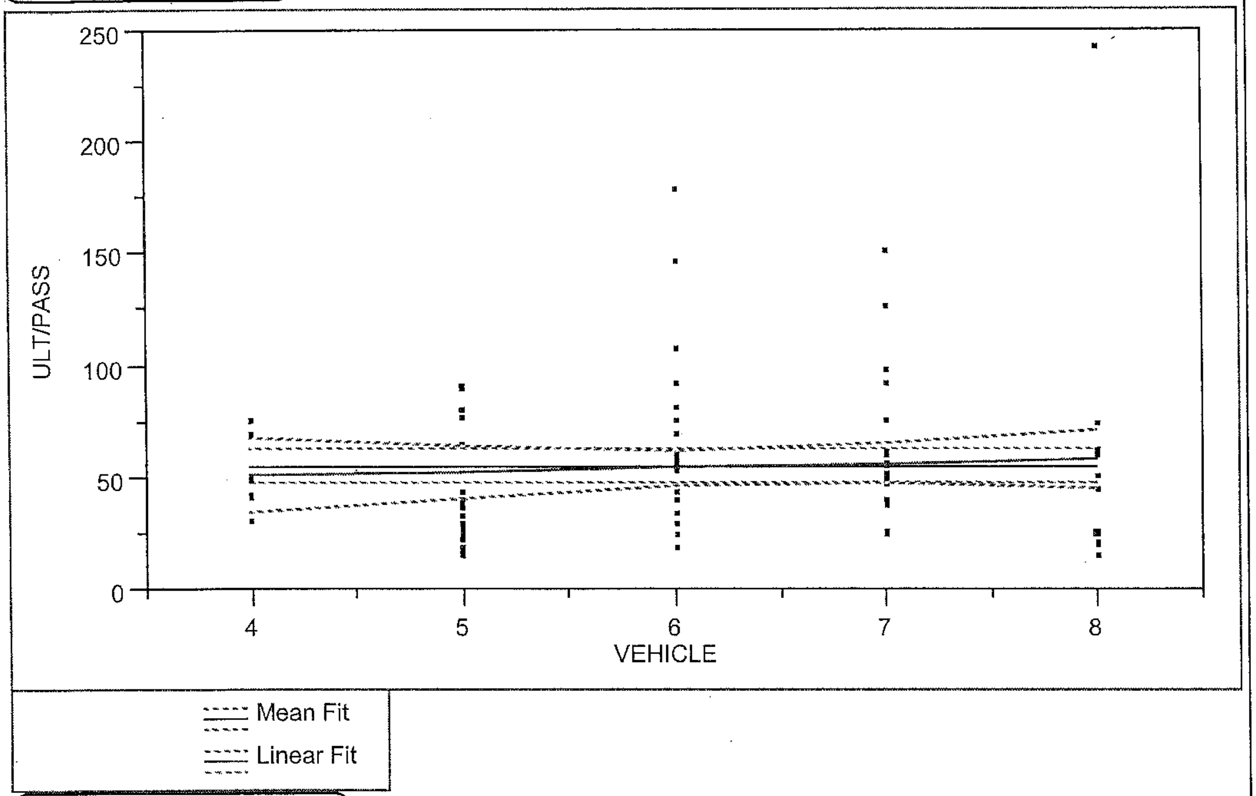
maximum	100.0%	244.00
	99.5%	244.00
	97.5%	170.90
	90.0%	93.00
quartile	75.0%	70.00
median	50.0%	49.00
quartile	25.0%	27.25
	10.0%	21.65
	2.5%	16.65
	0.5%	16.00
minimum	0.0%	16.00

Moments

Mean	55.28913
Std Dev	37.15427
Std Error Mean	3.87360
Upper 95% Mean	62.98360
Lower 95% Mean	47.59466
N	92.00000
Sum Weights	92.00000
Sum	5086.6
Variance	1380.4394
Skewness	2.28525
Kurtosis	7.73250
CV	67.19995

ox Plot For Unload Times For All passenger Types On Available Vehicles In Galavan
ate: 07/18/2002

ULT/PASS By VEHICLE



Mean Fit

Mean	55.28913
Std Dev [RMSE]	37.15427
Std Error	3.8736
SSE	125620

Linear Fit

ULT/PASS = 43.9411 + 1.79077 VEHICLE

Summary of Fit

RSquare	0.003486
RSquare Adj	-0.00759
Root Mean Square Error	37.29493
Mean of Response	55.28913
Observations (or Sum Wgts)	92

Analysis of Variance

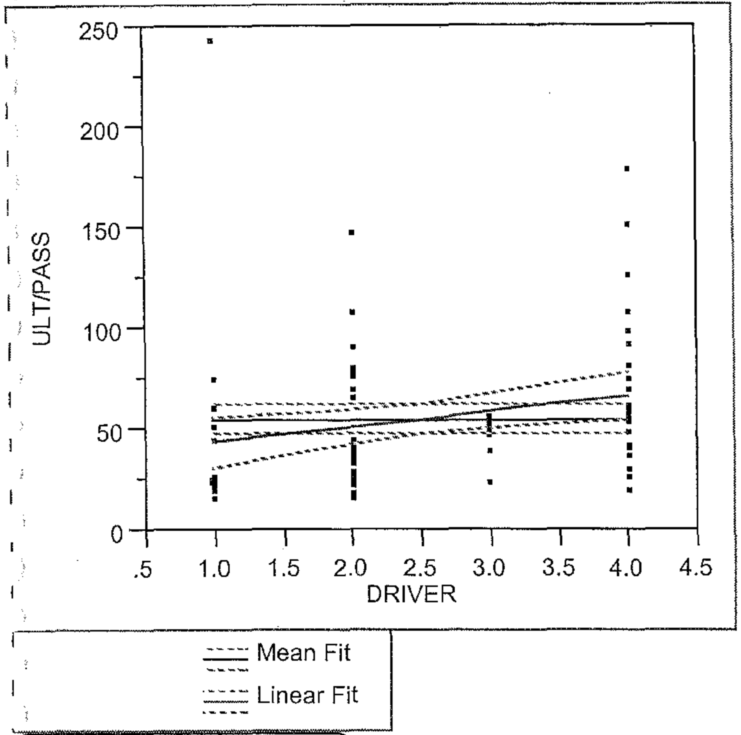
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	437.91	437.91	0.3148
Error	90	125182.08	1390.91	Prob>F
C Total	91	125619.99		0.5761

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	43.941121	20.59488	2.13	0.0356	3.0255992	84.856642	0
VEHICLE	1.7907665	3.191516	0.56	0.5761	-4.549769	8.1313019	0.059042

Scattar Plot For Unload Times For All Passenger Types Based On Vehicles In Galavan
Date: 07/18/2002

ULT/PASS By DRIVER



Mean Fit

Mean	55.28913
Std Dev [RMSE]	37.15427
Std Error	3.8736
SSE	125620

Linear Fit

ULT/PASS = 36.0058 + 7.67995 DRIVER

Summary of Fit

RSquare	0.058686
RSquare Adj	0.048226
Root Mean Square Error	36.24729
Mean of Response	55.28913
Observations (or Sum Wgts)	92

Analysis of Variance

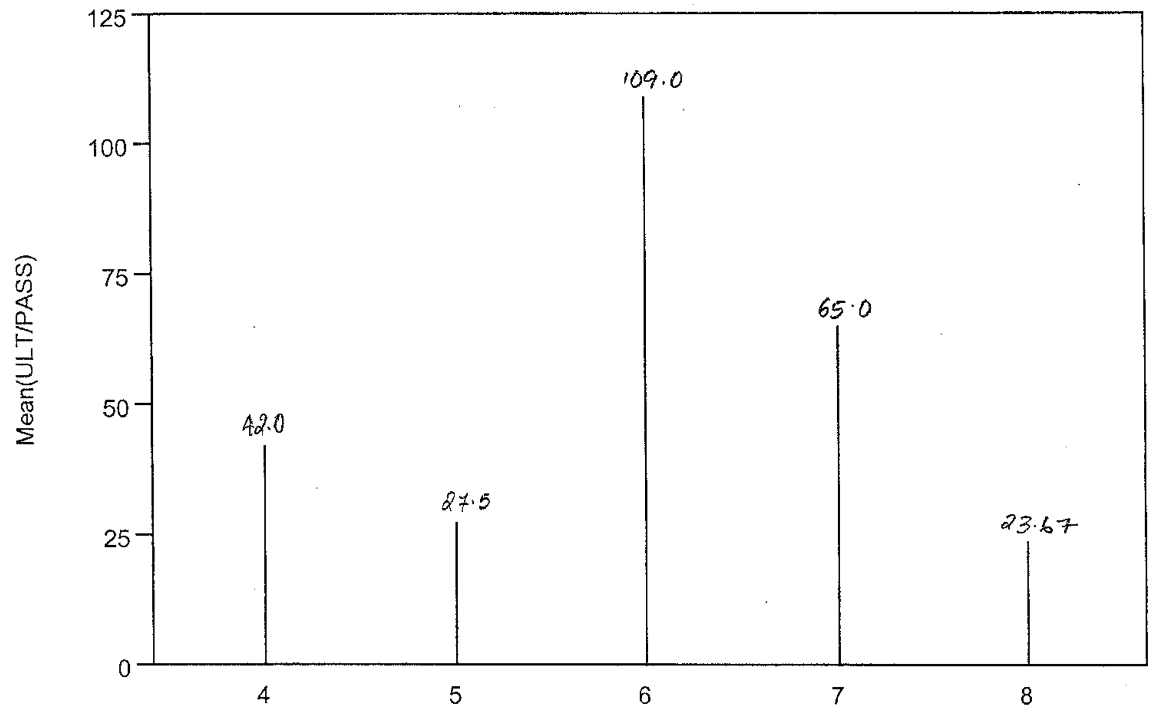
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	7372.07	7372.07	5.6110
Error	90	118247.92	1313.87	Prob>F
C Total	91	125619.99		0.0200

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	36.005766	8.975115	4.01	0.0001	18.175046	53.836486	0
DRIVER	7.6799548	3.242197	2.37	0.0200	1.2387332	14.121176	0.242251

Scattar Plot For Unload times of All Passenger Types For Available Drivers in Galavan
ate: 07/18/2002

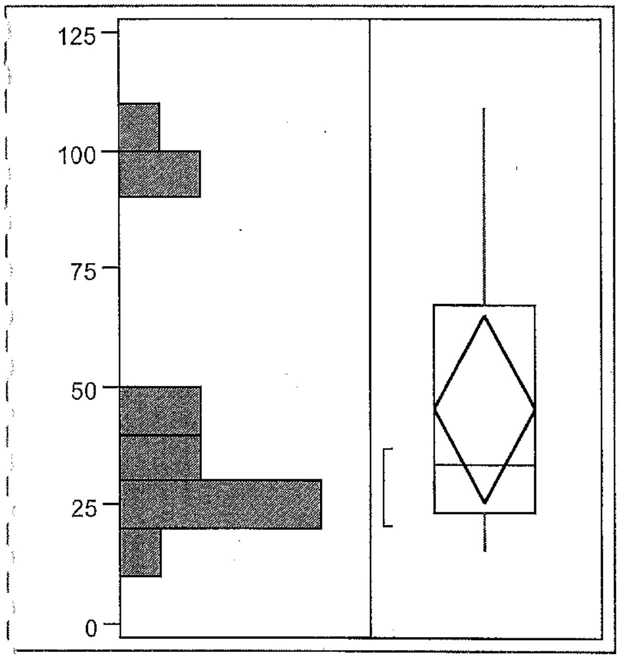
Mean Unload Time vs Disabled Passengers by Vehicle



Mean Unload Times For Disabled Passengers in Vehicles used by Galavan
Date: 07/17/2002

VEHICLE Levels Options
Mean(ULT/PASS)

ULT/PASS



Quantiles

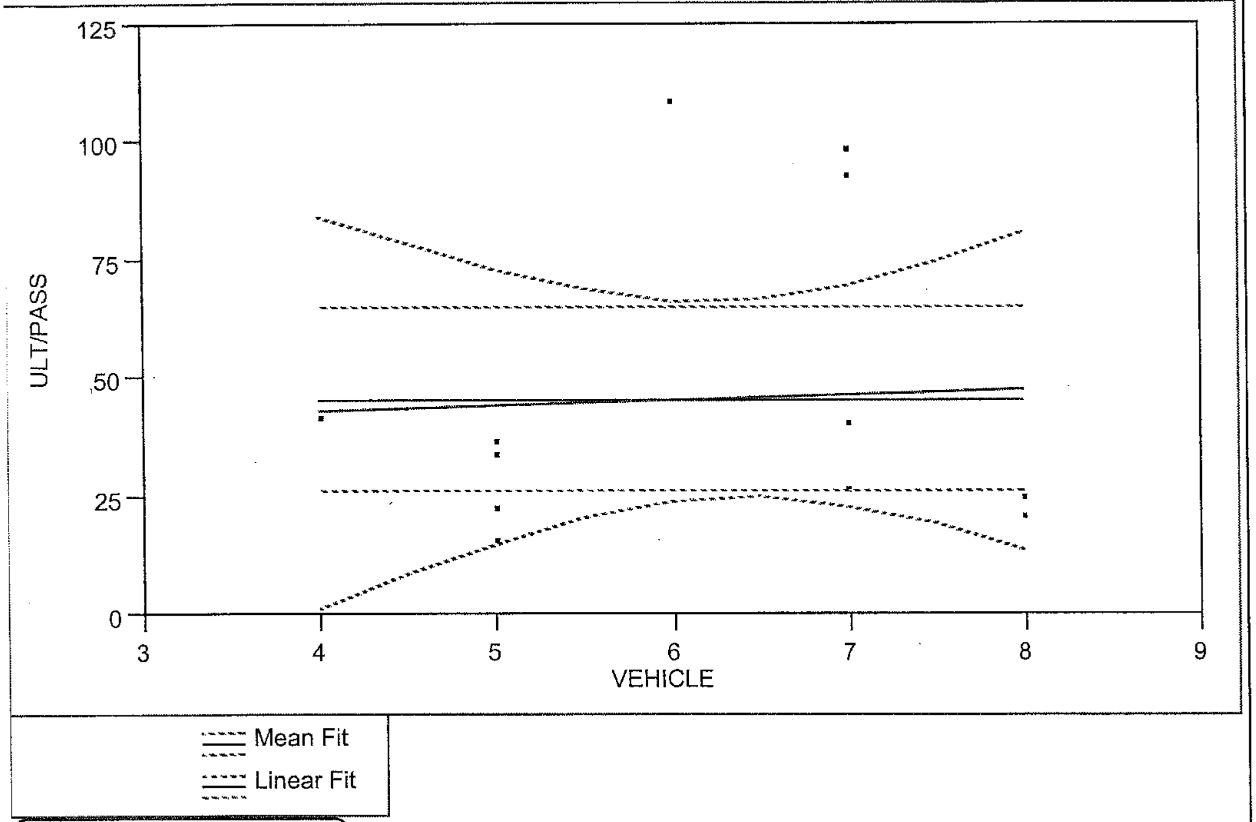
maximum	100.0%	109.00
	99.5%	109.00
	97.5%	109.00
	90.0%	105.00
quartile	75.0%	67.50
median	50.0%	34.00
quartile	25.0%	24.00
	10.0%	18.00
	2.5%	16.00
	0.5%	16.00
minimum	0.0%	16.00

Moments

Mean	45.53846
Std Dev	32.33578
Std Error Mean	8.96833
Upper 95% Mean	65.07881
Lower 95% Mean	25.99812
N	13.00000
Sum Weights	13.00000
Sum	592.00000
Variance	1045.6026
Skewness	1.27380
Kurtosis	0.02544
CV	71.00762

ox Plot For Unload Times of Disabled Passengers
Date: 07/17/2002

ULT/PASS By VEHICLE



Mean Fit

Mean	45.53846
Std Dev [RMSE]	32.33578
Std Error	8.968331
SSE	12547.23

Linear Fit

ULT/PASS = 38.3784 + 1.13514 VEHICLE

Summary of Fit

RSquare	0.002338
RSquare Adj	-0.08836
Root Mean Square Error	33.73411
Mean of Response	45.53846
Observations (or Sum Wgts)	13

Analysis of Variance

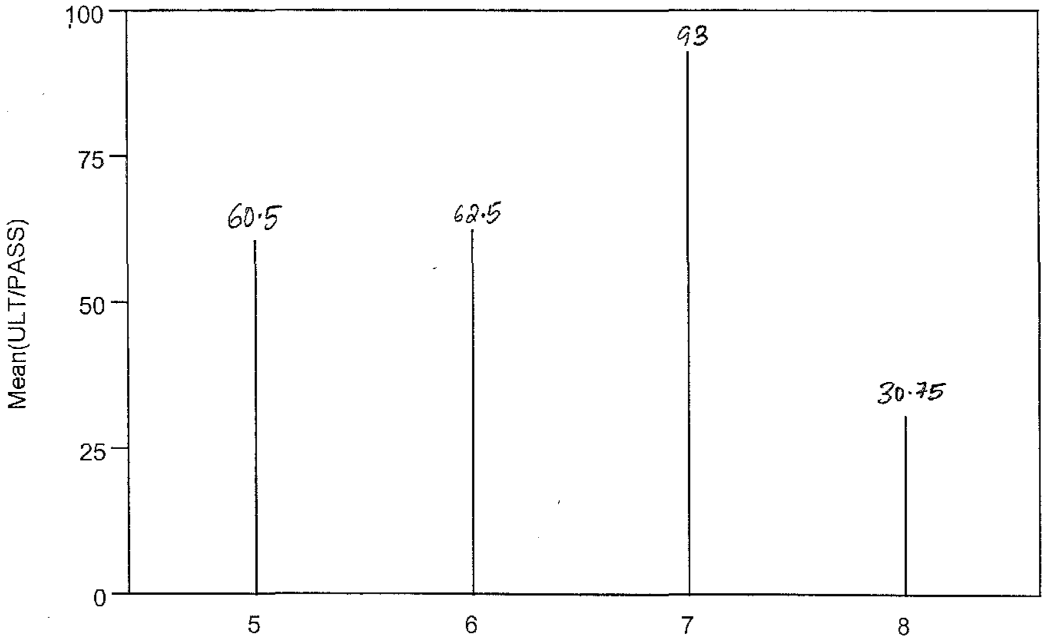
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	29.339	29.34	0.0258
Error	11	12517.892	1137.99	Prob>F
C Total	12	12547.231		0.8753

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	38.378378	45.56384	0.84	0.4176	-61.90733	138.66409	0
VEHICLE	1.1351351	7.069604	0.16	0.8753	-14.42502	16.695288	0.048356

Scatter Plot For Unload Times Per Disabled Passengers by Vehicles Used in Galavan
Date: 07/17/2002

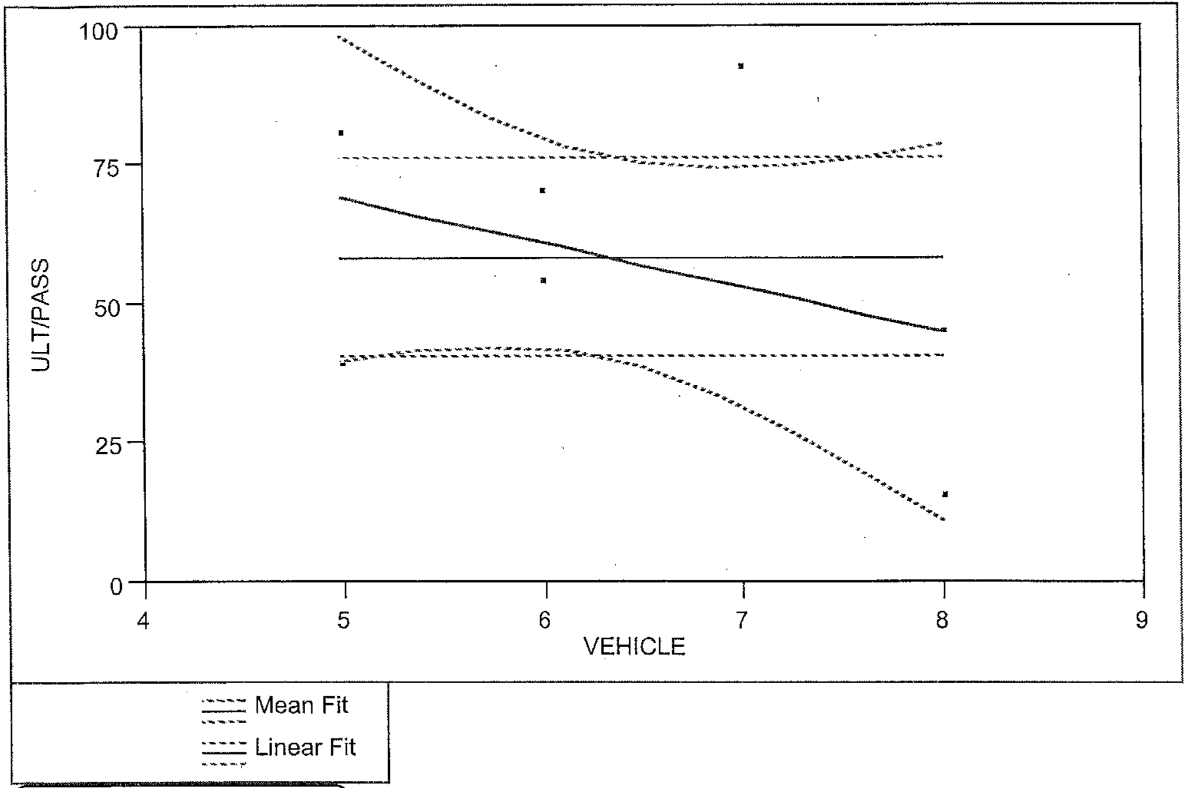
Mean Unload Time vs Special Category Passengers by Vehicle



Mean Unload Time of Special Category Passengers Based On The Vehicle Type
ate: 07/17/2002

VEHICLE Levels Options
Mean(ULT/PASS)

ULT/PASS By VEHICLE



Mean Fit

Mean	58.38889
Std Dev [RMSE]	23.27523
Std Error	7.758408
SSE	4333.889

Linear Fit

ULT/PASS = 109.161 – 8.01667 VEHICLE

Summary of Fit

RSquare	0.148289
RSquare Adj	0.026616
Root Mean Square Error	22.96339
Mean of Response	58.38889
Observations (or Sum Wgts)	9

Analysis of Variance

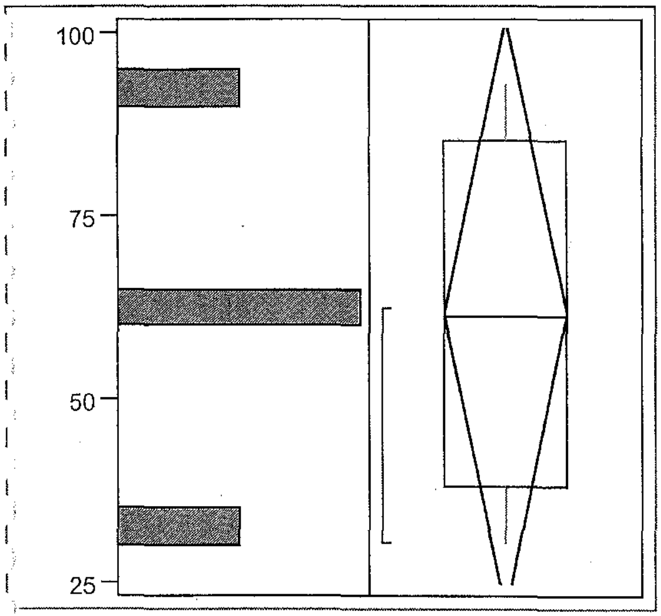
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	642.6694	642.669	1.2188
Error	7	3691.2194	527.317	Prob>F
C Total	8	4333.8889		0.3061

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	109.16111	46.62315	2.34	0.0517	-1.086005	219.40823	0
VEHICLE	-8.016667	7.26166	-1.10	0.3061	-25.1879	9.1545686	-0.38508

Scattar Plot Of Unload Times For Special Category People based On Vehicles Used In Galavan
Date: 07/17/2002

Mean(ULT/PASS)



Quantiles

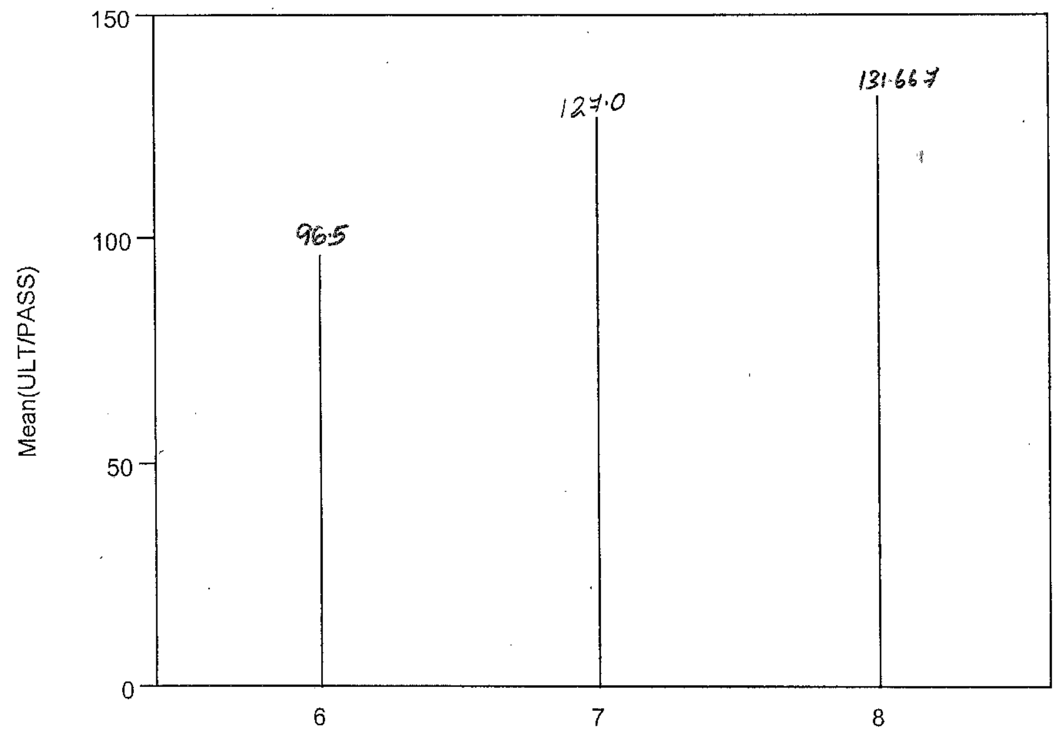
maximum	100.0%	93.000
	99.5%	93.000
	97.5%	93.000
	90.0%	93.000
quartile	75.0%	85.375
median	50.0%	61.500
quartile	25.0%	38.188
	10.0%	30.750
	2.5%	30.750
	0.5%	30.750
minimum	0.0%	30.750

Moments

Mean	61.6875
Std Dev	25.4275
Std Error Mean	12.7137
Upper 95% Mean	102.1490
Lower 95% Mean	21.2260
N	4.0000
Sum Weights	4.0000
Sum	246.7500
Variance	646.5573
Skewness	0.0441
Kurtosis	1.4702
CV	41.2198

ox Plot For The Unload Times of Passengers In Special Category For All Vehicles
ate: 07/17/2002

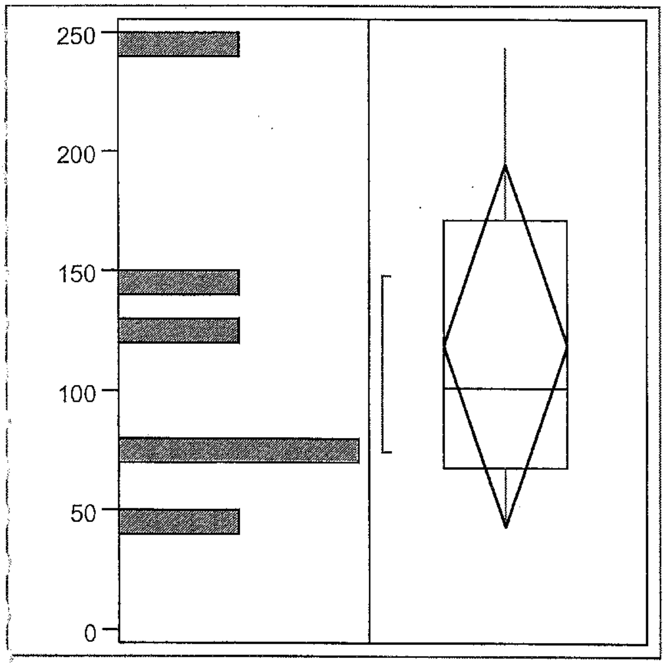
Mean Unload Time vs Wheel Chair Passengers by Vehicle



Mean Unload Time Of Wheel Chair Passengers For Each Vehicle Type in Galavan
Date: 07/17/2002

VEHICLE Levels Options
Mean(ULT/PASS)

ULT/PASS



Quantiles

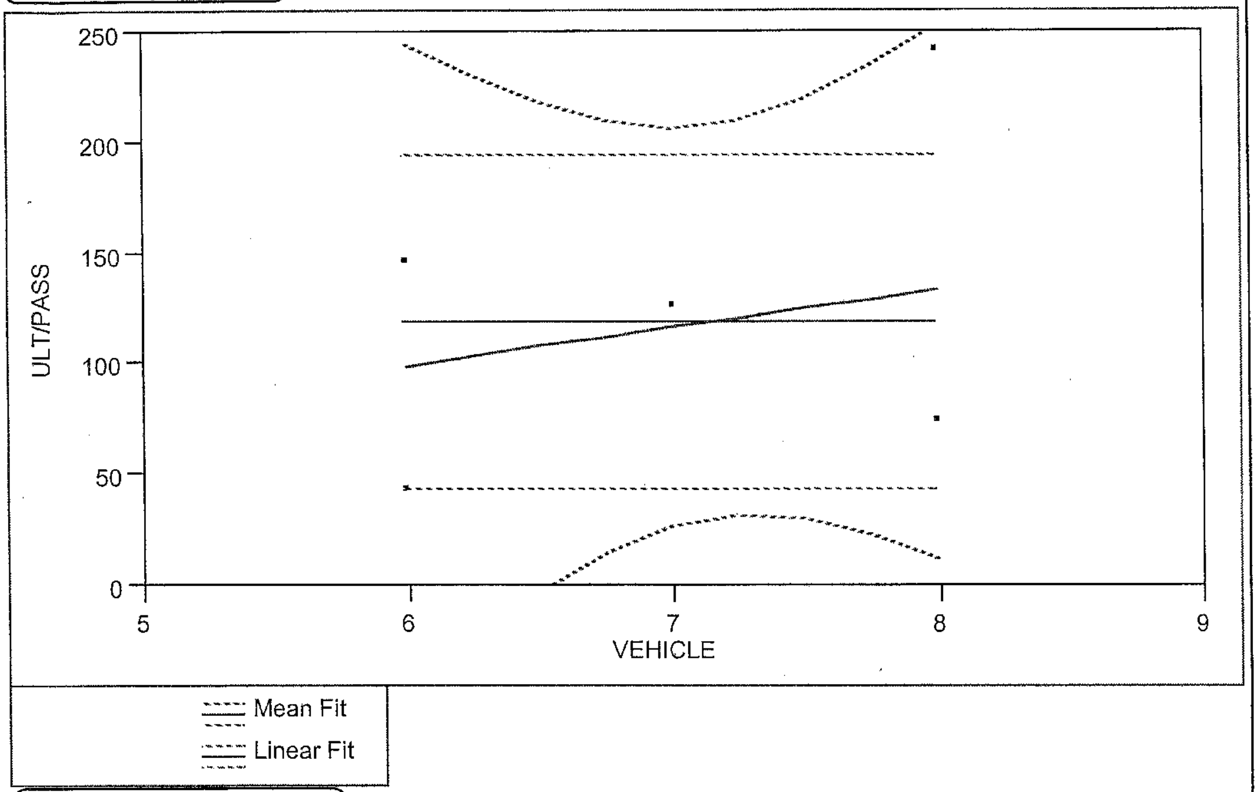
maximum	100.0%	244.00
	99.5%	244.00
	97.5%	244.00
	90.0%	244.00
quartile	75.0%	172.00
median	50.0%	101.25
quartile	25.0%	67.88
	10.0%	45.00
	2.5%	45.00
	0.5%	45.00
minimum	0.0%	45.00

Moments

Mean	119.1667
Std Dev	71.8197
Std Error Mean	29.3203
Upper 95% Mean	194.5357
Lower 95% Mean	43.7976
N	6.0000
Sum Weights	6.0000
Sum	715.0000
Variance	5158.0667
Skewness	1.1299
Kurtosis	1.1449
CV	60.2683

ox Plot of Unload Times of Wheel Chair Passengers For Available Vehicle Types
Date: 07/17/2002

ULT/PASS By VEHICLE



Mean Fit

Mean	119.1667
Std Dev [RMSE]	71.81968
Std Error	29.32026
SSE	25790.33

Linear Fit

ULT/PASS = -3.6552 + 17.1379 VEHICLE

Summary of Fit

RSquare	0.055044
RSquare Adj	-0.1812
Root Mean Square Error	78.05566
Mean of Response	119.1667
Observations (or Sum Wgts)	6

Analysis of Variance

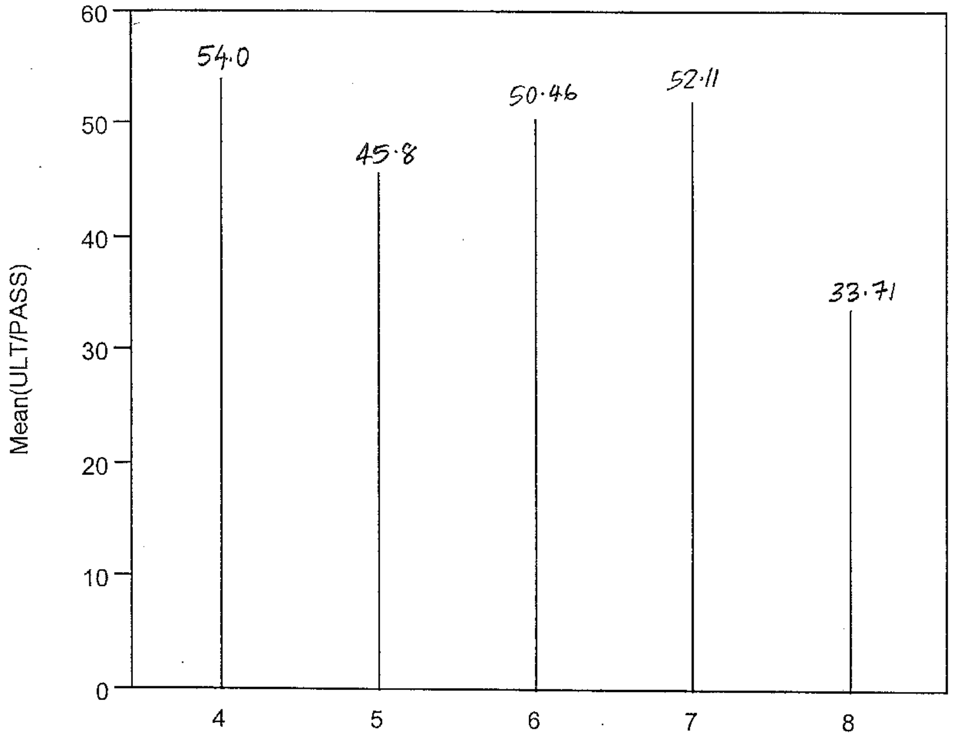
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1419.592	1419.59	0.2330
Error	4	24370.741	6092.69	Prob>F
C Total	5	25790.333		0.6545

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	-3.655172	256.4351	-0.01	0.9893	-715.6236	708.3133	0
VEHICLE	17.137931	35.5043	0.48	0.6545	-81.43649	115.71235	0.234614

Scattar Plot of Unload Times For Wheel Chair Passengers For Available Vehicle Types in Galavan
Date: 07/17/2002

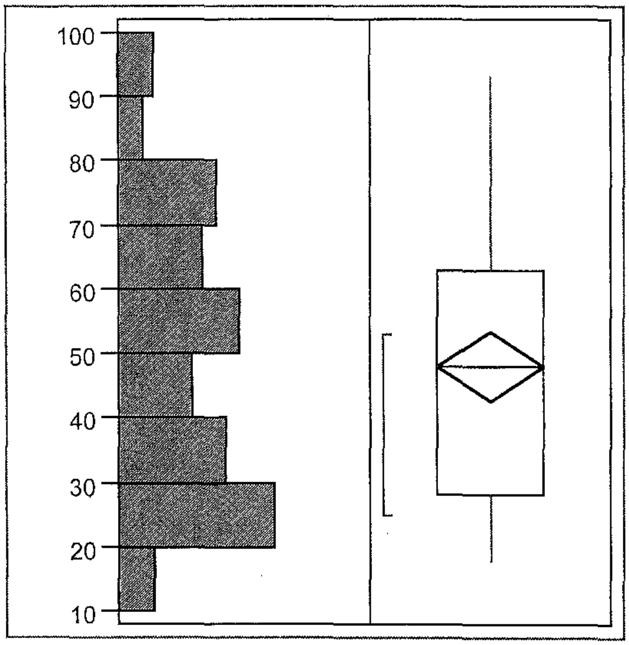
Mean Unload Time vs Elderly Passengers by Vehicle



Mean Unload Time of Elderly Passengers For Each Type of Vehicle in Galavan
ate: 07/17/2002

VEHICLE Levels Options
Mean(ULT/PASS)

ULT/PASS

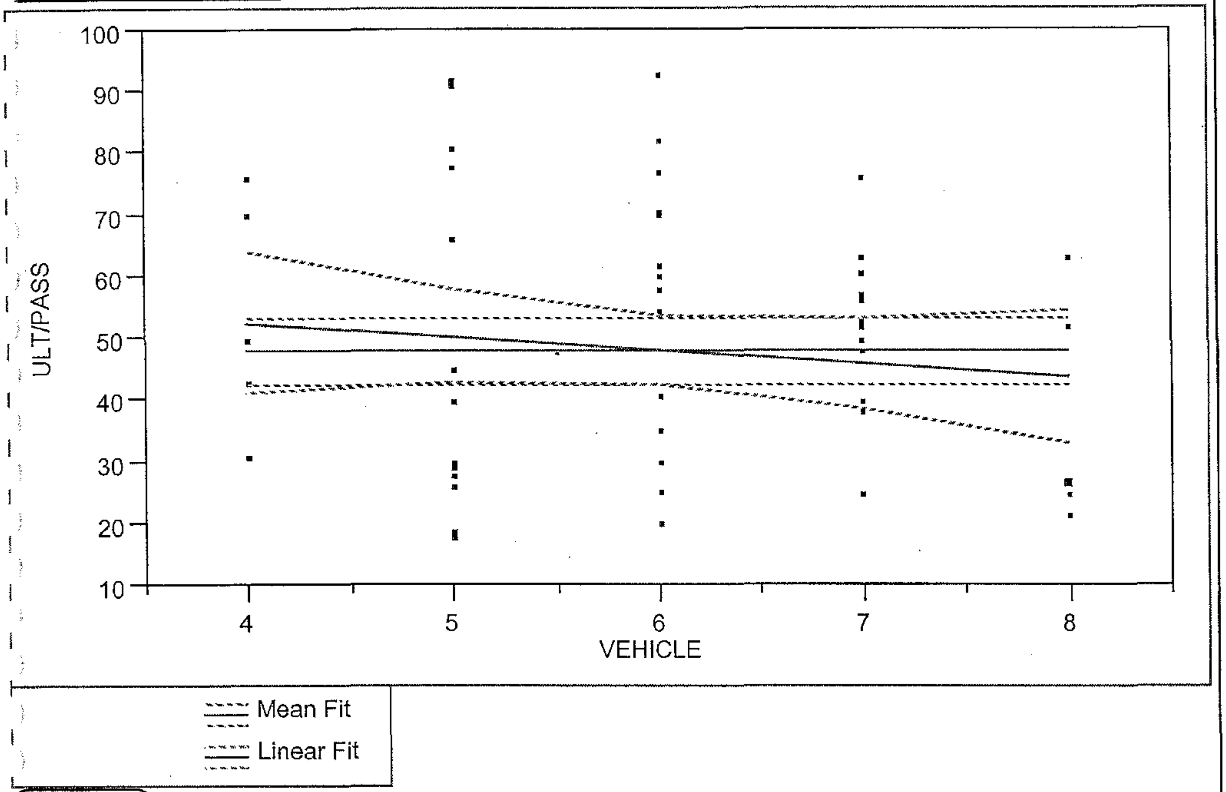


```
Quantiles
 maximum   100.0%    93.000
            99.5%    93.000
            97.5%    92.450
            90.0%    77.800
 quartile   75.0%    63.000
 median     50.0%    48.000
 quartile   25.0%    28.500
            10.0%    22.200
             2.5%    18.000
             0.5%    18.000
 minimum     0.0%    18.000
```

```
Moments
Mean               48.05902
Std Dev            21.19547
Std Error Mean      2.71380
Upper 95% Mean     53.48743
Lower 95% Mean     42.63060
N                  61.00000
Sum Weights        61.00000
Sum                  2931.6
Variance          449.24779
Skewness            0.38813
Kurtosis           -0.91593
CV                 44.10300
```

Box Plot for Unload Times of Elderly Passengers
Date: 07/17/2002

ULT/PASS By VEHICLE



Mean Fit

Linear Fit

ULT/PASS = 61.4146 – 2.20783 VEHICLE

Summary of Fit

RSquare	0.013898
RSquare Adj	-0.00282
Root Mean Square Error	21.22528
Mean of Response	48.05902
Observations (or Sum Wgts)	61

Analysis of Variance

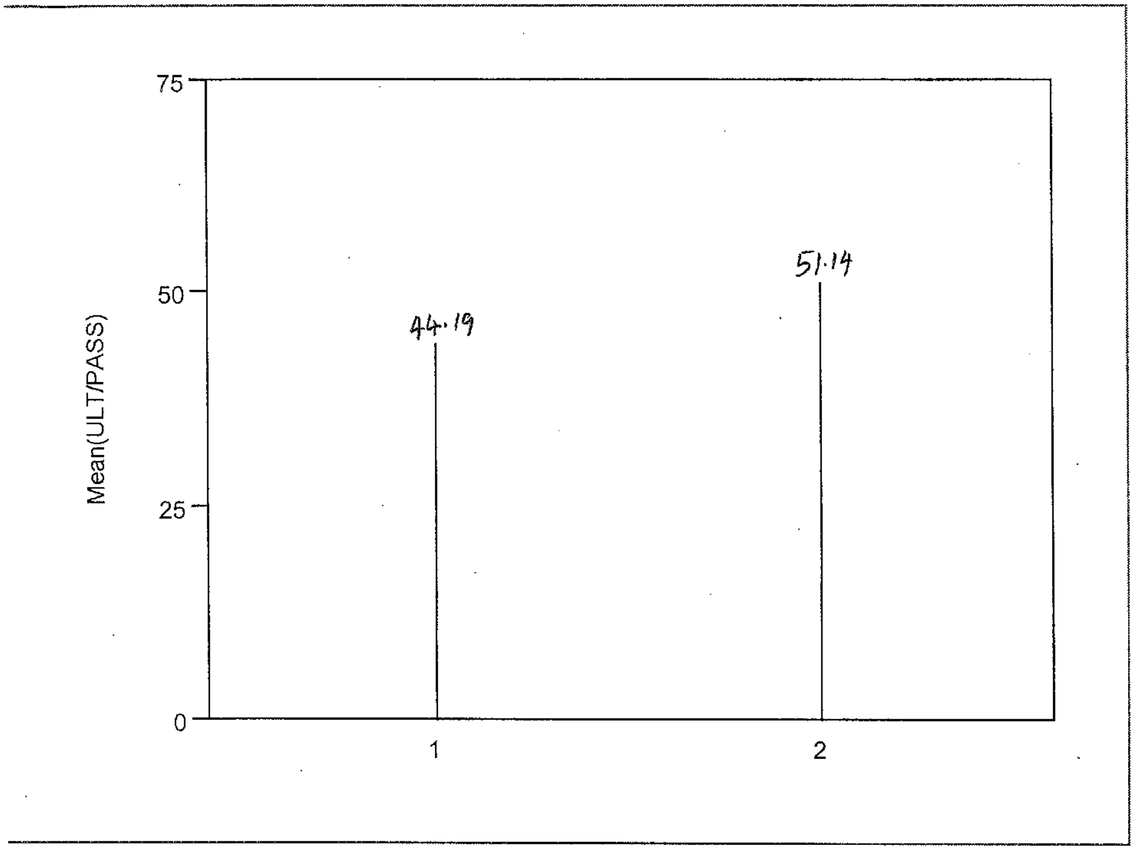
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	374.618	374.618	0.8315
Error	59	26580.250	450.513	Prob>F
C Total	60	26954.868		0.3655

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	61.414569	14.89607	4.12	0.0001	31.607601	91.221537	0
VEHICLE	-2.207828	2.421166	-0.91	0.3655	-7.052572	2.6369146	-0.11789

Scatter Plot of Unload Times For Elderly Passengers on All Vehicles in Galavan
Date: 07/17/2002

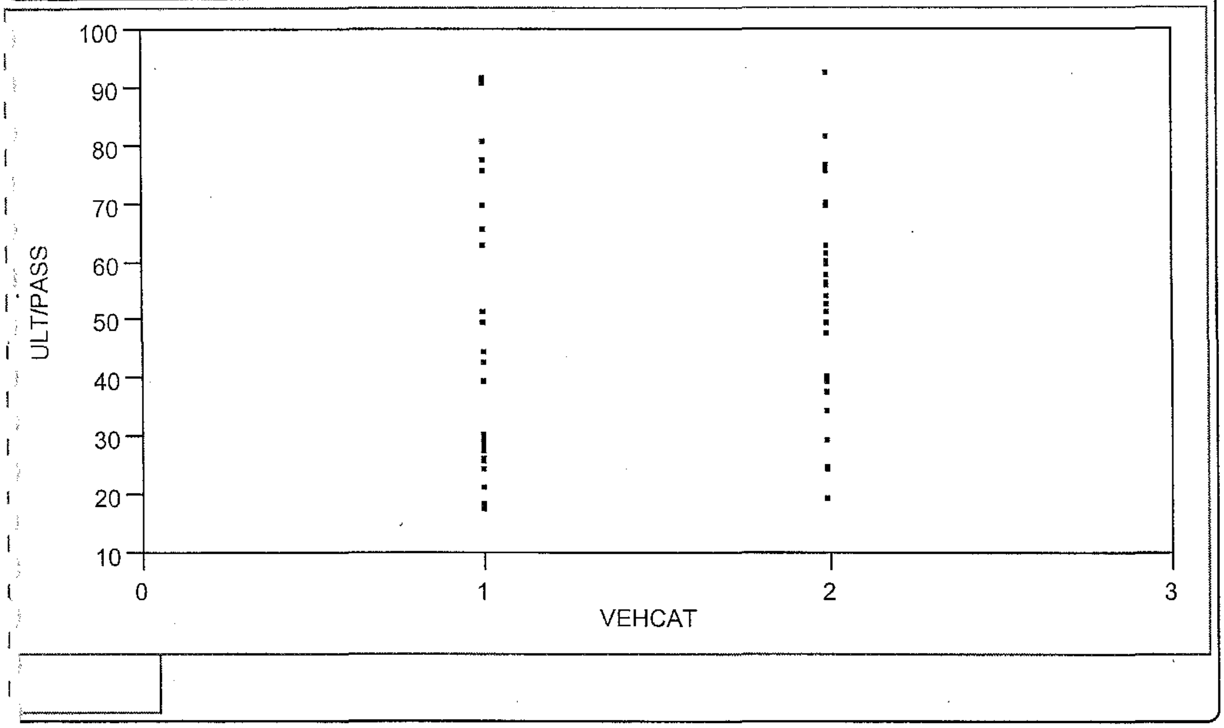
Mean Unload Time vs Vehicle Categories



Mean Unload Time For the Available Vehicles Categorized Based on Features
Date: 07/17/2002

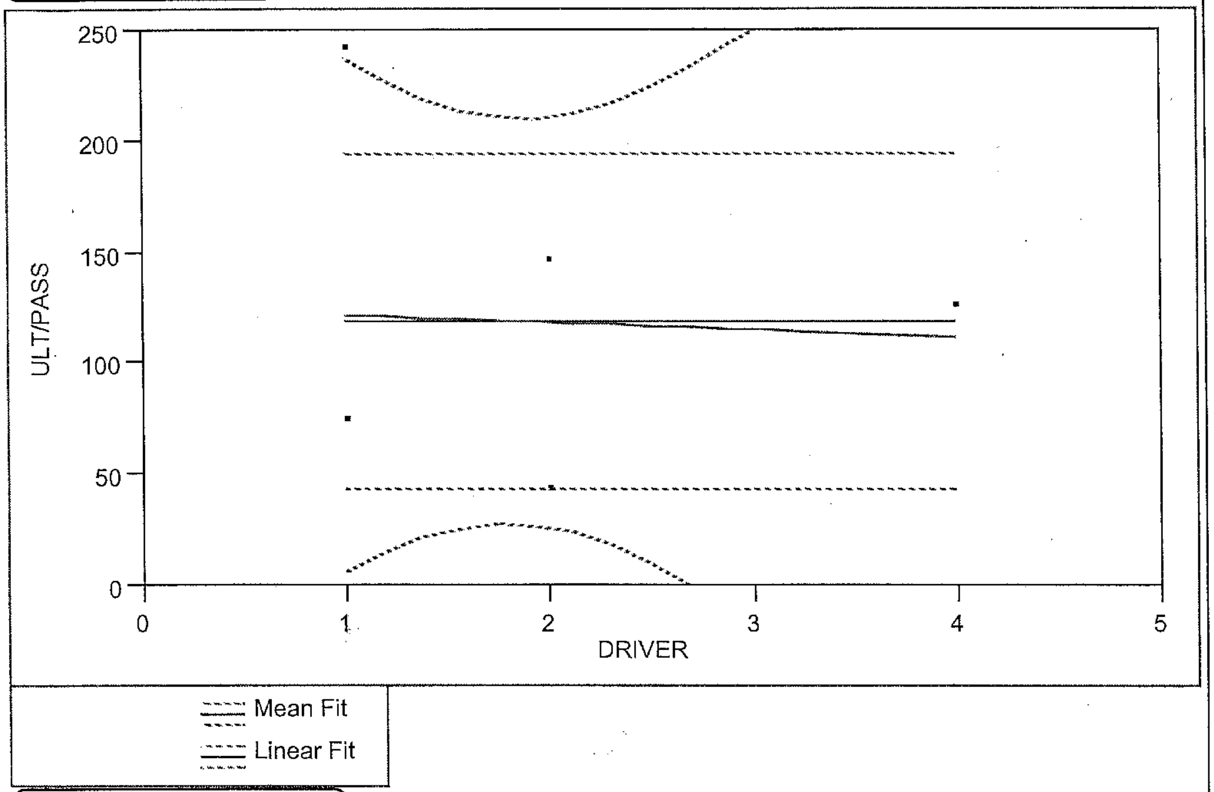
VEHCAT Levels Options
Mean(ULT/PASS)

ULT/PASS By VEHCAT



Scatter Plot of Unload Times For Elderly Passengers by Vehicles Grouped into Categories
Date: 07/17/2002

ULT/PASS By DRIVER



Mean Fit

Mean	119.1667
Std Dev [RMSE]	71.81968
Std Error	29.32026
SSE	25790.33

Linear Fit

ULT/PASS = 125.024 – 3.19512 DRIVER

Summary of Fit

RSquare	0.002705
RSquare Adj	-0.24662
Root Mean Square Error	80.18817
Mean of Response	119.1667
Observations (or Sum Wgts)	6

Analysis of Variance

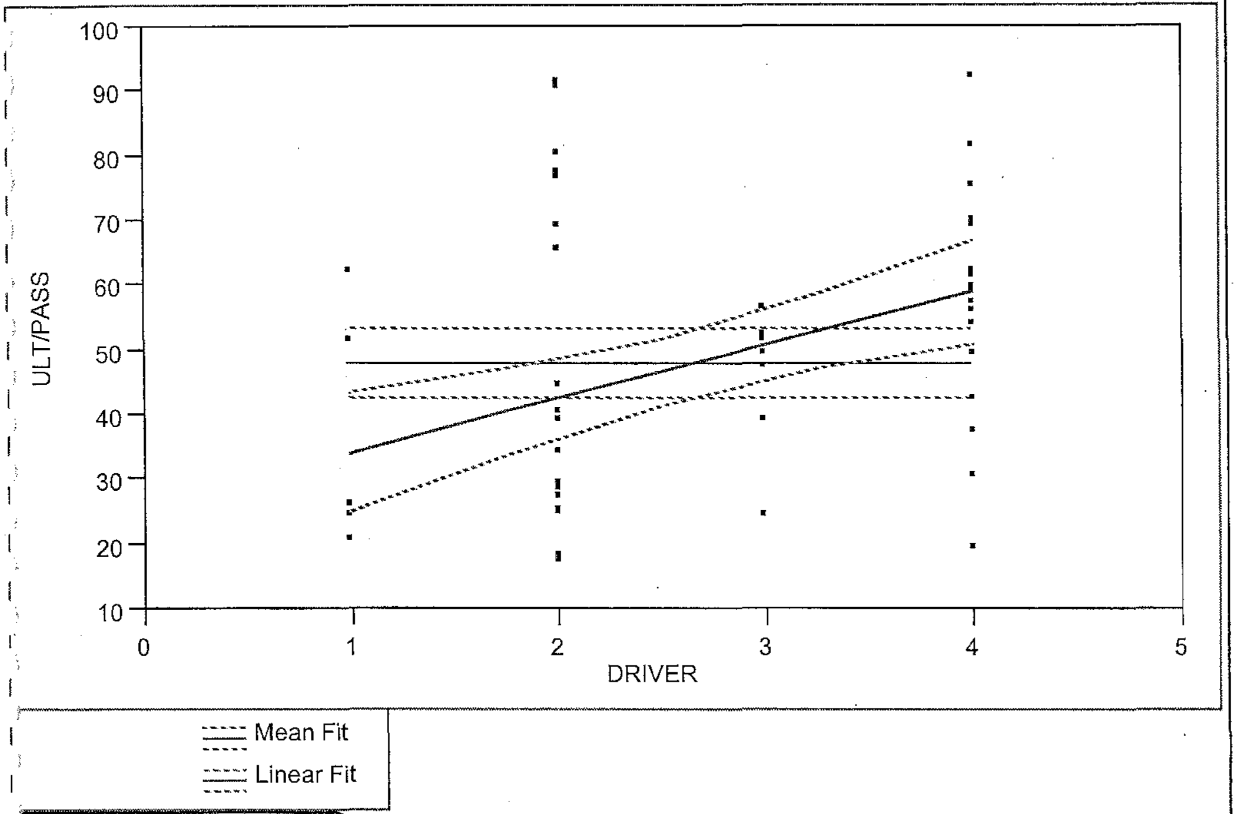
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	69.760	69.76	0.0108
Error	4	25720.573	6430.14	Prob>F
C Total	5	25790.333		0.9221

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	125.02439	65.07292	1.92	0.1271	-55.64455	305.69333	0
DRIVER	-3.195122	30.67567	-0.10	0.9221	-88.36328	81.973033	-0.05201

Scatter Plot of Unload Times for Wheel Chair Passengers by Drivers of Galavan
Date: 07/17/2002

ULT/PASS By DRIVER



Mean Fit

Mean	48.05902
Std Dev [RMSE]	21.19547
Std Error	2.713801
SSE	26954.87

Linear Fit

ULT/PASS = 25.9276 + 8.2823 DRIVER

Summary of Fit

RSquare	0.171633
RSquare Adj	0.157592
Root Mean Square Error	19.45378
Mean of Response	48.05902
Observations (or Sum Wgts)	61

Analysis of Variance

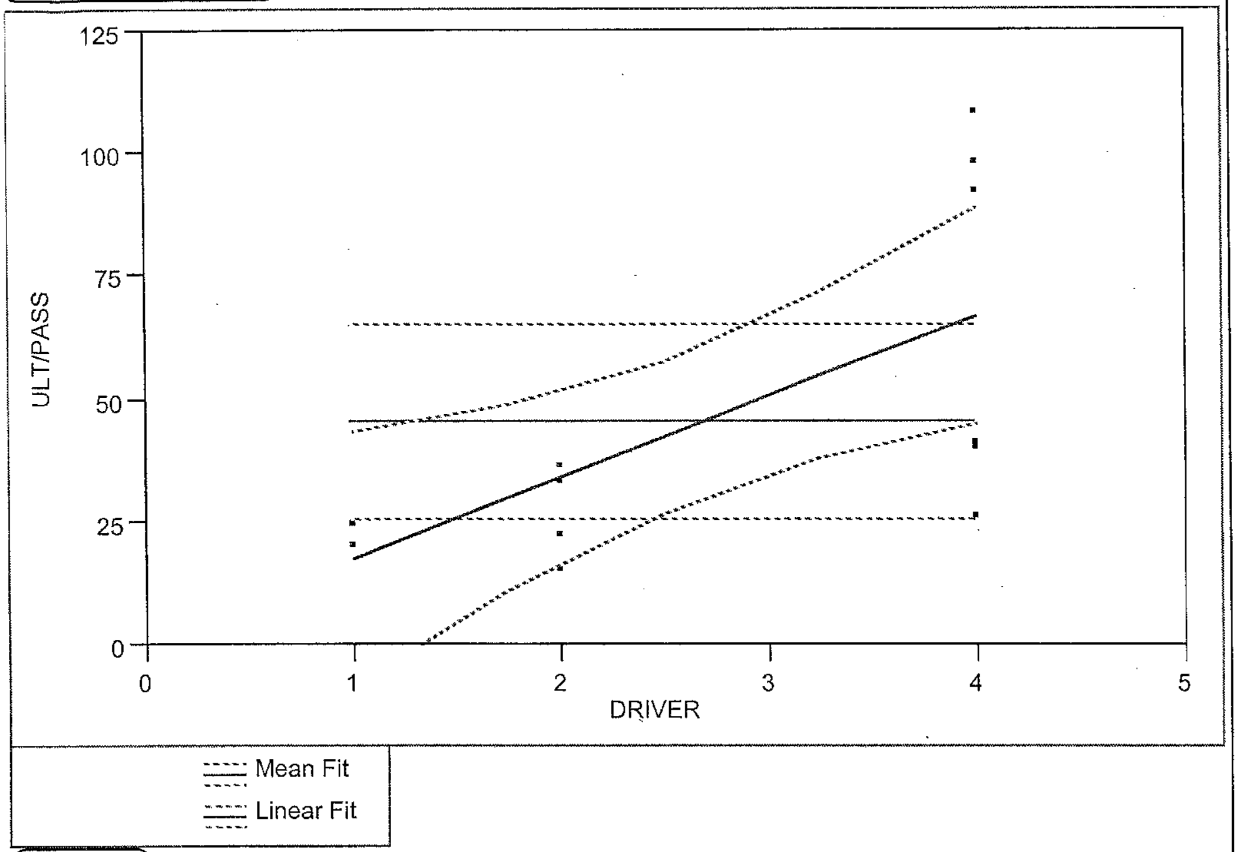
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4626.332	4626.33	12.2244
Error	59	22328.535	378.45	Prob>F
C Total	60	26954.868		0.0009

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	25.927613	6.802303	3.81	0.0003	12.316236	39.53899	0
DRIVER	8.2823043	2.368846	3.50	0.0009	3.5422535	13.022355	0.414286

Scatter Plot of Unload Times for Elderly Passengers by Drivers of Galavan
Date: 07/17/2002

ULT/PASS By DRIVER



Mean Fit

Linear Fit

ULT/PASS = 1.31481 + 16.4259 DRIVER

Summary of Fit

RSquare	0.446614
RSquare Adj	0.396306
Root Mean Square Error	25.12417
Mean of Response	45.53846
Observations (or Sum Wgts)	13

Analysis of Variance

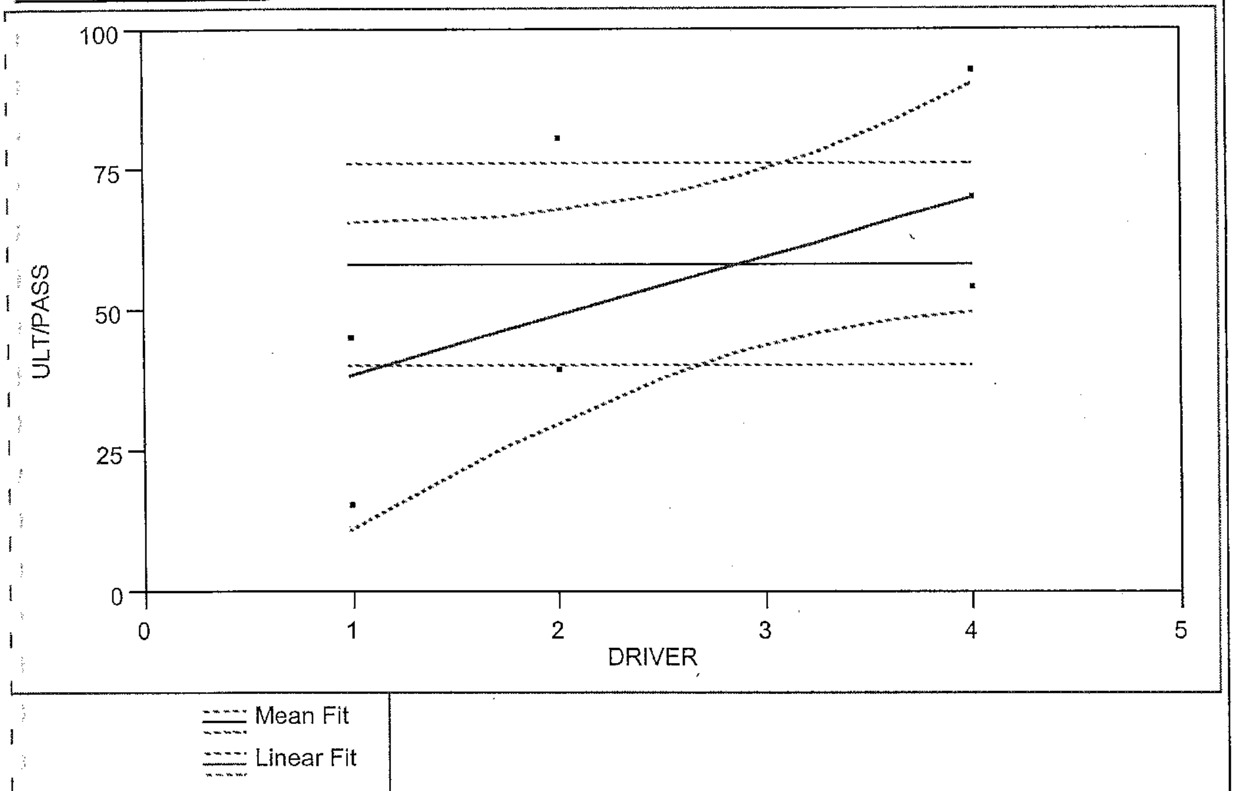
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	5603.768	5603.77	8.8776
Error	11	6943.463	631.22	Prob>F
C Total	12	12547.231		0.0125

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	1.3148148	16.39679	0.08	0.9375	-34.77441	37.404038	0
DRIVER	16.425926	5.512918	2.98	0.0125	4.2920294	28.559822	0.668292

Scatter Plot For Unload Times Per Disabled Passengers by Drivers Employed in Galavan
Date: 07/17/2002

ULT/PASS By DRIVER



Mean Fit

Mean	58.38889
Std Dev [RMSE]	23.27523
Std Error	7.758408
SSE	4333.889

Linear Fit

ULT/PASS = 27.8507 + 10.5709 DRIVER

Summary of Fit

RSquare	0.383891
RSquare Adj	0.295876
Root Mean Square Error	19.53074
Mean of Response	58.38889
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1663.7415	1663.74	4.3616
Error	7	2670.1474	381.45	Prob>F
C Total	8	4333.8889		0.0751

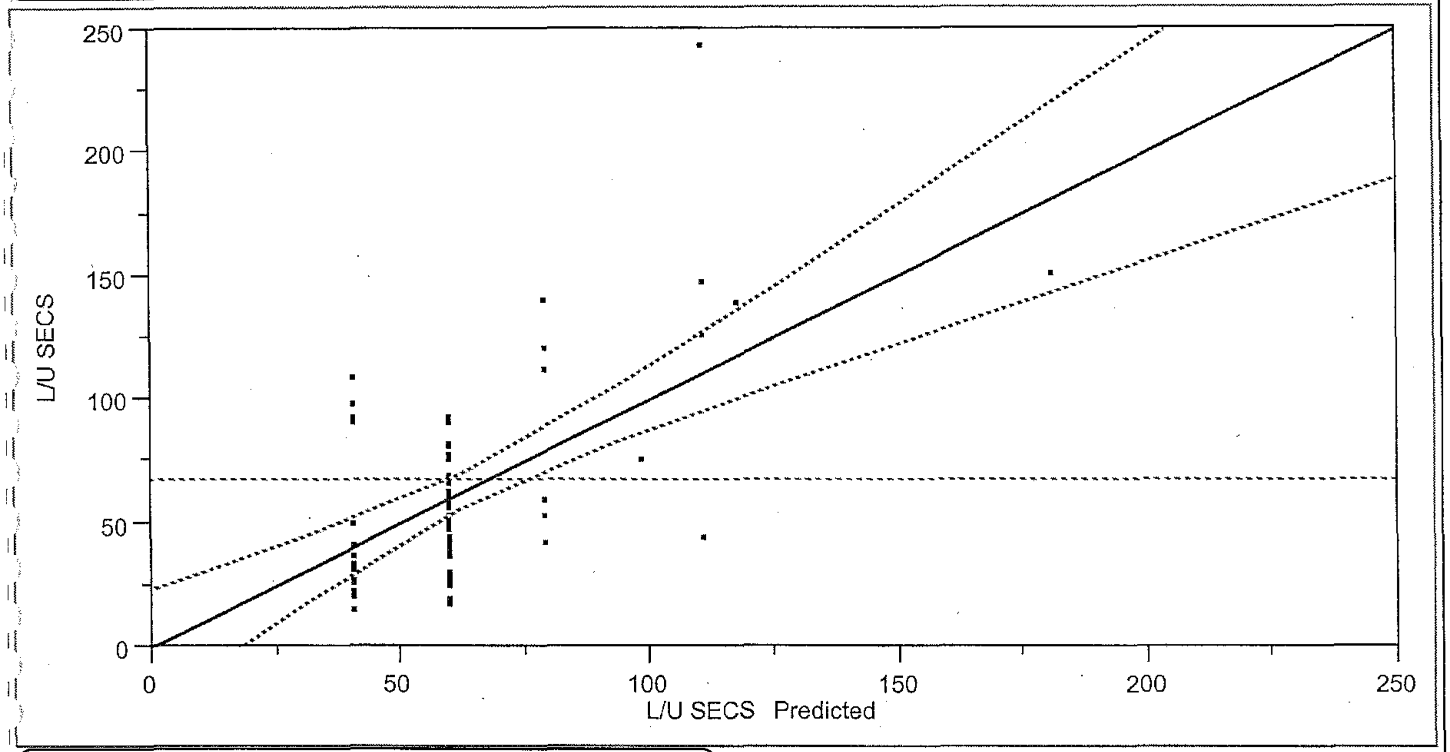
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	27.850746	16.00617	1.74	0.1254	-9.998138	65.69963	0
DRIVER	10.570896	5.061596	2.09	0.0751	-1.397973	22.539764	0.619589

Scattar Plot For Unload Times of Passengers in Special category Based on Drivers Employed in Galavan
Date: 07/17/2002

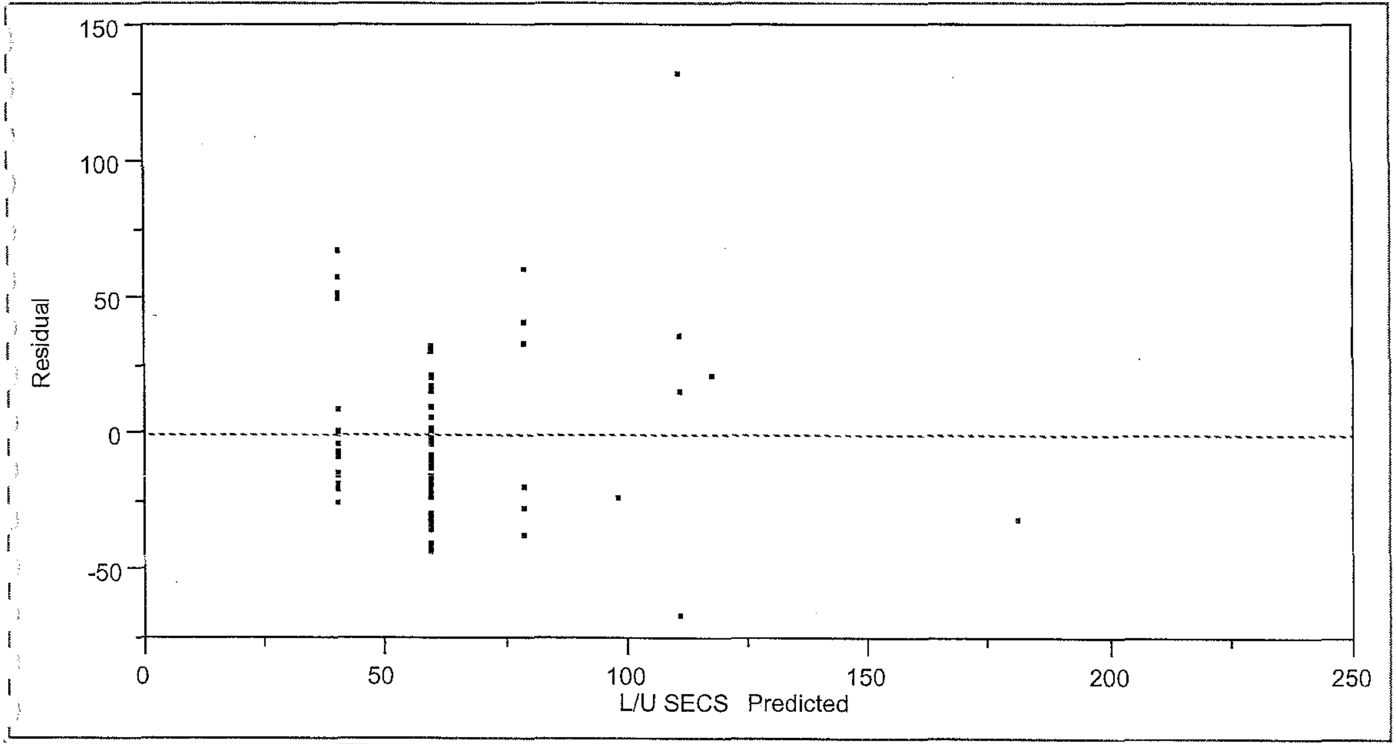
```
Response:  L/U SECS

Summary of Fit
RSquare                        0.411275
RSquare Adj                    0.396916
Root Mean Square Error         33.09911
Mean of Response               67.03529
Observations (or Sum Wgts)           85

Lack of Fit
Source        DF   Sum of Squares   Mean Square    F Ratio
Lack of Fit    4        14407.466       3601.87     3.7247
Pure Error    78        75427.725        967.02     Prob>F
Total Error   82        89835.191                   0.0079
                                                   Max RSq
                                                    0.5057

Parameter Estimates
Term          Estimate   Std Error   t Ratio   Prob>|t|   Lower 95%   Upper 95%   Std Beta
Intercept    40.367169    5.666981      7.12    <.0001    29.093694   51.640643          0
# E          19.356995    3.879409      4.99    <.0001    11.639584   27.074406   0.440142
# W          70.421888    10.27468      6.85    <.0001     49.98219   90.861586   0.604589

Effect Test
Source   Nparm   DF   Sum of Squares    F Ratio    Prob>F
# E          1    1        27275.788    24.8969    <.0001
# W          1    1        51464.895    46.9763    <.0001
```

Whole-Model Test

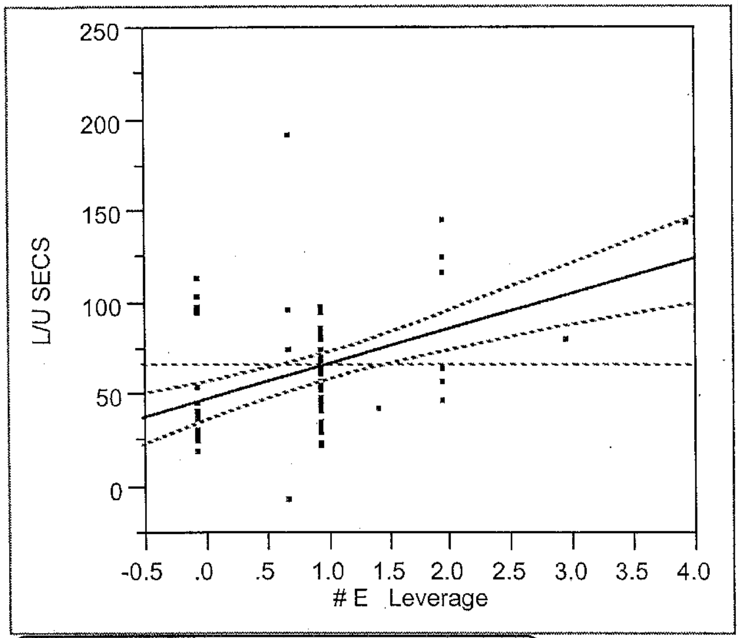


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	62757.70	31378.9	28.6421
Error	82	89835.19	1095.6	Prob>F
C Total	84	152592.89		<.0001



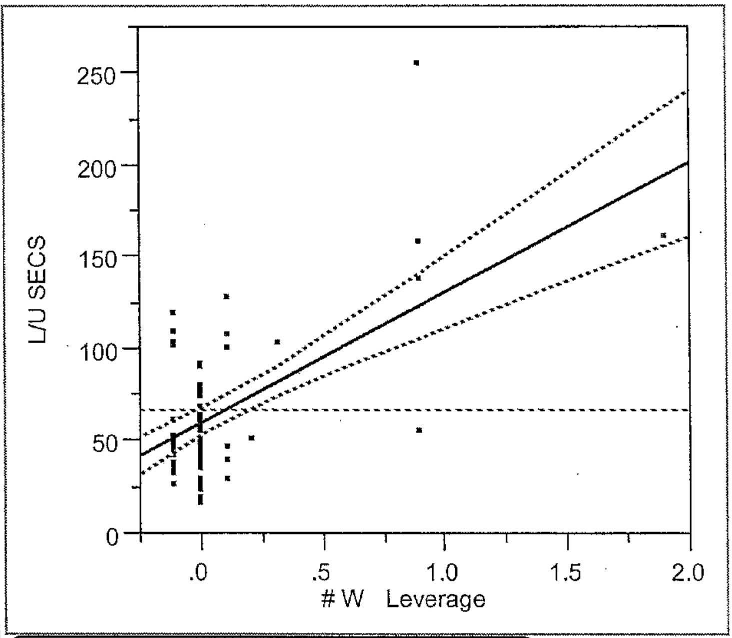
 # E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
27275.788	24.8969	1	<.0001

 # W



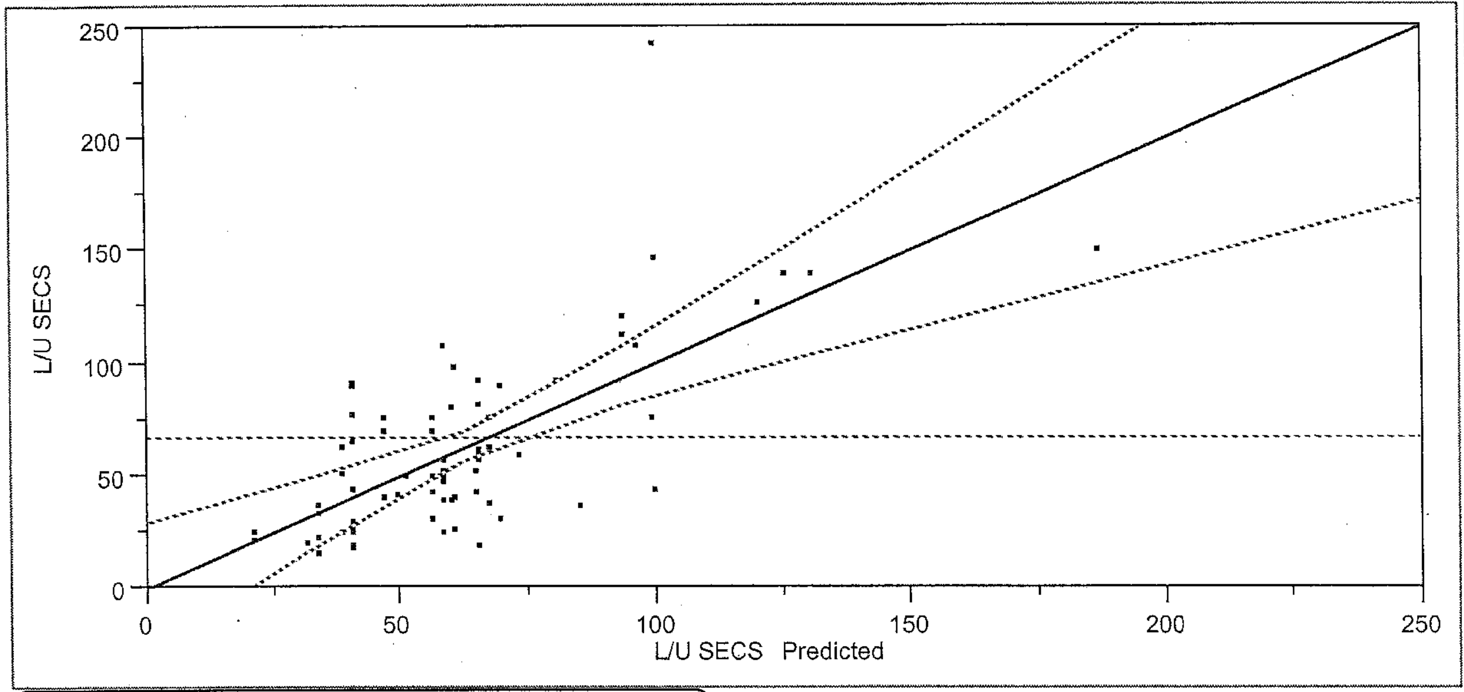
Effect Test

Sum of Squares	F Ratio	DF	Prob>F
51464.895	46.9763	1	<.0001

Initial Multiple Regression Model for Predicting Unload Times
Equation: Uest = g0 + g1.Y1+ g2.Y2;
Date: 07/20/2002

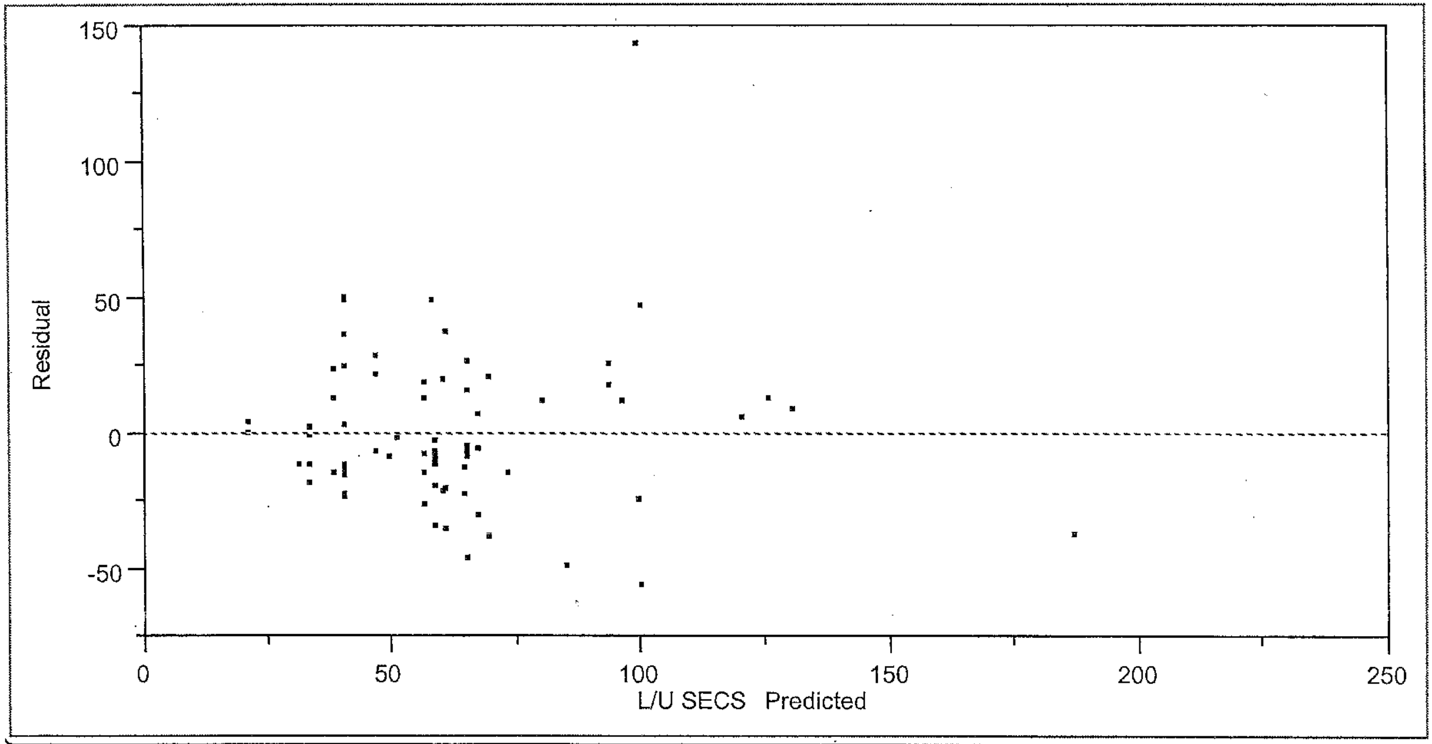
```
esponse:

Summary of Fit
RSquare                        0.572462
RSquare Adj                    0.521158
Root Mean Square Error         29.49333
Mean of Response               67.03529
Observations (or Sum Wgts)           85

Lack of Fit
Source        DF   Sum of Squares   Mean Square    F Ratio
Lack of Fit   19        37048.469       1949.92     3.8734
Pure Error    56        28190.772        503.41     Prob>F
Total Error   75        65239.241                   <.0001
                                                   Max RSq
                                                    0.8153

Parameter Estimates
Term          Estimate   Std Error  t Ratio  Prob>|t|   Lower 95%   Upper 95%   Std Beta
Intercept    -19.46743    23.95402    -0.81    0.4190   -67.18643   28.251564          0   insignificant
VEHICLE      2.3081713    3.600208     0.64    0.5234   -4.863832   9.4801746   0.065879   insignificant
VEHCAT        4.210022    11.11256     0.38    0.7059   -17.92739   26.347438   0.049678   insignificant
DRIVER       9.0776382    4.798122     1.89    0.0624   -0.480739   18.636015   0.244844
# E          26.200716    5.146169     5.09    <.0001   15.948991   36.452441   0.595756
# W          95.905178    28.37897     3.38    0.0012   39.371206   152.43915   0.823369
#WVEH        -8.508288    21.72686    -0.39    0.6965   -51.79055   34.773971   -0.09637   insignificant
# D          19.372714    9.111455     2.13    0.0368   1.2217121   37.523716   0.200549
# O          8.8706371    12.40239     0.72    0.4767   -15.83626   33.577538   0.082651   insignificant
# SP         19.656093    8.543266     2.30    0.0242   2.6369838   36.675202   0.234369

Effect Test
Source     Nparm  DF  Sum of Squares   F Ratio   Prob>F
VEHICLE        1   1         357.543    0.4110   0.5234
VEHCAT         1   1         124.850    0.1435   0.7059
DRIVER         1   1        3113.514    3.5793   0.0624
# E            1   1       22547.885   25.9214   <.0001
# W            1   1        9934.328   11.4207   0.0012
#WVEH          1   1         133.394    0.1534   0.6965
# D            1   1        3932.359    4.5207   0.0368
# O            1   1         444.986    0.5116   0.4767
# SP           1   1        4604.624    5.2935   0.0242
```

Whole-Model Test

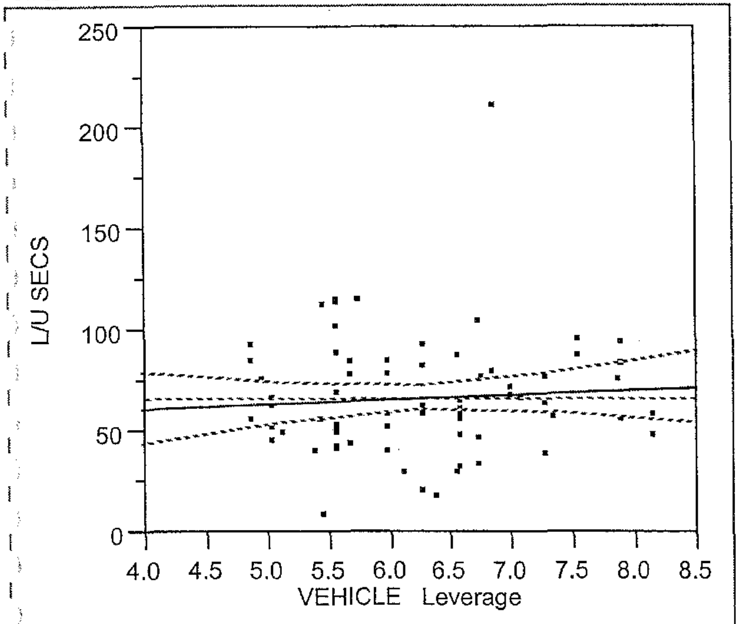


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	87353.65	9705.96	11.1581
Error	75	65239.24	869.86	Prob>F
C Total	84	152592.89		<.0001



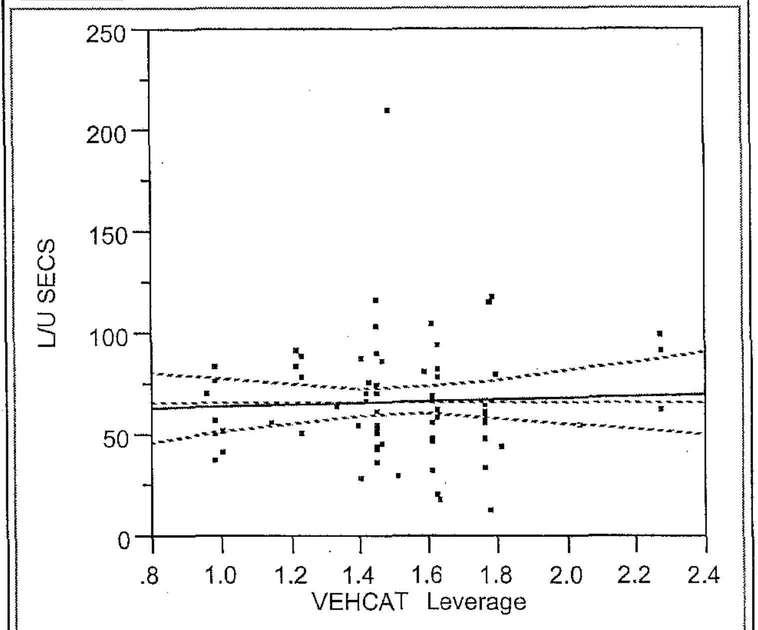
VEHICLE



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
357.54317	0.4110	1	0.5234

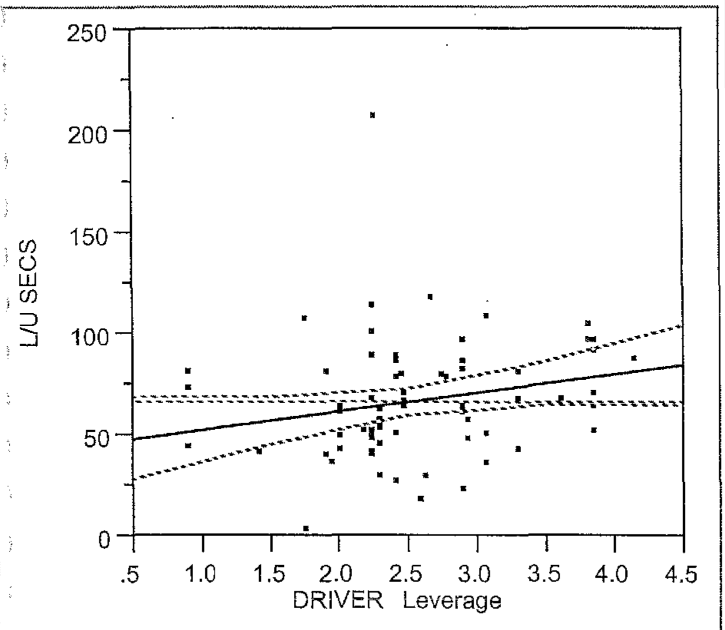
VEHCAT



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
124.84991	0.1435	1	0.7059

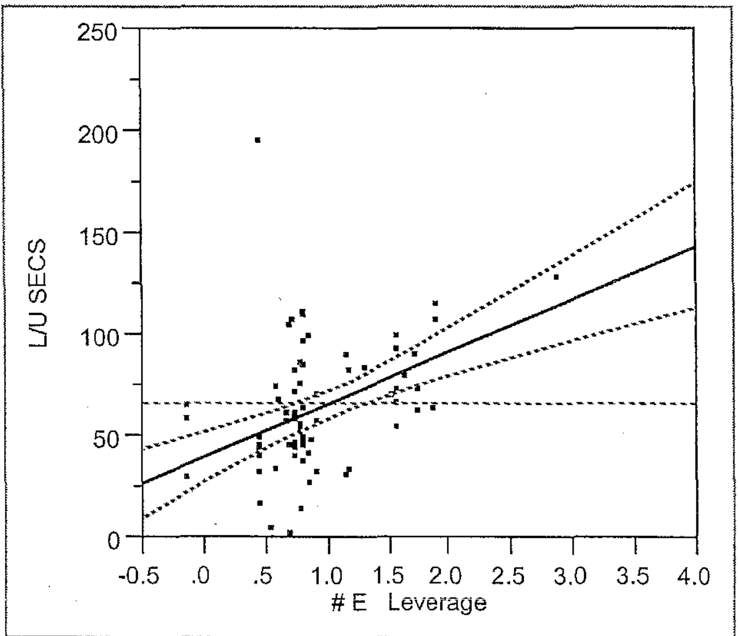
DRIVER



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
3113.5137	3.5793	1	0.0624

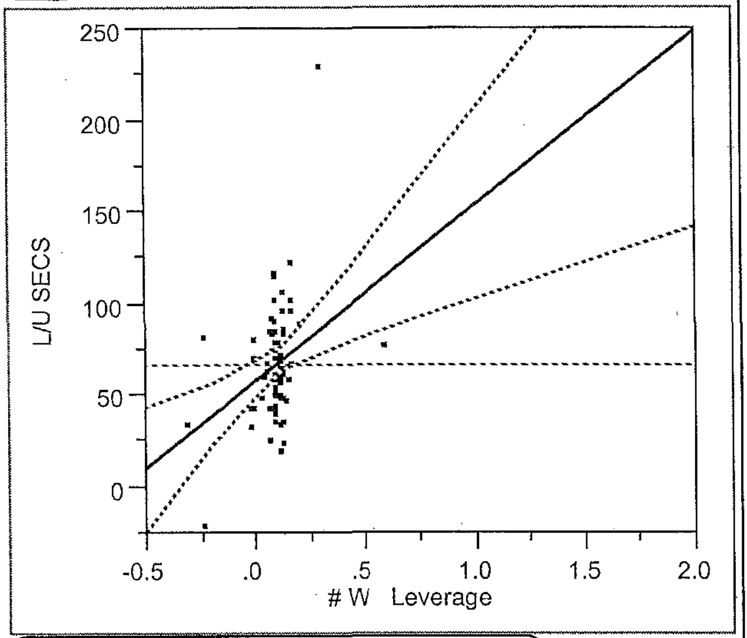
E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
22547.885	25.9214	1	<.0001

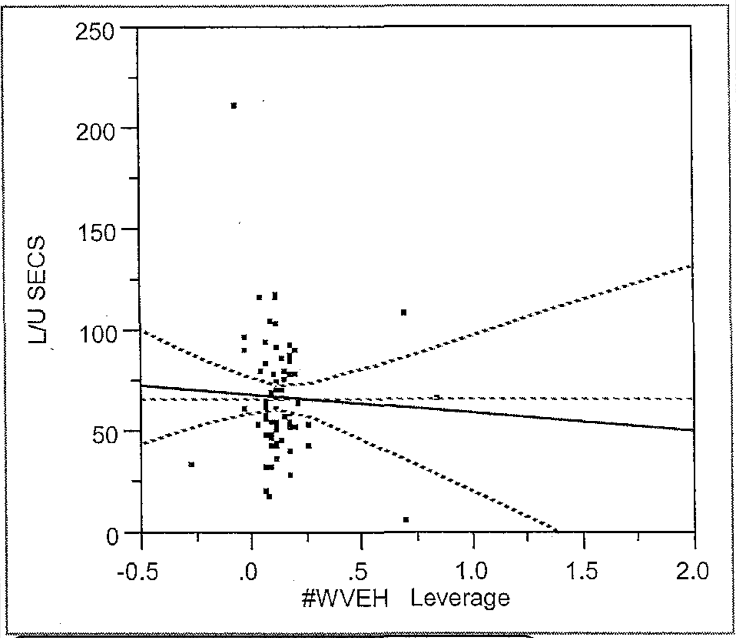
 # W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
9934.3280	11.4207	1	0.0012

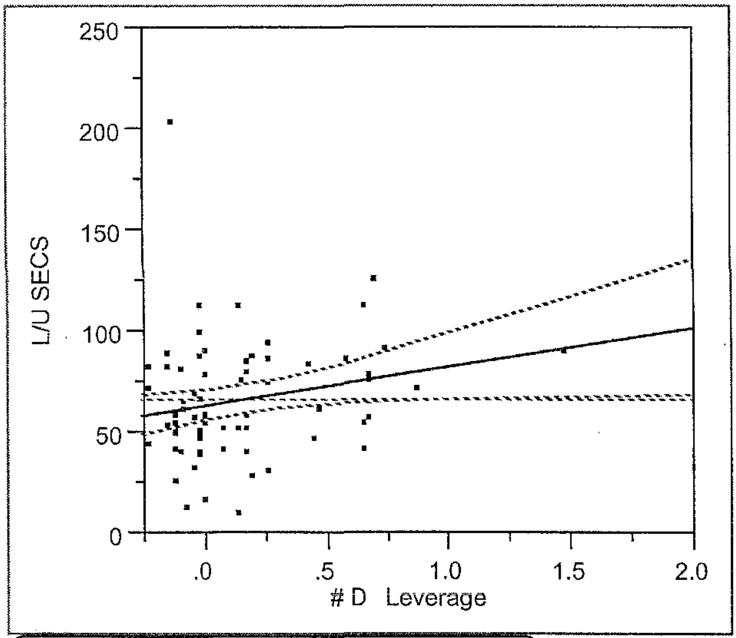
#WVEH



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
133.39449	0.1534	1	0.6965

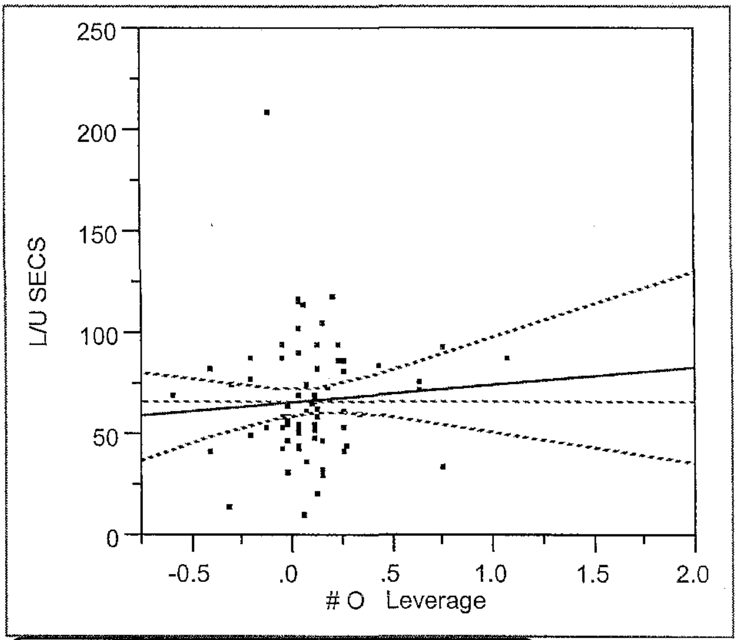
 # D



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
3932.3586	4.5207	1	0.0368

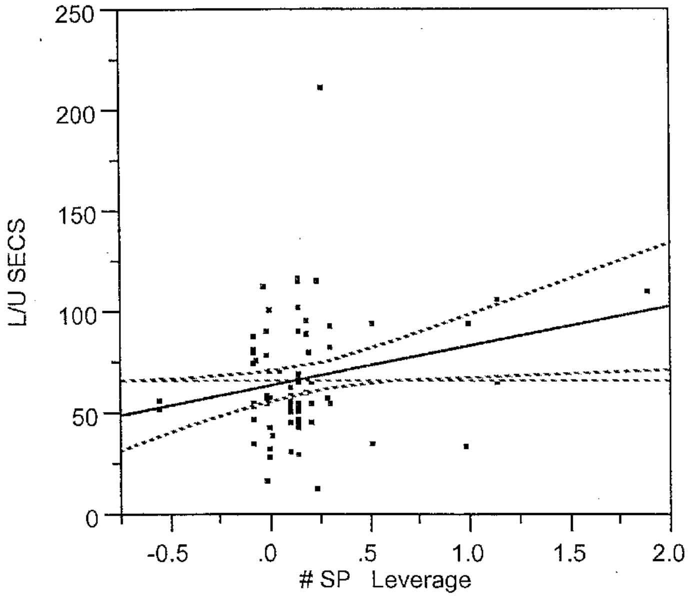
 # O



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
444.98611	0.5116	1	0.4767

SP



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
4604.6235	5.2935	1	0.0242

Intermediate Multiple Regression Model to Predict Unload Times Containing all Variables
Date: 07/20/2002
Equation:

Response: L/U SECS

Summary of Fit

RSquare	0.559225
RSquare Adj	0.531328
Root Mean Square Error	29.17845
Mean of Response	67.03529
Observations (or Sum Wgts)	85

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	18	35262.649	1959.04	3.7348
Pure Error	61	31996.515	524.53	Prob>F
Total Error	79	67259.164		<.0001
				Max RSq
				0.7903

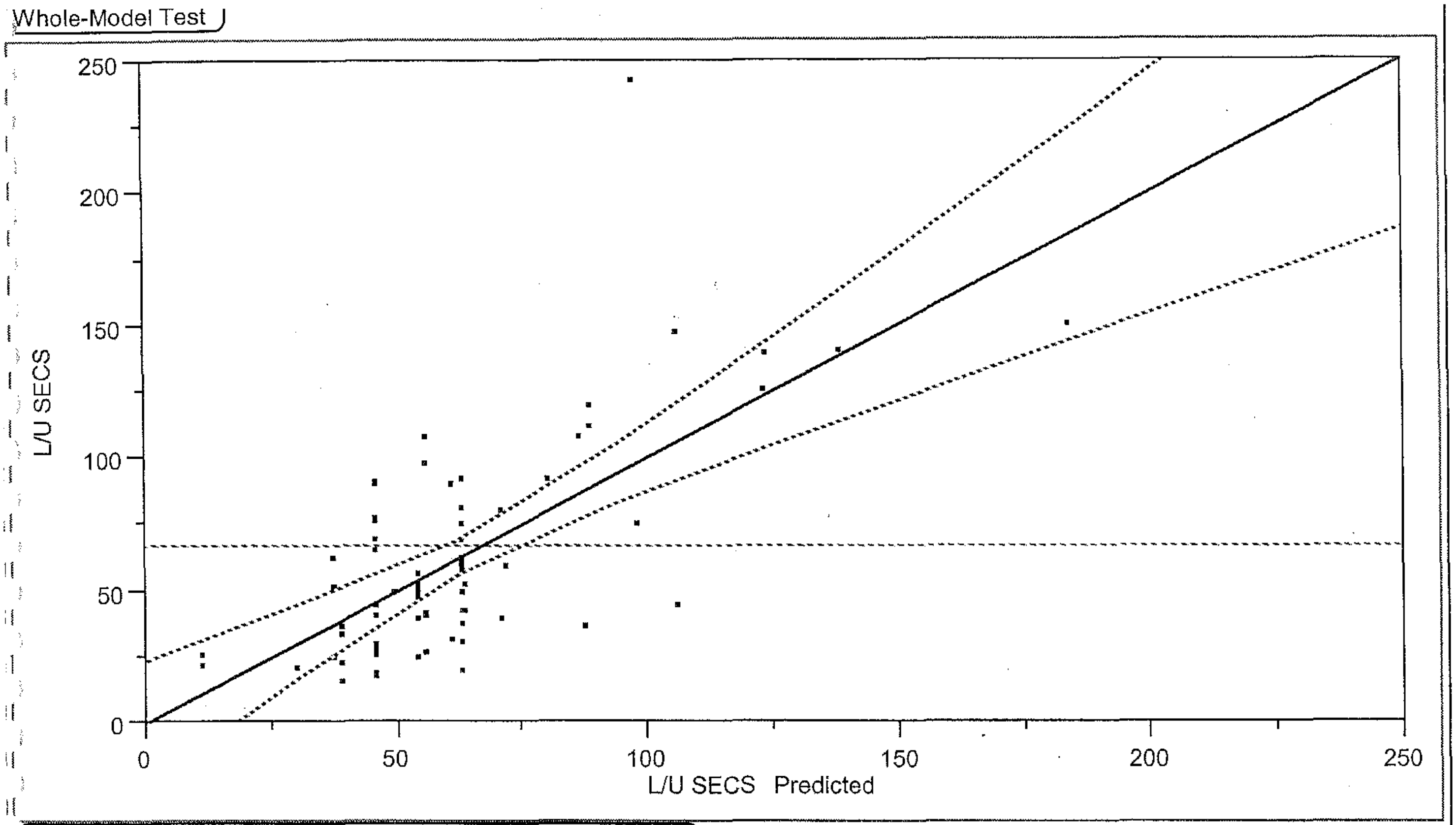
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	2.9008666	10.40369	0.28	0.7811	-17.80724	23.608971	0
# E	26.013058	3.993908	6.51	<.0001	18.063356	33.962761	0.591489
# W	86.201324	9.760045	8.83	<.0001	66.774372	105.62828	0.740059
# D	18.926275	8.437748	2.24	0.0277	2.1312984	35.721252	0.195928
# SP	24.737327	6.420154	3.85	0.0002	11.958286	37.516368	0.294956
DRIVER	8.4905526	2.861157	2.97	0.0040	2.7955413	14.185564	0.229009

Effect Test

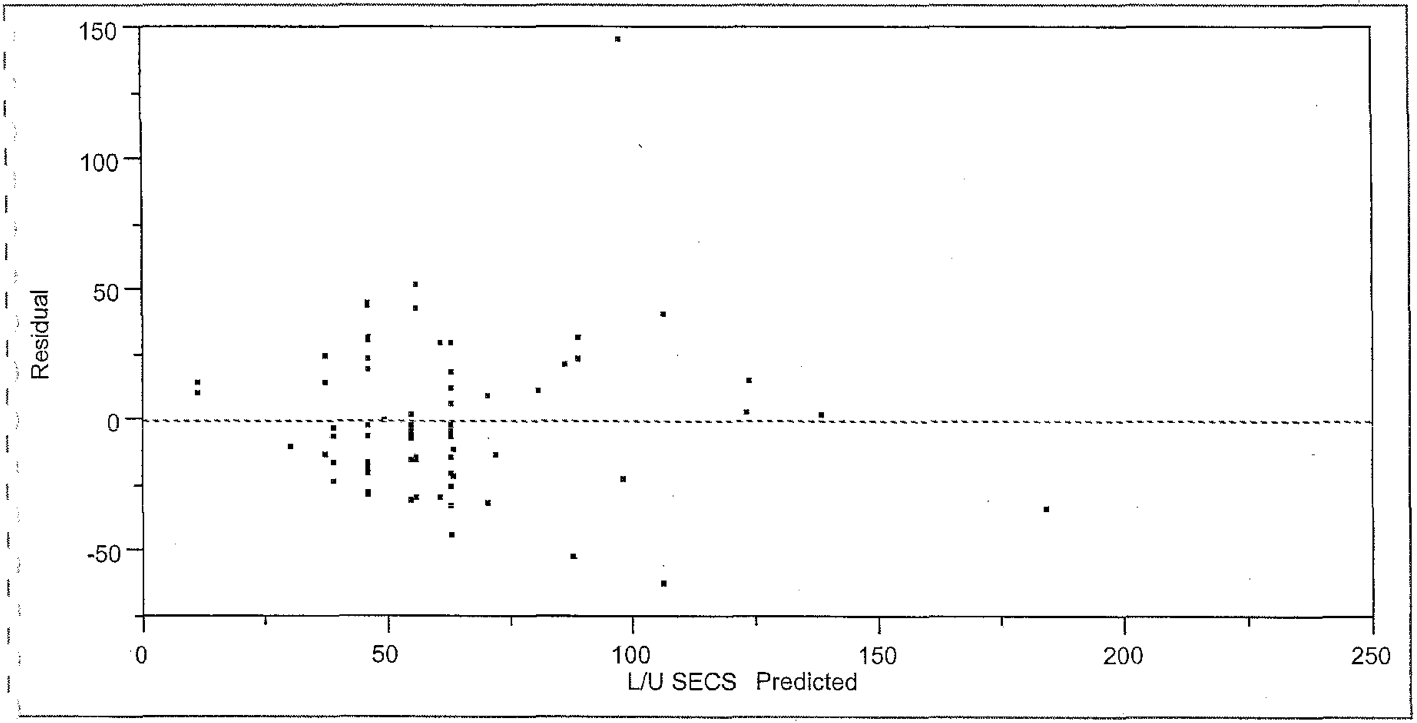
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
# E	1	1	36116.956	42.4216	<.0001
# W	1	1	66412.313	78.0053	<.0001
# D	1	1	4283.527	5.0313	0.0277
# SP	1	1	12639.767	14.8462	0.0002
DRIVER	1	1	7497.436	8.8062	0.0040

Whole-Model Test

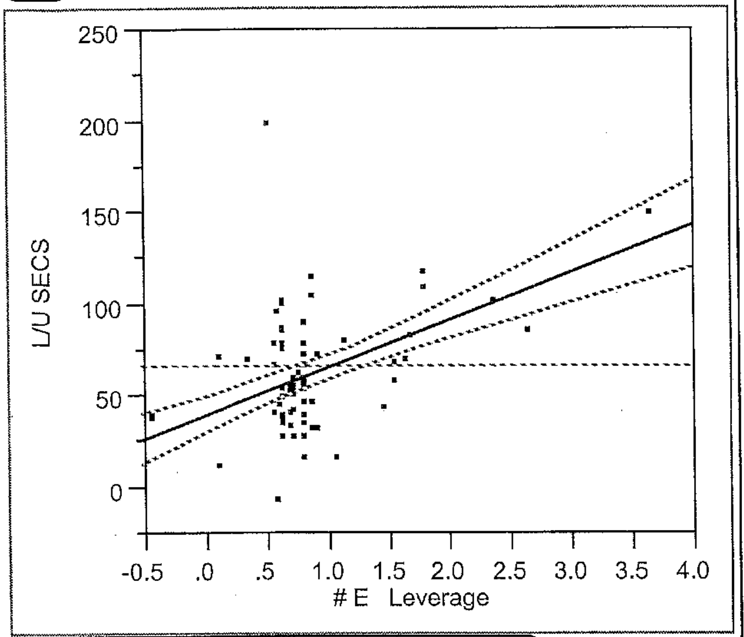


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	85333.73	17066.7	20.0459
Error	79	67259.16	851.4	Prob>F
C Total	84	152592.89		<.0001



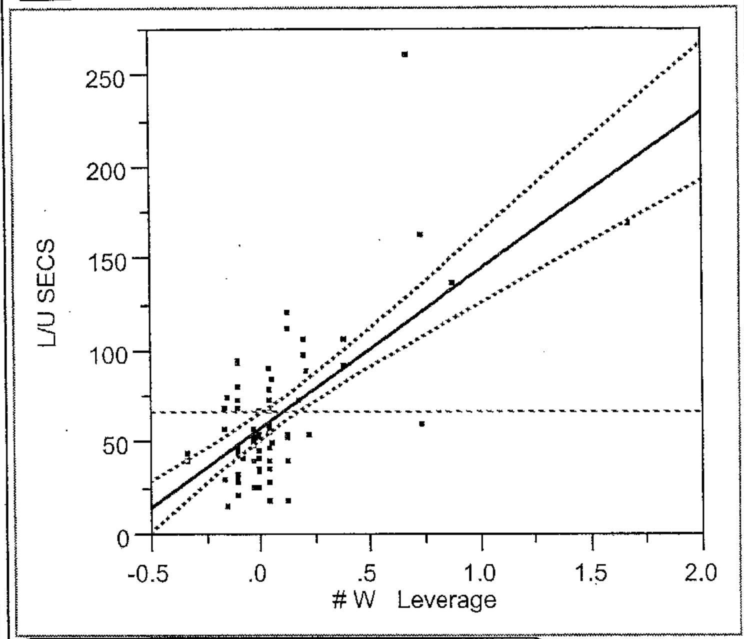
 # E



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
36116.956	42.4216	1	<.0001

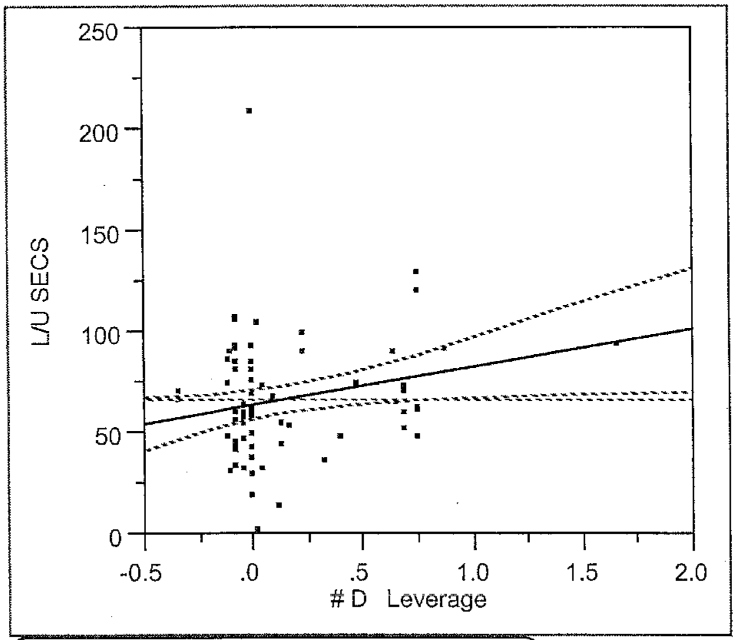
 # W



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
66412.313	78.0053	1	<.0001

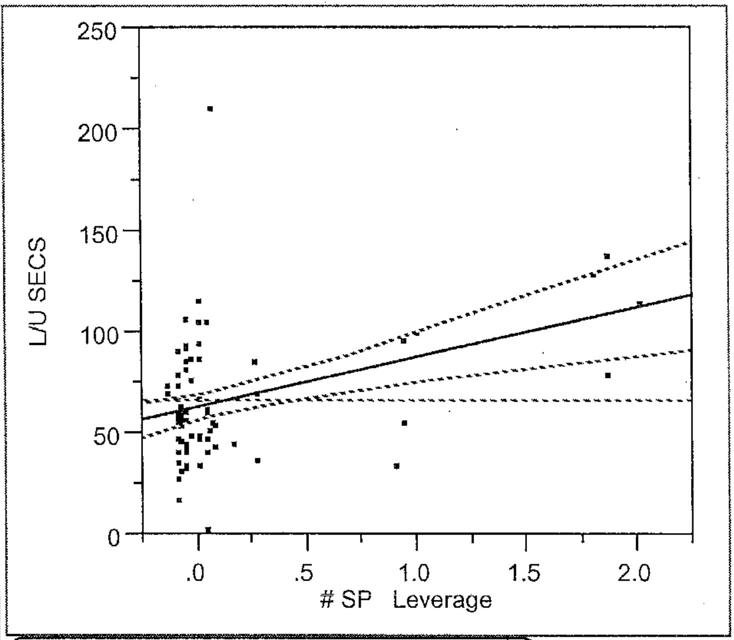
 # D



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
4283.5273	5.0313	1	0.0277

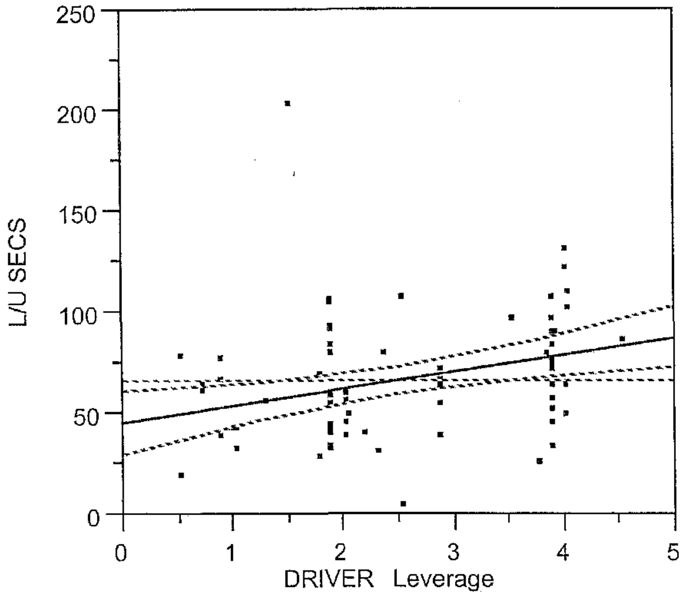
 # SP



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
12639.767	14.8462	1	0.0002

DRIVER



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
7497.4363	8.8062	1	0.0040

Final Multiple Regression Model to Predict Unload Times
Equation: Uest = g0 + g1.Y1+ g2.Y2 + g3.Y3 + g5.Y5 + g7.Y7;
Date: 07/20/2002

APPENDIX – VIII

OBSERVATIONS DROPPED FROM UNLOAD TIME DATA

Removed Unload Times from the data for normalization. These outliers occurred due to reasons that are not intended to cover under the present study. The reasons for their occurrence are explained against the dropped observations.

1. Passenger No: 4, on U6, date: 06/24/2002, driver: 2 is dropped from data. This is because after dropping her at destination there was a wait for her to get her ride card punched and buys a new one. This time cannot be counted as unload time.
2. Passenger No: 89, on U6, date: 06/25/2002, driver: 4 is dropped from data. The reason is the person needed a changed time for pickup and the driver waited to radio the other driver who is picking him up after his medical appointment.
3. Passenger No: 4, on U7, date: 06/26/2002, driver: 4 is dropped from data. The lady forgets to get her ride punched so the driver walks back from hospital entrance to punch it and go back to give to her. This time cannot be counted as load times.
4. Passenger No: 31, on U8, date: 06/27/2002, driver: 1 is dropped from data. The passenger was unloaded in the time when a wheel chair was unloaded from the bus. So the elderly person got the unload time for a wheel chair which skews the data.
5. Passenger No: 24, on U8, date: 06/27/2002, driver: 1 is dropped from data. The passenger was unloaded in the time when a wheel chair was unloaded from the bus. So the elderly person got the unload time for a wheel chair which skews the data.
6. Passenger No: 25, on U8, date: 06/27/2002, driver: 1 is dropped from data. The passenger was unloaded in the time when a wheel chair was unloaded from the bus. So the elderly person got the unload time for a wheel chair which skews the data.
7. Passenger No: 32, on U8, date: 06/27/2002, driver: 1 is dropped from data. The passenger was unloaded in the time when a wheel chair was unloaded from the bus. So the disabled person got the unload time for a wheel chair which skews the data.

APPENDIX - IX

TRAVEL TIME ANALYSIS APPENDIX

Some of the possible factors other than distance that could affect travel time in a paratransit operation are described in detail.

- Traffic – According to most of the drivers, at certain stages they take a longer route to reduce their travel times, because the shorter route has a large volume of traffic that slows their average speed down. This resulted in an increased travel time.
- Weather – In a place where drastic variation of weather exists, travel times became dependent on weather. The drivers find themselves behind the schedule more times in winter with snow on ground rather than a dry and sunny summer day. The presence of hazardous driving condition due to weather was a factor that determines the travel times. But in the current study the weather remained almost the same except for some mild showers. So this was a factor that needs to be studied depending on suitable climatic changes.
- Timeliness – Many of the passengers in the Galavan Transit facility had medical, doctor or other appointments due. Due to some reason if the driver goes behind the schedule, to make up time they tend to travel faster than they would normally do in a situation where they were ahead of schedule. So the pressure of keeping appointments can also affect the travel times.
- Time of day – Certain times in a day was usually busy through out the city. This was like the 8 – 9 am, 11 am – 1 noon, 4 – 6 pm etc. Usually at these times the streets close to the schools, college, and office complexes were busy. Also as a whole in the city there was more amount of commutation going on. This increase in commutation on mainly used streets tends to push some of the traffic overflows to the side streets that were otherwise having light traffic. This phenomenon was said to be influencing the travel times.
- Condition of Street – The road condition was an important factor in determining the travel times. Since by federal regulations the body of the vehicles that transport wheel chair passengers should be 6 inches lower than the normal loading platform. This regulation results in a vehicle with a lesser ground clearance than that of a normal one. So the streets where there were tall speed breakers, the undercarriage will brush against the humped surface. This factor forces the driver to avoid certain streets that may be shorter compared to others.

Simple regression analysis was conducted to find out whether the above stated factors have any significance with the travel times. If the above stated claims could be statistically substantiated, then a model could be developed to predict the travel times. So each of the factors stated above were quantified in numerical terms from the subjective terms to identify the relations existing. The following conventions are used to quantify the subjective data.

- Traffic – rated by the driver. Three ratings apply. Light, Medium and Heavy. The important criterion in rating was that the traffic was rated for that particular street being traversed. Also the rating was for the particular time of traversing compared to other days. The traffic was calculated as a weighted sum of traffic rating of all streets between included in the segment. The following numbers were used to represent the traffic between the segments.
    - 1 – Light Traffic Flow in the From – To road segments.
    - 2 – Between Light and Medium Traffic Flow in the From – To road segments.
    - 3 – Medium Traffic Flow in the From – To road segments.
    - 4 - Between Medium and Heavy Traffic Flow in the From – To road segments.

  - 5 - Heavy Traffic Flow in the From – To road segments

  When a simple regression was conducted with traffic and travel times an RSquare value = 0.396 was observed. It could be concluded that traffic accounts for around 40% of the variability in the model individually. So traffic was kept as a factor for doing detailed multiple regression analysis.

- Capacity – rated by driver. This was used to determine the effect of running behind the schedule on the travel times. The rating was subjective with three possible values. They are Ahead, In time and Behind. This was quantified as follows:
  - 1 – Ahead of scheduled pickup and drop-off times.
  - 2 – In time for scheduled pickup and drop-off times.
  - 3 – Behind of scheduled pickup and drop-off times.

  By doing a simple regression on the capacity an RSquare value = 0.015 was observed. This says that capacity by itself only explains for just 1.5% of the variability in the travel times. But based on the drivers' claim and possibility of an improvement it was still kept in for the detailed analysis.

- Condition – rated based on the data provided in GIS database. Three ratings are followed. They were; Poor, Fair, Good and Excellent. The numeral values assigned are:
  - 1 – Poor Road Condition
  - 2 – Fair Road Condition
  - 3 – Good Road Condition
  - 4 – Excellent Road Condition
  - Any decimal values between these numerals means that the segment has a set of roads that fall into different categories and the rating of a journey leg was between the assigned standard.

  A simple regression analysis on the road condition the observed RSquare value was 0.011. This says that only 1.1% of the variability in travel times was being accounted by road condition individually. But the significance of this in an interaction can only be judged by doing a detailed multiple regression. So the variable was kept on.

- Distance – as stated above distance is speed/time. So the more the distance has to be traveled, the more time it takes provided the speed remains the same. As through out the town the speed limit imposed was 25 mph, the assumption of speed remaining the same has some validity. The regression plot on distance versus travel time yielded an RSquare value = 0.396. So around 40% of variability was being explained by distance too. So this variable was also kept in for detailed analysis.
- Distance X Traffic – the interaction between the distance and traffic seems to have a large impact on the travel times. When a simple regression analysis was done with the distance-traffic interaction, an RSquare value = 0.635 was observed. So this was also considered in doing the detailed multiple regression analysis. This behavior can be explained with the following conclusions.
  - Shorter distance with heavy traffic can take more time than a longer route with low traffic.
  - From the drivers comments itself it was evident that they usually take longer routes with low traffic to reach destinations faster.
- Distance X Condition – the interaction between distance and road condition seems to be capable of making an impact in travel times. When the simple regression analysis of Distance-condition interaction was done an RSquare value = 0.219 was observed. This

says that some of the variability can be explained by this interaction. So it was included for final detailed multiple regression analysis.

- Traffic X Condition – this interaction was considered because some drivers of Galavan tend to take good condition roads on the assumption that they could make up time by traveling up to the speed limit when compared to traveling slow on a damaged shorter road. By doing a simple regression analysis on the interaction, RSquare value = 0.039 was observed. This suggests that around 4% of the variability of the system is explained by this interaction variable. Still as it explains some portion it was kept for the final analysis.
- Distance X Traffic X Condition – during the drive around with the drivers they used to suggest that they take certain roads in Bozeman because even though they were little longer than other paths, the condition was excellent and the traffic is very low. So they finally reach their destination well ahead of the shorter distance route (mainly main street). In some cases these roads help in avoiding taking left turns from Main Street that can be quite a wait due to the flow of traffic. A simple regression was conducted on this interaction and an RSquare value = 0.397 was observed.

DETAILED ANALYSIS

To do the multiple regression variables were added one by one to the model and thereby monitoring the change in RSquare value. The order of addition was also changed to see the effect that it makes in the RSquare of the model. Also by adding the new variable the results in the parameter estimates changed. By adding a new variable some became less significant and some became more significant. This was also noted down to reach the best possible combination of the factors that could predict the travel time to a good percentage possible.

To start with, multiple regression analysis was performed with just distance and traffic. The equation became as being shown below in Equation 1;

$T_{est} = \beta_0 + \beta_1.X_1 + \beta_2.X_2$; where T_{est} is the predicted Travel Time.

$$T_{est} = -118.42 + 113.31\ X_1 + 71.27\ X_2$$

Equation 1 - Initial Multiple Regression equation for Travel Time estimation

The t-ratio evaluation for finding the significance for each of the factors was conducted. The procedure was the same as the hypothesis testing in statistics. In this regard the null hypothesis and the alternative hypothesis were as follows.

H_0: $\beta_1 = 0$; $\beta_2 = 0$. (Insignificance).
H_1: $\beta_1 \neq 0$; $\beta_2 \neq 0$. (Significance).

The probabilities were small enough (< 0.001) to state the significance of distance and traffic. So the null hypothesis was rejected (or alternate hypothesis was accepted). The RSquare value for the equation was 0.629. This implied that together distance and traffic explained around 63% of the variability in the model.

The analysis was continued by adding variables one at a time and observing the changes until all variables were added. When all the variables were added the resultant equation gave a good value for RSquare fit. But some of the terms were not making any relevance when interpreted physically. An example was Distance having a negative co-efficient. This would interpret to be more the distance less the travel time, which was a kind of counter intuitive. The statistical details of the analysis were given in at the end of this section.

The Equation 2 was of the following form when all of the variables were added.

$$T_{est} = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{12t} + \beta_4 X_{3t} + \beta_5 X_{4t} + \beta_6 X_{24t} + \beta_7 X_{14t} + \beta_8 X_{124t};$$

Where T_{est} is the predicted travel time.

$$T_{est} = 900.57 - 312.16 X_{1t} - 230.73 X_{2t} + 157.84 X_{12t} - 7.73 X_{3t} - 422.32 X_{4t} + 120.11 X_{24t} + 169.39 X_{14t} - 60.06 X_{124t};$$

Equation 2 - Intermediate multiple regression equation for travel time estimation

With the addition of the estimates of slopes (β values), the final equation was of the form as given in the Equation 2.

The evaluation of t-ratio was conducted to find the significance of each of the involved parameters. The null and alternative hypothesis was stated as follows.

H_0: $\beta_0 = 0$; $\beta_1 = 0$; $\beta_2 = 0$; $\beta_3 = 0$; $\beta_4 = 0$; $\beta_5 = 0$; $\beta_6 = 0$; $\beta_7 = 0$; $\beta_8 = 0$. (Insignificance).

H_1: $\beta_0 \neq 0$; $\beta_1 \neq 0$; $\beta_2 \neq 0$; $\beta_3 \neq 0$; $\beta_4 \neq 0$; $\beta_5 \neq 0$; $\beta_6 \neq 0$; $\beta_7 \neq 0$; $\beta_8 \neq 0$. (Significance).

The final t-ratio estimates for each of the variables involved in the multiple regression equation are given in the following Table 1.

Table 1 - Significance estimation of coefficents with F-test for Travel time model

Sl. No	Coefficients	Values	t-ratio	Prob > | t |	Conclusion
1	β_C	900.57	3.02	0.0038	Significant; Accept H_1
2	β_1	-312.16	-2.28	0.0266	Significant; Accept H_1
3	β_2	-230.73	-2.54	0.0142	Significant; Accept H_1
4	β_3	157.84	3.35	0.0015	Significant; Accept H_1
5	β_4	-7.73	-0.53	0.6001	Insignificant; Accept H_0
6	β_5	-422.32	-3.13	0.0028	Significant; Accept H_1
7	β_6	120.11	2.90	0.0055	Significant; Accept H_1
8	β_7	169.39	2.87	0.0059	Significant; Accept H_1

9	β_8	-60.06	-2.96	0.0046	Significant; Accept H_1

The RSquare value for the model was = 0.755. This implies that the model explained 75.5% of the variability in the predicted travel times. But from the analysis it was clear that meanwhile all factors were significant the β_4 was insignificant, or in other words Capacity was insignificant. So the final multiple regression model for predicting the travel times was created by avoiding the capacity and then doing the regression analysis one more time. The modified regression equation is given below..

$$T_{est} = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{12t} + \beta_5 X_{4t} + \beta_6 X_{24t} + \beta_7 X_{14t} + \beta_8 X_{124t};$$

Where T_{est} is the predicted travel time.

$$T_{est} = 878.40 - 307.16 X_{1t} - 226.90 X_{2t} + 155.79 X_{12t} - 420.73 X_{4t} + 119.90 X_{24t} + 168.57 X_{14t} - 59.94 X_{124t};$$

Equation 3 - Multiple regression equation with significant terms for predicting travel times

With the addition of the estimates of slopes (β values), the final Multiple Regression Equation was of the form as given in the Equation 3.

The evaluation of t-ratio was conducted to find the modified significance of each of the involved parameters. The null and alternative hypothesis was stated as follows.

H_0: $\beta_0 = 0$; $\beta_1 = 0$; $\beta_2 = 0$; $\beta_3 = 0$; $\beta_5 = 0$; $\beta_6 = 0$; $\beta_7 = 0$; $\beta_8 = 0$. (Insignificance).

H_1: $\beta_0 \neq 0$; $\beta_1 \neq 0$; $\beta_2 \neq 0$; $\beta_3 \neq 0$; $\beta_5 \neq 0$; $\beta_6 \neq 0$; $\beta_7 \neq 0$; $\beta_8 \neq 0$. (Significance).

The final t-ratio estimates for each of the variables involved in the multiple regression equation are given in the following TABLE.

Table 2 - Significance estimation for parameters in Travel Time estimation model

Sl. No	Coefficients	Values	t-ratio	Prob > | t |	Conclusion
1	β_0	878.40	3.00	0.0041	Significant; Accept H_1
2	β_1	-307.16	-2.26	0.0275	Significant; Accept H_1
3	β_2	-226.90	-2.52	0.0148	Significant; Accept H_1
4	β_3	155.79	3.34	0.0015	Significant; Accept H_1
5	β_5	-420.73	-3.14	0.0027	Significant; Accept H_1
6	β_6	119.90	2.91	0.0052	Significant; Accept H_1
7	β_7	168.57	2.87	0.0058	Significant; Accept H_1
8	β_8	-59.94	-2.97	0.0044	Significant; Accept H_1

The RSquare value for this model is = 0.7534. This value interprets as that the model explains 75.34% of the total variability of the system. This accounted for a good portion of the variability considering the fact that there are not many observations.

But by looking at the coefficients of the terms in the equation it does not make physical sense. The cause of the above stated behavior can be attributed to the addition of interaction terms for traffic and distance based on road condition. The road condition was based on the data obtained from the GIS database. The database itself is not complete and there are no measures by which the judgment of the road condition could be validated. So most of the road conditions were taken as fair or good and it ended up in just multiplying the distance with a common factor.

We believe that the road condition is still an important factor in a door-to-door paratransit operation in a small rural/urban community. The reason is that there is a higher chance of having roads that are bad and could affect the travel times adversely. But in the current situation we don't have enough data to substantiate that. Thus the final model was based on dropping the interaction of road condition with other independent variables.

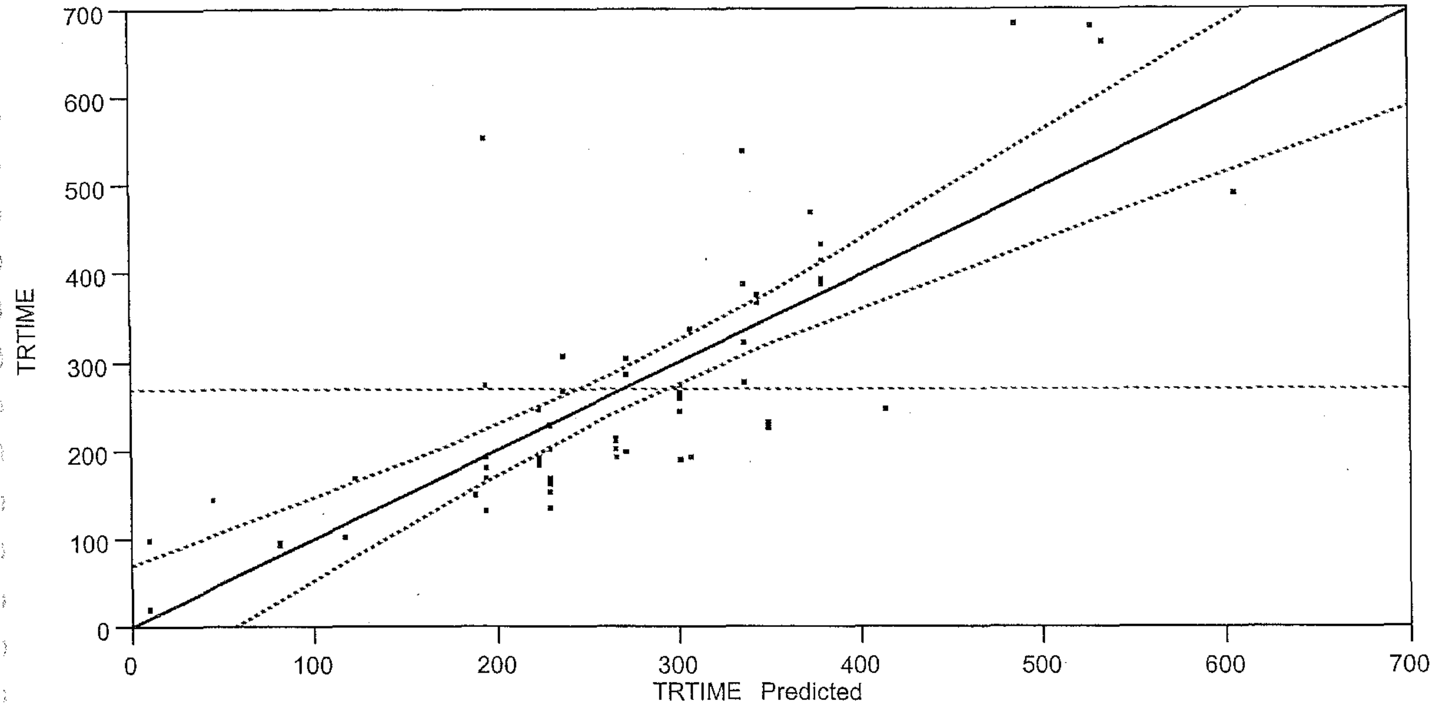
The final independent variables used in the equation are given in the following Table 3. The coefficients represent the slope terms for that variable in the multiple regression equation. These variables are all having linear relationships that are explained by the scatter plots of them with travel times. The statistical details from Jumpin are included in the rest of the pages in this section of Appendix. They were included for the technical completeness of this section of report.

Table 3 - List of parameters finally decided to be in the Travel Time estimation Model

Sl. No	Variable Description	Abbreviation	Symbol	Coefficients
1	Distance	DIST	X_1	β_1
2	Traffic	TRAF	X_2	β_2
3	Distance-Traffic Interaction	DISTRAF	X_{12}	β_{12}
4	Condition	COND	X_4	β_4

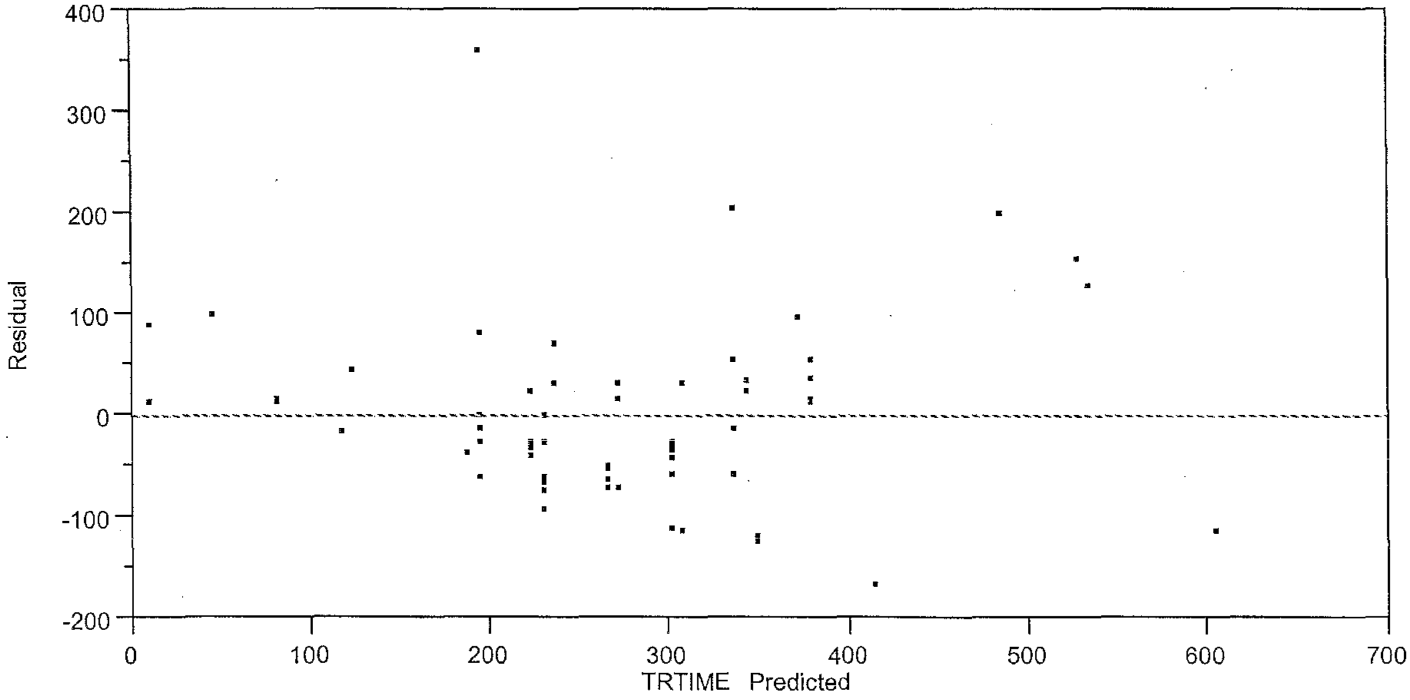
```
Response:  TRTIME
Summary of Fit
RSquare                        0.629198
RSquare Adj                    0.616838
Root Mean Square Error         88.65622
Mean of Response               270.9524
Observations (or Sum Wgts)           63

Lack of Fit
Source        DF   Sum of Squares   Mean Square    F Ratio
Lack of Fit   21        259934.26       12377.8     2.2807
Pure Error    39        211661.26        5427.2     Prob>F
Total Error   60        471595.52                   0.0127
                                                   Max RSq
                                                    0.8336

Parameter Estimates
Term          Estimate   Std Error   t Ratio   Prob>|t|    Lower 95%    Upper 95%   Std Beta
Intercept    -118.4164    42.83434     -2.76     0.0076    -204.0978    -32.73489          0
DIST         113.31221    12.53621      9.04     <.0001    88.236055    138.38837   0.724101
TRAF         71.271401    11.60754      6.14     <.0001    48.052858    94.489945   0.491885

Effect Test
Source   Nparm   DF   Sum of Squares    F Ratio    Prob>F
DIST         1    1        642154.43    81.6998    <.0001
TRAF         1    1        296325.23    37.7008    <.0001
```

Whole-Model Test

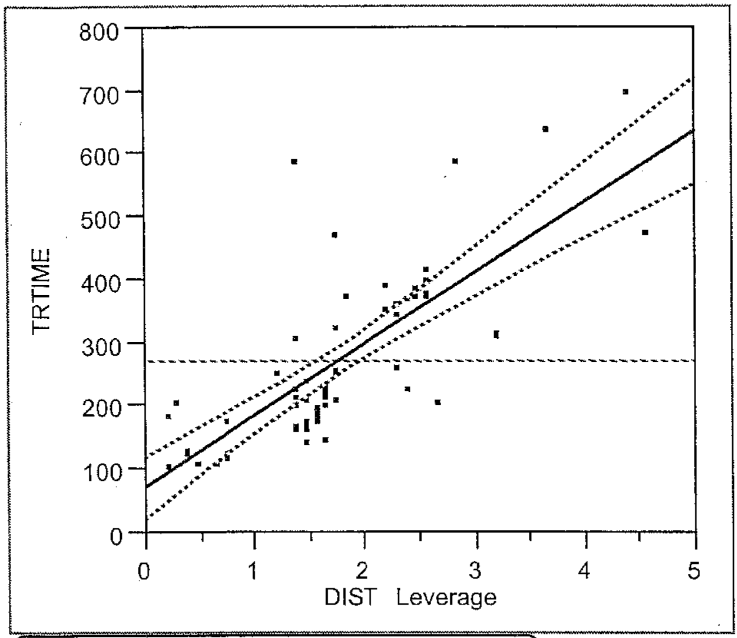


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	800229.3	400115	50.9057
Error	60	471595.5	7860	Prob>F
C Total	62	1271824.9		<.0001



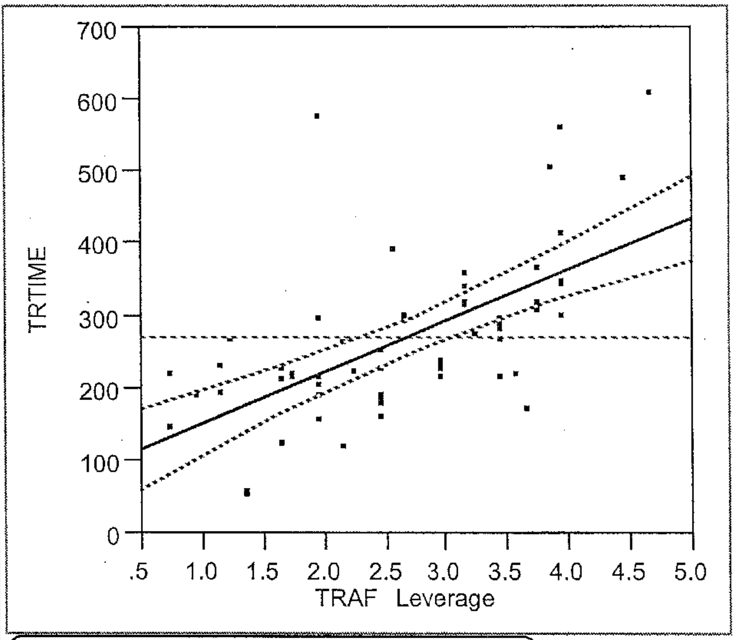
DIST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
642154.43	81.6998	1	<.0001

TRAF



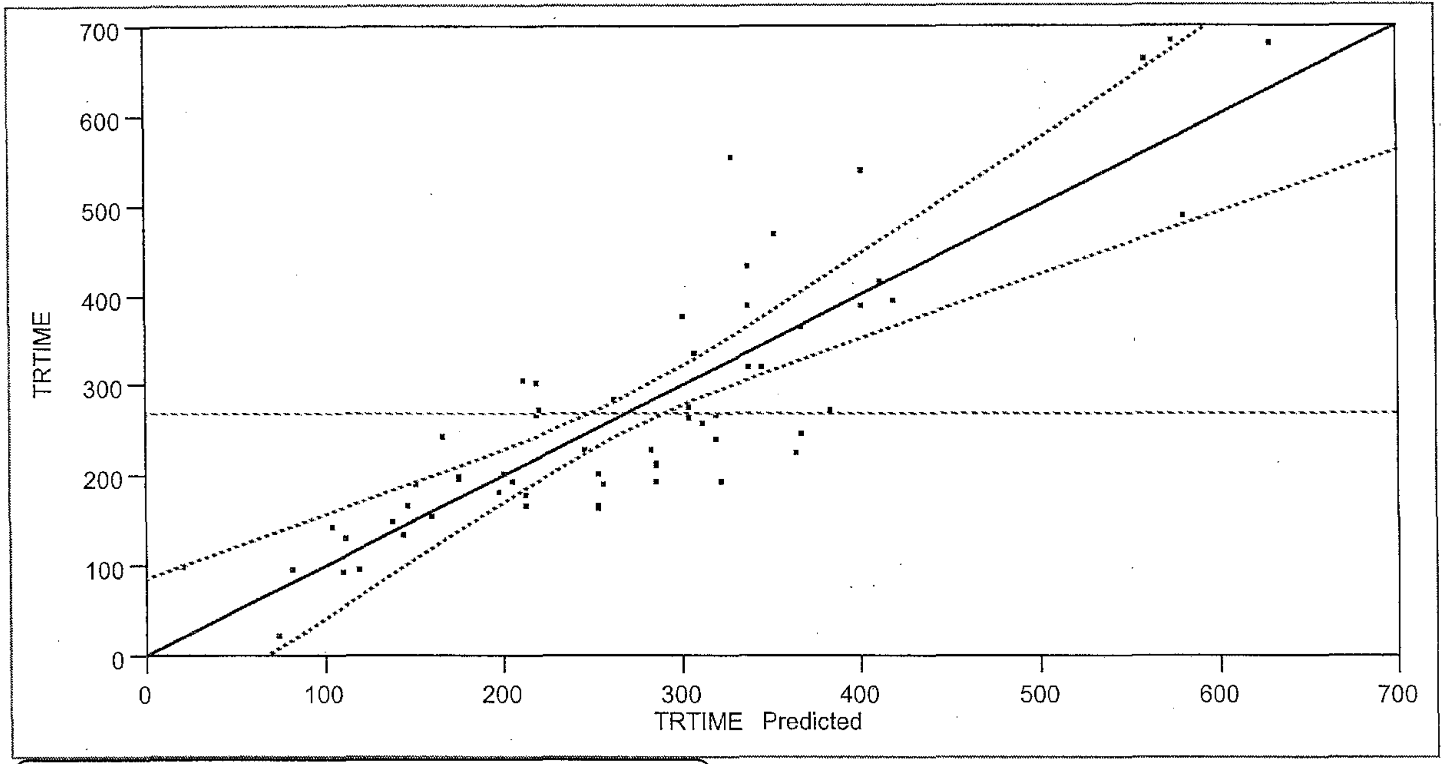
Effect Test

Sum of Squares	F Ratio	DF	Prob>F
296325.23	37.7008	1	<.0001

Initial Multiple Regression Model to Predict Travel Times
Equation: Test = b0 + b1.X1 + b2.X2;
Date: 07/27/2002

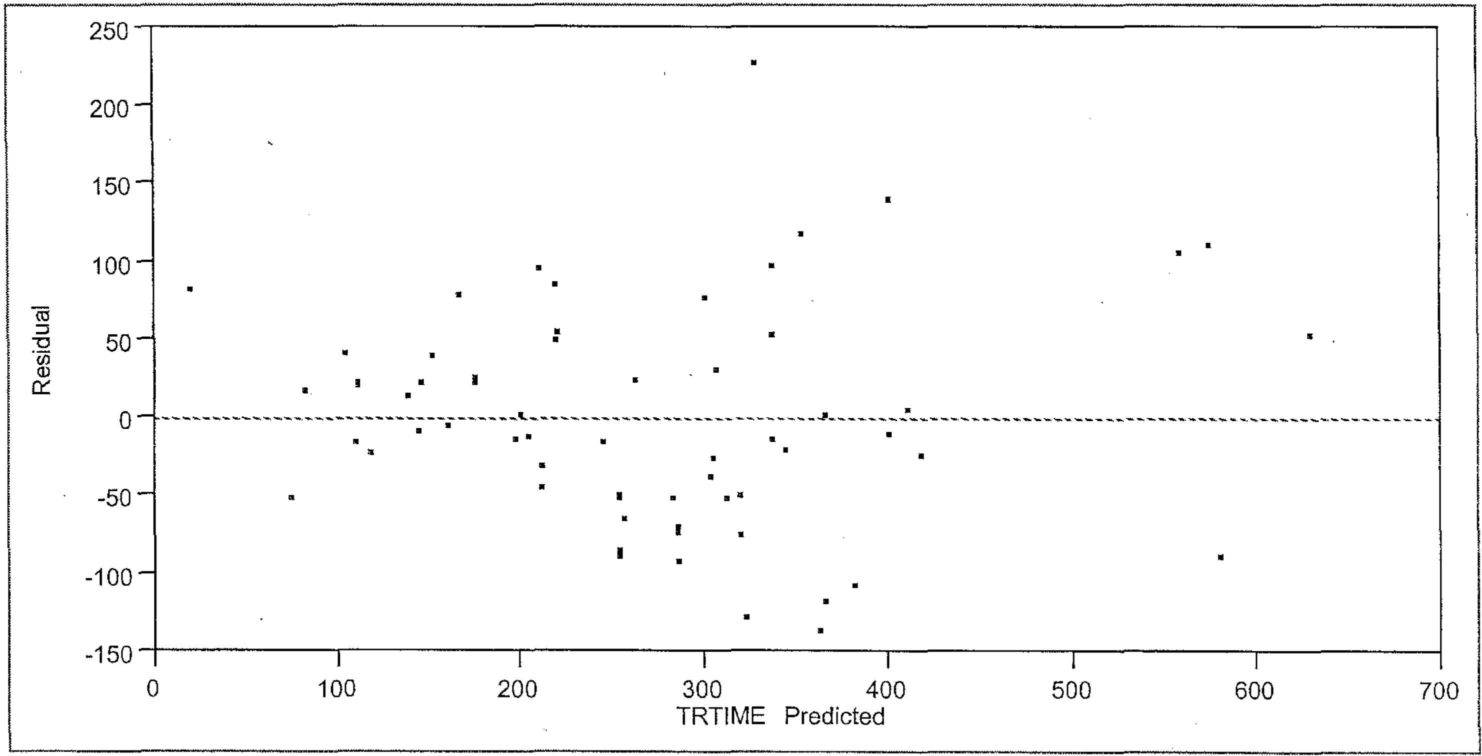
```
esponse: TRTIME
Summary of Fit
RSquare                        0.754638
RSquare Adj                    0.718288
Root Mean Square Error         76.01867
Mean of Response               270.9524
Observations (or Sum Wgts)           63

Lack of Fit
Source        DF   Sum of Squares   Mean Square    F Ratio
Lack of Fit   43        297780.77       6925.13     5.3358
Pure Error    11         14276.50       1297.86     Prob>F
Total Error   54        312057.27                   0.0024
                                                   Max RSq
                                                    0.9888

Parameter Estimates
Term          Estimate   Std Error   t Ratio   Prob>|t|    Lower 95%    Upper 95%    Std Beta
Intercept    900.56656   298.1023      3.02     0.0038      302.908    1498.2251           0
DIST         -312.1624   136.8913     -2.28     0.0266    -586.6126    -37.71217    -1.99482
TRAF         -230.7268   91.01057     -2.54     0.0142    -413.1919    -48.26183    -1.59238
DISTRAF      157.83842     47.112      3.35     0.0015    63.384633    252.29221    2.940086
CAP          -7.727689   14.65495     -0.53     0.6001    -37.10906     21.65368    -0.03841
COND         -422.3222   134.7431     -3.13     0.0028    -692.4656    -152.1788    -1.83215
TRAFCON      120.10873   41.47994      2.90     0.0055    36.946533    203.27092    2.287794
DISTCOND     169.38964   59.12027      2.87     0.0059    50.860765    287.91852    3.316108
DSTRCD       -60.05702   20.32314     -2.96     0.0046    -100.8024    -19.31162    -3.12026

Effect Test
Source      Nparm   DF   Sum of Squares    F Ratio    Prob>F
DIST            1    1        30050.389     5.2001    0.0266
TRAF            1    1        37140.963     6.4271    0.0142
DISTRAF         1    1        64863.863    11.2244    0.0015
CAP             1    1         1606.835     0.2781    0.6001
COND            1    1        56769.513     9.8237    0.0028
TRAFCON         1    1        48452.185     8.3844    0.0055
DISTCOND        1    1        47439.650     8.2092    0.0059
DSTRCD          1    1        50464.556     8.7326    0.0046
```

Whole-Model Test

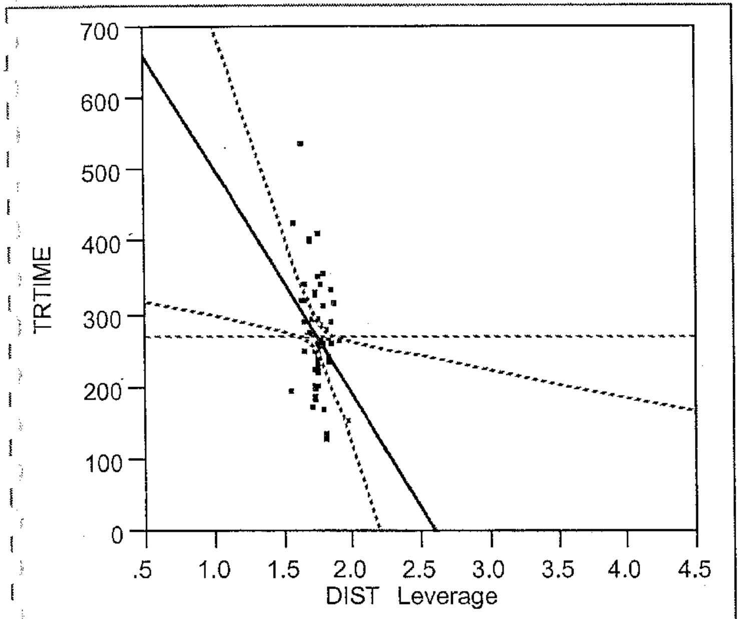


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	959767.6	119971	20.7604
Error	54	312057.3	5779	Prob>F
C Total	62	1271824.9		<.0001



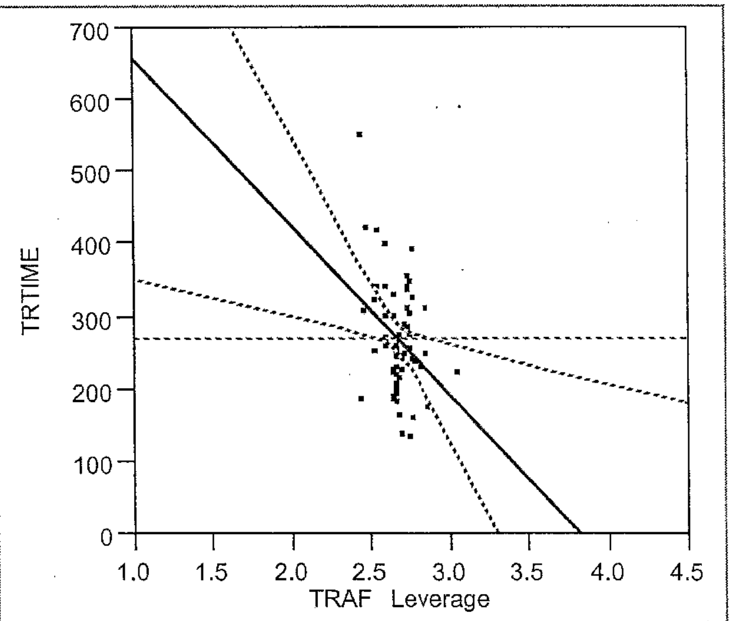
DIST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
30050.389	5.2001	1	0.0266

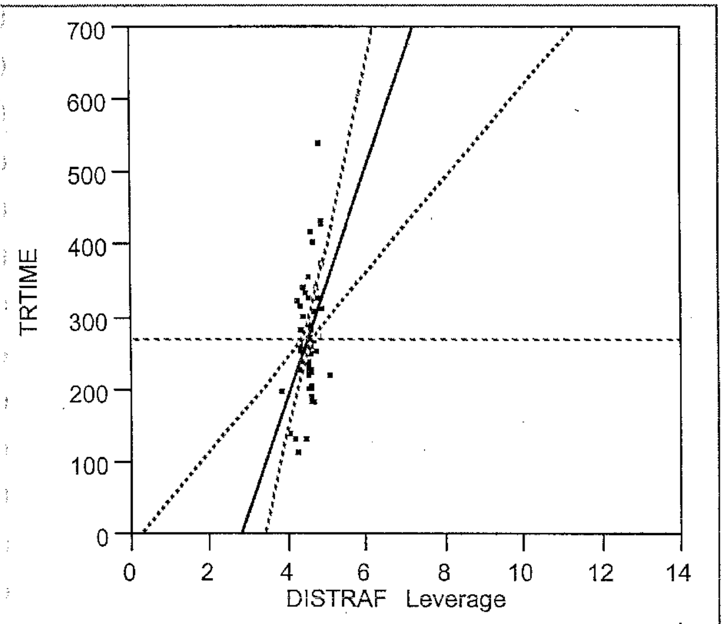
TRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
37140.963	6.4271	1	0.0142

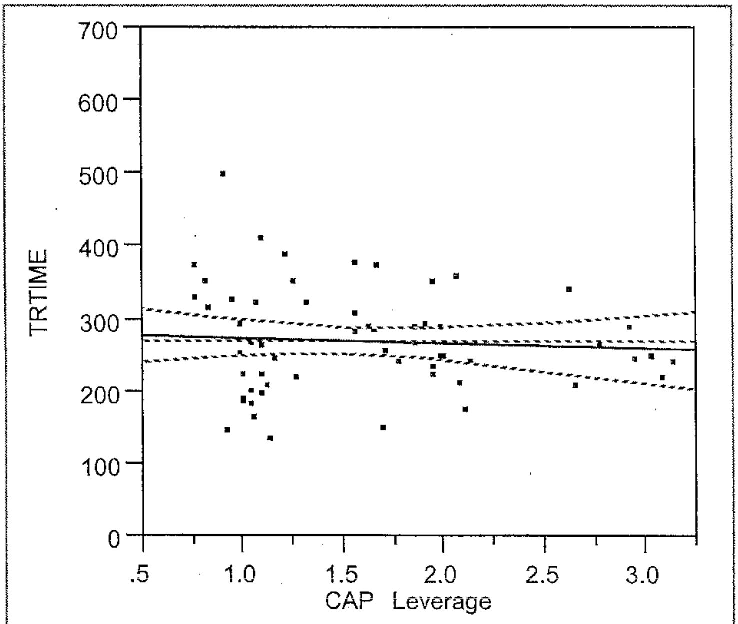
DISTRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
64863.863	11.2244	1	0.0015

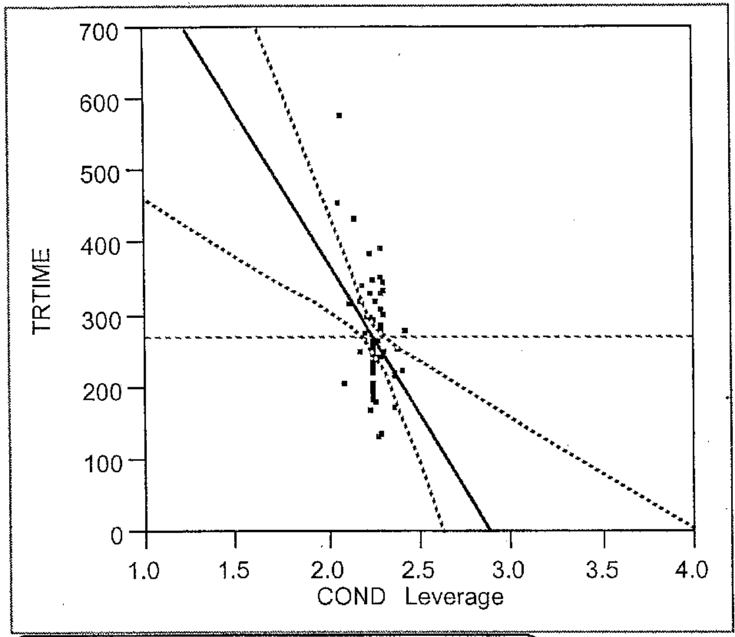
CAP



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
1606.8351	0.2781	1	0.6001

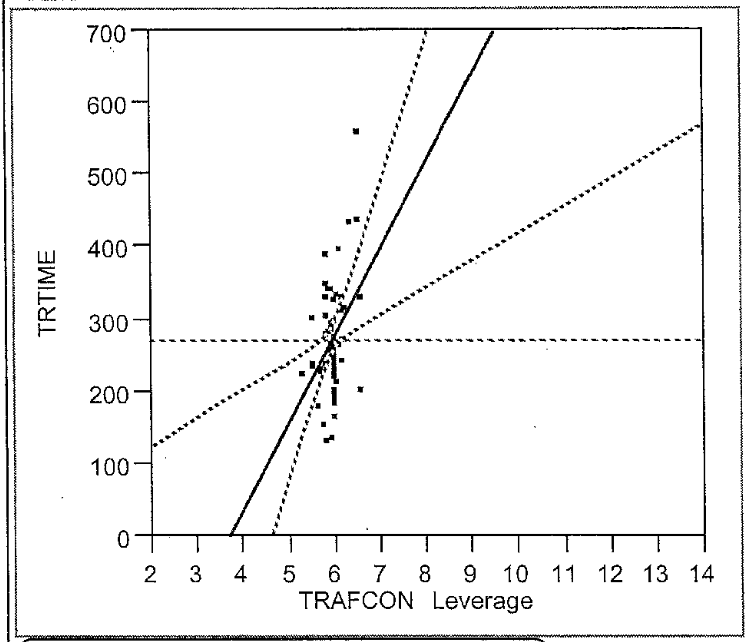
COND



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
56769.513	9.8237	1	0.0028

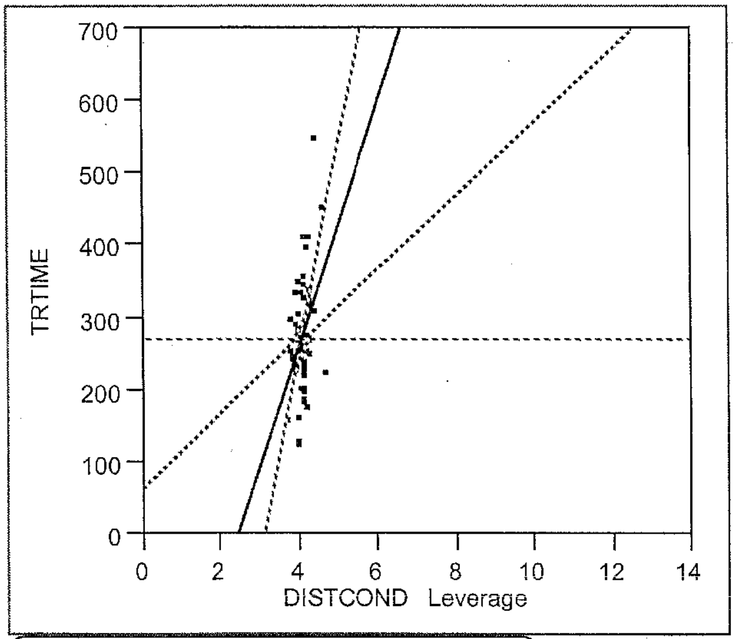
TRAFCON



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
48452.185	8.3844	1	0.0055

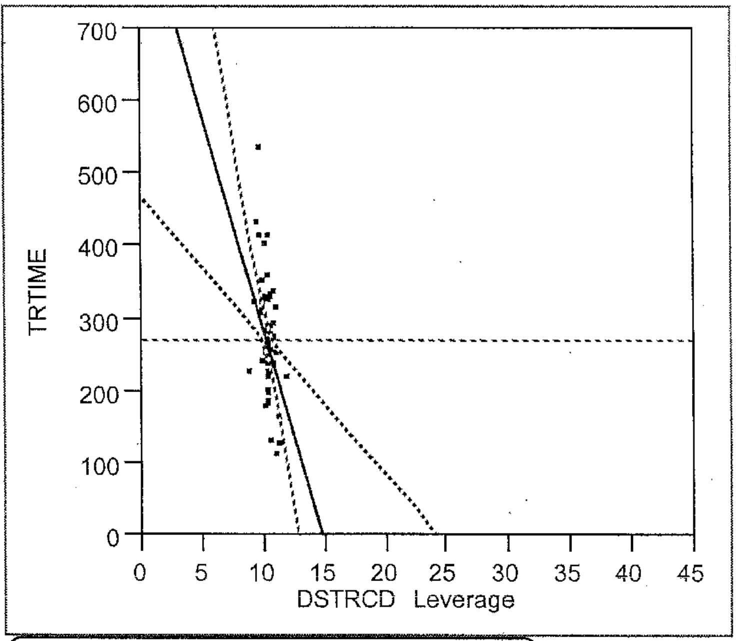
DISTCOND



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
47439.650	8.2092	1	0.0059

DSTRCD



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
50464.556	8.7326	1	0.0046

Intermediate Multiple Regression Equation to Predict Travel Times
Date: 07/27/2002
Equation: Test = b0 + b1 X1t + b2 X2t + b3 X12t + b4 X3t + b5 X4t + b6 X24t + b7 X14t + b8 X124t;

Summary of Fit

RSquare	0.753375
RSquare Adj	0.721986
Root Mean Square Error	75.5181
Mean of Response	270.9524
Observations (or Sum Wgts)	63

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	31	275396.90	8883.77	5.5716
Pure Error	24	38267.20	1594.47	Prob>F
Total Error	55	313664.10		<.0001
				Max RSq
				0.9699

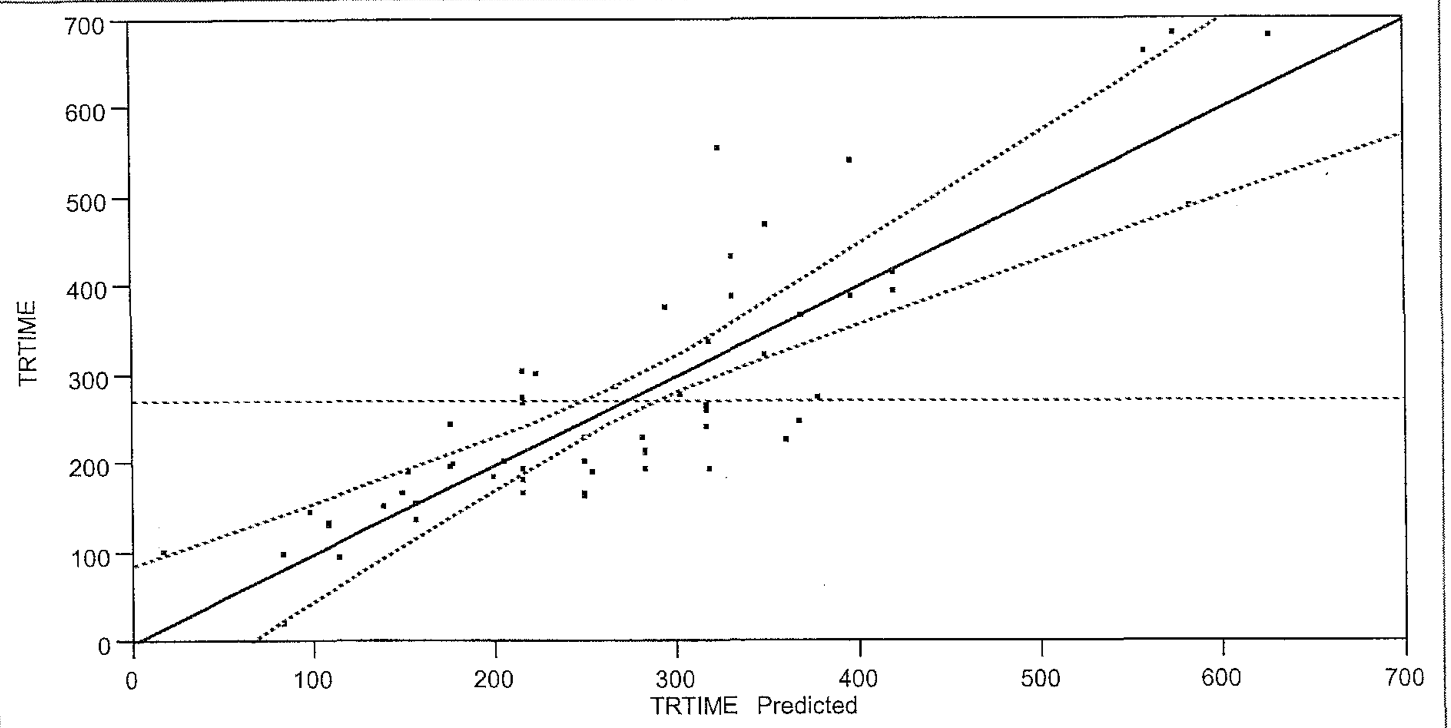
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	878.40201	293.1807	3.00	0.0041	290.85523	1465.9488	0
DIST	-307.1585	135.6627	-2.26	0.0275	-579.0325	-35.28454	-1.96284
TRAF	-226.9026	90.12377	-2.52	0.0148	-407.5145	-46.2907	-1.56599
DISTRAF	155.79367	46.64298	3.34	0.0015	62.319124	249.26821	2.901998
COND	-420.7255	133.8221	-3.14	0.0027	-688.9106	-152.5403	-1.82522
TRAFCON	119.90174	41.20496	2.91	0.0052	37.325222	202.47826	2.283851
DISTCOND	168.57171	58.71075	2.87	0.0058	50.912825	286.23059	3.300096
DSTRCD	-59.93746	20.18806	-2.97	0.0044	-100.3952	-19.47971	-3.11405

Effect Test

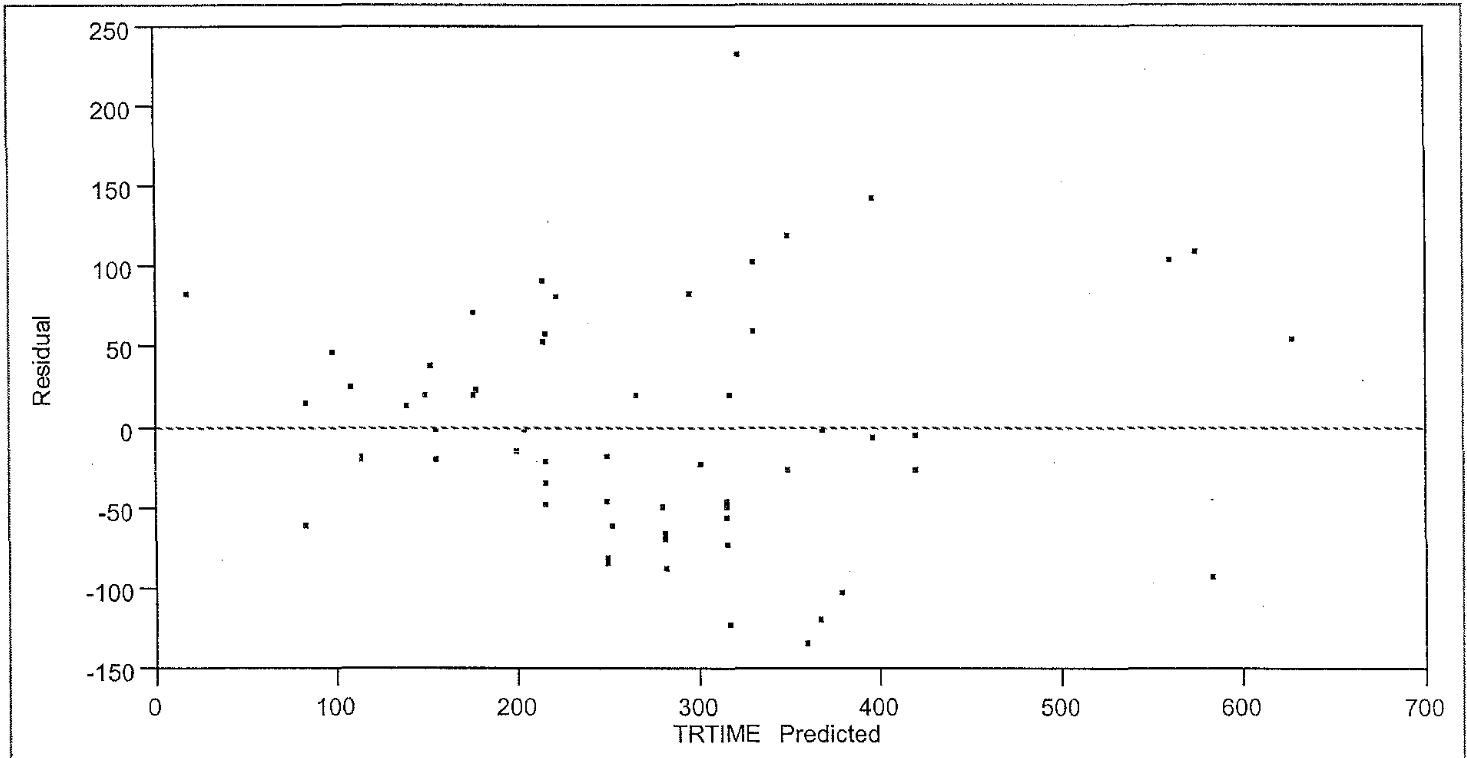
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
DIST	1	1	29235.203	5.1263	0.0275
TRAF	1	1	36149.514	6.3387	0.0148
DISTRAF	1	1	63625.202	11.1565	0.0015
COND	1	1	56369.512	9.8842	0.0027
TRAFCON	1	1	48289.657	8.4674	0.0052
DISTCOND	1	1	47014.976	8.2439	0.0058
DSTRCD	1	1	50270.082	8.8147	0.0044

Whole-Model Test

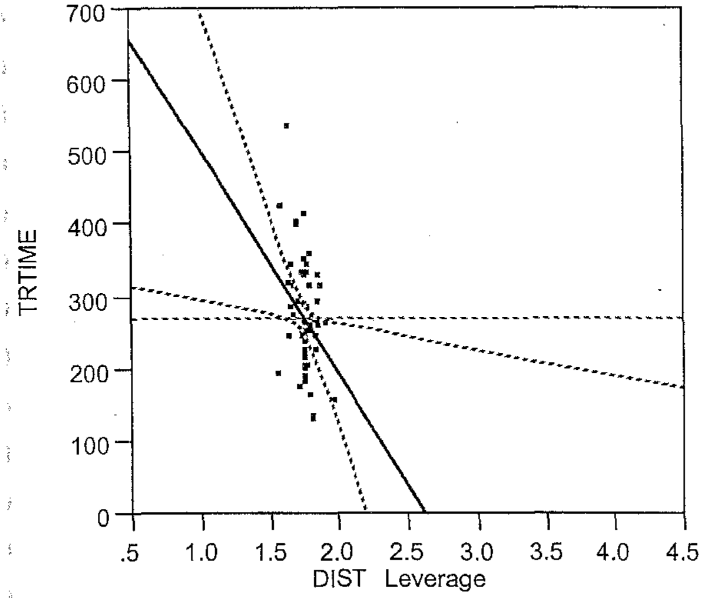


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	958160.8	136880	24.0015
Error	55	313664.1	5703	Prob>F
C Total	62	1271824.9		<.0001



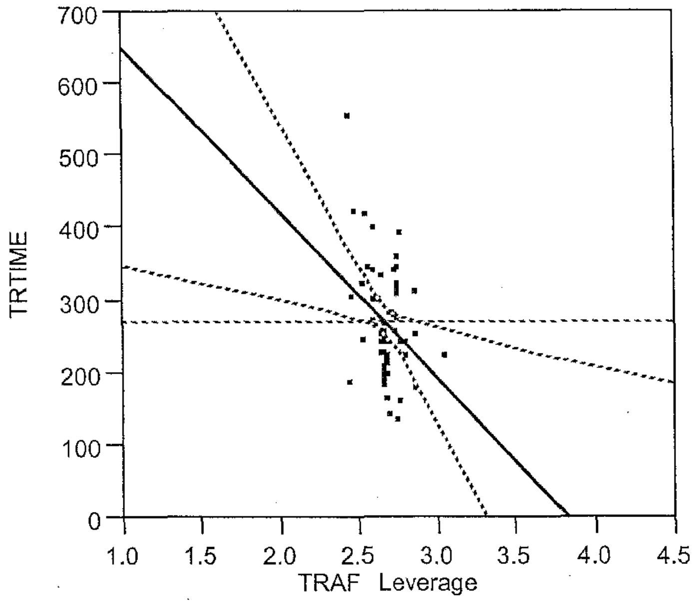
DIST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
29235.203	5.1263	1	0.0275

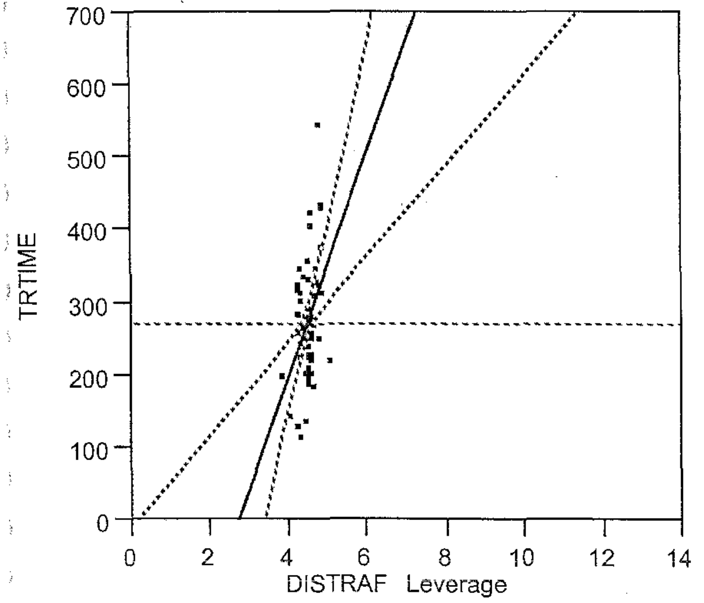
TRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
36149.514	6.3387	1	0.0148

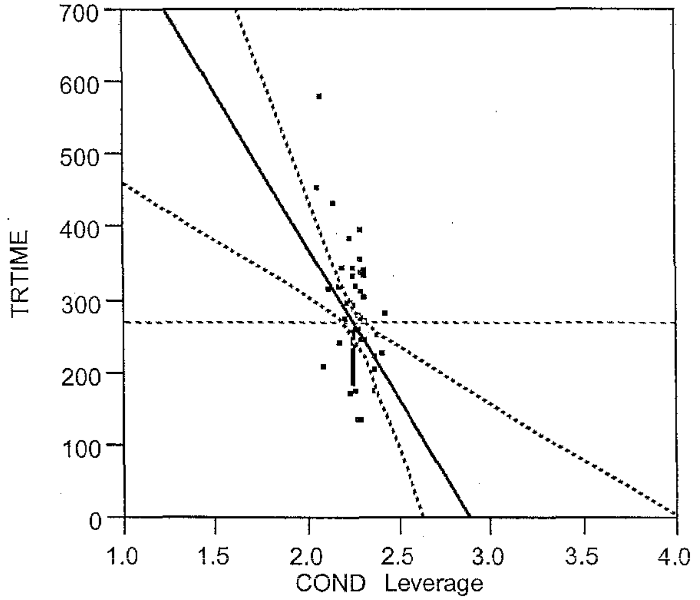
DISTRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
63625.202	11.1565	1	0.0015

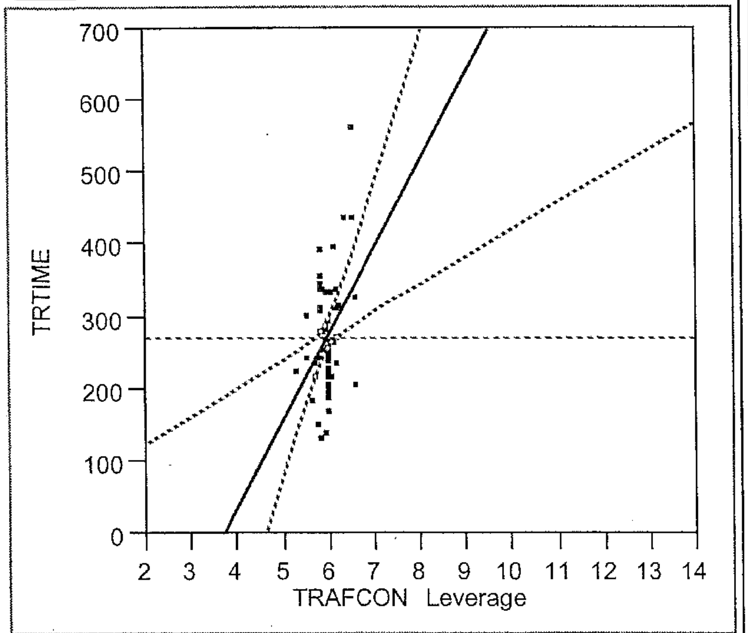
COND



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
56369.512	9.8842	1	0.0027

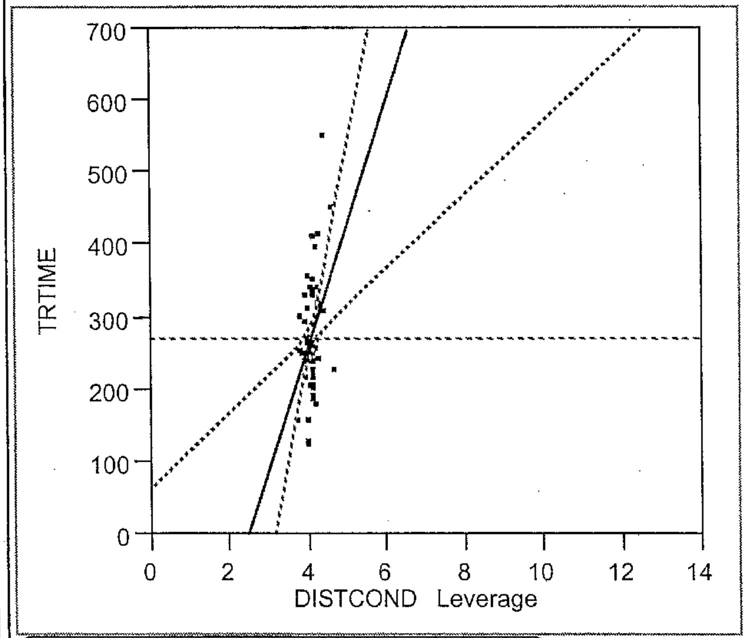
TRAFCON



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
48289.657	8.4674	1	0.0052

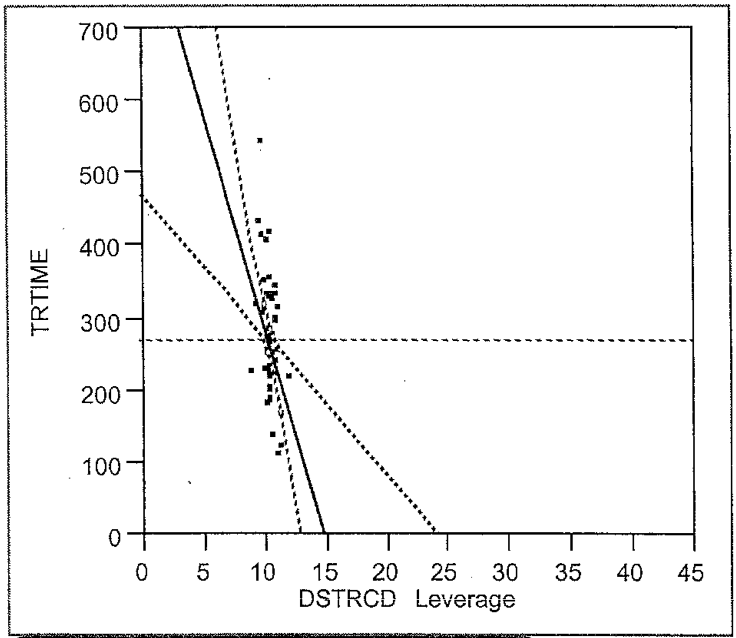
DISTCOND



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
47014.976	8.2439	1	0.0058

DSTRCD



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
50270.082	8.8147	1	0.0044

Intermediate Multiple Regression Model for Travel Time Analysis
Date: 07/27/2002
Equation: Test = b0 + b1 X1t + b2 X2t + b3 X12t + b5 X4t + b6 X24t + b7 X14t + b8 X124t;

Summary of Fit

RSquare	0.712489
RSquare Adj	0.692661
Root Mean Square Error	79.40118
Mean of Response	270.9524
Observations (or Sum Wgts)	63

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	34	327396.59	9629.31	6.0392
Pure Error	24	38267.20	1594.47	Prob>F
Total Error	58	365663.79		<.0001
				Max RSq
				0.9699

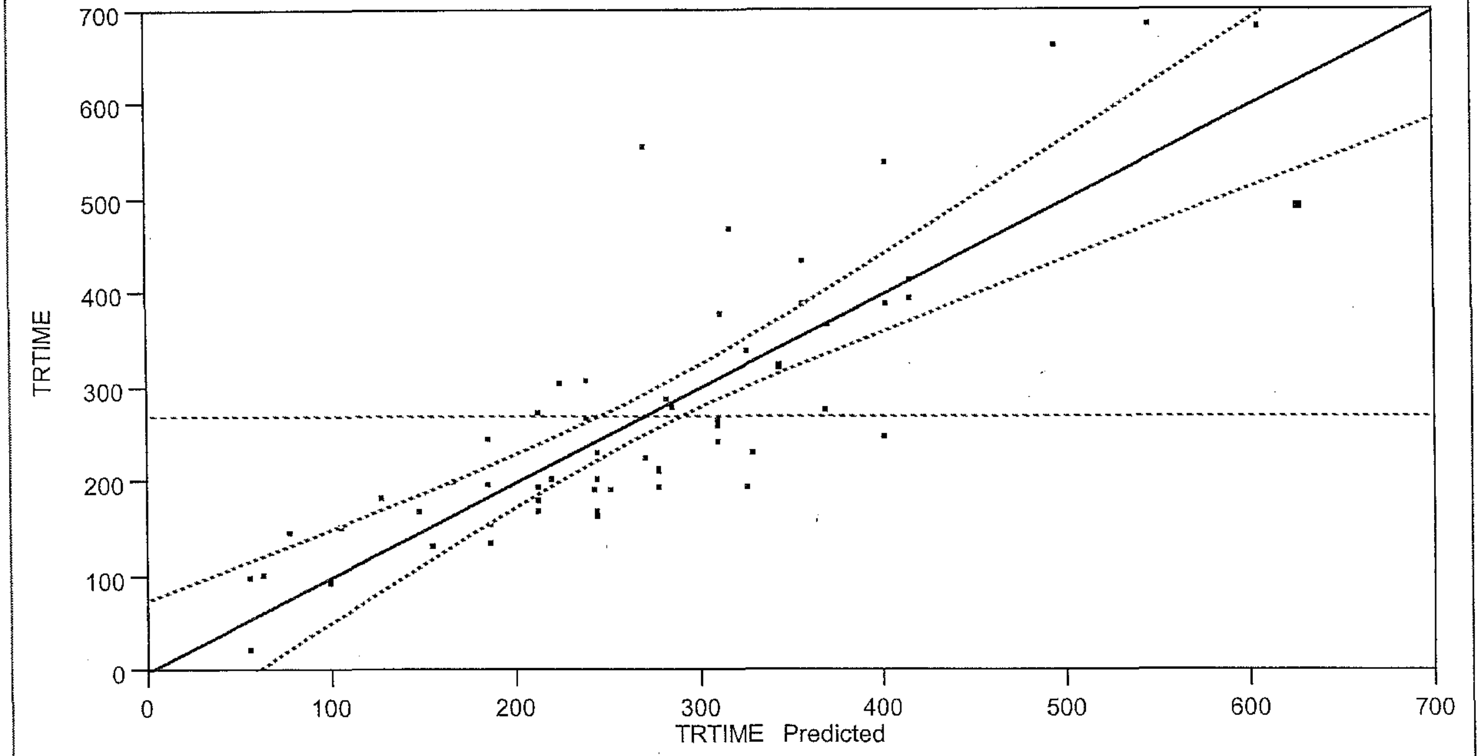
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	95.520297	68.235	1.40	0.1669	-41.06687	232.10747	0
DIST	68.653177	29.02469	2.37	0.0214	10.553961	126.75239	0.438716
TRAF	31.670227	21.11653	1.50	0.1391	-10.59909	73.939546	0.218575
DISTRAF	22.389153	10.93357	2.05	0.0451	0.5032412	44.275065	0.417047
COND	-58.06831	16.81909	-3.45	0.0010	-91.73536	-24.40125	-0.25192

Effect Test

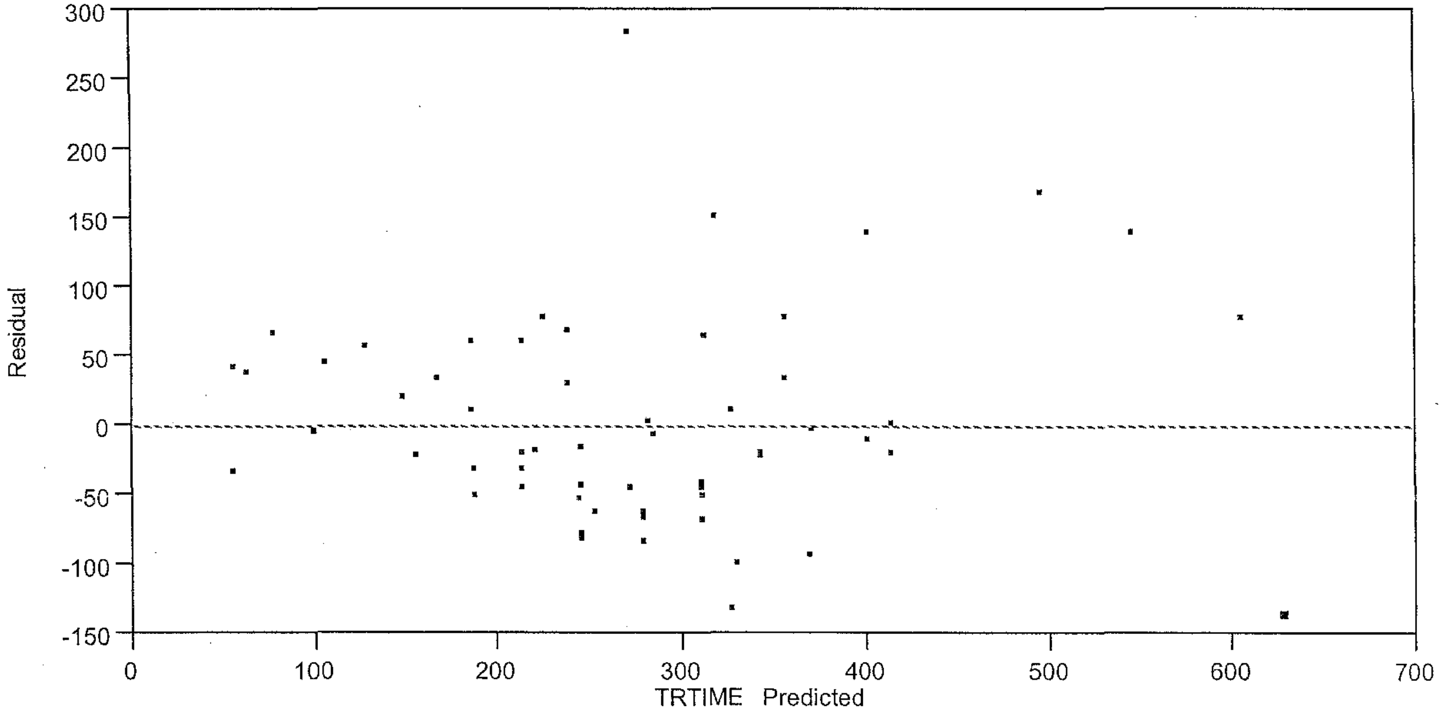
Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
DIST	1	1	35272.816	5.5948	0.0214
TRAF	1	1	14181.143	2.2494	0.1391
DISTRAF	1	1	26436.590	4.1933	0.0451
COND	1	1	75149.728	11.9199	0.0010

Whole-Model Test

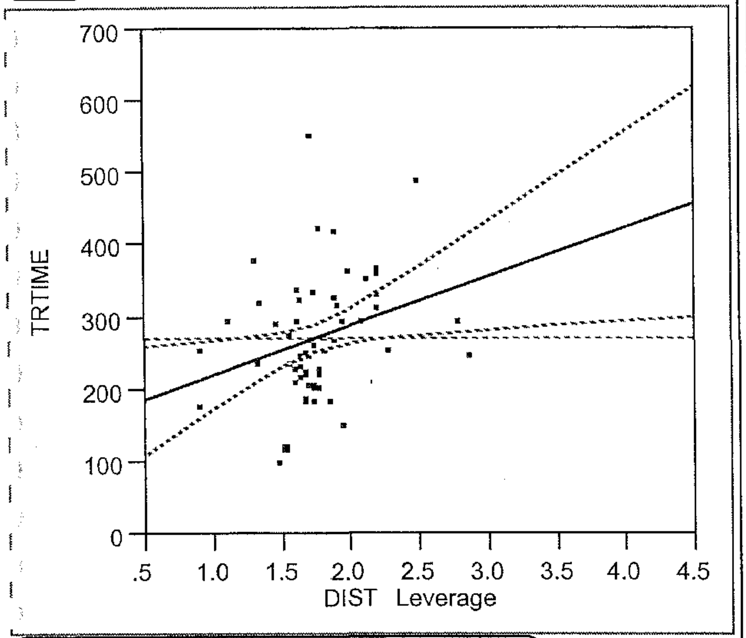


Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	906161.1	226540	35.9328
Error	58	365663.8	6305	Prob>F
C Total	62	1271824.9		<.0001



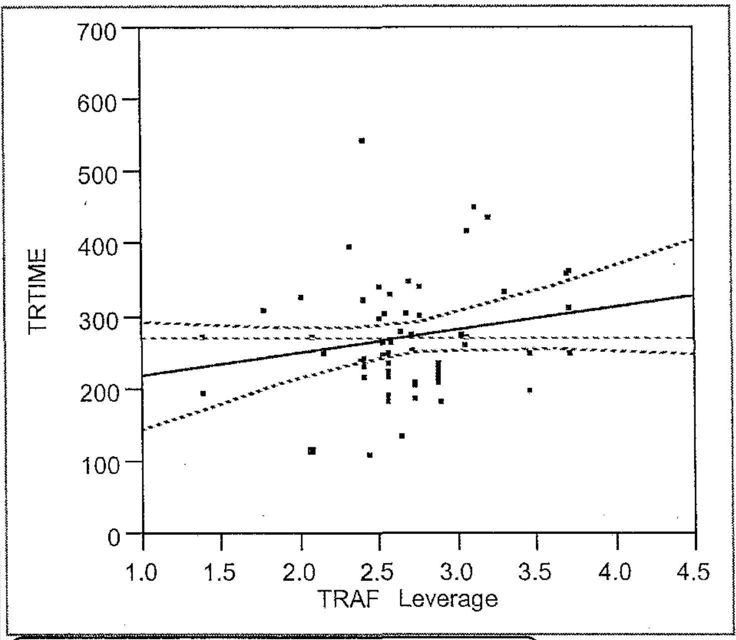
DIST



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
35272.816	5.5948	1	0.0214

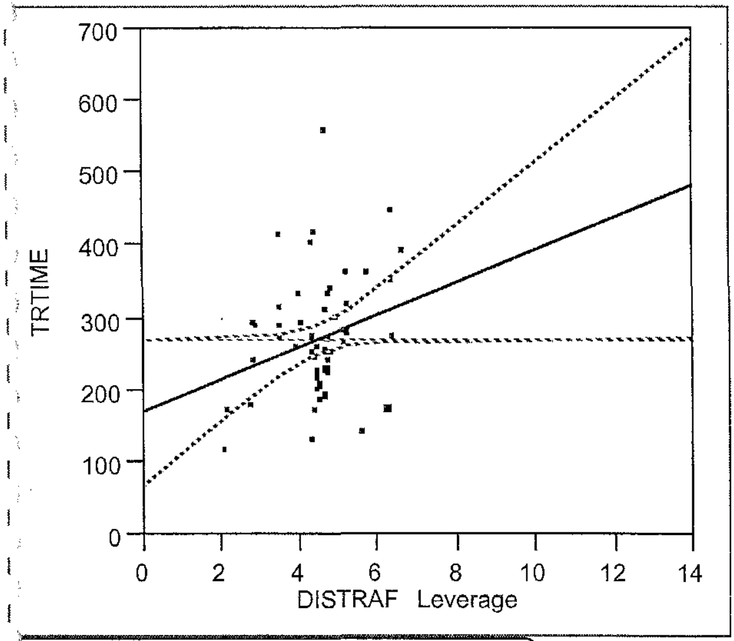
TRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
14181.143	2.2494	1	0.1391

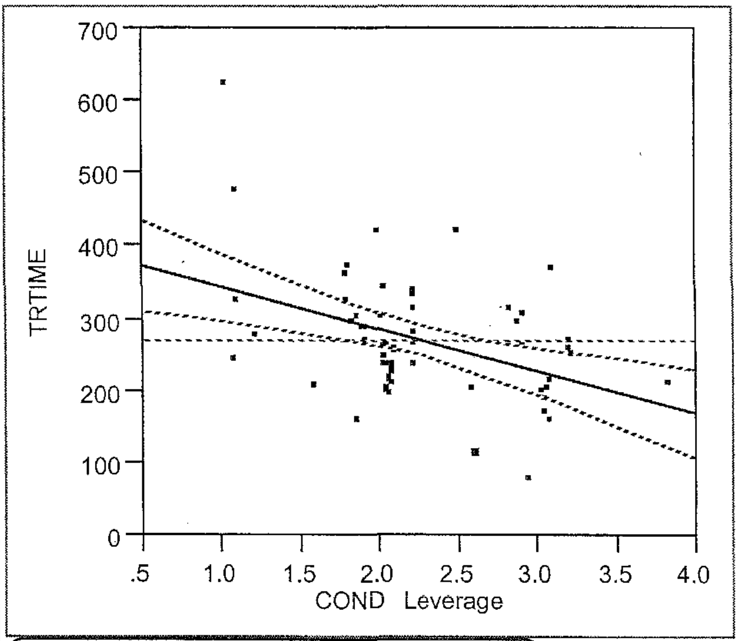
DISTRAF



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
26436.590	4.1933	1	0.0451

COND



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
75149.728	11.9199	1	0.0010

Equation: Test = b0 + b1 X1 + b2 X2 + b12 X12 + b4 X4;

APPENDIX – X

OBSERVATIONS DROPPED FROM TRAVEL TIME DATA

Data removed from travel time dataset due to its erratic relationship with the studied process. These outliers occurred due to reasons that are not intended to cover in this study. The reasons are explained next to each of the discarded observations.

1. Drive to Gas station to fill gas – Start Time 1:49:56, End Time 1:53:44. No passenger was hauled at that time. Date: 7/16/2002
2. Drive from gas station to BSSC – Start Time 1:58:57, End Time 2:03:36. No passenger was hauled at this trip. Date: 7/16/2002
3. Drive from 220 S 18th AVE to BSSC – Start Time 3:30:38, End Time 3:40:36. No passenger was hauled. The trip was for the Lunch break. Date: 7/16/2002
4. Drive from NYE'S Cloth Line to BSSC – Start Time 1:00:39, End Time 1:05:26. No passenger was hauled. The trip was for a break. Date: 7/16/2002
5. Drive from 418 N 15th AVE to BSSC – Start Time 2:10:22, End Time 2:14:42. No passenger hauled. The trip was for a break.
6. Drive from DM to BSSC – Start Time 3:26:31, End Time 3:27:15. No passenger hauled. Last trip of the day to park the vehicle in BSSC.

APPENDIX - XI

MODEL VALIDATION APPENDIX

The verification was based on the basic principles of statistics. The main analysis performed was the R^2 fit of the model proposed with the freshly collected data. In this way if the model fits with the freshly collected data with a proper R^2, we can generalize the model for a similar situation under study.

After collecting the data, it was put into an Excel spreadsheet to do the verification analysis. When all the fields of the verification analysis (same as initial time study analysis) were populated with necessary data, analysis was done. The first step was to predict the time of the activity under analysis with the equations developed from the initial time study. Then the difference in the predicted times and actual times are found and these are the absolute errors. They were plotted against observation numbers to check for any recognizable patterns. This analysis is called as Residual Analysis. The plot of residuals with the predicted values (statistically known as estimates) is often used in the design of experiments to validate the regression model for its applicability over the range of data.

So for finding out the R^2 initially $(Y_{est} - \tilde{Y})$ and $(Y - \tilde{Y})$ were calculated. Then they were squared to make all the negative values positive. The aggregate sums of the squared errors were then found out. The sum of squared errors of estimated error is then divided with the sum of squared errors of total error. This quotient gave the value of R^2 for the collected model.

When the obtained value of R^2 with the fresh set of data in the same experimental conditions is close enough to the prediction (or estimation) model R^2 fit value during estimation, then model is validated over the data collected in similar scenarios. So by validation we conclude statistically that the proposed models are good enough in predicting Load, Unload and Travel times in a Paratransit operational scenario.

This appendix details the data collected for validation and the R^2 calculations in the following pages. The plots of residuals versus the predicted values are included in the last portion of this section of appendix to ensure the technical accuracy of the report. All the plots show no identifiable patterns, which make sure that the assumption of independence holds good.

LOAD TIME VERIFICATION ANALYSIS:

DATE	VEH	PASS ID	DRIV	VEHCAT	VEH-DRI	DRI-VEH	ADDRESS	EV TYPE	START TIME	END TIME	# E	# W	#WVEH	# D	# O	# SP
8/6/02	7	49;50	1	2	7-1	1-7	BSSC	L	0:00:00	0:01:29	2	0	0	0	0	0
8/6/02	7	61	1	2	7-1	1-7	LV	L	0:06:06	0:06:51	1	0	0	0	0	0
8/6/02	7	52	1	2	7-1	1-7	211 MICHEAL GROVE 'B'	L	0:13:53	0:15:01	1	0	0	0	0	0
8/6/02	7	63	1	2	7-1	1-7	111 S.YELLOWSTONE #4	L	0:20:47	0:22:11	1	0	0	0	0	0
8/6/02	7	75	1	2	7-1	1-7	LV #116	L	0:55:59	0:57:34	0	1	2	0	1	0
8/6/02	7	97	1	2	7-1	1-7	COUNTY MARKET	L	1:19:52	1:22:29	1	0	0	0	0	0
8/6/02	7	80;81	1	2	7-1	1-7	GCRH	L	1:30:06	1:31:19	2	0	0	0	0	0
8/6/02	7	69	1	2	7-1	1-7	414 S 15TH	L	1:38:31	1:39:49	0	0	0	1	0	0
8/6/02	7	84	1	2	7-1	1-7	6 N. 24TH 'A'	L	1:53:38	1:54:45	1	0	0	0	0	0
8/6/02	7	82	1	2	7-1	1-7	REALISTIC DESIGN	L	2:18:02	2:18:52	1	0	0	0	0	0
8/6/02	7	92;94;93	1	2	7-1	1-7	BSSC	L	2:22:00	2:25:03	2	0	0	1	0	0
8/6/02	7	96	1	2	7-1	1-7	GCRH	L	2:31:02	2:32:07	1	0	0	0	0	0
8/6/02	7	103	1	2	7-1	1-7	ASMSU	L	2:58:01	2:59:20	0	0	0	1	0	0
8/7/02	8	60	1	1	8-1	8-1	GCRH	L	0:43:33	0:44:01	1	0	0	0	0	0
8/7/02	8	62	1	1	8-1	8-1	2200 W DICKERSON	L	0:52:41	0:53:41	1	0	0	0	0	0
8/7/02	8	65	1	1	8-1	8-1	ROBERTS; HP2L2	L	1:12:12	1:15:11	0	1	1	0	0	0
8/7/02	8	66	1	1	8-1	8-1	WINDGATE INN	L	1:45:36	1:49:21	0	1	1	0	0	0

EQUATIONS:

$$L_{est} = 17.65 + 59.88 \times \#EL + 289.65 \times \#WC + 43.99 \times \#DB + 69.92 \times \#SP - 106.89 \times \#WCVH;$$

$$\text{RSQUARE} = R^2 = \frac{\Sigma(Y_{est} - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2} = \frac{\text{EXPLAINED VARIABILITY}}{\text{TOTAL VARIABILITY}}$$

L/U TIMES	HR	MIN	SEC	LT SECS	LT / PASS	PREDICT	YEST - YBAR	Y - YBAR	(YES-YBR)2	(Y-YBAR)2	ERROR
0:01:29	0	1	29	89	44.5	137.41	41.8218	-6.5882	1749.062955	43.40437924	48.41
0:00:45	0	0	45	45	45	77.53	-18.0582	-50.5882	326.0985872	2559.165979	32.53
0:01:08	0	1	8	68	68	77.53	-18.0582	-27.5882	326.0985872	761.1087792	9.53
0:01:24	0	1	24	84	84	77.53	-18.0582	-11.5882	326.0985872	134.2863792	-6.47
0:01:35	0	1	35	95	95	93.52	-2.0682	-0.5882	4.27745124	0.34597924	-1.48
0:02:37	0	2	37	157	157	77.53	-18.0582	61.4118	326.0985872	3771.409179	-79.47
0:01:13	0	1	13	73	36.5	137.41	41.8218	-22.5882	1749.062955	510.2267792	64.41
0:01:18	0	1	18	78	78	61.64	-33.9482	-17.5882	1152.480283	309.3447792	-16.36
0:01:07	0	1	7	67	67	77.53	-18.0582	-28.5882	326.0985872	817.2851792	10.53
0:00:50	0	0	50	50	50	77.53	-18.0582	-45.5882	326.0985872	2078.283979	27.53
0:03:03	0	3	3	183	61	181.4	85.8118	87.4118	7363.665019	7640.822779	-1.6
0:01:05	0	1	5	65	65	77.53	-18.0582	-30.5882	326.0985872	935.6379792	12.53
0:01:19	0	1	19	79	79	61.64	-33.9482	-16.5882	1152.480283	275.1683792	-17.36
0:00:28	0	0	28	28	28	77.53	-18.0582	-67.5882	326.0985872	4568.164779	49.53
0:01:00	0	1	0	60	60	77.53	-18.0582	-35.5882	326.0985872	1266.519979	17.53
0:02:59	0	2	59	179	179	200.41	104.8218	83.4118	10987.60976	6957.528379	21.41
0:03:45	0	3	45	225	225	200.41	104.8218	129.4118	10987.60976	16747.41398	-24.59

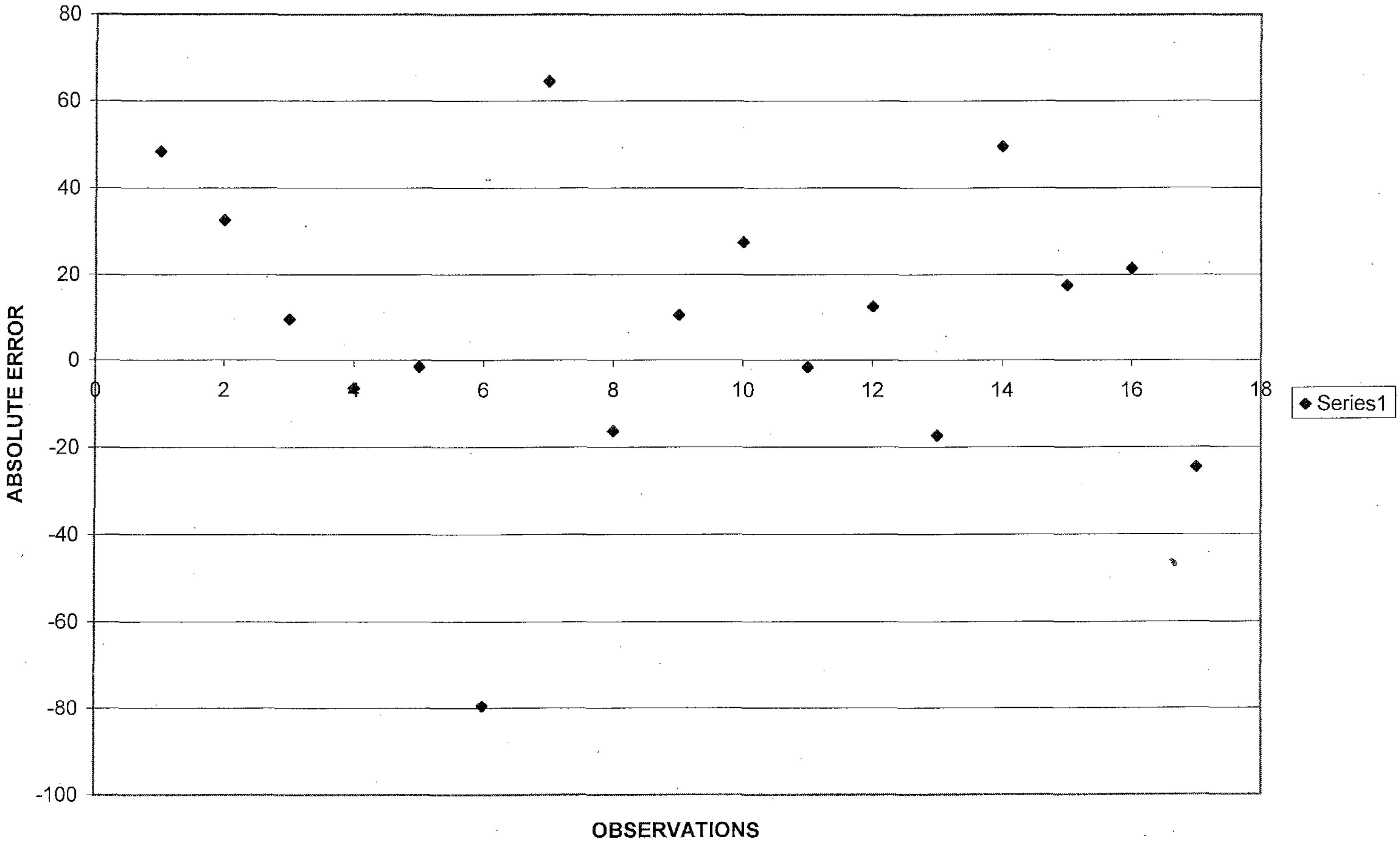
YBAR 95.5882

SIG(YEST) 38081.13574

SIG(Y) 49376.11765

RSQUARE 0.771246051

ERROR PLOT OF PREDICTED LOAD TIMES



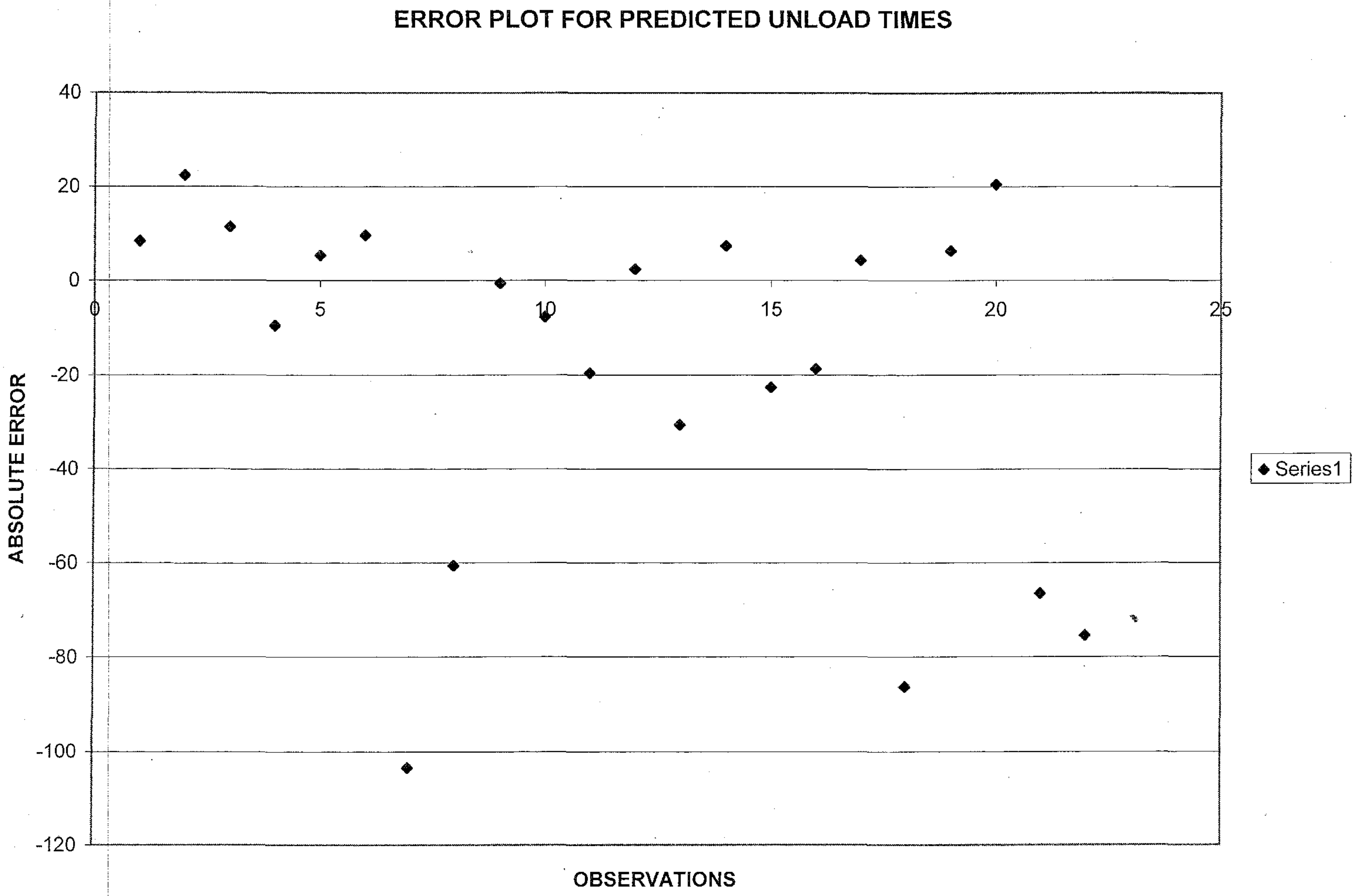
DATE	VEH	PASS ID	DRIV	VEHCAT	VEH-DRI	DRI-VEH	ADDRESS	EV TYPE	START TIME	END TIME	# E	# W	#WVEH	# D	# O	# SP	L/U TIME
8/6/02	7	61	1	2	7-1	1-7	GCRH	U	0:07:43	0:08:12	1	0	0	0	0	0	0:00:2
8/6/02	7	50	1	2	7-1	1-7	50 MICHEAL GROVE	U	0:15:28	0:15:43	1	0	0	0	0	0	0:00:1
8/6/02	7	49	1	2	7-1	1-7	3508 GOLDEN VALLEY	U	0:18:39	0:19:05	1	0	0	0	0	0	0:00:2
8/6/02	7	52	1	2	7-1	1-7	GCRH	U	0:29:42	0:30:29	1	0	0	0	0	0	0:00:4
8/6/02	7	63	1	2	7-1	1-7	REALISTIC DESIGN	U	0:34:08	0:34:40	1	0	0	0	0	0	0:00:3
8/6/02	7	75	1	2	7-1	1-7	ROBBINS; HP3-L2	U	1:07:56	1:09:24	0	1	2	0	1	0	0:01:2
8/6/02	7	97	1	2	7-1	1-7	DM	U	1:24:52	1:27:13	1	0	0	0	0	0	0:02:2
8/6/02	7	81	1	2	7-1	1-7	LV	U	1:32:54	1:34:32	1	0	0	0	0	0	0:01:3
8/6/02	7	80	1	2	7-1	1-7	NYE'S CLOTHSLINE	U	1:37:01	1:37:39	1	0	0	0	0	0	0:00:3
8/6/02	7	69	1	2	7-1	1-7	M/A BACK	U	2:01:56	2:02:34	0	0	0	1	0	0	0:00:3
8/6/02	7	84	1	2	7-1	1-7	MCLAUGHLIN; HP3-L3	U	2:09:50	2:10:47	1	0	0	0	0	0	0:00:5
8/6/02	7	94	1	2	7-1	1-7	DM	U	2:27:16	2:27:51	1	0	0	0	0	0	0:00:3
8/6/02	7	93	1	2	7-1	1-7	2400 W. DURSTON #6	U	2:35:41	2:36:49	1	0	0	0	0	0	0:01:0
8/6/02	7	96	1	2	7-1	1-7	211 MICHEAL GROVE 'B'	U	2:38:54	2:39:24	1	0	0	0	0	0	0:00:3
8/6/02	7	94	1	2	7-1	1-7	111 S.YELLOWSTONE #4	U	2:41:51	2:42:51	1	0	0	0	0	0	0:01:0
8/6/02	7	92	1	2	7-1	1-7	418 N 15TH	U	2:51:33	2:52:22	0	0	0	1	0	0	0:00:4
8/6/02	7	103	1	2	7-1	1-7	2200 W DICKERSON	U	3:02:16	3:02:42	0	0	0	1	0	0	0:00:2
8/7/02	8	56; 57	1	1	8-1	8-1	HP PERK	U	0:07:12	0:11:42	0	2	2	0	0	0	0:04:3
8/7/02	8	60	1	1	8-1	8-1	LV	U	0:45:50	0:46:21	1	0	0	0	0	0	0:00:3
8/7/02	8	62	1	1	8-1	8-1	PHARM ENT; HPM	U	1:11:17	1:11:34	1	0	0	0	0	0	0:00:1
8/7/02	8	65	1	1	8-1	8-1	LV	U	1:26:45	1:29:29	0	1	1	0	0	0	0:02:4
8/7/02	8	66	1	1	8-1	8-1	414 S 15TH	U	1:59:31	2:02:24	0	1	1	0	0	0	0:02:5

EQUATION USED÷

$$U_{est} = 2.9 + 26.01 \times \#EL + 86.20 \times \#WC + 18.92 \times \#DB + 24.74 \times \#SP + 8.49 \times DRIV;$$

$$\text{RSQUARE} = R^2 = \frac{\Sigma(Y_{EST} - \bar{Y})^2}{\Sigma(Y - \bar{Y})^2} = \frac{\text{EXPLAINED VARIATION}}{\text{TOTAL VARIATION}}$$

HR	MIN	SEC	UL SECS	ULT/PASS	PREDICT	YEST-YBAR	Y-YBAR	(YES-YBR)2	(Y-YBAR)2	ERROR
0	0	29	29	29	37.4	-32.23636	-40.63636	1039.182906	1651.31375	8.4
0	0	15	15	15	37.4	-32.23636	-54.63636	1039.182906	2985.13183	22.4
0	0	26	26	26	37.4	-32.23636	-43.63636	1039.182906	1904.13191	11.4
0	0	47	47	47	37.4	-32.23636	-22.63636	1039.182906	512.404794	-9.6
0	0	32	32	32	37.4	-32.23636	-37.63636	1039.182906	1416.49559	5.4
0	1	28	88	88	97.59	27.95364	18.36364	781.4059892	337.223274	9.59
0	2	21	141	141	37.4	-32.23636	71.36364	1039.182906	5092.76911	-103.6
0	1	38	98	98	37.4	-32.23636	28.36364	1039.182906	804.496074	-60.6
0	0	38	38	38	37.4	-32.23636	-31.63636	1039.182906	1000.85927	-0.6
0	0	38	38	38	30.31	-39.32636	-31.63636	1546.562591	1000.85927	-7.69
0	0	57	57	57	37.4	-32.23636	-12.63636	1039.182906	159.677594	-19.6
0	0	35	35	35	37.4	-32.23636	-34.63636	1039.182906	1199.67743	2.4
0	1	8	68	68	37.4	-32.23636	-1.63636	1039.182906	2.67767405	-30.6
0	0	30	30	30	37.4	-32.23636	-39.63636	1039.182906	1571.04103	7.4
0	1	0	60	60	37.4	-32.23636	-9.63636	1039.182906	92.859434	-22.6
0	0	49	49	49	30.31	-39.32636	-20.63636	1546.562591	425.859354	-18.69
0	0	26	26	26	30.31	-39.32636	-43.63636	1546.562591	1904.13191	4.31
0	4	30	270	135	183.79	114.15364	200.36364	13031.05353	40145.5882	-86.21
0	0	31	31	31	37.4	-32.23636	-38.63636	1039.182906	1492.76831	6.4
0	0	17	17	17	37.4	-32.23636	-52.63636	1039.182906	2770.58639	20.4
0	2	44	164	164	97.59	27.95364	94.36364	781.4059892	8904.49655	-66.41
0	2	53	173	173	97.59	27.95364	103.36364	781.4059892	10684.0421	-75.41
		YBAR	69.63636				SIG(YBAR)	35602.70286		
							SIG(Y)		86059.0909	
							RSQUARE	0.413700662		


ERROR PLOT FOR PREDICTED UNLOAD TIMES
40
20
0
-20
-40
-60
-80
-100
-120
0
5
10
15
20
25
ABSOLUTE ERROR
OBSERVATIONS
◆ Series1

TRAVEL TIME MODEL VERIFICATION ANALYSIS

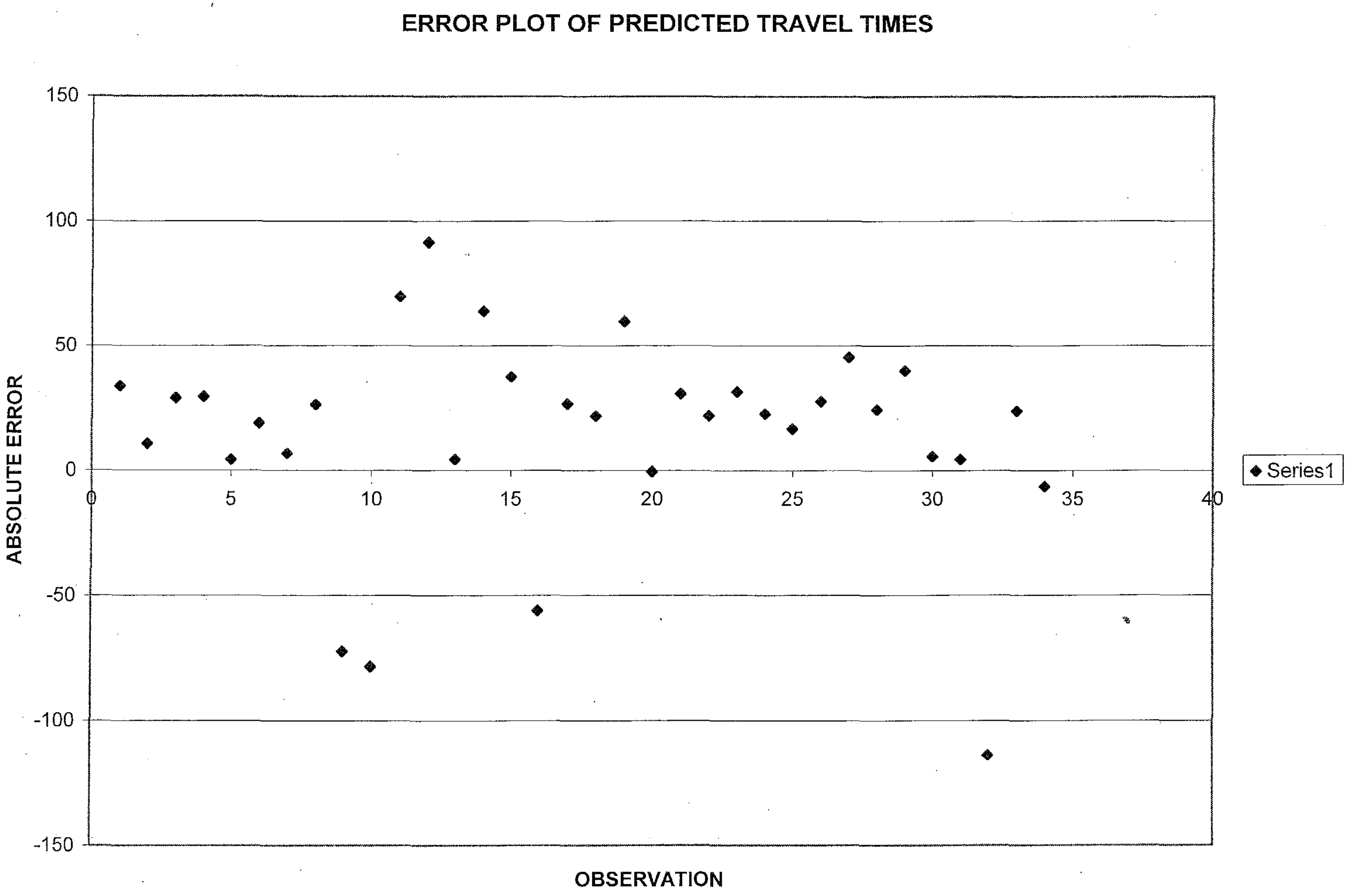
DATE	DRIV	VEH	FROM	TO	ODO STR	ODO END	DIST	TRAF	DISTRAF	CAP	WEAT	COND	TRAFCON	DISTCOND
8/6/02	1	7	BSSC	LV	89942	89943	1.5	3.5	5.25	1	1	2	7	3
8/6/02	1	7	LV	GCRH	89943	89943	0.5	2.5	1.25	1	1	3	7.5	1.5
8/6/02	1	7	GCRH	211 MICHEAL GROVE	89943	89945	2.5	2.5	6.25	1	1	2	5	5
8/6/02	1	7	211 MICHEAL GROVE	50 MICHEAL GROVE	89945	89945	0.5	1	0.5	1	1	2	2	1
8/6/02	1	7	50 MICHEAL GROVE	3508 GOLDEN VALLEY	89945	89946	1.5	1.5	2.25	1	1	2	3	3
8/6/02	1	7	3508 GOLDEN VALLEY	111 S.YELLOWSTONE	89946	89946	0.5	2.5	1.25	1	1	2	5	1
8/6/02	1	7	111 S.YELLOWSTONE	GCRH	89946	89948	2.5	3.5	8.75	1	1	2	7	5
8/6/02	1	7	GCRH	REALISTIC DESIGN	89948	89949	1.5	2.5	3.75	1	1	2	5	3
8/6/02	1	7	LV	ROBBINS; HP3-L2	89951	89954	3.5	3	10.5	1	1	2	6	7
8/6/02	1	7	ROBBINS; HP3-L2	COUNTY MARKET	89954	89957	3.5	3	10.5	1	1	2	6	7
8/6/02	1	7	COUNTY MARKET	DM	89957	89958	1.5	2	3	1	1	2	4	3
8/6/02	1	7	DM	GCRH	89958	89958	0.5	4.5	2.25	1	1	1	4.5	0.5
8/6/02	1	7	GCRH	LV	89958	89958	0.5	2	1	1	1	2	4	1
8/6/02	1	7	LV	NYE'S CLOTHSLINE	89958	89959	1.5	2	3	1	1	2	4	3
8/6/02	1	7	NYE'S CLOTHSLINE	414 S 15TH	89959	89960	1.5	1	1.5	3	1	3	3	4.5
8/6/02	1	7	414 S 15TH	6 N 24TH	89960	89963	3.5	4.5	15.75	3	1	1	4.5	3.5
8/6/02	1	7	6 N 24TH	M/A BACK	89963	89965	2.5	3.5	8.75	3	1	2	7	5
8/6/02	1	7	M/A BACK	MCLAUGHLIN; HP3-L3	89965	89967	2.5	3.5	8.75	2	1	2	7	5
8/6/02	1	7	MCLAUGHLIN; HP3-L3	REALISTIC DESIGN	89967	89970	3.5	2.5	8.75	3	1	2	5	7
8/6/02	1	7	REALISTIC DESIGN	BSSC	89970	89971	1.5	2.5	3.75	3	1	3	7.5	4.5
8/6/02	1	7	BSSC	DM	89971	89971	0.5	3.5	1.75	3	1	2	7	1
8/6/02	1	7	DM	GCRH	89971	89972	1.5	2	3	3	1	2	4	3
8/6/02	1	7	GCRH	2400 W DURSTON	89972	89973	1.5	2.5	3.75	3	1	2	5	3
8/6/02	1	7	2400 W DURSTON	211 MICHEAL GROVE	89973	89974	1.5	1	1.5	3	1	2	2	3
8/6/02	1	7	211 MICHEAL GROVE	111 S YELLOWSTONE	89974	89974	0.5	3.5	1.75	3	1	2	7	1
8/6/02	1	7	111 S YELLOWSTONE	418 N 15TH	89974	89977	3.5	3	10.5	2	1	2	6	7
8/6/02	1	7	418 N 15TH	ASMSU	89977	89979	2.5	2	5	2	1	1	2	2.5
8/6/02	1	7	ASMSU	2200 W DICKERSON	89979	89979	0.5	3	1.5	2	1	1	3	0.5
8/7/02	1	8	BSSC	HP PERK	11636	11638	2.5	3	7.5	1	1	1	3	2.5
8/7/02	1	8	GCRH	LV	11641	11641	0.5	1	0.5	1	1	1	1	0.5
8/7/02	1	8	LV	2200 W DICKERSON	11641	11643	2.5	2	5	1	1	1	2	2.5
8/7/02	1	8	2200 W DICKERSON	PHARM ENT; HPM	11643	11647	4.5	4.5	20.25	1	1	1	4.5	4.5
8/7/02	1	8	PHARM ENT; HPM	LV	11647	11650	3.5	4	14	1	1	1	4	3.5
8/7/02	1	8	WINDGATE INN	414 S 15TH	11654	11656	2.5	4.5	11.25	1	1	1	4.5	2.5

ND.

EQUATIONS USED÷

$$T_{est} = 95.52 + 68.65 \times DIST + 31.67 \times TRAF + 22.39 \times DISTRAF - 58.07 \times COND;$$

DSTRCD	STRT TIME	END TIME	O TIME	HR	MIN	SECS	TR TIME	PREDICT	ERROR	YEST - YBAR	Y - YBAR	(YEST-YBAR)2	(Y-YBAR)2
10.5	0:01:29	0:06:06	0:04:37	0	4	37	277	310.7475	33.7475	-11.4285	-45.176	130.6106122	2040.870976
3.75	0:06:51	0:07:43	0:00:52	0	0	52	52	62.7975	10.7975	-259.3785	-270.176	67277.20626	72995.07098
12.5	0:08:12	0:13:53	0:05:41	0	5	41	341	370.1175	29.1175	47.9415	18.824	2298.387422	354.342976
1	0:15:01	0:15:28	0:00:27	0	0	27	27	56.57	29.57	-265.606	-295.176	70546.54724	87128.87098
4.5	0:15:43	0:18:39	0:02:56	0	2	56	176	180.2375	4.2375	-141.9385	-146.176	20146.53778	21367.42298
2.5	0:19:05	0:20:47	0:01:42	0	1	42	102	120.8675	18.8675	-201.3085	-220.176	40525.11217	48477.47098
17.5	0:22:11	0:29:42	0:07:31	0	7	31	451	457.7625	6.7625	135.5865	128.824	18383.69898	16595.62298
7.5	0:30:29	0:34:08	0:03:39	0	3	39	219	245.4925	26.4925	-76.6835	-103.176	5880.359172	10645.28698
21	0:57:34	1:07:56	0:10:22	0	10	22	622	549.76	-72.24	227.584	299.824	51794.47706	89894.43098
21	1:09:24	1:19:52	0:10:28	0	10	28	628	549.76	-78.24	227.584	305.824	51794.47706	93528.31898
6	1:22:29	1:24:52	0:02:23	0	2	23	143	212.865	69.865	-109.311	-179.176	11948.89472	32104.03898
2.25	1:27:13	1:30:06	0:02:53	0	2	53	173	264.6675	91.6675	-57.5085	-149.176	3307.227572	22253.47898
2	1:31:19	1:32:54	0:01:35	0	1	35	95	99.435	4.435	-222.741	-227.176	49613.55308	51608.93498
6	1:34:32	1:37:01	0:02:29	0	2	29	149	212.865	63.865	-109.311	-173.176	11948.89472	29989.92698
4.5	1:37:39	1:38:31	0:00:52	0	0	52	52	89.54	37.54	-232.636	-270.176	54119.5085	72995.07098
15.75	1:39:49	1:53:38	0:13:49	0	13	49	829	772.8825	-56.1175	450.7065	506.824	203136.3491	256870.567
17.5	1:54:45	2:01:56	0:07:11	0	7	11	431	457.7625	26.7625	135.5865	108.824	18383.69898	11842.66298
17.5	2:02:34	2:09:50	0:07:16	0	7	16	436	457.7625	21.7625	135.5865	113.824	18383.69898	12955.90298
17.5	2:10:47	2:18:02	0:07:15	0	7	15	435	494.7425	59.7425	172.5665	112.824	29779.19692	12729.25498
11.25	2:18:52	2:22:00	0:03:08	0	3	8	188	187.4225	-0.5775	-134.7535	-134.176	18158.50576	18003.19898
3.5	2:25:03	2:27:16	0:02:13	0	2	13	133	163.7325	30.7325	-158.4435	-189.176	25104.34269	35787.55898
6	2:27:51	2:31:02	0:03:11	0	3	11	191	212.865	21.865	-109.311	-131.176	11948.89472	17207.14298
7.5	2:32:07	2:35:41	0:03:34	0	3	34	214	245.4925	31.4925	-76.6835	-108.176	5880.359172	11702.04698
3	2:36:49	2:38:54	0:02:05	0	2	5	125	147.61	22.61	-174.566	-197.176	30473.28836	38878.37498
3.5	2:39:24	2:41:51	0:02:27	0	2	27	147	163.7325	16.7325	-158.4435	-175.176	25104.34269	30686.63098
21	2:42:51	2:51:33	0:08:42	0	8	42	522	549.76	27.76	227.584	199.824	51794.47706	39929.63098
5	2:52:22	2:58:01	0:05:39	0	5	39	339	384.365	45.365	62.189	16.824	3867.471721	283.046976
1.5	2:59:20	3:02:16	0:02:56	0	2	56	176	200.37	24.37	-121.806	-146.176	14836.70164	21367.42298
7.5	0:00:00	0:07:12	0:07:12	0	7	12	432	472.01	40.01	149.834	109.824	22450.22756	12061.31098
0.5	0:44:01	0:45:50	0:01:49	0	1	49	109	114.64	5.64	-207.536	-213.176	43071.1913	45444.00698
5	0:46:21	0:52:41	0:06:20	0	6	20	380	384.365	4.365	62.189	57.824	3867.471721	3343.614976
20.25	0:53:41	1:11:17	0:17:36	0	17	36	1056	942.2875	-113.7125	620.1115	733.824	384538.2724	538497.663
14	1:15:11	1:26:45	0:11:34	0	11	34	694	717.865	23.865	395.689	371.824	156569.7847	138253.087
11.25	1:49:21	1:59:31	0:10:10	0	10	10	610	603.4775	-6.5225	281.3015	287.824	79130.5339	82842.65498
						YBAR	322.1765				SIG(Y-YBR)	1606194.302	1980664.941
											RSQUARE	0.810936907	


ERROR PLOT OF PREDICTED TRAVEL TIMES
150
100
50
0
-50
-100
-150
ABSOLUTE ERROR
0
5
10
15
20
25
30
35
40
OBSERVATION
◆ Series1