An Evaluation of RouteMatch Software in the Billings MET Special Transit System

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Disclaimer

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Western Transportation Institute, Montana State University-Bozeman; RouteMatch Software; or the management, dispatchers or drivers of the Billings MET Transit system.

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Executive Summary

In 2003, MET Transit in Billings, Montana was notified that the Mobility Master software it was using for its MET Special Transit (MST) service would no longer be supported, and wanted to research alternative software solutions. MET Transit contracted with the Western Transportation Institute to assist in an analysis of the technology currently used in MST, MET Transit's paratransit operations.

In addition to the software analysis, MST asked WTI to review the benefits of adding automatic vehicle location (AVL) and Mobile Data Communications (MDC). To review the benefits of these additional technologies, the Western Transportation Institute performed a literature review and incorporated those findings into a report for MET Transit [1].

Subsequently, the City of Billings developed a Request for Proposals, and ultimately selected RouteMatch Software. Both MET Transit and RouteMatch Software were interested in evaluating the effect the new software would have on the system. The Western Transportation Institute (WTI) performed an evaluation that looked at both quantitative factors (rides per mile, rides per hour, on-time performance) as well as qualitative factors (surveys of the drivers and dispatchers).

For the evaluation, researchers compared three months (July, August and September) in 2005 with the same three months in 2006, roughly six months after the RouteMatch software was installed. They believed that it was necessary to have comparison data that would show the impact of the software, and decided that after six months of using the new RouteMatch software, the dispatchers should be proficient with the system.

The results indicate that MET Special Transit operations were more efficient after the software was installed. This conclusion is based on data that the rides per mile and rides per hour were higher during the three-month evaluation period for 2006. However, researchers did not have enough data on cost parameters (fuel, insurance costs, etc.) to conduct a definitive analysis of whether or not the RouteMatch software had a positive benefit to cost ratio ("paid for itself").

A break-even analysis, however, did indicate that only a slight gain in efficiency could lead to a positive benefit/cost ratio. The data shows that if the cost of the hardware and software is amortized over a five-year period, and taking into account the annual maintenance fees, MET Special Transit (MST) would only need to decrease mileage and/or hours by approximately three percent for the software to have a positive cost savings for the organization. This is a relatively modest gain in efficiency. As indicated within this report, these appear to be achievable goals.

One item to note about the gains in efficiency is that during the time the RouteMatch software was being used, the MST dispatchers did not use the RouteMatch Scheduling Engine (RSE) function of the software. The RouteMatch Scheduling Engine component is the function that can be utilized to maximize the efficiency of the transportation (transit) service. One hypothesis of why MET Special Transit did not use the RSE is that MST has many contracts with various agencies to provide rides, and was already very efficient at grouping these rides. Therefore, a transportation agency that schedules more individual rides may see a greater benefit from using RouteMatch software, than was experienced by MET Transit.

The analysis of pick up and drop off times indicated that slightly fewer pick ups were made within the 30 minute window established by MET Transit when the RouteMatch software was in use (84.5 percent in 2006, versus 87.5 percent in 2005). In 2006, slightly more drop offs were made within 15 minutes (plus or minus) of the scheduled time (84.5 percent in 2006 versus 79.8 percent in 2005) with the use of RouteMatch software.

One hypothesis on the differences in the pick up and drop off times is that the RouteMatch software is creating a more "normal" distribution of the times, whereas when the Mobility Master software was being used, and the rides were being scheduled manually, the dispatchers may have provided extra time between origins and destinations, leading to the drop off times being closer to scheduled times.

While a definitive benefit/costs analysis could not be conducted to determine if the RouteMatch Software paid for itself, as indicated by this review, it does appear that only a minor gain in efficiency is necessary for the RouteMatch software to pay for itself (reach the break-even point). The data herein, and previous national studies, indicated that these gains in efficiency are achievable.

Introduction

Billings MET Special Transit (MST) is a paratransit service that operates within the Billings, Montana city limits. Service is available between the hours of 6:30 a.m. and 6:00 p.m. during the weekdays, and between 9:00 a.m. and 5:30 p.m. on Saturdays. The service is offered to persons who qualify as ADA Paratransit eligible.

On average, MST provides 250 to 300 rides on a typical day. Approximately half of these rides are subscription rides, meaning the same rides occur at the same time each day. Currently, these rides are all assigned to a specific route. MST has 15 paratransit vehicles at its disposal. Typically, half of these are out at any particular time, and on busy days, as many as 12 vehicles may be in service. The number of vehicles in service is a function of the number of ride requests, the time of day, and the geographic location of origins and destinations.

In order to handle ride requests, MST has two dispatchers available throughout the week between the hours of 7:00 a.m. and 5:00 p.m. and a third person that can dispatch as needed. In order to schedule a ride, an individual must call in a ride request at least 24 hours in advance. The individual cannot schedule a ride more than two weeks in advance. Same day ride requests are scheduled only if time in the current manifests permits.

The process of receiving, scheduling and dispatching rides is a complicated process. For MST it was even more difficult, because the dispatcher was doing the scheduling with no support from the software. MST was using Mobility Master software, which was not working properly, and very little technical support was offered. In fact, MST learned that by the end of 2003, no more support would be provided for the software.

The difficulty with manual dispatching, especially when dealing with more than three or four vehicles, is that the dispatcher/scheduler needs to know where the vehicles are, the current load of the vehicle, and whether the vehicle can handle dropping off the passengers by the required time. This process is typically much more efficient when dispatchers can use Computer Aided Scheduling and Dispatching (CASD) software.

MET Transit contracted with the Western Transportation Institute (WTI) to conduct research to determine the potential benefits of Computer Aided Scheduling and Dispatching software, and other technologies, such as Automated Vehicle Location (AVL) and Mobile Data Communications (MDC). WTI presented its findings to MET Transit [1] and based on the information, Billings MET Transit decided to purchase a new software system for their paratransit service MST.

Subsequently, MET Transit contracted with WTI to assist in writing a Request for Proposals (RFP), which was used to select a software vendor. The RFP was completed and RouteMatch was selected as the software vendor. RouteMatch Software is headquartered in Atlanta, Georgia, with seven additional offices across the U.S. and comprises a team of software engineers, Internet technologists, computer scientists, management information experts, database management professionals, and transportation consultants. RouteMatch provides solutions for demand responsive and fixed route systems, and partners with other vendors to provide additional components (applications) including AVL and MDT/MDC. More information about RouteMatch can be found at www.routematch.com.

Both MET Transit and RouteMatch were interested in knowing the impact of the new RouteMatch software on the operations of MET Special Transit. While research has shown benefits of using Computer Aided Scheduling and Dispatching software [2,3,4], and RouteMatch has issued case studies highlighting the benefits of their software, there are relatively few cases where the switch to a new software system has been independently evaluated. With the opportunity presented in Billings, RouteMatch contracted with the Western Transportation Institute to conduct an independent evaluation of the effects of its software on the Billings MET Special Transit (MST) system.

The remainder of this document provides an overview of Computer Aided Scheduling and Dispatching software, and other related technologies; the evaluation of the RouteMatch software in Billings, and conclusions from the evaluation.

Public Transportation Technologies

MET Transit was interested in exploring three primary technologies: computer-assisted scheduling and dispatching software (CASD), automatic vehicle location (AVL), and mobile data communications (MDC) technologies.

Technology Overview

Advances in technology along with federal and state transportation initiatives in the United States over the last decade have provided an impetus for paratransit operators to invest in technological upgrades such as computer-assisted dispatching, automatic vehicle location and advanced communication technologies. Computer-assisted scheduling and dispatching (CASD) software has the potential to improve performance in a number of ways, including increased vehicle load ratios, interagency connections, interactive voice driven reservation systems and dramatically streamlined billing operations [2].

While Computer-assisted scheduling and dispatching software on its own has the potential to improve the efficiency of paratransit operations, many transportation providers are also adding AVL and MDC technologies. The now common use of global position satellite (GPS) technology has further increased the use of AVL/MDC technologies [3]. The AVL/MDC technologies interface with CASD to provide a powerful tool to increase the efficiency of a transportation provider.

Software

Computer-assisted scheduling and dispatching (CASD) software is used to assign demand-responsive transit customers to vehicles. The software makes recommendations, in either real-time or batch processing mode, on which vehicle run to place a requested trip. The software may use Geographic Information Systems to map the source and destination address for making recommendations [3].

Because it is difficult for a human mind to keep track of more than about three vehicles at a time, the CASD software is valuable in providing an initial solution. The dispatcher can then review the manifests (schedule) and make any changes necessary. CASD can be a powerful tool for increasing a transportation provider's efficiency.

In Santa Clara County, California, a paratransit operator, OUTREACH, utilized CASD software and was able to reduce its number of vehicles in service from 200 to 130. Using CASD software, the Winston-Salem Transit Authority was able to reduce its operating cost per vehicle-mile 8.5 % and its operating cost per passenger 2.4% [4].

By utilizing new CASD software, it was anticipated that MET Transit should be able to increase its efficiency, allowing more clients to be served for the same operational budget. When tied to other technologies, such as automatic vehicle location (AVL) and mobile data communications (MDC), it was believed that further benefits would be achieved.

Other Technologies

While computer-assisted scheduling and dispatching software is a powerful tool alone, utilizing it in conjunction automatic vehicle location and mobile data communications expands the power of the software.

Automatic vehicle location (AVL) technologies measure the real-time location of vehicles using onboard computers and a positioning system (such as a global positioning system) and relay this information to a central location (such as the dispatching office). With an AVL system, the dispatcher, or CASD software, knows the exact position of each paratransit vehicle and can use that information to assign a ride (such as a “will call” or same day request) to the nearest vehicle.

When changes are made to the schedule, or ride requests are processed, agencies typically use a radio to notify drivers of the change. However, many agencies are now using mobile data communications to relay this information between the drivers and the dispatching center. Mobile data communications (MDC) are accomplished by providing a link between the dispatch center and the paratransit vehicle, equipped with a mobile data terminal (MDT).

Mobile data terminals are small computer terminals in the vehicle that allow a driver to receive and send text and numerical data by radio signal. This communication system, when tied into an AVL and CASD software package, allows the dispatcher to make changes to schedules and relay those changes without making a radio call. Further, by monitoring the progress of the schedules, the CASD/AVL/MDC system can alert the dispatcher if any of the paratransit vehicles are falling behind schedule, and can provide recommendations for shifting rides to other vehicles.

While each of the technologies, CASD, AVL and MDC, provide a unique advantage, the technologies are most effective when they are combined. It was recommended that if MET Transit pursues new technologies that it should invest in all three of the above noted systems. As of the writing of this report, MET Special Transit is using the RouteMatch software with Automatic Vehicle Location technology. MET Transit hopes to invest in Mobile Data Communications when it can secure additional funding.

Evaluation

The focus of this project was to evaluate the effect, if any, that the introduction of RouteMatch software had on the service provided by MET Special Transit (MST). The analysis procedure is summarized as follows.

- An initial set of data was collected for the months of July, August and September in Year 2005, which is before the purchase and installation of the software.
- An analysis was performed on the data so that performance measures (benchmarks) were established.
- A second set of data was collected for the same three month period in 2006, which is approximately six months after the installation of the software.
- A data analysis was performed on the 2006 set of data.
- The values (two sets of data) were compared to each other to determine the effect of the software.

It should be noted that during the period of this analysis that the dispatchers at MET Special Transit did not use the RouteMatch Scheduling Engine (RSE) that is part of the RouteMatch Software. RSE is typically used to optimize the schedule (manifest) for the demand-responsive service. One reason given for not using RouteMatch Scheduling Engine was that many of the rides provided for by MST are already grouped, and that using RSE would not lead to any significant improvements in the schedule. This is discussed in more detail later in this section.

Performance Measures

Demand responsive transportation systems such as MST are judged (measured) by different people on different parameters. Administration/management typically looks at parameters ("measures of effectiveness" or "MOEs") such as the cost per ride, rides per hour and rides per mile. Dispatchers and drivers may use more subjective parameters, such as the ease of creating and/or driving the schedule (based on the manifest). Riders use both subjective and objective measures, such as the timeliness of the pick up and drop off times, as well as how long they are on the vehicle.

In this project, we considered both the objective and subjective measurements. However the only measurement with a passenger's perspective is the timeliness of the pick up and/or drop off. All other measurements are based on MET Transit's perspective, including both the administration/management and dispatch/driver perspectives.

The specific measures of effectiveness used in the evaluation include:

- Rides per mile
- Rides per hour
- Cost per ride
- Pick up time performance
- Drop off time performance
- Survey results from the dispatchers
- Survey results from the drivers

In evaluating the RouteMatch software, an attempt has been made to account for all of the extraneous variables, to the maximum extent possible. This allows for a true accounting/analysis of the impact the software has had on MST operations. The following sections provide an explanation of these measures, and the results from the evaluation.

Rides per Mile/Rides per Hour

The rides per mile and rides per hour measures are used to determine how efficiently the service is being operated. An inefficient service would have very few rides per hour or rides per mile. Both of these factors can be influenced by the size of the area a transportation provider services. For example, if a provider typically travels 20-30 miles to get one rider, their rides per mile may be significantly lower than a provider who travels only 5-10 miles to pick up riders.

However, by efficiently scheduling and dispatching rides, a transportation provider can "group" more rides on each vehicle, and be more productive with assets (vehicles and drivers). As previously noted, some transportation systems have been able to decrease the number of vehicles in service by 35 percent by being more efficient in their scheduling, primarily by using computer aided scheduling and dispatching software [4].

Table 1 shows the rides, hours and mileage for the July-September period in 2005 and 2006 that are used for this report. Table 2 and Table 3 show the differences in the rides per hour and rides per mile for MST, before (2005) and after (2006) the use of the RouteMatch software. The full data used for this comparison is shown in Appendix A.

Table 1: 2005-2006 Data

	2005	2006	Difference	Percentage
Rides	17,007	16,097	-910	-5.35%
Hours	4,790	4,241	-549	-11.46%
Mileage	54,742	50,566	-4,176	-7.63%

Table 2: MST Rides per Hour

Month	2005	2006	Difference	Percentage
July	3.56	3.70	0.14	3.93%
August	3.55	3.85	0.30	8.45%
September	3.54	3.83	0.29	8.19%
3-month avg.	3.55	3.80	0.25	7.04%

Table 3: MST Rides per Mile

Month	2005	2006	Difference	Percentage
July	0.31	0.32	0.01	3.23%
August	0.31	0.32	0.01	3.23%
September	0.31	0.32	0.01	3.23%
3-month avg.	0.31	0.32	0.01	3.23%

Table 1 indicates that while fewer rides were provided during the July-September period in 2006, the hours and mileage decreased at a greater rate during this time period. Table 2 and Table 3 highlight an increase in efficiency as the rides provided on a per mile and per hour basis were slightly higher when the RouteMatch software was in use. However, it is important to note that the Route Schedule Engine (RSE) portion of the RouteMatch software was not being utilized during this time. It is unclear, therefore, what caused the changes in these metrics.

Cost per Ride

The cost per ride is another measure of efficiency and system performance. For example, if it costs a transportation system $500,000 to provide paratransit service, and a total of 100,000 rides are provided, the cost per ride is five dollars ($5) or $500,000/100,000=$5.

It is important to note that the cost per ride may increase, without any service changes in a transportation system. For example, if the paratransit system's insurance increased by $10,000 per year, the total cost for providing the service would increase to $510,000. Based on this information, the cost per ride would increase to five dollars and ten cents ($5.10). Therefore, when the cost per ride increases (or decreases), it is always important to analyze why the change occurred. Unfortunately, not enough data was available to account for variables such as fuel and insurance costs. MET Transit acknowledged that their fuel and insurance costs had increased, but they could not specify by how much. Therefore, the data was not available for a cost-per-ride comparison based on the introduction of RouteMatch Software for MET Special Transit. However, a break-even analysis was conducted to determine how much would have to be saved on an annual basis to make the RouteMatch Software cost effective.

Break-even Analysis

MET Transit paid a total of $83,575 for the RouteMatch Software, including the hardware necessary to operate the software. For the purpose of this analysis, it was calculated that the software and hardware will have a five-year lifespan. Based on this scenario, MET Transit would need to save approximately $16,715 per year to reach the break-even point. However, there is a software maintenance fee of $11,835 per year. When this maintenance fee is included with the amortized purchase price, a total of $28,550 would need to be saved on an annual basis for the software to have a positive benefit/cost ratio.

Based on MET Special Transit's costs of $55.22 per vehicle revenue hour, and $4.81 per mile for 2005 (see Appendix A), MST would need to save approximately $1.83 per hour, or $0.16 per mile for a positive benefit/cost ratio for the software, with all other costs being equal (see below).

$28,550 / 15,568 hours = $1.83 per hour (3.31%)
$28,550 / 178,627 miles = $0.16 per mile (3.33%)

A second way to conduct this analysis is to include the $28,550 annualized software cost into the total annual operating costs, and then determine the number of hours or miles that would need to be reduced to reach the break-even point. MET Transit's costs for its demand responsive service were $859,612 in 2005. If the $28,550 annual cost for the RouteMatch Software was added to the 2005 costs, a total of $888,162 is used as a balance for calculating necessary savings. The following calculations yield the needed savings to achieve a break-even point:

$888,162 / 15,568 hours = $57.05 per hour
$28,550 / $57.05 per hour = 500 hours (reduction to reach the break-even point)

$888,162 / 178,627 miles = $4.97 per mile
$28,550 / $4.97 per mile = 5,744 miles (reduction to reach the break-even point)

The savings necessary in hours or miles to achieve a break-even point equate to a three percent reduction [500 hours / 15,568 hours = 3.2%; 5,744 miles / 178,627 miles = 3.2%]

As noted earlier in this document, transportation systems implementing computer-aided scheduling and dispatching systems have seen a significant increase in efficiency. While Billings MET Special Transit has been relatively efficient in that it has several contracts that allows the service to group rides, the data in Table 1, Table 2 and Table 3 indicate that MST was more efficient during the period analyzed when the RouteMatch software was being used. Because not enough cost factors such as fuel and insurance were tracked, it was not possible to determine the specific benefit/cost ratio.

As indicated in this analysis, however, only a relatively minor gain in efficiency is necessary to reach a break-even point for the software. A three percent reduction in mileage or revenue hours is all that is required for the software to "pay for itself."

In addition to the RouteMatch Software, Billings MET Transit also spent approximately $43,500 to add Automatic Vehicle Location (AVL) technology to its vehicles. This technology is a "stand alone" system, in that it was not required as part of the purchase and installation of the RouteMatch software. If the cost of the AVL system is amortized over a five-year period, and a analysis similar to the software costs is conducted, Billings MET Transit would need to reduce its mileage and/or revenue hours by approximately 0.9 percent (142 hours; 1,626 miles) for the AVL system to reach the break-even point.

Finally, the break-even analysis did not take into account additional benefits that may be achieved by using the RouteMatch software, such as a reduction in the amount of time it takes to compile reports about the transportation systems performance, or invoicing. A time study of the dispatchers/schedulers and paratransit managers would have been necessary to capture this data. Due to the time and budget of this project, the time study was not possible. Anecdotal evidence of an improvement in some of the areas can be captured through the surveys, however, which are noted later in this document.

Time Performance

There are two times that concern a rider, when they are picked up and when they are dropped off. Some riders are more concerned with when they are picked up, while others focus on when they are dropped off. The transit agency tries to make sure that they pick up their clients as close to the scheduled time as possible, and drop the clients off in as timely a manner as possible.

In analyzing the time performance, it is also important to remember that while the dispatcher, utilizing the software, may create an efficient (timely) manifest, the drivers may chose to alter the manifest, or pick up and/or drop off clients in a different order than is indicated by the manifest. Further, weather and traffic conditions may warrant changing the order of the rides on the manifest. Therefore, while a change in scheduling and dispatching software can have a significant impact on the timeliness of a transit system, other factors, such as the drivers' adherence to the manifest is also important to consider.

For this analysis, the data was reviewed and "outliers" were removed. Outliers are typically a function of how the software and/or the dispatchers/schedulers deal with "will call" rides. Will call rides are rides that do not have a specific time, typically a pick up time, associated with them. For instance, a rider may be dropped off at a doctors' appointment, and then will call the transit agency when the appointment is done for a pick up. One agency may "guess" that the appointment will last an hour or hour and a half, and schedule the return ride based on that information, another agency may schedule the return ride for a 5:00 pm pick up and then revise that time once the rider calls.

Based on how will call rides are scheduled, the pick up and drop off time performance of a transit system may be skewed. That is why the data was reviewed and "cleaned" before the analysis was conducted. This is also why the number of pick up and drop off times are not exactly related to the total number of rides that are used in this document. In 2005, we analyzed 12,036 pick up and 11,842 drop off times, but noted 17,007 rides. In 2006, 13,647 pick up and 13,173 drop off times were analyzed and 16,097 rides noted.

From these figures it can bee seen that cleaning the data leads to an unequal number of pick up and drop off times and rides (one pick up and one drop off would equal one ride). The ridership is also higher than the number of pick up and drop off times based on how attendants are scheduled. If a ride is schedule for a client (one pick up and drop off time), but the client has an attendant, then two rides are provided for one pick up and drop off time. Therefore, the number of rides in this analysis is higher than the pick up and drop off times because of two factors, the "cleaning" of the data and the attendant rides. Additional information on the data can be found in Appendix D.

Pick up Time Performance

While transportation providers make every effort to arrive as close to the scheduled pick up time as possible, the Federal Transit Administration and Americans with Disabilities Act provides for a thirty (30) minute "window" for the pick up time for paratransit passengers. Transit providers can set this window. Billings MET Special Transit (MST) uses a window of ten (10) minutes prior to, and twenty (20) minutes after the scheduled pick up time. For example, if a rider schedules a ride with a pick up time of 9:30 am, the vehicle may arrive (and the passenger needs to be ready) anytime from 9:20 am to 9:50 am. Further, an early pick up is desirable to passengers, as long as the vehicle does not arrive too early [5].

In order to evaluate the effectiveness of the RouteMatch software, the pick up times are evaluated using the "window" established by MST. Figure 1 and Figure 2 show the distribution of pick up times for the July-September periods for 2005 and 2006 that were analyzed for this report.

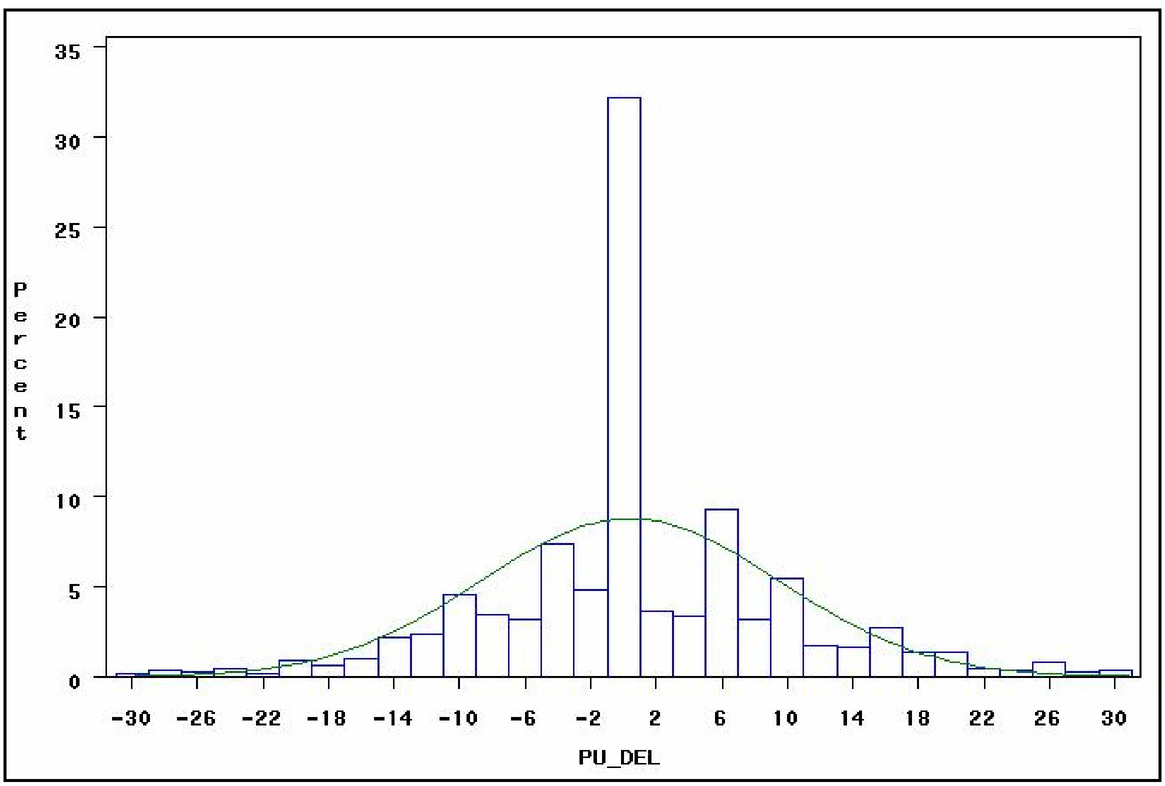

Figure 1: Distribution of pick up time deviations for 2005

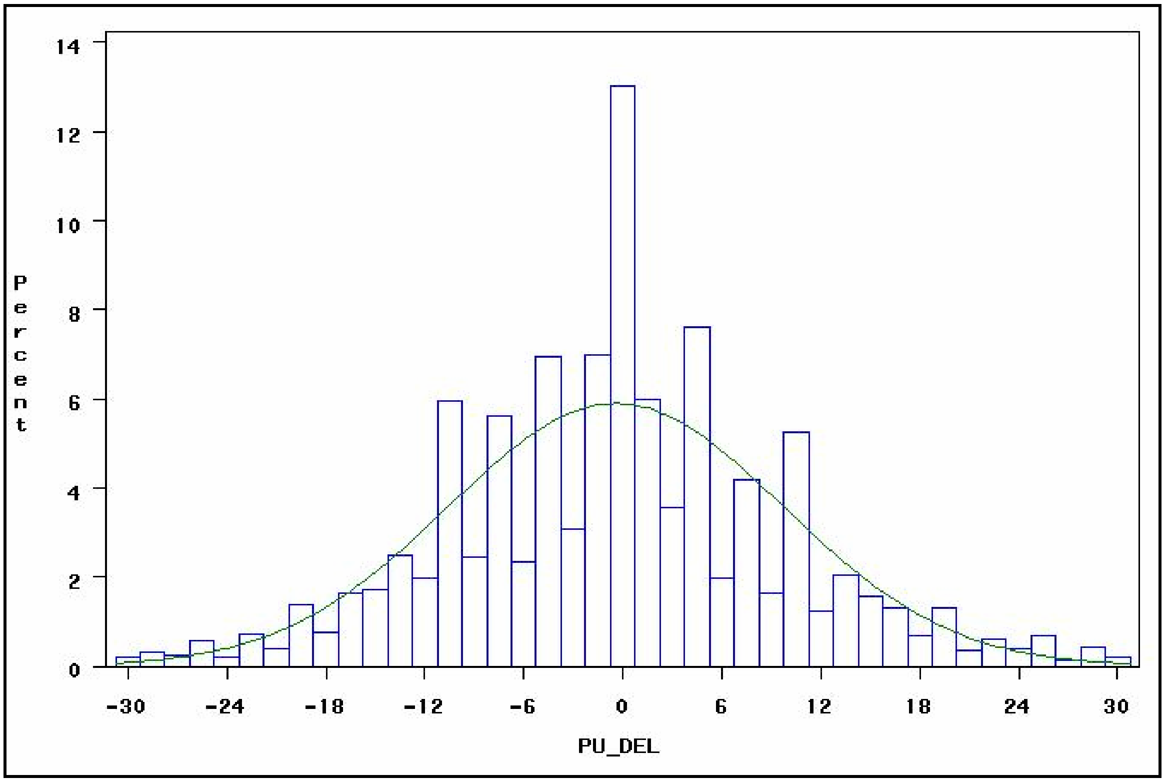

Figure 2: Distribution of pick up time deviation for 2006

The pick up times were analyzed further, and that data is shown in Table 4, Table 5, and Table 6.

Table 4: Comparison of pick up times

	2005		2006	
Pick up Time	count	percent	count	percent
More than 15 minutes early	700	5.80%	837	6.13%
11-15 minutes early	634	5.26%	874	6.40%
6-10 minutes early	1,163	9.64%	1,565	11.47%
0-5 minutes early	1,841	15.26%	2,342	17.16%
On time	3,685	30.55%	1,775	13.01%
0-5 minutes late	1,668	13.83%	2,321	17.01%
6-10 minutes late	1,237	10.25%	2,018	14.79%
11-15 minutes late	664	5.50%	1,050	7.69%
16-20 minutes late	295	2.45%	512	3.75%
more than 20 minutes late	176	1.46%	353	2.59%
Totals	**12,063**	**100.00%**	**13,647**	**100.00%**

Table 5: Summary statistics for early pick up times

Statistical Measures	2005 (Min)	2006 (Min)
Number of Observations (N)	8,023	7,393
Sample Mean ($\bar{x}$)	4.9811	6.7047
Sample Median ($\tilde{x}$)	2.0	5.0
Standard Deviation (s)	6.5662	6.8584
Inter Quartile Range (IQR)	8.0	9.0

Table 6: Summary statistics for late pick up times

Statistical Measures	2005 (Min)	2006 (Min)
Number of Observations (N)	7,725	8,029
Sample Mean ($\bar{x}$)	-4.5377	-6.8789
Sample Median ($\tilde{x}$)	-1.0	-5.0
Standard Deviation (s)	6.1565	6.59
Inter Quartile Range (IQR)	8.0	9.0

This data shows that in 2005, 87.5 percent of the pick ups were made within the “window” established by MET (10 minutes prior, and up to 20 minutes after the scheduled time). In 2006, 84.9 percent of pick up times were made within the window. Slightly more rides in 2006 were more than 10 minutes early compared to 2005, 12.5 percent versus 11.1 percent, but more pick ups in 2006 were also more than 20 minutes late, 2.6 percent, versus 1.5 percent in 2005.

This is further reflected in Table 5 and Table 6, as we see the mean time for an early pick up increasing almost two minutes between 2005 and 2006 (5 minutes versus 6.7 minutes early), with a similar increase in late pick up times (4.5 minutes late versus 6.9 minutes late). The standard deviation for the pick up times also increased between 2005 and 2006, so the software may be causing more of a normal distribution in pick up times than was realized with the Mobility Master software, when rides were manually scheduled.

Drop off Time Performance

As noted earlier, passengers sometimes focus on the pick up time and/or the drop off time. This section focuses on the drop off time performance of MET Special Transit, before and after the use of RouteMatch software. Unlike pick up times which have a “window” for use, drop off times are more dynamic.

For example, a customer may be picked-up five minutes early, and expect that they would be dropped-off five minutes early. However, they may end up being dropped-off ten minutes late. Also, customers may have an expectation that the transit service will take close to the same amount of time for a trip as would be expected in a car. Those who frequently ride a transit system, be it fixed route or demand-responsive, usually realize that it typically takes longer to cover the same distance (take a trip) on a transit system versus a car. With this being said, however, it is still important to analyze the changes in drop off time performance based on the change in software.

Figure 3 and Figure 4 show the distribution of drop off times before (2005) and after (2006) the implementation of the RouteMatch Software. Table 7, Table 8 and Table 9 show the drop off data and analysis.

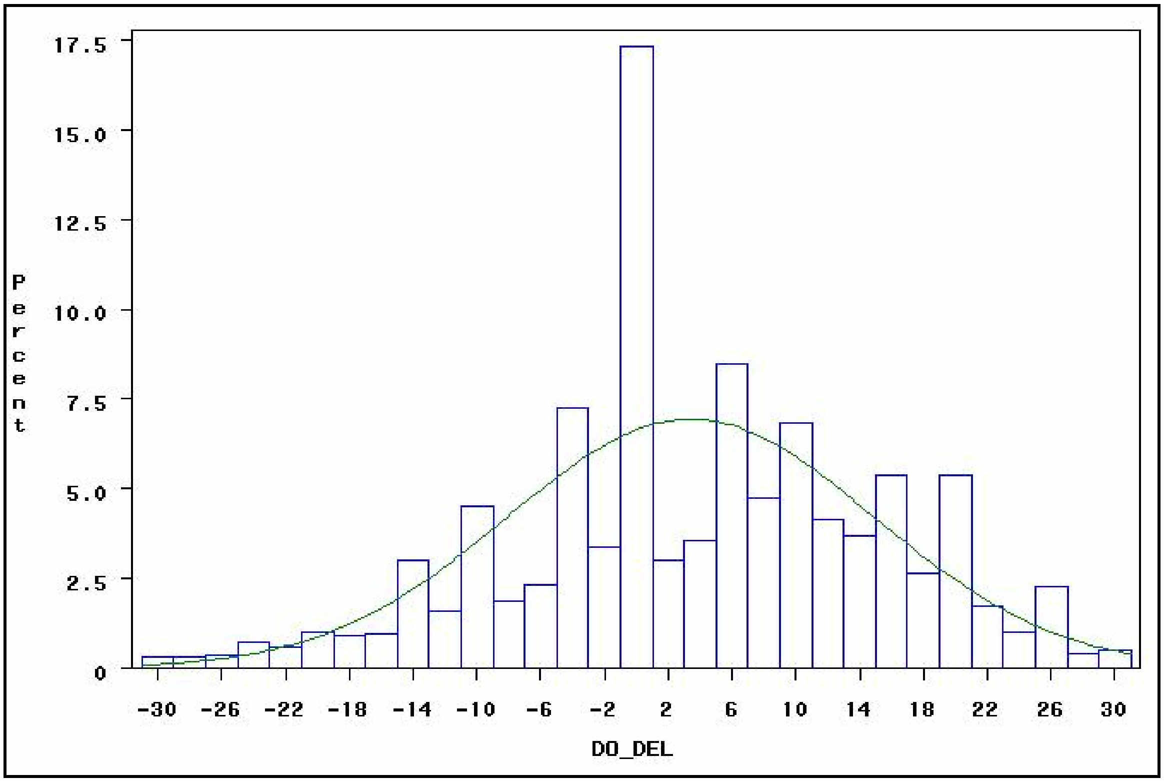

Figure 3: Distribution of drop off time deviations for 2005

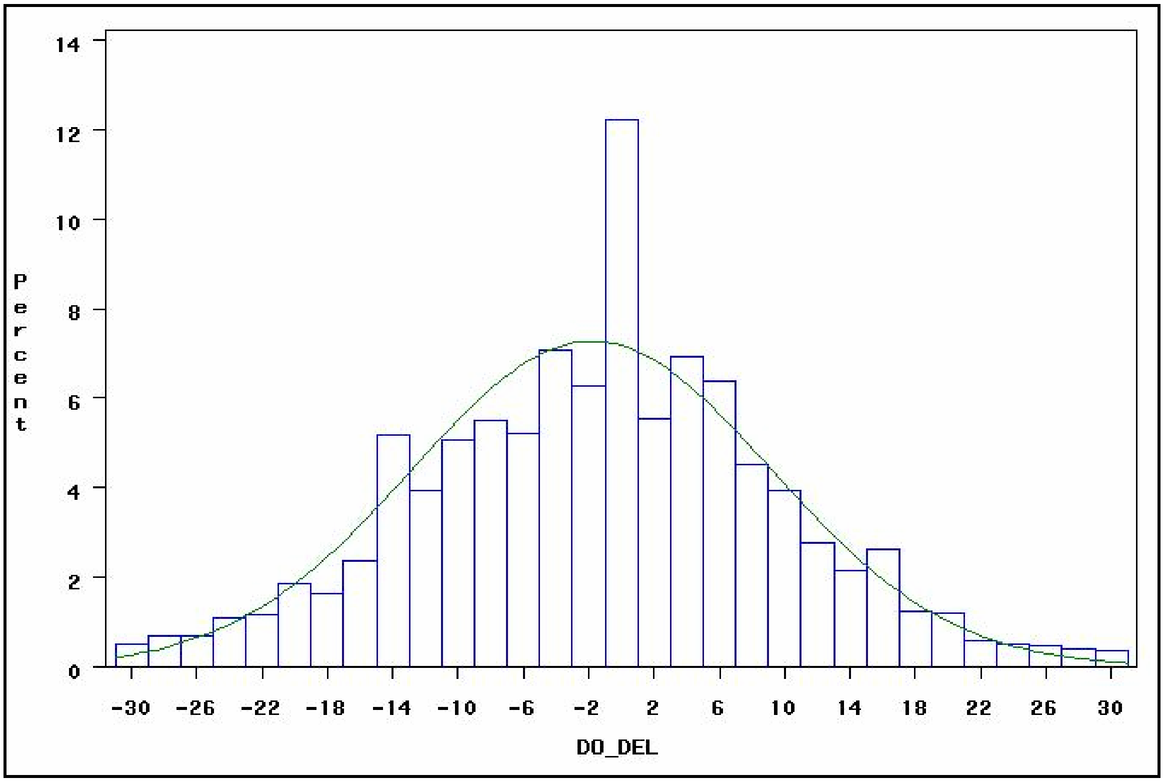

Figure 4: Distribution of drop off time deviations for 2006

Table 7: Comparison of drop off times

	2005		2006	
Drop off Time	count	percent	count	percent
More than 15 minutes early	1,783	15.06%	727	5.52%
11-15 minutes early	1,422	12.01%	895	6.79%
6-10 minutes early	1,565	13.22%	1,396	10.60%
.1-5 minutes early	1,584	13.38%	2,194	16.66%
On time	1,896	16.01%	1,151	8.74%
.1-5 minutes late	1,409	11.90%	2,220	16.85%
6-10 minutes late	936	7.90%	1,825	13.85%
11-15 minutes late	638	5.39%	1,449	11.00%
more than 15 minutes late	609	5.14%	1,316	9.99%
Totals	**11,842**	**100.00%**	**13,173**	**100.00%**

Table 8: Summary statistics for early drop off data for Billings MET Transit

Statistical Measures	2005 (Min)	2006 (Min)
Number of Observations (N)	8,250	6,363
Sample Mean ($\bar{x}$)	9.1555	7.0773
Sample Median ($\tilde{x}$)	8.0	5.000
Standard Deviation (s)	7.8206	6.6799
Inter Quartile Range (IQR)	14.0	9.0

Table 9: Summary statistics for late drop off time for MET Transit data

Statistical Measures	2005 (Min)	2006 (Min)
Number of Observations (N)	5,488	7,961
Sample Mean ($\bar{x}$)	-6.4133	-8.6376
Sample Median ($\tilde{x}$)	-5.0	-7.0
Standard Deviation (s)	7.1957	7.3709
Inter Quartile Range (IQR)	10.0	12.0

The data indicates that 79.8 percent of the drop offs in 2005 were on-time, or within 15 minutes on either side (early or late) of the scheduled drop off time. In 2006, this figure rose to 84.5 percent of drop off times. However, there was an increase in the percentage of drop offs between 2005 and 2006 that were more than 15 minutes late, 5 percent versus 10 percent.

The variance in early and late drop offs is also reflected in the data shown in Table 8 and Table 9. The average early drop off time decreased almost two minutes between 2005 and 2006, 9.2 versus 7 minutes), and the standard deviation also decreased, by approximately 1.1 minutes. Late drop offs increased, however, as the time increased 2.2 minutes from 2005 to 2006 (6.4 versus 8.6 minutes), and the standard deviation increased, although very little (7.2 versus 7.4 minutes).

It is important to remember that the drop off time is typically a function of the software. Prior to implementation of RouteMatch, the dispatchers were manually scheduling rides, and may have allowed more time between origins and destinations. Therefore, more drop offs could have been early, or at least not as late, as when the RouteMatch software was scheduling the rides. While analyzing the pick up and drop off times is valuable, it is also valuable to determine the views of the people who are using the software, scheduling and dispatching the rides, and operating the vehicles. The following section reviews the surveys distributed to MST’s drivers and dispatchers.

Dispatcher and Driver Surveys

Two sets of surveys were distributed to both the dispatchers and drivers of MET Special Transit (MST). One set was distributed in December 2005 while the Mobility Master software was in use, and the second set of surveys was distributed while the RouteMatch software was in use (September 2006 for the drivers and April 2007 for the dispatchers). The survey instruments are shown in Appendix B. The questions for the two surveys (based on the software) were similar, so comparisons could be made. The comments of the dispatchers and drivers are summarized in this section, while the full comments can be found in Appendix C.

The survey administered to the dispatchers was used to determine their opinion on how much the software aided them with their duties. The first question of the survey used a seven-point scale (7=strongly agree, 1=strongly disagree) so the dispatchers could indicate how strongly they agreed the software aided them in various tasks they perform. MST has a total of three dispatchers, so therefore the responses of one dispatcher can have a significant influence on the mean score. It is also important to note that when the initial survey for the RouteMatch software was distributed in September 2006, one of the dispatchers was on maternity leave, and no surveys were returned. That is why a second attempt was made in April 2007 to have the dispatchers complete the survey, which they did. It is not known whether or not having the survey conducted at a later time had any influence on the results. The dispatchers' responses to the first question of the survey are shown in Table 10.

Table 10: Dispatchers' Responses to Survey Question 1

Question/Factor	Mobility Master Mean Score	RouteMatch Mean Score
a) The software helps me schedule individual rides	1.33	5.67
b) The software helps me schedule group rides	1.33	3.00
c) The software helps me schedule subscription (recurring) rides	1.33	4.00
d) The software helps me provide a manifest for the drivers	6.33	7.00
e) The manifest (routing) produced by the software is efficient	2.33	6.33
f) The manifest produced by the software is accurate in the time it takes to get from one stop to another	3.33	2.67
g) The drivers follow the manifest produced by the software	5.67	6.67
h) It is easy to make changes to the manifest	6.00	6.33
i) The software is helpful in generating reports	4.67	6.00
j) Overall the software help me perform my job	5.33	6.00

In general, these results indicate that the dispatchers believe that the RouteMatch software is better at assisting them with their various tasks. This may be based on the fact that Mobility Master software was not performing any scheduling tasks, and the dispatchers had to schedule all of the rides manually. More detailed information about the specifics of the software was obtained from the remaining questions of the dispatcher survey, questions 2-4. These questions were open-ended questions that were used to try and get more detailed information about the dispatchers' view of the software.

Question 2 asked, "If there was one thing you could change about the (Mobility Master or RouteMatch) software, what would it be?" Question 3 asked the dispatchers to "Please provide any comments you have about how the (Mobility Master or RouteMatch) software may or may not assist you with your dispatching/scheduling duties." Finally, Question 4 asked the dispatchers to "Please provide any other comments you have about technologies, policies or procedures that could assist you with your dispatching/scheduling duties." The complete comments from the dispatcher and driver surveys can be found in Appendix C.

Driver Surveys

The drivers' surveys (one for each of the software) asked a total of four questions. Question 1 used a seven-point scale (7=strongly agree, 1=strongly disagree), so that the drivers could indicate their response to seven items related to the software. A total of five drivers completed the survey for each software. The drivers' responses are shown in Table 11.

Table 11: Drivers' Responses to Survey Question 1

Item	Mean Score Mobility Master	Mean Score RouteMatch
a) The manifest I get from the dispatchers is accurate	6.0	4.2
b) The manifest I get from the dispatchers is efficient (provides a good routing)	5.6	4.0
c) The manifest is accurate in the time it takes to get from one stop to another	4.0	3.6
d) I follow the manifest as it is printed	5.2	4.8
e) In order to be more efficient, I don't always follow the pick up/drop off order of the manifest	6.6	6.4
f) I believe that I could create a better manifest (routing) that is provided by the current software	3.2	4.6
g) Overall, the manifest created by the software helps me perform my job	6.2	4.8

In general, the results of the drivers survey tends to indicate that the drivers preferred the manifests received from the Mobility Master software. The only item for which RouteMatch scored better than Mobility Master was the item relating to whether or not the driver believed that they could create a better manifest (item f).

The remaining questions of the survey (Questions 2-4), were open-ended questions that were used to obtain more information from the drivers. Question 2 asked, "If there was one thing you could change about the manifests you receive from the dispatchers/schedulers, what would it be?" Question 3 asked the drivers to "Please provide any comments you have about how the software may or may not assist you with your driving duties." Finally, Question 4 asked the drivers to "Please provide any other comments you have about technologies, policies or procedures that could assist you with your driving duties." The responses to these questions for both the Mobility Master and RouteMatch software are shown in Appendix C.

As previously noted, the dispatchers did not use the RouteMatch Scheduling Engine (RSE) within the RouteMatch software. Therefore, while the manifests that were produced by the dispatchers did look different to the drivers, the dispatchers were still manually scheduling most of the rides with the RouteMatch software, as they had with the Mobility Master software. Possibly, this was due in part to the fact that many of the rides provided by MET Special Transit (MST) are based on contracts, and many of the riders are already grouped by pick up and drop off locations.

It is unclear from this analysis which factors contributed to the changes in the scores in the drivers' survey. One hypothesis could be that the drivers were simply not used to the change in the appearance of the manifests. It is possible that a second driver survey, a year after the RouteMatch software has been in use, may yield different results.

Conclusions

Previous studies have shown how the use of computer-aided scheduling and dispatching systems can increase efficiency in demand-response (or paratransit) organizations [2,4]. The purpose of this research was to identify the effects, if any, that implementing RouteMatch software would have on the operations of Billings MET Special Transit (MST). MST had been using Mobility Master software in its operations, but the dispatchers were manually scheduling rides due to issues with the software. MET Special Transit was relatively efficient, mainly due to the fact that it has numerous contracts for services, and is skilled at grouping rides.

The introduction of the RouteMatch software allowed the possibility of the software scheduling the rides, to hopefully increase the efficiency of the demand-responsive transit system. The Western Transportation Institute (WTI) examined two three-month periods, before and after the implementation of the RouteMatch software, to determine the impacts, if any, the software had on MST's operations.

"Before" and "after" data was collected and compared. The data collected for analysis included:

- Rides per hour
- Rides per mile
- Dispatcher and driver attitudes
- Pick up time performance
- Drop off time performance

It was planned that a cost-benefit analysis would occur; however, not enough cost parameters such as fuel and insurance prices were collected so that this analysis could be conducted. A break-even analysis was conducted, however, which provided information as to how much money would need to be saved, in terms of reduced mileage or hours in service, for the RouteMatch software to pay for itself.

The results of the analysis indicate that MST was more efficient when the RouteMatch software was being used. This is evident by the rides per hour increasing between the three-month comparison period (2005 versus 2006) at 7.04 percent, and the rides per mile increasing by 3.23 percent. It is this gain in efficiency that allows for the software to save money and achieve a break-even point, or "pay for itself."

Due to the fact that not enough information on cost factors such as average fuel prices, insurance costs, etc. were collected for analysis, a direct benefit/cost analysis could not be conducted. The break-even analysis that was conducted, however, indicated that only a relatively minor (three percent) gain in efficiency would be necessary to reach the break-even point. For example, MET Special Transit would only need to provide the same number of rides, while reducing mileage (or hours) by three percent. As indicated herein, and by other research, this is certainly an attainable goal.

In addition to the quantifiable information that was analyzed, qualitative data, in the form of dispatcher and driver surveys was collected. The dispatchers' responses indicated that they believed the RouteMatch software helped them accomplish their various tasks better than the Mobility Master software they were previously using.

The drivers' surveys indicate that the drivers preferred, for the most part, the manifests (routing) provided by the Mobility Master software. In one seemingly contradictory response, however, the drivers indicated that the RouteMatch software was superior in producing the manifest (routing). One hypothesis for the responses is that the survey was conducted only six months after the RouteMatch software was in use, and the drivers may not have adjusted to the new manifests. A follow-up survey a year or so after RouteMatch has been in use may yield different results.

The final quantitative data that was analyzed was the pick up and drop off time performance of MET Special Transit before and after the implementation of the RouteMatch software. The data indicated that fewer pick ups times fell within the 30-minute window established by MST when the RouteMatch software was being used (84.9% versus 87.5%). The data also indicated that in 2006, more pick up times were earlier than the 10-minute window parameter (12.5% versus 11.1%), but pick up times that were more than 20 minutes late, or fell outside the window, also increased when RouteMatch was in use (2.6% versus 1.5%). The drop off time performance analysis indicated slightly different results.

Drop off times do not have a similar window as pick up times, but for this analysis we constructed a "window" that was plus or minus fifteen minutes of the scheduled drop off time. In 2006, when RouteMatch software was in use, more drop off times fell within the 30-minute window (84.5% versus 79.8%). Fewer drop off times in 2006, when RouteMatch software was in use, were earlier than in 2005 (5.52% versus 15.06%); however, more drop off times were late when RouteMatch software was being used (9.99% versus 5.14%). There are several hypotheses for the differences in the timing data.

The first hypothesis is that when RouteMatch was not being used (in 2005), the dispatchers that were creating the manifests allowed extra time between origins and destinations, so that more pick up and drop off times were within the windows, or were early. This is somewhat related to the second hypothesis, which is that when the RouteMatch software was in use, the software tried to create a "normal distribution" within the window, which resulted in the results indicated herein.

In summary, based on the data from other research, as well as the data contained herein, the implementation of computer-aided scheduling and dispatching software can increase the efficiency of demand-responsive (paratransit) organizations. Further, as indicated by the data herein specific to MET Special Transit, a gain in efficiency of only three percent, will lead to the break-even point to where the software will begin to pay for itself. This relatively short-term analysis concluded that MET Special Transit was more efficient with the Route Match software, and that the efficiencies necessary to reach the break-even point are achievable.

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4. Volpe National Transportation Systems Center. *Benefits Assessment of Advanced Public Transportation System Technologies Update 2000*. Washington, DC: Federal Transit Administration Report FTA-MA-26-7007-00-4, November 2000.

5. Tom Brennan and Will Rodman, "Performance Measures and Measuring Results – Best Practices Today and Tomorrow", Nelson/Nygaard Consulting Associates, PowerPoint Presentation on NYS Public Transit Fall Training Program Albany, NY, November 18, 2005.

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Appendix A – Data for Analysis

The following is the data that was utilized for comparison purposes. The data was obtained from Billings MET Transit, with further data obtained from the National Transit Database.

Billings MST Data

	Jul 05	Jul 06	Aug 05	Aug 06	Sep 05	Sep 06	7/05-9/05	7/06-9/06
Rides	5,439	4,988	6,034	5,941	5,534	5,168	17,007	16,097
Hours	1,527	1,348	1,701	1,542	1,562	1,351	4,790	4,241
Miles	17,611	15,721	19,370	18,488	17,761	16,357	54,742	50,566
Rides/Hour	3.56	3.70	3.55	3.85	3.54	3.83	3.55	3.80
Rides/Mile	0.31	0.32	0.31	0.32	0.31	0.32	0.31	0.32

Rides = Ambulatory and Wheel Chair Rides

Hours = Revenue Hours (Vehicle Hours)

Miles = Vehicle Miles (Service Miles)

Billings MET Transit (Demand Responsive) Data – 2005 Totals

Operating Expenses: $859,612

Vehicle Revenue Miles: 178,627

Vehicle Revenue Hours: 15,568

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Appendix B – Dispatcher and Driver Surveys

Surveys were distributed to both the dispatchers and drivers based on both software, Mobility Master and RouteMatch. Only the RouteMatch versions of the surveys are included herein.

Billings Dispatcher Survey
RouteMatch Software

This survey is being conducted by the Western Transportation Institute-Montana State University/ Bozeman to help determine the benefits of Scheduling/Dispatching Software.

1. To what level do you agree or disagree with the following statements about the RouteMatch Software?

	Strongly Agree 7	6	5	Neutral 4	3	2	Strongly Disagree 1
a) The software helps me schedule individual rides.	☐	☐	☐	☐	☐	☐	☐
b) The software helps me schedule group rides.	☐	☐	☐	☐	☐	☐	☐
c) The software helps me schedule subscription (recurring) rides.	☐	☐	☐	☐	☐	☐	☐
d) The software helps provide a manifest for the drivers.	☐	☐	☐	☐	☐	☐	☐
e) The manifest (routing) produced by the software is efficient.	☐	☐	☐	☐	☐	☐	☐
f) The manifest produced by the software is accurate in the time it takes to get from one stop to another.	☐	☐	☐	☐	☐	☐	☐
g) The drivers follow the manifest produced by the software.	☐	☐	☐	☐	☐	☐	☐
h) It is easy to make changes to the manifest.	☐	☐	☐	☐	☐	☐	☐
i) The software is helpful in generating reports.	☐	☐	☐	☐	☐	☐	☐
j) Overall, the software helps me perform my job.	☐	☐	☐	☐	☐	☐	☐

2. If there was one thing you could change about the RouteMatch software, what would it be?

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Over►

3. **Please provide any comments you have about how the RouteMatch software may or may not assist you with your dispatching/scheduling duties.**

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4. **Please provide any other comments you have about technologies, policies or procedures that could assist you with your dispatching/scheduling duties.**

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Thank you for your time!

Billings MST Driver Survey
RouteMatch Software

This survey is being conducted by the Western Transportation Institute-Montana State University/ Bozeman to help determine the benefits of Scheduling/Dispatching Software.

1. **To what level do you agree or disagree with the following statements about the manifests you receive from the dispatchers/schedulers (using RouteMatch Software)?**

	Strongly Agree 7	6	5	Neutral 4	3	2	Strongly Disagree 1
a) The manifest I get from the dispatchers is accurate.	☐	☐	☐	☐	☐	☐	☐
b) The manifest I get from the dispatchers is efficient (provides a good routing).	☐	☐	☐	☐	☐	☐	☐
c) The manifest is accurate in the time it takes to get from one stop to another.	☐	☐	☐	☐	☐	☐	☐
d) I follow the manifest as it is printed.	☐	☐	☐	☐	☐	☐	☐
e) In order to be more efficient, I don't always follow the pick-up/drop-off order of the manifest.	☐	☐	☐	☐	☐	☐	☐
f) I believe that I could create a better manifest (routing) than is provided by the current software.	☐	☐	☐	☐	☐	☐	☐
g) Overall, the manifest created by the software helps me perform my job.	☐	☐	☐	☐	☐	☐	☐

2. **If there was one thing you could change about the manifests you receive from the dispatchers/schedulers, what would it be?**

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Over►

3. Please provide any comments you have about how the RouteMatch software may or may not assist you with your driving duties.

4. Please provide any other comments you have about technologies, policies or procedures that could assist you with your driving duties.

Thank you for your time!

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Appendix C – Survey Comments

Dispatcher Comments – Mobility Master
Notes: The number next to comment is survey number for tracking purposes. Edits were not made to the comments.

Q2. If there was one thing you could change about the Mobility Master software, what would it be?

1) Common locations should be viewed in alphabetical order.
2) Speed
3) MM is basically a data entry program w/ no ability to assist in scheduling.

Q3. Please provide any comments you have about how the Mobility Master software may or may not assist you with your dispatching/scheduling duties.

1) The dispatchers report is on too may sheets of paper. I would like to be able to view more quickly for dispatching purposes. Same for the "TBS" sheet.

Q4. Please provide any other comments you have about technologies, policies or procedures that could assist you with your dispatching/scheduling duties.

2) Speed-accuracy.

Dispatcher Comments – RouteMatch
Q2. If there was one thing you could change about the RouteMatch software, what would it be?

1) When I put in times for pick up or drop off in trips the program doesn't leave them there. I have to go into scheduling and change the times. Example: Time to p/u is 9AM, I schedule the trip and it pops up in a different time. It's frustrating.

2) That you can uncancel trips. Ability to cancel all trips according to destination. Holiday cancellations by the day. On time reporting. Would like to see better reports on ridership, denials, ridership – I get different figures from billing & NTD Report customized for us

3) I would like to be able to copy & paste times in verification.

Q3. Please provide any comments you have about how the RouteMatch software may or may not assist you with your dispatching/scheduling duties.

2) The scheduling engine to schedule group rides need some adjusting – I have this issue reported to the help desk. The recommendation tool to schedule one ride at a time will give us similar trips but not always a feasible schedule

3) Often times the software chooses ridiculous choices when it comes to scheduling. However, overall, the software is better than the software we have used in the past.

Q4. Please provide any other comments you have about technologies, policies or procedures that could assist you with your dispatching/scheduling duties.

1) There are times when going from one screen to another clicques (editor note: could mean "clicks") occur on the new screen. Does timing have to do with this?

Driver - Mobility Master Survey Comments

Q2. If there was one thing you could change about the manifests you receive from the dispatchers/schedulers, what would it be?

1) It's OK.
3) It's fine as-is.
5) Listing of more accurate times. E.g. p/u 1:00 d/o xtown 1:05

Q3. Please provide any comments you have about how the Mobility Master software may or may not assist you with your driving duties.

3) The manifest works very well for me, and it is easy to read and follow.

Q4. Please provide any other comments you have about technologies, policies or procedures that could assist you with your driving duties.

(No comments received)

Driver - RouteMatch Survey Comments

Q2. If there was one thing you could change about the RouteMatch software, what would it be?

2) The time they give you to go from point A to point B. They will give you 5 min. to drive 6 miles and 15 min. to drive 2 miles.
4) Sometimes, there is no business name with the addresses or apartment #s, but for the most part, the people are the same, so you remember where to go I guess.
5) Times given-inaccurate

Q3. Please provide any comments you have about how the RouteMatch software may or may not assist you with your driving duties.

2) The times on the manifest did not change at all when they got the new software-not even close to reality. Sometimes they have wrong addresses on manifests or not enough information at all-telling management about this things doesn't do any good-nothing changes.

3) Doesn't always allow proper times between stops.

4) Its OK for the most part.

5) Keeps me on my toes-confuses me daily.

Q4. Please provide any other comments you have about technologies, policies or procedures that could assist you with your driving duties.

2) Some of these parking lots and driveways ware are sent to are next to impossible to get around in and if we do any damage it is our butt on the line-management and dispatchers don't have a clue what we go through, they don't seem to tell everybody (clients) about the 10 min. policy and then people get mad at us for doing our job, manifests are pretty much of a joke; we strap people in, but have no control over people if they loosen or undo their seatbelts, we have to drive in crazy traffic and can't watch clients every minute and if something happens, we get written up for it.

3) Take into consideration traffic in certain areas of town.

5) There has to be a better way.

Appendix D – Detailed Time Analysis

There were two sets of data collected to conduct this analysis. The first set of data contains the information about all the rides provided by Billings MET Special Transit for the months of July, August and September for the year 2005. The data has 12,202 observations, documenting pick up and drop off times of every ride provided during the time period. We initially conducted a dot plot to analyze the integrity of the data. The pick up times and drop off times were plotted separately.

Unprocessed Data Analysis

Figure 5 shows the pick up time dot plot. It is evident from the dot plot that there are large outlying values. These values occur due to the way the "Will Call" rides are setup. Will call rides are used by dispatchers for rides such as after a doctor's appointment, when the rider will call and say they are ready to be picked-up. Thus after examining the dot plots and the frequency table for the data, we decided to reject data values with pick up deviations that are earlier than or later than 30 minutes as outliers.

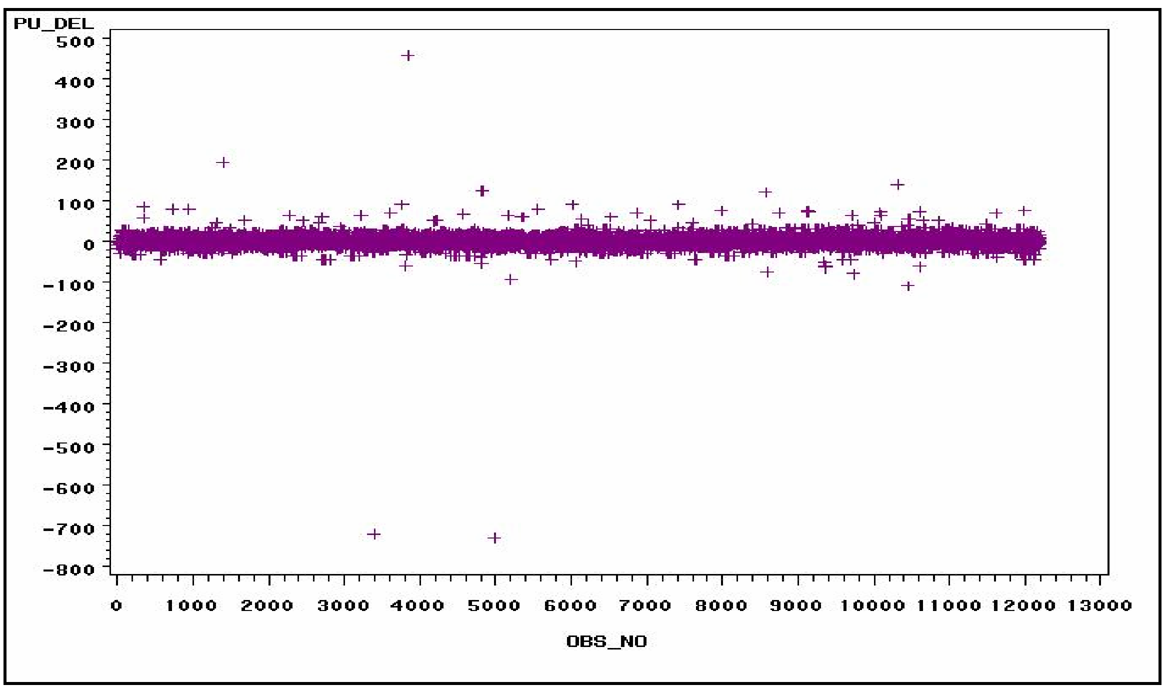

Figure 5: Dot plot showing unprocessed data for pick up time deviations

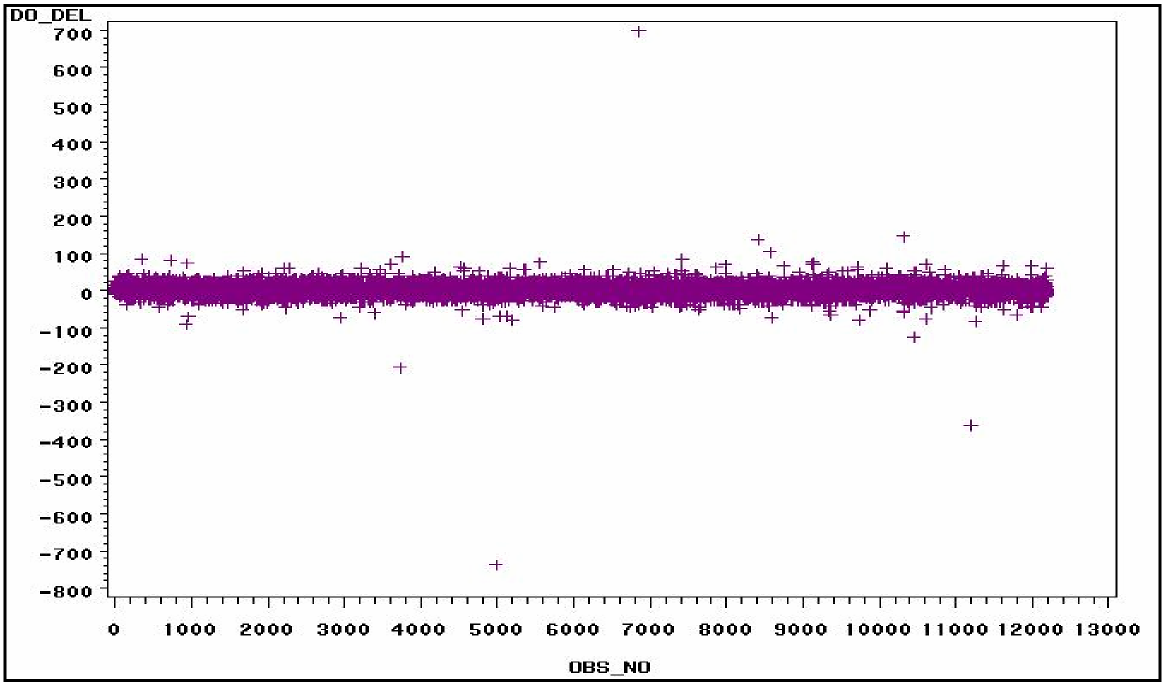

Figure 6: Dot plot showing unprocessed data for drop off time deviations

Figure 6 shows that a similar pattern is noticeable in drop off times as well. The same practice of marking "Will Calls" at the end of the day results in the outliers. After combined examination with the frequency distribution and the dot plots we decided to discard drop off time deviations earlier of later than 45 minutes as outliers.

The initial analyses on the unprocessed data provided us with the information necessary to filter and clean the data. Only the filtered data was used for our analysis. Table 12 summarizes the raw and clean data.

Table 12: Summary information on pick up and drop off data after filtering

Year	Data Characteristic	Total Obs	Valid Obs	Usable %	Outlier %
2005	Pick up times	12,202	12,063	98.86	1.14
	Drop off times	12,202	11,842	97.05	2.95
2006	Pick up times	13,965	13,647	97.72	2.28
	Drop off times	13,965	13,173	94.33	5.67

The data was then split into four groups, which were:

1. Early passenger pick up
2. Late passenger pick up
3. Early passenger drop off
4. Late passenger drop off

Processed Data Analysis

Much of the data was presented in the main section of this document. However, additional analysis is included herein for those interested in further details. To show the spread and characteristics of the data we created a box plot for pick up and drop off times. We utilized the labels shown in Table 12 for the box plots. Figure 7 shows the box plot for early pick up times for 2005, while Figure 8 shows the box plot for year 2006. It can be seen that all the three quartiles with median is visible for all time categories for year 2006, and shows almost uniform variation, supporting the fact that the software has reduced variability in pick up times by grouping rides.

Table 13: Time Measures of Effectiveness

Description	Comments
More than 15 minutes early	Unacceptable (UA)
10.1-15 minutes early	Satisfactory (S)
5.1 – 10 minutes early	Acceptable (A)
.1 – 6 minutes early	Somewhat Desirable (SD)
On time pick up (0 minutes early)	Most Desirable (MD)
.1-5 minutes late	Somewhat Desirable (SD)
5.1-10 minutes late	Acceptable (A)
10.1 – 20 minutes late	Satisfactory (S)
More than 20 minutes late	Unacceptable (UA)

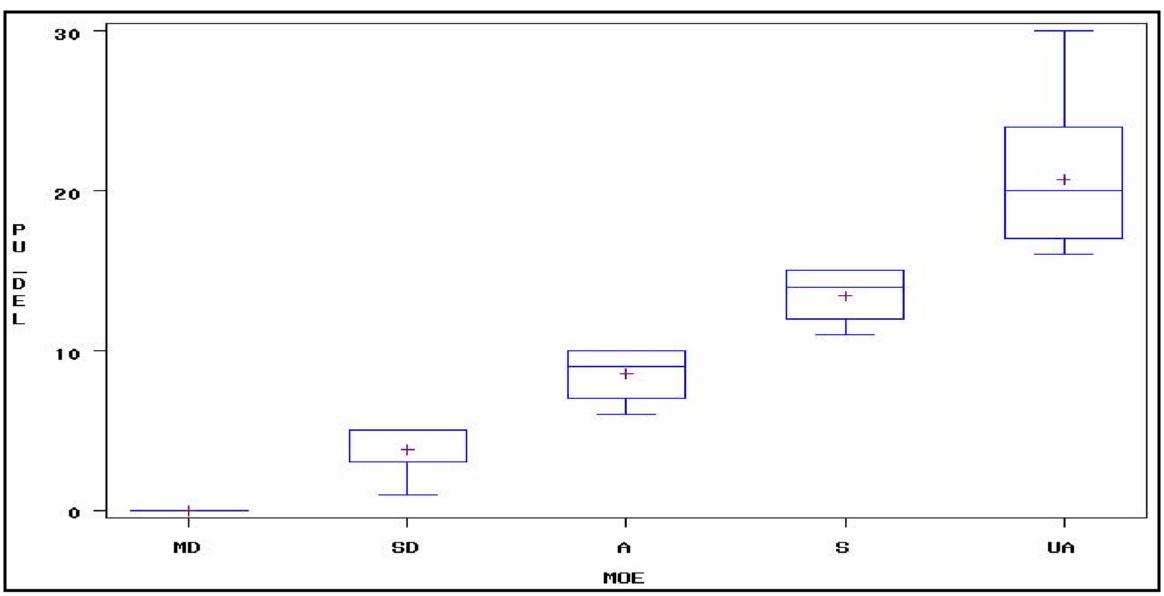

Figure 7: Box plot of early pick up times categories for 2005

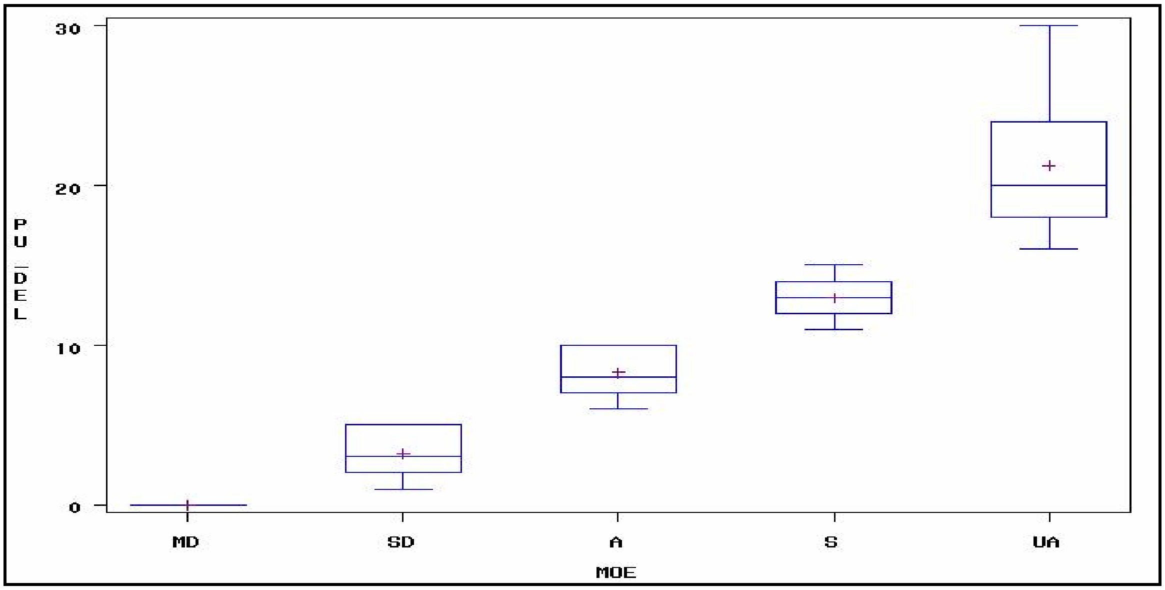

Figure 8: Box plot of early pick up time categories for 2006

Figure 9 shows the box plot for early drop off times for 2005, while Figure 10 shows the data for 2006. By comparing both diagrams we can see that in year 2006, the variability within the 10 minute window of the scheduled drop off time is minimal. This may be achieved by grouping rides to similar locations, which might be the work of the scheduling algorithm, which would result in dropping-off passengers closer to their scheduled time, as compared to 2005.

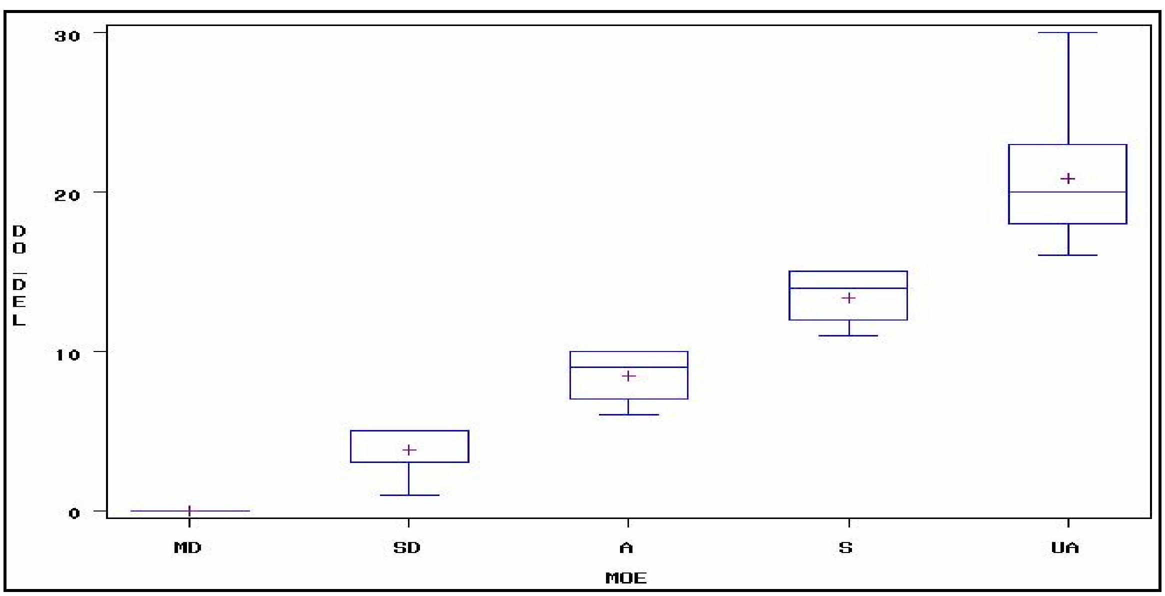

Figure 9: Box plot of early drop off time categories for 2005

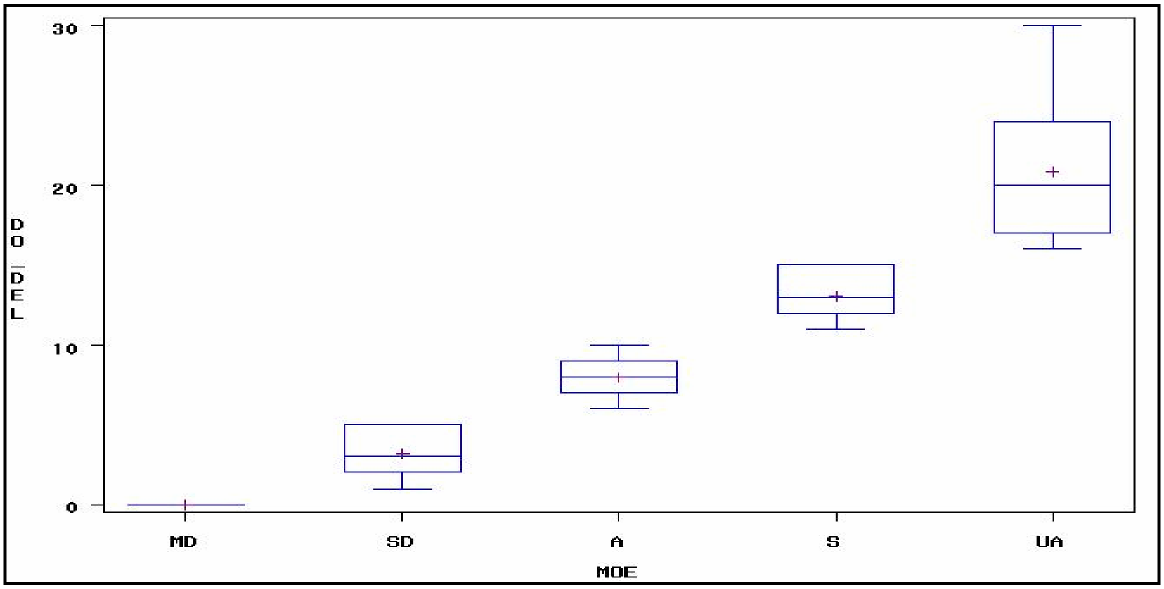

Figure 10: Box plot of early drop off time categories for 2006

Figure 11 represents the box plot showing the categories for the late pick up data for 2005, while Figure 12 shows the same data for 2006. Interestingly, we can see that the 6 -10 minute late pick ups and 11 – 15 minutes late pick up displays similar spread and quartiles, suggesting that two subdivisions could be considered together. From Figure 12 it is worth noticing that the variation in the lateness for year 2006 shows a uniform behavior compared to the non-uniformity shown in year 2005 in Figure 11.

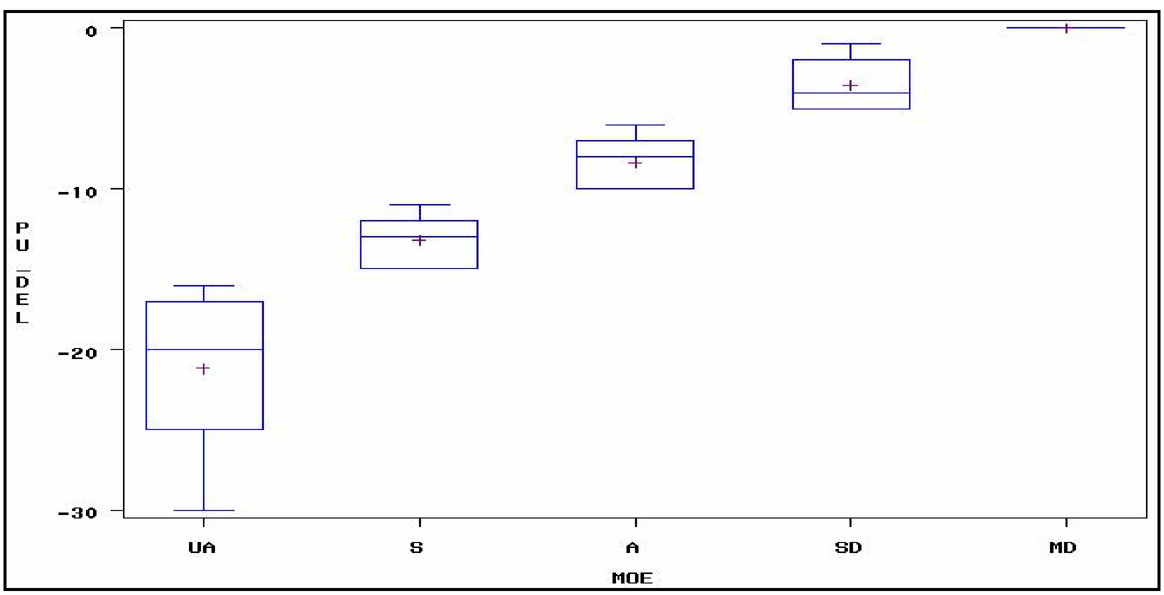

Figure 11: Box plot for late pick up categories for 2005

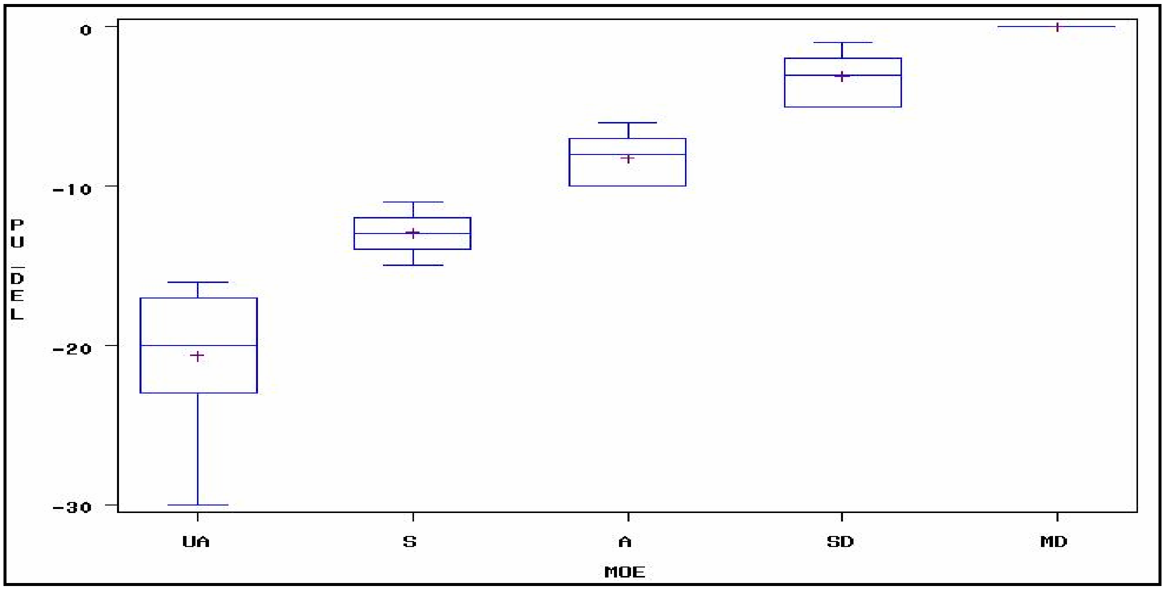

Figure 12: Box plot for late pick up categories for 2006

Figure 13 represents the box plot showing the spread of the late drop off data for 2005. It is noticeable that the 10 – 15 minute late and greater than 15 minute late categories exhibit the same pattern in year 2006 (Figure 14). This point to the situation where rides that are already delayed are further delayed to keep the rides that are on time to be completed within the scheduled time. The scheduling algorithm parameter settings need to be known to make a complete analysis.

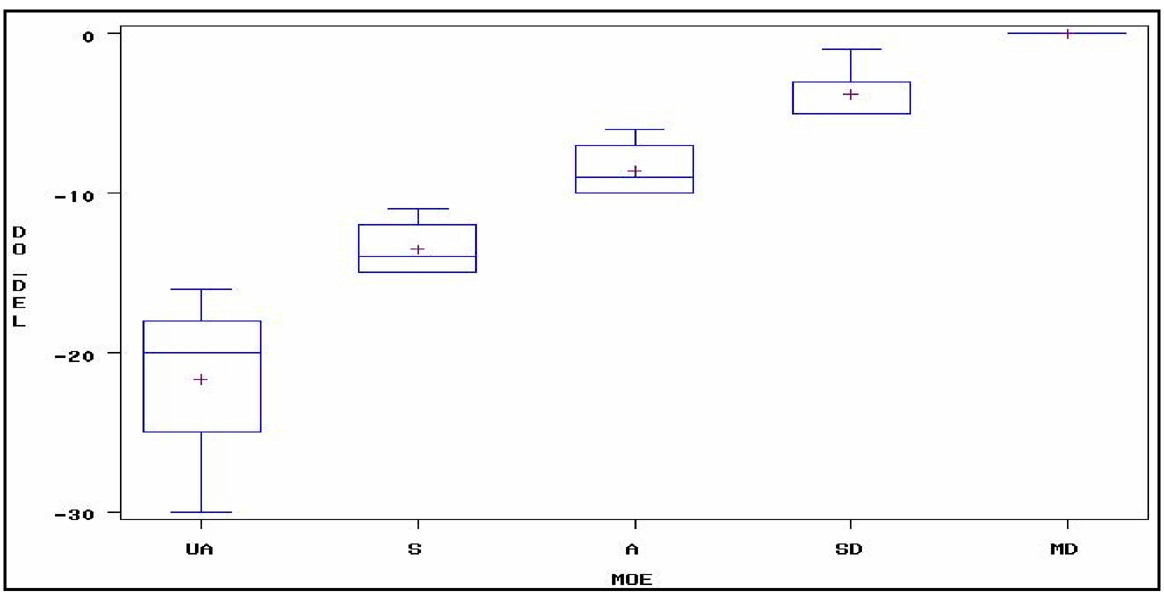

Figure 13: Box plot for late drop off categories for 2005

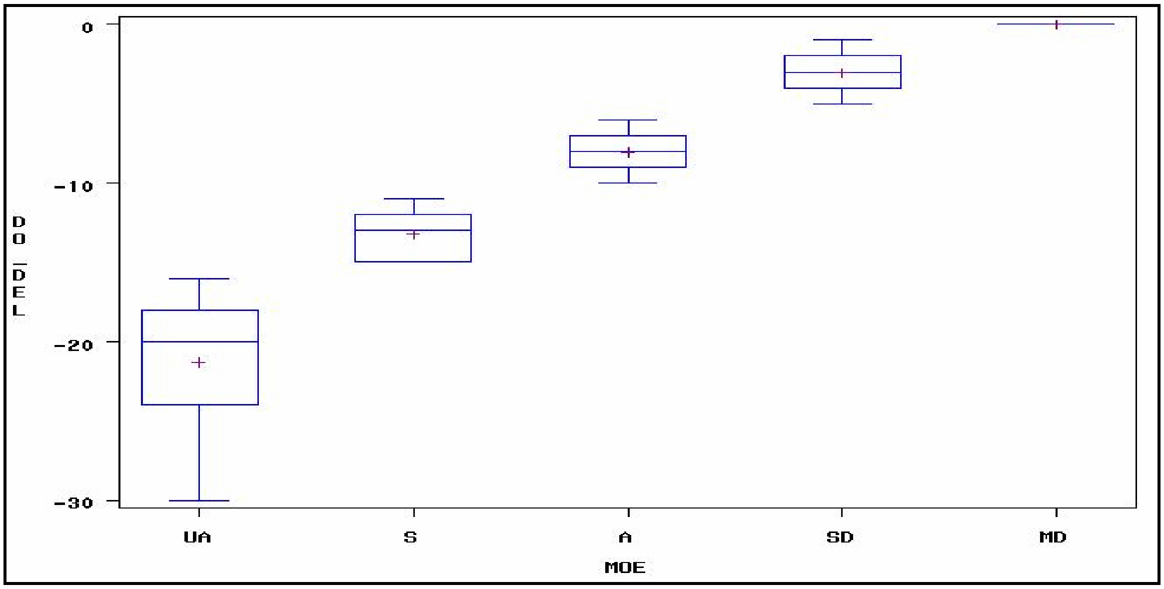

Figure 14: Box plot for late drop off categories for 2006

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Appendix E - SAS Analysis Program for Time-Related Data

```
* Program to read the ride data for Billings MET transit system and thus
evaluate the effectiveness of the RouteMatch program;
* Code written by Deepu Philip;
* Date: 05/23/2006;
* Please notice:
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applies to all files:

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   MA  02111-1307, USA, or browse to http://www.gnu.org/licenses/gpl.html.;

* this section obtains data from the file based on given file type;
DATA RIDE; * read the accident data from file;
    INFILE 'C:\DEEPU\WTI\2006SUMMER\BILLINGSDATAJULYSEPT2005.CSV' DLM = ','
        FIRSTOBS = 2 LRECL = 500;

    LENGTH SRV_DATE $ 25; * service date;
    LENGTH PUTM $ 25;  * Pickup time;
    LENGTH DOTM $ 25;  * Dropoff time;
    LENGTH ACT_PUTM $ 25;  * actual Pickup time;
    LENGTH ACT_DOTM $ 25;  * actual Dropoff time;
    LENGTH PU_EL $ 6;   * Pickup early or late;
    LENGTH DO_EL $ 6;   *Dropoff early or late;
    LENGTH TRIP_SC $ 5;  * trip status code;
    LENGTH TRIP_SD $ 10;  * trip status description;
    LENGTH TRIP_TYP $ 3;  * trip type;

      * input all the fields in the data file for program to read;
    INPUT SRV_DATE $ PUTM $ DOTM $ ACT_PUTM $ ACT_DOTM $ PU_DEL PU_EL $
          DO_DEL DO_EL $ TRIP_SC $ TRIP_SD $ TRIP_TYP $;

      * any non numeric values are removed;
      IF DO_DEL=. THEN DELETE;
      IF PU_DEL=. THEN DELETE;

      OBS_NO + 1;  * adding an observation number with the data set;
```

```
    DROP SRV_DATE;  * drop unused variables;
RUN;

* check whether the input is correct
This is again another debug option and will be turned off during runs;
PROC PRINT DATA = RIDE;
    TITLE 'BILLINGS RIDE DATA YEAR 2005';
    VAR OBS_NO DOTM PU_DEL DO_DEL TRIP_TYP;  * variables to print;
RUN;


DATA RIDEMODIF;   * modify the ride data;
    SET RIDE;   * set old data;

    * now parse the scheduled pickup and drop off times;
    LENGTH PUDATE $ 10;   * scheduled pickup date;
    LENGTH DODATE $ 10;   * scheduled dropoff date;
    LENGTH PUTIME $ 6;    * scheduled pickup time;
    LENGTH DOTIME $ 6;    * scheduled dropoff time;

    PUDATE = SCAN(PUTM,1,' ');  * get date information from the string;
    PUTIME = SCAN(PUTM,2,' ');  * get time information;
    PUTIMEHRS = 0 + SCAN(PUTIME,1,':');  * hour of pickup;
    PUTIMEMIN = SCAN(PUTIME,2,':');   * minute of pickup;

    DODATE = SCAN(DOTM,1,' ');  * get date information from the string;
    DOTIME = SCAN(DOTM,2,' ');  * get time information;
    DOTIMEHRS = 0 + SCAN(DOTIME,1,':');  * hour of dropoff;
    DOTIMEMIN = SCAN(DOTIME,2,':');   * minute of dropoff;

    DROP PUTM DOTM PUTIME DOTIME;  * drop parsed variables;

    * now convert the pickup early late to binary variable;
    IF PU_EL EQ 'early' THEN BNPUEL = 1;   * early is denoted by 1;
    ELSE IF PU_EL EQ 'late' THEN BNPUEL = 0;   * late is denoted by 0;
    ELSE BNPUEL = 99;  * missing values;

    DROP PU_EL;   * drop the string;

    * now convert the dropoff early late to binary variable;
    IF DO_EL EQ 'early' THEN BNDOEL = 1;   * early is denoted by 1;
    ELSE IF DO_EL EQ 'late' THEN BNDOEL = 0;   * late is denoted by 0;
    ELSE BNDOEL = 99;   * missing values if any;

    DROP DO_EL;   * drop the string;

    * now parse the actual pickup and drop off times;
    /* this info is redundant as we can obtain the same from the deltas
    LENGTH APUDATE $ 10;   * actual pickup date;
    LENGTH ADODATE $ 10;   * actual dropoff date;
    LENGTH APUTIME $ 6;    * actual pickup time;
    LENGTH ADOTIME $ 6;    * actual dropoff time;

    APUDATE = SCAN(ACT_PUTM,1,' ');  * get date information from the string;
    APUTIME = SCAN(ACT_PUTM,2,' ');  * get time information;
```

```
    ADODATE = SCAN(ACT_DOTM,1,' ');  * get date information from the string;
    ADOTIME = SCAN(ACT_DOTM,2,' ');  * get time information; */

    DROP ACT_PUTM ACT_DOTM;  * drop parsed variables;
RUN;

* check whether the data modification is correct
just for debugging and will only be turned on when needed;
PROC PRINT DATA = RIDEMODIF;
    TITLE 'BILLINGS RIDE PARSED DATA';
    VAR PUDATE PUTIMEHRS PUTIMEMIN PU_DEL BNPUEL DOTIME DO_DEL TRIP_TYP;  *
variables to print;
RUN;

* now the initial analysis of the data begins.
The analysis is accomplished by a series of sas procedures
generate a frequency distribution for pickup deltas;
PROC FREQ DATA = RIDEMODIF;
    TITLE 'Billings scheduled pickup times - frequency distribution';
    TABLES PU_DEL;
RUN;

* generate a frequency distribution for drop off deltas;
PROC FREQ DATA = RIDEMODIF;
    TITLE 'Billings scheduled drop off times - frequency distribution';
    TABLES DO_DEL;
RUN;

* we now do the dot plots to visualize the spread of the data;
* set the graphics environment for doing the dot plots;
GOPTIONS RESET=all;
SYMBOL COLOR = PURPLE;
* generate dot plot for the pickup times;
PROC GPLOT DATA = RIDEMODIF;
      PLOT PU_DEL*OBS_NO;
RUN;

* generate dot plot for the dropoff times;
PROC GPLOT DATA = RIDEMODIF;
      PLOT DO_DEL*OBS_NO;
RUN;

* from analysis it is clear that there are extreme observations that are
creating a skew in the data.
The reasons for the outliers are the current way of putting the willcalls.
So we are modifying the data after discarding the outliers.
Create data sets for pickup and drop off times;
DATA PICKUP(KEEP = OBS_NO PUDATE PUTIMEHRS PUTIMEMIN PU_DEL)
     DROPOFF(KEEP = OBS_NO DODATE DOTIMEHRS DOTIMEMIN DO_DEL);
    SET RIDEMODIF;   * initially analyzed data set;
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = PICKUP;
    TITLE 'Billings passenger pickup time data only (2005)';
    VAR OBS_NO PUDATE PUTIMEHRS PU_DEL;  * variables to print;
```

```
RUN;

* create early pickup data set from the pickup;
DATA PICKUPE;
      SET PICKUP;
      IF PU_DEL < 0 THEN DELETE; * keep only the positive pickup times;
      IF PU_DEL > 30 THEN DELETE; * remove outliers;
RUN;

* create late pickup data set from the pickup;
DATA PICKUPL;
      SET PICKUP;
    * include zero in the late pickup according to the coding in data;
      IF PU_DEL > 0 THEN DELETE; * keep only the negative pickup times;
      IF PU_DEL < -30 THEN DELETE; * remove outliers;
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = PICKUPL;
    TITLE 'Billings passenger late pickup time data only (2005)';
    VAR OBS_NO PUDATE PUTIMEHRS PU_DEL;  * variables to print;
RUN;

* now modify the early pickup data with MOE;
DATA PICKUPE_MOE;
      SET PICKUPE;
    LENGTH MOE $ 2;
      * now analyze generate variables for earliness;
      IF PU_DEL = 0 THEN MOE = 'MD';
      ELSE IF 0 < PU_DEL <= 5 THEN MOE = 'SD';
      ELSE IF 5 < PU_DEL <= 10 THEN MOE = 'A';
      ELSE IF 10 < PU_DEL <= 15 THEN MOE = 'S';
      ELSE IF PU_DEL > 15 THEN MOE = 'UA';
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = PICKUPE_MOE;
    TITLE 'Billings passenger early pickup modified data (2005)';
    VAR OBS_NO PUDATE PUTIMEHRS PU_DEL MOE;  * variables to print;
RUN;

* now obtain the frequency table for the MOE from the early pickup data;
PROC FREQ DATA = PICKUPE_MOE;
      TITLE 'Frequency Distribution for Early Pickup Data - Billings (2005)';
      TABLES MOE;
RUN;

* sort the data to generate a box plot for early pickup times;
PROC SORT DATA = PICKUPE_MOE OUT = PICKUPE_MOEST;
      BY PU_DEL;
RUN;

* now create the box plot;
TITLE 'Boxplot for Early Pickup Times Data - Billings (2005)';
PROC BOXPLOT DATA = PICKUPE_MOEST;
```

```
      PLOT PU_DEL * MOE / BOXSTYLE = SCHEMATICID CBOXES = BLUE BOXWIDTH = 10;
RUN;

* run the procedure for generating summary statistics for early pickup data;
PROC UNIVARIATE DATA = PICKUPE_MOEST NORMAL PLOT;
      TITLE 'Summary statistics for Early Pickup data - Billings (2005)';
      VAR PU_DEL;
RUN;

* now modify the late pickup data with MOE;
DATA PICKUPL_MOE;
      SET PICKUPL;
    LENGTH MOE $ 2;
      * now analyze generate variables for lateness;
      IF PU_DEL = 0 THEN MOE = 'MD';
      ELSE IF 0 > PU_DEL >= -5 THEN MOE = 'SD';
      ELSE IF -5 > PU_DEL >= -10 THEN MOE = 'A';
      ELSE IF -10 > PU_DEL >= -15 THEN MOE = 'S';
      ELSE IF PU_DEL < -15 THEN MOE = 'UA';
RUN;

* now obtain the frequency table for the MOE from the late pickup data;
PROC FREQ DATA = PICKUPL_MOE;
      TITLE 'Frequency Distribution for Late Pickup Data - Billings (2005)';
      TABLES MOE;
RUN;

* sort the data to generate a box plot for late pickup times;
PROC SORT DATA = PICKUPL_MOE OUT = PICKUPL_MOEST;
      BY PU_DEL;
RUN;

* now create the box plot;
TITLE 'Boxplot for Late Pickup Times Data - Billings (2005)';
PROC BOXPLOT DATA = PICKUPL_MOEST;
      PLOT PU_DEL * MOE / BOXSTYLE = SCHEMATICID CBOXES = BLUE BOXWIDTH = 10;
RUN;

* run the procedure for generating summary statistics for late pickup data;
PROC UNIVARIATE DATA = PICKUPL_MOEST NORMAL PLOT;
      TITLE 'Summary statistics for Late Pickup data - Billings (2005)';
      VAR PU_DEL;
RUN;

* now replicate the analysis for the drop off times
create the early and late drop off time data;
* create early pickup data set from the pickup;
DATA DROPOFFE;
      SET DROPOFF;
      IF DO_DEL < 0 THEN DELETE; * keep only the positive pickup times;
      IF DO_DEL > 30 THEN DELETE; * remove outliers;
RUN;

* create late pickup data set from the pickup;
DATA DROPOFFL;
      SET DROPOFF;
    * include zero in the late pickup according to the coding in data;
```

```
      IF DO_DEL > 0 THEN DELETE; * keep only the negative pickup times;
      IF DO_DEL < -30 THEN DELETE; * remove outliers;
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = DROPOFFE;
    TITLE 'Billings passenger early drop off time data only (2005)';
    VAR OBS_NO DODATE DOTIMEHRS DO_DEL;  * variables to print;
RUN;

* now modify the early drop off data with MOE;
DATA DROPOFFE_MOE;
      SET DROPOFFE;
    LENGTH MOE $ 2;
      * now analyze generate variables for earliness;
      IF DO_DEL = 0 THEN MOE = 'MD';
      ELSE IF 0 < DO_DEL <= 5 THEN MOE = 'SD';
      ELSE IF 5 < DO_DEL <= 10 THEN MOE = 'A';
      ELSE IF 10 < DO_DEL <= 15 THEN MOE = 'S';
      ELSE IF DO_DEL > 15 THEN MOE = 'UA';
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = DROPOFFE_MOE;
    TITLE 'Billings passenger early drop off modified data with MOE (2005)';
    VAR OBS_NO DODATE DOTIMEHRS DO_DEL MOE;  * variables to print;
RUN;

* now obtain the frequency table for the MOE from the early drop off data;
PROC FREQ DATA = DROPOFFE_MOE;
      TITLE 'Frequency Distribution for Early Drop off Data - Billings
(2005)';
      TABLES MOE;
RUN;

* sort the data to generate a box plot for early drop off times;
PROC SORT DATA = DROPOFFE_MOE OUT = DROPOFFE_MOEST;
      BY DO_DEL;
RUN;

* now create the box plot;
TITLE 'Boxplot for Early Drop off Times Data - Billings (2005)';
PROC BOXPLOT DATA = DROPOFFE_MOEST;
      PLOT DO_DEL * MOE / BOXSTYLE = SCHEMATICID CBOXES = BLUE BOXWIDTH = 10;
RUN;

* run the procedure for generating summary statistics for early drop off
data;
PROC UNIVARIATE DATA = DROPOFFE_MOEST NORMAL PLOT;
      TITLE 'Summary statistics for Early Drop off data - Billings (2005)';
      VAR DO_DEL;
RUN;


* now modify the late drop off data with MOE;
```

```
DATA DROPOFFL_MOE;
      SET DROPOFFL;
    LENGTH MOE $ 2;
      * now analyze generate variables for lateness;
      IF DO_DEL = 0 THEN MOE = 'MD';
      ELSE IF 0 > DO_DEL >= -5 THEN MOE = 'SD';
      ELSE IF -5 > DO_DEL >= -10 THEN MOE = 'A';
      ELSE IF -10 > DO_DEL >= -15 THEN MOE = 'S';
      ELSE IF DO_DEL < -15 THEN MOE = 'UA';
RUN;

* print to see whether the data sets are created correctly
this is just a debug tool;
PROC PRINT DATA = DROPOFFL_MOE;
    TITLE 'Billings passenger late drop off modified data with MOE (2005)';
    VAR OBS_NO DODATE DOTIMEHRS DO_DEL MOE;  * variables to print;
RUN; */

* now obtain the frequency table for the MOE from the late drop off data;
PROC FREQ DATA = DROPOFFL_MOE;
      TITLE 'Frequency Distribution for Late Drop off Data - Billings
(2005)';
      TABLES MOE;
RUN;

* sort the data to generate a box plot for late drop off times;
PROC SORT DATA = DROPOFFL_MOE OUT = DROPOFFL_MOEST;
      BY DO_DEL;
RUN;

* now create the box plot;
TITLE 'Boxplot for Late Drop off Times Data - Billings (2005)';
PROC BOXPLOT DATA = DROPOFFL_MOEST;
      PLOT DO_DEL * MOE / BOXSTYLE = SCHEMATICID CBOXES = BLUE BOXWIDTH = 10;
RUN;

* run the procedure for generating summary statistics for late drop off data;
PROC UNIVARIATE DATA = DROPOFFL_MOEST NORMAL PLOT;
      TITLE 'Summary statistics for Late Drop off data - Billings (2005)';
      VAR DO_DEL;
RUN;

DATA PICKUPT;
      SET PICKUP;
      IF PU_DEL < -30 THEN DELETE; * outliers;
      IF PU_DEL > 30 THEN DELETE; * outliers;
RUN;

* now modify the pickup data data with MOE;
DATA PICKUPT_MOE;
      SET PICKUPT;
    LENGTH MOE $ 2;
      * now analyze generate variables for lateness;
      IF PU_DEL >= -15 THEN MOE = 'A';
      ELSE IF -15 > PU_DEL >= -10 THEN MOE = 'B';
      ELSE IF -10 > PU_DEL >= -6 THEN MOE = 'C';
      ELSE IF PU_DEL = -5 THEN MOE = 'D';
```

```
      ELSE IF PU_DEL = -4 THEN MOE = 'E';
      ELSE IF PU_DEL = -3 THEN MOE = 'F';
      ELSE IF PU_DEL = -2 THEN MOE = 'G';
      ELSE IF PU_DEL = -1 THEN MOE = 'H';
      ELSE IF PU_DEL = 0 THEN MOE = 'I';
      ELSE IF PU_DEL = 1 THEN MOE = 'J';
      ELSE IF PU_DEL = 2 THEN MOE = 'K';
      ELSE IF PU_DEL = 3 THEN MOE = 'L';
      ELSE IF PU_DEL = 4 THEN MOE = 'M';
      ELSE IF PU_DEL = 5 THEN MOE = 'N';
      ELSE IF 5 < PU_DEL <= 10 THEN MOE = 'O';
      ELSE IF 10 < PU_DEL <= 15 THEN MOE = 'P';
      ELSE IF PU_DEL> 15 THEN MOE = 'Q';
RUN;

* now sort the pickup times with MOE for normal plot;
PROC SORT DATA=PICKUPT_MOE;
 BY MOE;
RUN;

* create the normal plot on the whole pickup times;
* the normal plot procedure code is modifed as a macro;
TITLE 'NORMAL PLOT FOR WHOLE PICKUP TIMES - Billings (2005)';
PROC UNIVARIATE DATA=PICKUPT_MOE;
  HISTOGRAM PU_DEL/ CBARLINE = BLUE NORMAL;
RUN;

* drop off analysis begin here - the procedure remains the same;
* different data sets are used;
* now do the same analysis for drop off times;
DATA DROPOFFT;
      SET DROPOFF;
      IF DO_DEL < -30 THEN DELETE; * outliers;
      IF DO_DEL > 30 THEN DELETE; * outliers;
RUN;

* now modify the pickup data data with MOE;
DATA DROPOFFT_MOE;
      SET DROPOFFT;
    LENGTH MOE $ 2;
      * now analyze generate variables for lateness;
      IF DO_DEL >= -15 THEN MOE = 'A';
      ELSE IF -15 > DO_DEL >= -10 THEN MOE = 'B';
      ELSE IF -10 > DO_DEL >= -6 THEN MOE = 'C';
      ELSE IF DO_DEL = -5 THEN MOE = 'D';
      ELSE IF DO_DEL = -4 THEN MOE = 'E';
      ELSE IF DO_DEL = -3 THEN MOE = 'F';
      ELSE IF DO_DEL = -2 THEN MOE = 'G';
      ELSE IF DO_DEL = -1 THEN MOE = 'H';
      ELSE IF DO_DEL = 0 THEN MOE = 'I';
      ELSE IF DO_DEL = 1 THEN MOE = 'J';
      ELSE IF DO_DEL = 2 THEN MOE = 'K';
      ELSE IF DO_DEL = 3 THEN MOE = 'L';
      ELSE IF DO_DEL = 4 THEN MOE = 'M';
      ELSE IF DO_DEL = 5 THEN MOE = 'N';
      ELSE IF 5 < DO_DEL <= 10 THEN MOE = 'O';
      ELSE IF 10 < DO_DEL <= 15 THEN MOE = 'P';
```

```
      ELSE IF DO_DEL> 15 THEN MOE = 'Q';
RUN;

* sort the drop off times for normal plot;
PROC SORT DATA=DROPOFFT_MOE;
 BY MOE;
RUN;

* now display the normal plot for the drop off times;
* the modified procedure is used as a macro;
TITLE 'NORMAL PLOT FOR WHOLE DROPOFF TIMES - Billings (2005)';
PROC UNIVARIATE DATA=DROPOFFT_MOE;
  HISTOGRAM DO_DEL/ CBARLINE = BLUE NORMAL;
RUN;

QUIT;
```