Telephone System Operations Evaluation: Before AOS Implementation

Executive Summary

This study provides a detailed baseline analysis of telephone system performance before AOS implementation. By the time of the preparation of this report, the phone system component of AOS had not been implemented.

Overview of AATA's Advanced Operating System

In 1997, the Ann Arbor (Michigan) Transportation Authority began deploying advanced public transportation systems (APTS) technologies in its fixed route and paratransit operations. The project's concept is the integration of a range of such technologies into a comprehensive system, termed the "Advanced Operating System" (AOS) to "smart buses", "smart travelers," and a "smart operation center" to benefit from timely and coordinated information on critical aspects of transit operation and maintenance. The prime contractor for the project was Rockwell, and providers of other integrated subsystems included: Digital Recorders Research of Triangle Park, North Carolina; Trapeze Software of Mississauga, Ontario; Prima Facie of King of Prussia, Pennsylvania; REI of Omaha, Nebraska; Red Pines Instruments of Denbigh, Ontario; and Multisystems, Inc. Cambridge, Massachusetts. Evaluator for the project was a team from the Urban and Regional Planning Program of the College of Architecture and Urban Planning, University of Michigan.

"The Smart Bus"

Central to the system is the deployment of automatic vehicle location (AVL) technology in order to provide continuous real time data on the location of transit vehicles. Each bus determines its location using global positioning satellite (GPS) technology; differential corrections are broadcast to the vehicles so they can calculate their locations within one or two meters. A Mobile Data Terminal (MDT) in each vehicle stores complete route schedules on an insertable memory card. The GPS system provides accurate time to the vehicles. Buses compare scheduled times and locations with actual locations to determine their schedule adherence. If a bus determines that it is running late, the driver is advised, and if necessary, the onboard computer notifies the Operation Center. The AVL also triggers an outside destination announcement and the internal next-stop signs and announcement. It also integrates location data with fare collection, electronic controlled engine data and ultimately, automated passenger counters,

The AATA network makes use of extensive timed transfers at four major transfer points. When a bus is running behind schedule, AOS enables digital bus-to-bus communications to improve the transfer between buses; the driver of the first bus can send a digital request (that includes the bus' location) to hold the second bus to ensure that a passenger will not miss a desired transfer.

Video surveillance is provided on board vehicles for security, as well as to help resolve any claims that may arise.

On the paratransit side, drivers receive their entire schedules and mark their arrival and departure times with date, time and location information as well as all the features above.

"The Smart Operation Center"

The AATA Operation Center collects and acts upon information provided by the transit vehicle and drivers. Each AATA bus has an 800 MHZ radio and onboard computer. The system minimizes voice transmissions by providing data messages that summarize vehicle status, operating condition, and location. Out-of-tolerance engine conditions such as oil pressure and temperature are reported in real time to the onboard computer, the Operations Center and the Maintenance Department.

Through the use of real time displays of vehicle location and schedule adherence reporting, dispatchers working at the Operation Center can manage the system and assist drivers by inserting overload vehicles in the system or recommending re-routing options. All changes to the route and schedule database are noted and automatically updated.

Onboard the vehicle, the driver has an onboard emergency system. When encountering a life-threatening situation, the driver covertly alerts the dispatcher, who immediately notes the vehicle's location on the system's center map and dials the appropriate agency. The system also allows the dispatcher to open up a central public address system inside the vehicle to monitor the situation. The system also supports responsive reporting of routine, non-life-threatening emergencies, such as passenger inconvenience.

For paratransit vehicles, reservations, scheduling, flexible integration with fixed-route, and after-trip information utilize Trapeze software. All of these elements are based on real-time information generated with the Rockwell TransitMasterTM software.

"The Smart Traveler"

The "smart travler" a person informed about his or her transportation options, as well as about current conditions relative to transit use. Inside the bus, next stop announcements, date, time and route are given to passengers utilizing the onboard public address system and a two line LED display. The driver also has the ability to trigger timed and periodic announcements for special events that can be made to support the system. Outside the bus, the current route information is announced to waiting passengers, and the destination signs are changed based upon the location. Kiosks provide real-time bus location information at selected locations; ultimately this information will be provided to travelers at their home or workplace via telephone, cable television or internet.

Evaluation of Phone Systems

As part of its fixed route operations, the AATA provides route and schedule information to users who call a given telephone number. The telephone information system is available to callers between the hours of 8:00AM and 8:00PM on a daily basis except major holidays, and from 8:00 a.m. to 1:00 p.m. and from 2:00 p.m to 5:00 p.m. on weekends.

Simultaneously, the AATA began providing schedule and route information through the World Wide Web. Implementation of the AOS is expected to influence the information delivery process because information providers will be equipped with new and more advanced computer terminals that can expedite their tasks.

It is expected that both the AOS and the World Wide Web project will affect the delivery of information via the telephone system. On the one hand, higher visibility might increase call volumes; on the other hand, improved equipment for information visualization, scheduling and routing might improve the speed of delivery of information to callers.

The goal of this evaluation is to determine the influence of any AOS-related change, and more specifically of the display terminals to be used by operators, on specific indicators of quality of the information delivery process. This report provides preliminary descriptive statistics and analysis of the data currently available. Since the terminals have not been implemented the analysis provided herein corresponds to the before case of the analysis. A detailed description of the analytical tools to be used for a final evaluation once the AOS-telephone-related implementation is complete is given in the final section of this report. The report does not analyze the accuracy or the quality of information delivered; rather its focus is exclusively on the call handling characteristics of the system.

Data and Methods

Information delivery and caller acceptance can be measured in several ways. Two measurement categories considered for this evaluation and some specific examples of indicators are:

1. Volume of requests for information (number of calls per unit of time)
2. Speed of information delivery and service (waiting times, call length, call abandonment behavior)

Variations in the performance indicators are expected according to the time of day, day of week, and season. Performance along these categories has been tracked over almost 70 weeks, as detailed next, constituting the "before" period of the evaluation. The following summary and analysis underscore the importance of being able to gather after-period data to develop a complete evaluation.

Data

The AATA maintains paper records regarding the operations of the telephone system. These records, printed on a daily basis, provide per-hour information about the system. Overall almost two years of data covering the July 1996 to May 1998 period exists. Due to technical difficulties with the telephone system, the data set contains some gaps. Most important is the April 1997 to August 1997 gap, while other smaller gaps also exist. Complete data for almost 70 weeks exists. The data contains information on the volume of demand and some indicators of the quality of information delivery (calls abandoned and maximum waiting times). More detailed information about productivity and other information delivery indicators exist only after April 1997.

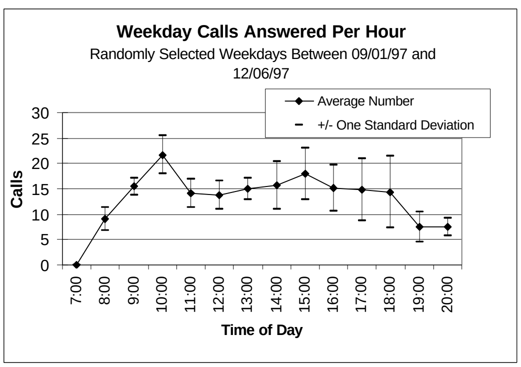
Methods

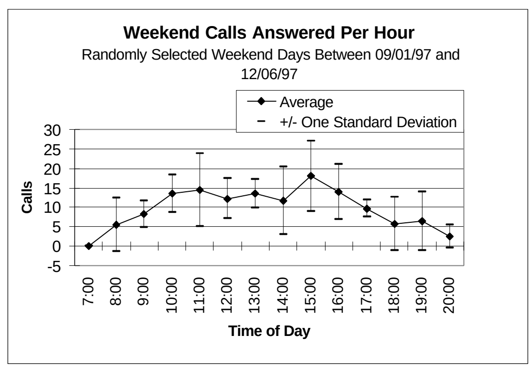
Members of the Evaluation Project entered descriptive summaries of the data on a per-day basis in a computer. This gave us flexibility in terms of aggregating the data into weeks or months, as needed. Similarly, *per-hour* information of a randomly selected weekday and weekend day between Sept. and December of 1997 was studied. The per-day data allow us to understand the relative and absolute magnitude of performance indicators and their change over time. Per-hour data allow us to establish i) differences between weekdays and weekends, and ii) if any peaking phenomena exist.

Descriptives and Analysis

Time-of-day and Day-of-Week Differences

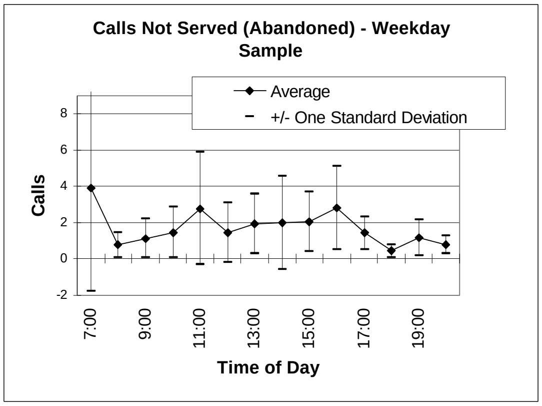
As expected, the volumes of calls requesting information during the weekdays and weekends have a different profile. Weekends are characterized by higher variance in the demand for information than weekdays. As a result, for the remainder of the analysis we chose to consider weekdays and weekends separately. The following figures, taken from the September 1997 to December 1997 period, were constructed by randomly selecting 8 (6) weekday (weekends) days during that period. The figures represent the average hourly number of calls answered on a random selection of weekdays during the study period.

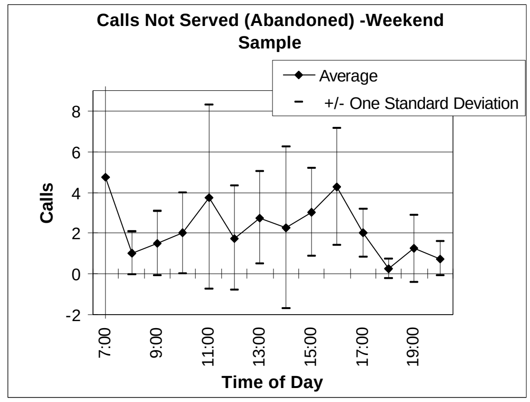




It is evident from the figures above that not only is the variance of demand significantly different during weekends, but the peaking activity also differs. The volume of calls served during the weekdays sampled is quite stable between 9AM and 6PM. The weekend peak is narrower than the weekday peak.

Since the above graphs only show Calls Answered, we explored call abandonment behavior with the same sample of disaggregate data. Our aim was to determine if i) call abandonment exhibited peaking behavior and ii) the weekday/weekend profiles have some similarity. The next set of figures shows that per-hour call abandonment during weekdays (with two information specialists on duty) is fairly stable, except at 7AM, when the operators are not working. The weekend graph exhibits a higher variance; these calls are handled by a single information specialist. These results confirmed our hypothesis that the data should be split in the weekend and weekday groups. Interestingly enough, a quick comparison of the two sets of charts above shows that call abandonment is not strongly related to the total calls served. One may think that at periods of high demand, call abandonment would increase. This finding was further confirmed by a simple regression that showed no significant correlation between call abandonment and either calls served per hour or cumulative calls served up to that hour[1].





Descriptive Statistics

This section provides descriptive statistics and graphs for the before period over a period of almost 70 weeks of valid data covering July 1996 through May 1998. Table 1 provides basic descriptive statistics for the performance categories considered. Similar descriptives will be used with the after groups once the after data when the AOS-telephone-related implementation is fully gathered and available.

[1] Calls abandoned before 8AM were excluded in this simple regression. A regression at the per day level (as opposed to a per-hour level) resulted in a significant r^2 of 0.716. In other words, days in which heavy call volumes tended also to have relatively high numbers of calls abandoned. But the abandonment phenomenon could not be linked to hour-specific volumes.

Table 1 -Descriptive Statistics Before Period

Parameter	Units	Statistic	Weekdays	Weekends
Demand Served per Week	# of Calls	Mean	222.96	111.9
		Std. Dev.	49.88	35.95
			(n=66)	(n=66)
Abandoned Calls per Week	# of Calls	Mean	34	30.98
		Std. Dev.	16.86	24.45
			(n=66)	(n=66)
Average Waiting Time per Call Abandoned	Seconds	Mean	804.7	272.4
		Std. Dev.	211.5	112.18
			(n=66)	(n=66)
Average Speed of Answer	Seconds	Mean	272	52.65
		Std. Dev.	122.95	27.19
			(n=33)	(n=32)
Average Time Operator is Busy	Minutes	Mean	2873.64	557.63
		Std. Dev.	618.0	238.38
			(n=33)	(n=32)
Average Time Operator is Present	Minutes	Mean	5,485.1	1,028.63
		Std. Dev.	536.92	248.51
			(n=33)	(n=32)
Average Time per Call Answered	Minutes	Mean	13.09	4.35
		Std. Dev.	2.91	1.36
			(n=33)	(n=32)

Figures 1 through 7 included in Appendix 2 provide a slightly better picture than means and standard deviation of Table 1 because they can depict any trends in the data. Direct comparison over time for a category and between categories are not productive because the observations may be correlated. For example, the number of calls received clearly affects the number of people abandoning the system. Thus, for example, if the number of calls increased, the mean calls abandoning the system could have gone up.

Interpretation of Graphs and Descriptive Statistics

The trends identified by Figures 1 through 7 will tell if the mean and standard deviation given in Table 1 for each category are meaningful descriptors of the data. In addition, determining if the figures exhibit trends that are statistically significant is important for the evaluation methodology proposed in the next section. Figure 1 shows that volumes for weekends are decreasing over time, but no trend is apparent for weekdays. The volume of calls served during a weekday is about twice as much as the volume of calls served during weekends. It is unclear if this is a cause or a consequence of having two operators in service during the weekdays and one during the weekends; service delivery figures will provide more detailed information about this phenomenon. The weekend series' decreasing trend is statistically significant at the 95% level. No seasonal effect (perhaps because the summer data is missing) was found in Figure 1.

Figure 2 shows the per week number of calls abandoned. These are individuals that enter the phone system queue but leave before being served. The figure suggests that the abandonment rates are not very different for weekends and weekdays, around 31 calls per day. Spikes are clear during the first two months of the year, suggesting some seasonal effects. Furthermore, regression analysis confirmed the existence of statistically significant decreasing trends for both series.

The relationship between calls served and calls abandoned is provided in Figure 3. On average about 20 percent of the weekend calls go unserved while about 12 percent go unserved for a typical weekday. These numbers are indicative of considerable demand being unmet. Figure 4 shows the number of seconds a person waited before abandoning the call. On average, a person is on hold 13.4 minutes during weekdays and 4.5 minutes during weekends before abandoning the queue. The multiplication of the average number of calls per week and the average wait time before abandoning shows that 44.95 hours a week are literally lost by callers due to phone system delays. No trends were found for Figure 3 or 4.

Figures 5 through 7 describe service times with customers. Figure 5 shows the average speed of answer per call. On average, each call was picked up after 272 seconds in the queue for weekdays and 52.7 seconds for weekends. These numbers should be interpreted with care because statistically significant decreasing trends were detected for the average speed of answer.

The average time an operator spends per caller is shown by Figure 6. This time includes the actual time with an operator and the time on hold while the operator finds the appropriate information requested. In contrast with previous figures the average time spent for each call is quite stable over time. The weekend trend was found statistically significant at a 95% level.

Finally, Figure 7 shows the percentage of time an operator is busy with a customer. As expected, the weekend operator is busier than the weekday operators are. In fact, a statistically significant trend was detected for the weekday series. On average, about 51 percent of the time is spent with customers on weekdays and 59 percent on weekends.

Evaluation Methodology

The analysis performed herein is only the first step of evaluating the impact of the influence of AOS-related telephone system improvements. The importance of gathering and analyzing after period information cannot be underscored. In this section we outline in detail the evaluation methodology to be used once the after data set is gathered.

The steps to be taken for the evaluation methodology are 1) remove trends and seasonal effects in data, 2) estimate statistical model, and 3) interpret the results.

1. Trends and Seasonal Effects. In general, a time series with significant trends cannot be meaningfully described by the overall mean and standard deviation, for both statistics will be influenced by the point and span in time at which the series is observed. Before any analysis is performed, trends and seasonal effects should be removed to make the data stationary (i.e., that the time series properties –e.g., mean and variance do not depend on time). Seasonal effects could be controlled using seasonal dummy variables insofar as these seasonal influences only affect the intercept of a regression equation. This is a reasonable assumption for the current data. In addition to removing any seasonal effects, it is proposed that any trends be eliminated using the first differencing method (Davidson, Godfrey and Mackinnon, 1985). This method removes the difference between successive values in a time series by finding the first order difference between them (i.e., for variable *X*, find X_t - X_{t-1} for times *t* and *t-1*). Thus, one observation is lost for each order of difference. The resulting differences are the "de-trended" observations. Several trend and seasonal effects have been identified above (See Figures 1,2, 5,6 and 7).

2. Estimation of Statistical Model. After understanding and organizing the data, a linear regression model using the before and after data groups will be estimated in order to determine the effect of the AOS-related phone system improvements on the performance indicators. Call Volumes and Operator Work Hours are used as independent variables, in addition to any seasonal dummy variables as described in 1). All performance indicators are used interchangeably as dependent variables. A dummy variable for the before and after study is also included in the analysis. Standard analysis techniques should be followed to ensure a minimal violation of regression model assumptions.

3. Interpretation of Results. The significance and magnitude of the coefficient for the period dummy variable will determine the importance of the AOS-related phone system improvements. Other coefficients estimated will also be appropriately interpreted.

References

Davidson, R., L.G. Godfrey and J.G. Mackinnon (1985) A Simplified Version of the Differencing Test. *International Economics Review*, 26, 639-647.

APPENDIX 1

Hourly data on the state of queues is provided by the system on paper. In the interest of tracking the changes in quality and productivity of the telephone system throughout without engaging in labor intensive data entry, summary daily data (as opposed to hourly) was input in electronic format.

Table 2 shows the fields exist for all the data groups for almost 70 weeks. Table 3 shows the data fields available only after September 1997.

Table 2 Relevant Data Fields Available During All Periods

Date	Number of Calls that Abandoned the Queue
Number of Calls Accepted	Average Waiting Time of Calls That Abandoned the Queue
Longest Wait Time	Service Factor (% of calls answered in less than a given time)

Table 3 Relevant Data Fields Available After September 1997

Number of Calls Answered	Average Time in System (incl. Hold and post-call processing)
Average Speed of Answer	Average Time with Operator
	Total Time Operator is Busy Taking Calls
	Total Time Operator is Available for Calls (incl. Busy Time)

APPENDIX 2

Figure 1 Total Demand per Day

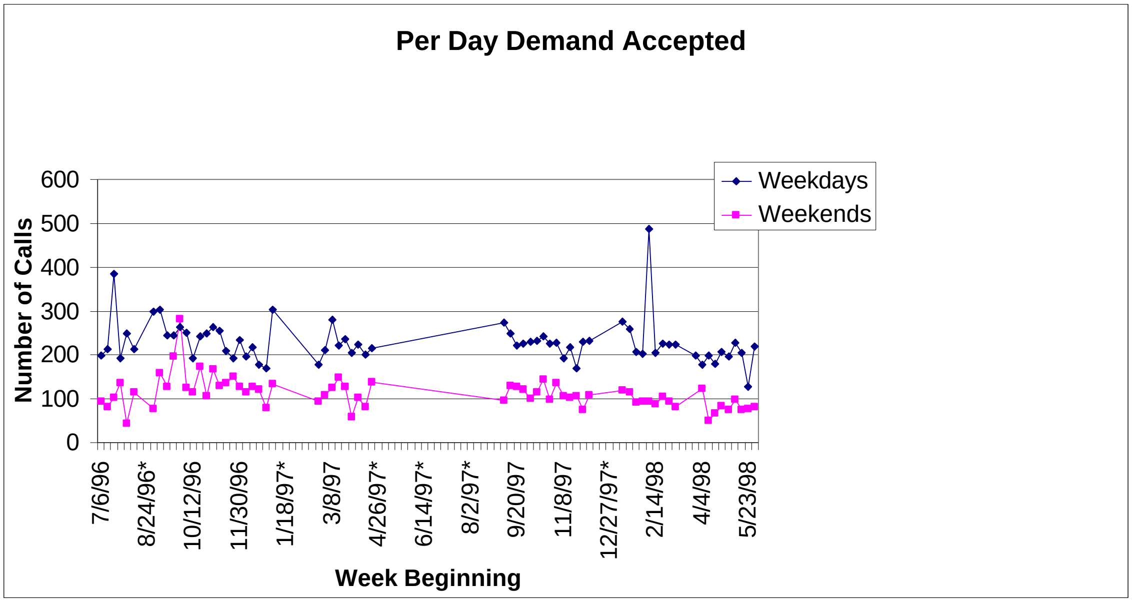


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Figure 2 Calls Abandoned per Day

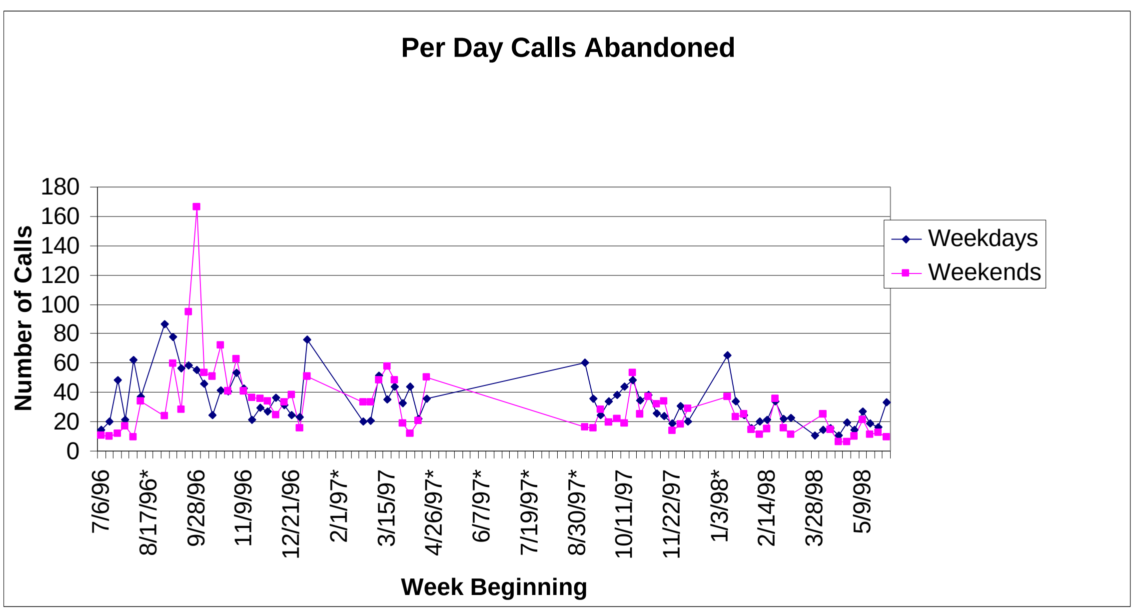

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Figure 3 Percentage of Calls Not Served

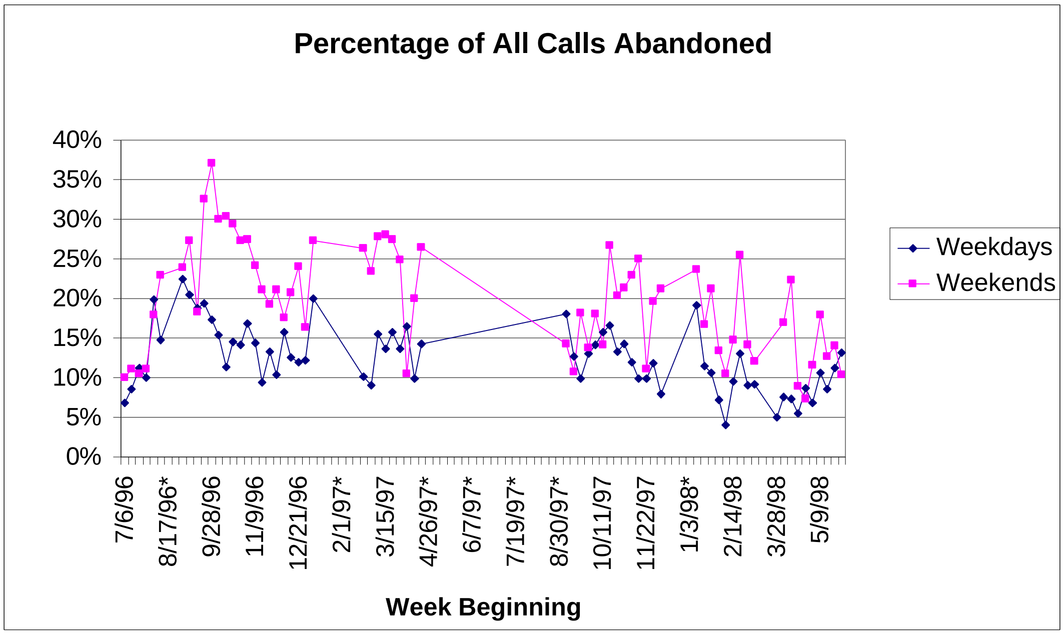

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Figure 4 Average Time Before Abandoning Call

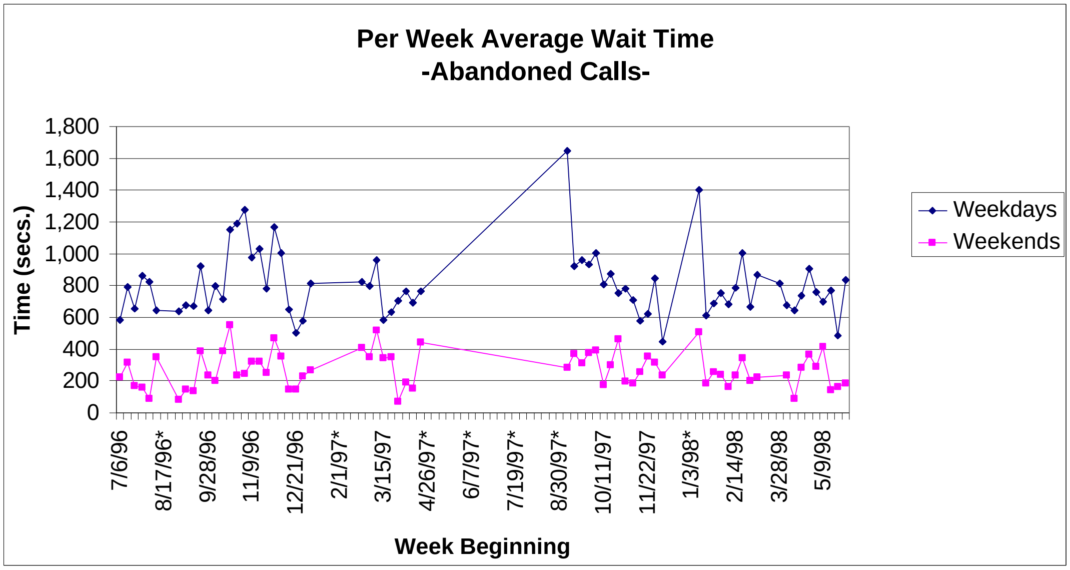

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Figure 5 Average Speed of Answer

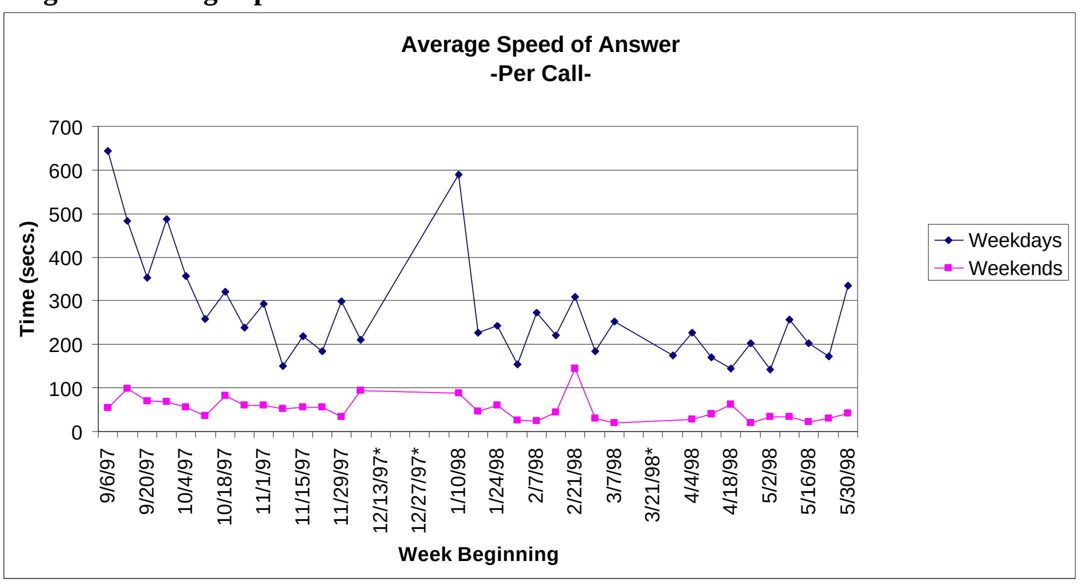

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Figure 6 Average Service Time Per Customer

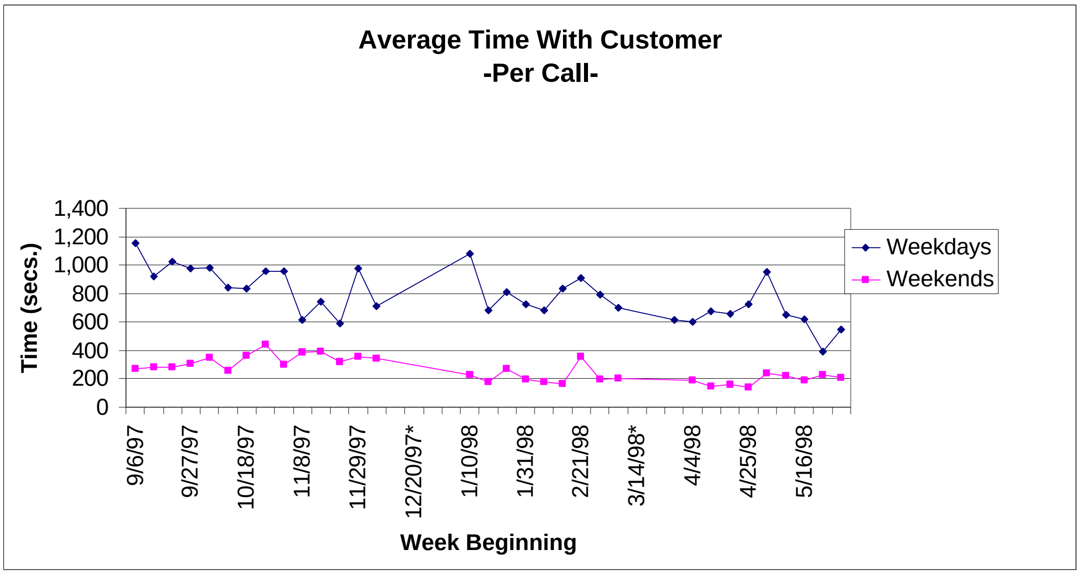

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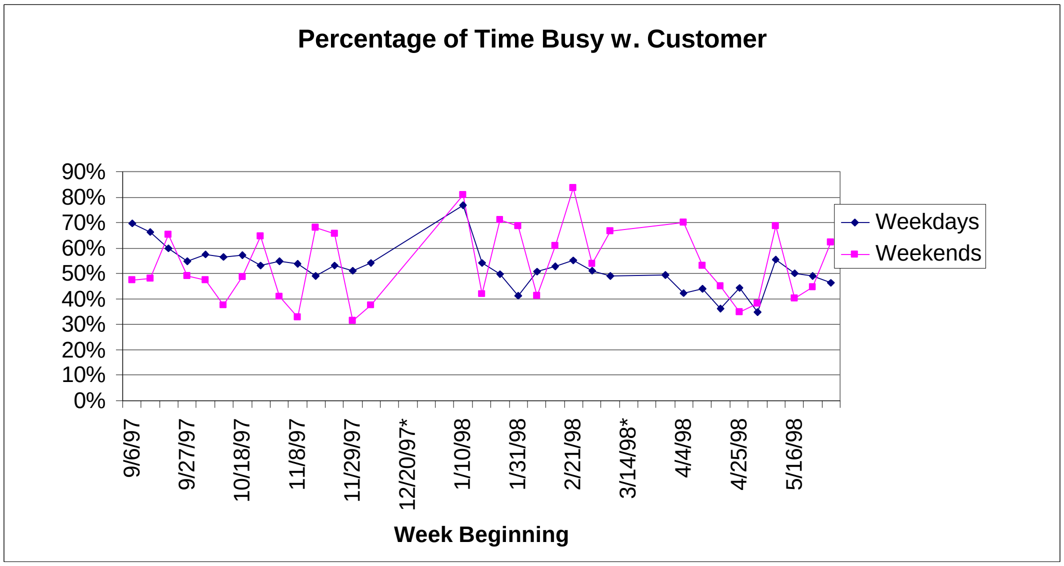
Figure 7 Percentage of Time Operator is Busy With A Customer



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