Programa de Desarrollo Profesional - ATI
University of Puerto Rico
Mayagüez Campus
Department of Civil Engineering
Mayagüez, PR.

Final Report
Group #2

"Implementation of a Methodology for Determining Quality of Service in Bus Routes"

Submitted by:

Adrián Del Moral Ballesteros, Undergraduate Student
adriandelmoral@yahoo.com
Department of Civil Engineering and Surveying
University of Puerto Rico – Mayagüez

Advisors:

Prof. Alberto Figueroa, Dept. of Civil Engineering and Surveying, RUM
amfigueroa@uprm.edu
Prof. Benjamín Colucci, Dept. of Civil Engineering and Surveying, RUM
bcolucci@uprm.edu

Submitted to:

Benjamín Colucci, PhD, PE, PTOE
bcolucci@uprm.edu
Program Director

December 2005

Abstract

Puerto Rico is a small island in the Caribbean. It has a population of approximately 3.8 million habitants with a high vehicular density of 247 vehicles/km^2. Transportation problems in the San Juan Metropolitan Area (SJMA) include concentrated population and employment, limited capacity of the highway system, inadequate public transport service, lack of intermodal connections and the constrained mobility for low income families. The Tren Urbano (TU) offers the SJMA an alternative to the traffic congestion problem that affects it, which is highly due to the high dependency of the population to its private vehicle. The TU and the buses need to be integrated, forming an intermodal transit system. Lack of coordination between transit modes might affect the current and potential users' reliability in the system. Choice riders will probably reconsider other trip options due to the unreliability of the bus system operation.

If information of the service frequency and quality were to be given to the bus users, the reliability of the system might increase, leading to a potential increase in ridership of the system. A good way to increase ridership and provide information about the quality of service to the users would be to get real and up-to-date data from the bus routes and evaluate their operation to develop a communicable quality of service level for the public.

The Transit Capacity and Quality of Service Manual was selected to obtain the proper methodology in bus quality of service evaluation utilizing Levels of Service (LOS). Implementation of the TCQSM was focused on, but not limited to, A-3 and B-21 bus routes of the AMA service. A survey was conducted in order to learn more about SJMA habitants' perception of the quality of service. Among the most important findings is that the actual frequency LOS of A-3 and B-21 are below those expected. Most users are willing to wait no more than 15 minutes for a bus and need late night to all day hours of service to satisfy their needs.

Table of Contents

List of Figures

List of Tables

I. Implementation of a Methodology for Determining Quality of Service in Bus Routes

Puerto Rico is a small island in the Caribbean, consisting of only 160 km of length and 56 km of width. However, it has a population of approximately 3.8 habitants with a high vehicular density of 247 vehicles/km^2. A high vehicle to person ratio of 1.69 puts it in the largest density of this type in the world, three times larger than any city in the USA. The San Juan Metropolitan Area consists of 13 municipalities, summing up to around 1036 km^2 (1, 2).

It has a population density of 1352 habitants per square kilometer. The SJMA generated 3.2 million trips per day in 1990, and by the year 2010 the number of trips is expected to increase by 45% (2).

Transportation problems in the SJMA include concentrated population and employment, limited capacity of the highway system, inadequate public transport service, lack of intermodal connections and the constrained mobility for low income families. It has a vehicular density of 56 vehicles per km (90 vehicles per mile) of paved street, higher than in any other city of the world. The SJMA has many parking and general congestion problems, contributing to excessive delays at almost every hour of the day. Commuters are willing to wait up to15 minutes or less between transfers (8). Above all, commuters want to feel secure and want to arrive on time at their destinations.

Statistics show that the mass transit usage has declined 40.7% from 438,000 in 1964 to 259,524 in 1990 (5). The available means of transportation in SJMA include the private vehicles, taxis, buses (AMA, Metrobus 1, and Metrobus 2), “Carros Publicos”, ferryboats, and the Tren Urbano (TU). The TU consists of a 16.9 km rail system of 16 stations and serves the municipalities of San Juan, Bayamon and Guaynabo. Figure #1 shows a map of SJMA and the TU’s transit service route.

Figure 1. San Juan Metropolitan Area and the TU.

The Tren Urbano (TU) offers the Metropolitan Area an alternative to the traffic congestion problem that affects it, which is highly due to the high dependency of the population to its private vehicle. The TU and the buses need to be integrated, forming an intermodal transit system. Advantages of this integration will be:

- It permits the use of various modes of transport, therefore expanding the service area and the time of service.
- An increase in the number of transported passengers.
- A decrease in fuel consumption, good for the environment.
- Money saving in the cost of gasoline for the vehicle, parking, maintenance and vehicle depreciation.

However, limitations and disadvantages exist. Within these is the necessity for an adequate coordination.

The Autoridad Metropolitana de Autobuses (AMA) has a fleet of approximately 244 buses. It operates 32 routes of which 21 were modified to serve in junction with the TU. However, its current schedule is not compatible with that of the TU, adding to the disadvantages of the integration which is not proving to work well because of coordination problems. The lack of coordination affects the current and potential users' reliability in the system. Choice riders will probably reconsider other trip options due to the unreliability of the bus system operation. Therefore, ridership growth is limited and diminished.

If information of the service frequency and quality were to be given to the bus users, the reliability of the system might increase, leading to a potential increase in ridership of the system. A good way to increase ridership and provide information about the quality of service to the users would be to get real and up-to-date data from the bus routes and evaluate their operation to develop a communicable quality of service level for the public. Automated Vehicle Location (AVL) data is needed to make such an analysis.

The bus routes selected for this study are the A-3 and B-21. Both routes serve places of importance and are integrated to the TU. Also, these routes serve train stations with much ridership.

II. Objectives

The main two objectives of this research are to evaluate the quality of service and analyze the delays of bus routes that serve the TU system.

Evaluation of Quality of Service

- To analyze quality of service of buses from the user's point of view.
- Identify and analyze different existing methodologies for the determination of a LOS for buses to be applied in Puerto Rico.
- To apply the methods to particular routes.
- To design an effective method to provide reliability information to the users.
- Identify the routes to be analyzed.
- Analyze the quality of service offered to users by taking in consideration delays, headways and travel speed.
- Identify critical segments of delay in routes.
    - Identify what is a critical delay according to the user using survey.
- Suggest possible changes in routes.

III. Justification

Transportation investments are influenced by the level of service ratings of the current and expected system performance (6). The Highway Capacity Manual (7) defines Level of Service (LOS) as a "quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions and comfort and convenience." Frequency of service is the primary evaluation measure for assessing transit LOS. The level of service LOS for transit is based on a number of factors. Common measures of LOS are local route headways, commuter route headways, service span, average interval between stops, and service span.

Up to now, no recent studies with a scientific nationally approved methodology have been done regarding the quality of service of the integrated AMA- TU bus routes.

IV. Evaluating Transit Quality of Service Literature Review

Progress in this research includes the determined methodology to assess quality of service. The methodology chosen to realize this study is that of the Transit Capacity and Quality of Service Manual. Due to the extreme similarities between the Highway Capacity Manual and the Transit Capacity and Quality of Service Manual, both methodologies may be interchanged for fixed-route buses. In this section a review of the chosen methodology for assessing quality of service for bus systems is provided.

Transit Capacity and Quality of Service Manual

This methodology is to be used for the evaluation of transit service quality of service. It consists in a quantitative measure of performance that best describes a particular aspect of the transit service from the passenger's point of view.

It is important to have in mind the following terms: quality of service, transit service measure, transit performance measure, and level of service.

- Transit service measure is a quantitative performance measure that best describes a particular aspect of transit service and represents the passenger's point of view.
- Quality of service is an overall measured or perceived performance of transit service from the passenger's point of view.
- Transit performance measure is a quantitative or qualitative factor used to evaluate a particular aspect of a transit service.
- Level of Service (LOS)—Six designated ranges of values for a particular service measure, graded forma A (best) to F (worst) based on a transit passenger's perception of a particular aspect of transit service.

In this study, transit service measures will be taken into account, not transit performance measures.

The Highway Capacity Manual and the Transit Capacity and Service Manual coincide on several important distinctions. Some of these are:

- Service measures represent the passenger's point of view, whereas performance measures can reflect any point of view.
- Service measures should be relatively easy to measure and interpret.
- Level of Service (LOS) is only for service measures.

The passenger point of view or quality of service, directly measures passengers' perception of the availability, comfort, and convenience of transit. Quality of service measures of transit service are divided into two main categories: availability, and comfort and convenience. According to the measure addressing spatial and temporal availability, if transit is located too far away or if it does not run at the times it is needed, a potential user would not consider the transit service available, and therefore the quality of service would be poor. If transit service is available, the quality measures to evaluate user perceptions of comfort and convenience can be applied. Such measures should be addressed at transit stops, route segments, and systems.

The type of route service that will be taken in consideration in this study is the fixed-route service. Paratransit service is not within the scope of this study.

V. The Transit Capacity and Quality of Service Manual Methodology

The quality of service framework for fixed-route transit measures can be divided in 2 main categories:

1- availability

2- comfort and convenience

Availability Measures

Quality of service may be measured used to measure at the stop, route segments, and the system. Since route segments are composed of a series of stops, stop-level measures are also applicable at the segment level.

Service Frequency

From the passenger's point of view, transit service frequency determines the number of times an hour a user has access to the transit mode. This is assuming that the transit service is within acceptable walking distance. Service frequency LOS is determined by destination.

Service frequency is also a measure of the convenience of transit service to choice riders and is component of overall transit trip time. Urban scheduled transit service includes all scheduled service within a city as well as service between cities within a larger metropolitan area. The service frequency LOS measure for urban scheduled transit service is headway. The SJMA's transit service falls in this category. Passengers, however, find it easier to understand schedules when clock headways are used. A clock headway is one that is evenly divisible into 60.

Buses on separate routes serving the same destination that arrive at a stop within 3 min of each other should be counted as one bus for the purposes of determining service frequency LOS.

Fig. 2 Exhibit 3-12 Fixed-Route Headway/Frequency LOS (From TCQSM)

LOS	Avg. Headway (min)	veh/h	Comments
A	<10	>6	Passengers do not need schedules
B	10-14	5-6	Frequent service, passengers consult schedules
C	15-20	3-4	Maximum desirable time to wait if bus/train missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during the hour
F	>60	<1	Service unattractive to all riders

Accessibility at Transit Stops:

This includes Pedestrian bicycle, automobile and ADA accessibility of transit stops. An evaluation of pedestrian accessibility should consider whether sidewalks are provided, the condition of the sidewalks, terrain, traffic volumes on streets that pedestrians must cross to access a transit stop and the kind of traffic control provided on streets. Accessibility considerations that apply to transit stops also apply to route segments.

Route Segment Hours of Service

Service span, or hours of serve, is the number of hours during the day when transit service is provided along a route, route segment, or between two locations. It plays an important role in determining availability of transit potential users. For fixed-route service, LOS is based on the number of hours per day when transit service is provided at least once an hour. One hour must be added to the span for the LOS determination. The hours of service LOS is intended only for transit service provided within cities. It does not apply to intercity transit.

The following table illustrates the corresponding LOS according to the hours of service.

Fig. 3 Exhibit 3-13 Fixed-Route Hours of Service LOS (From TCQSM)

LOS	Hours of Service	Comments
A	19-24	Night or "owl" service provided
B	17-18	Late evening service provided
C	14-16	Early evening service provided
D	12-13	Daytime service provided
E	4-11	Peak hour service only or limited midday service
F	0-3	Very limited or no service

Comfort and Convenience Measures

Passenger loads reflect the comfort level of the onboard vehicle portion of transit trip both in terms of being able to find a seat and in terms of overall crowding levels within the vehicle. Passenger load LOS for bus uses square meters per passengers. This LOS can be measured by time of day or by the amount of time a certain condition occurs.

Passengers may wear or carry objects that increase the space they occupy. Because of this, One may wish to use the concept of equivalent passengers, based on the projected area values given in the following table.

Fig. 4 Exhibit 3-25 Standing Passenger Areas (From TCQSM)

Situation	Projected Area (ft^2)	Projected Area (m^2)
Standing	1.6-2.2	0.15-0.20
... with briefcase	2.7-3.2	0.25-0.30
... with daypack	3.2-3.8	0.30-0.35
... with suitcases	3.8-5.9	0.35-0.55
... with stroller	10.2-12.4	0.95-1.15
... with bicycle (horizontal)	17.2-20.4	1.60-1.90
Holding on to stanchion	2.7	0.25
Minimum seated space	2.7-3.2	0.25-0.30
Tight double seat	3.8 per person	0.35 per person
Comfortable seating	5.9 per person	0.55 per person
Wheelchair space (ADA)	10.0 (30 in x 48 in)	0.93 (0.76 m x 1.22 m)

NOTE: Stroller and bicycle dimensions are based on a review of manufacturer specifications.

If standing passenger area is not known, the following steps can be used to estimate it.

1. Calculate the gross interior floor area.
2. Calculate the area occupied by seats and other objects.
3. Calculate the standing passenger area.

Once this is obtained, the following table is used to obtain the level of service.

Fig. 5 Exhibit 3-26 Fixed-Route Passenger Load/Area LOS

LOS	Load Factor (p/seat)	Standing Passenger Area (ft^2/p)	Standing Passenger Area (m^2/p)	Comments
A	0.00-0.50	>10.8†	>1.00†	No passenger need sit next to another
B	0.51-0.75	8.2-10.8†	0.76-1.00†	Passengers can choose where to sit
C	0.76-1.00	5.5-8.1†	0.51-0.75†	All passengers can sit
D	*1.01-1.25**	3.9-5.4	0.36-0.50	Comfortable standee load for design
E	*1.26-1.50**	2.2-3.8	0.20-0.35	Maximum schedule load
F	*>1.50**	<2.2	<0.20	Crush load

*Approximate value for comparison, for vehicles designed to have most passengers seated. LOS is based on area.
†Used for vehicles designed to have most passengers standing.

On time performance should be measured at locations of interest to passengers. On time is defined for this methodology as 0 to 5 minutes late, and can be applied to either arrivals or departures. Early

departures are not considered on-time at stops where passengers board. Early departures are considered on-time only in locations where no passengers would board, such as end of route.

On-time performance would typically be measured for a route over a series of days. It takes a minimum of 20 observations to achieve the 5% resolution between LOS grades.

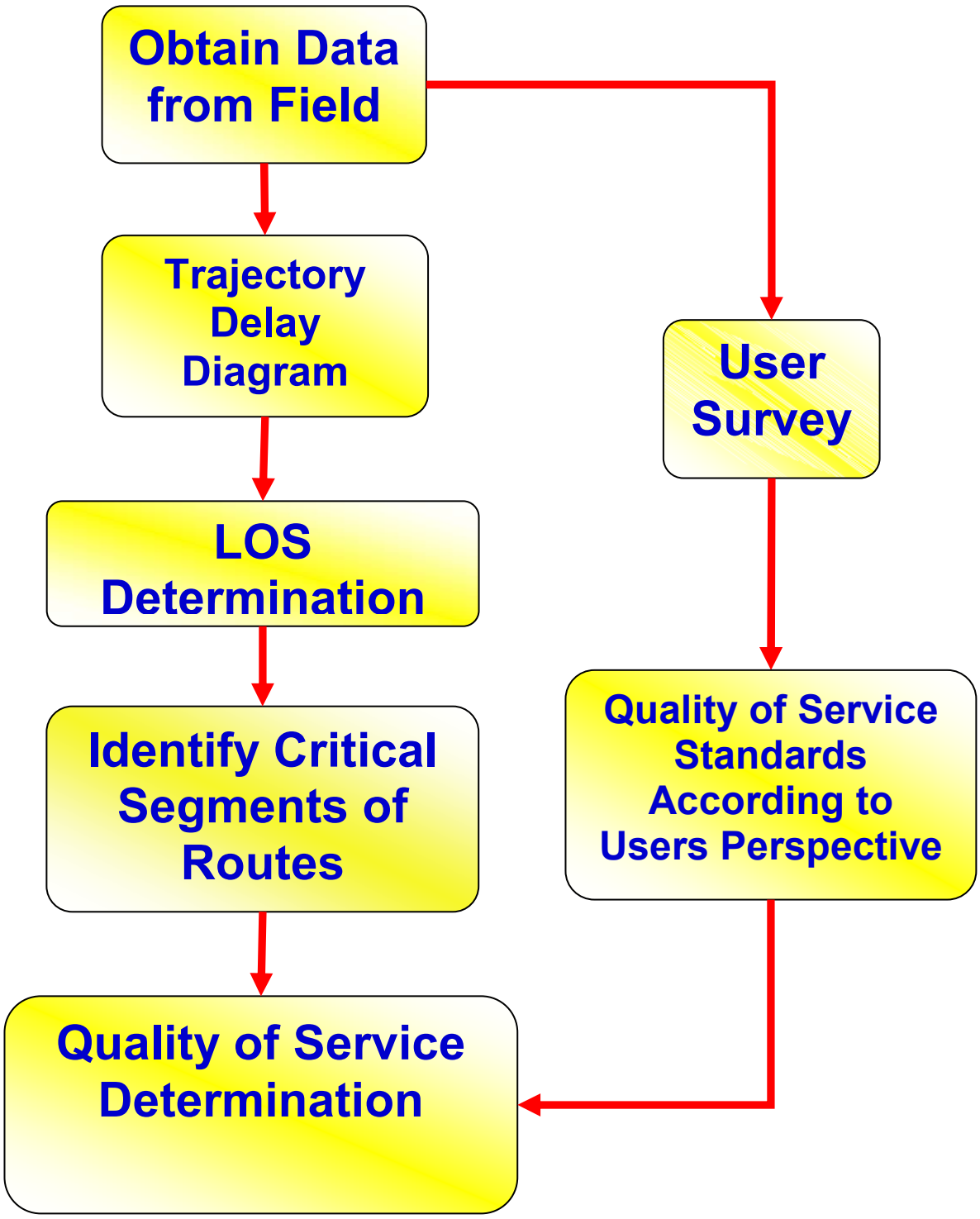
Fig. 6 Exhibit 3-29 Fixed-Route

LOS	On-Time Percentage	Comments*
A	95.0-100.0%	1 late transit vehicle every 2 weeks (no transfer)
B	90.0-94.9%	1 late transit vehicle every week (no transfer)
C	85.0-89.9%	3 late transit vehicles every 2 weeks (no transfer)
D	80.0-84.9%	2 late transit vehicles every week (no transfer)
E	75.0-79.9%	1 late transit vehicle every day (with a transfer)
F	<75.0%	1 late transit vehicle at least daily (with a transfer)

NOTE: Applies to routes with a published timetable, particularly to those with headways longer than 10 minutes.

VI. Methodology

Fig. 7



VII. Acquired Data

Technological devices may be used in order to develop frequency, headway, dwell times, and boarding and alighting data. Such devices include Automated Passenger Counters (APC) and Automatic Vehicle Location (AVL) technologies. Presently, these devices have not yet started to work efficiently on the AMA busses. For purposes of this research, such data must be acquired by visiting the field and measuring it. In the future, the methodology presented by this study may be used to obtain a quality of service measure. Following is some of the data obtained from the APC unit. However this data is still not trustworthy. The APC data was initially needed in this proyect as a means to identify routes with much ridership. However, such data can also be used for the determination of Passenger Area / Loading LOS.

Table 1. APC Output

Date	Day	Unit		Boarding	Alighting	Difference	> de 10 %	< de 10%
		APC	AMA				DIF.	DIF.
Nov 14,2005	Monday	62	2002-07	16	419	(403)	-96.2%	
		66	20001	3436	2947	489	14.2%	
		68	20003	4231	2442	1789	42.3%	
		73	20008	2024	1487	537	26.5%	
		83	20018	0	0	0		
		87	20022	3246	1790	1456	44.9%	
		112	20047	0	0	0		
		125	20060	17	366	(349)	-95.4%	
		128	20063	2624	2095	529	20.2%	

Table 2. Boarding and Alighting Measured On-Site for A-3.

Unit 20005	Arrival	Departure	In	Out	Standing	Acum.
Terminal Cataño		6:30:30	3	0	0	3
Stop Doral Bank/ HF Mortagers	6:31:55	6:31:57	1	0	0	4
Stop Plaza Cataño	6:33:03	6:33:13	1	0	0	5
Stop In front of Villa Concepcion	6:34:50					5
StopCorner. Calle Barbosa /Ponce de Leon	6:35:40	6:35:50	1	0	0	6
Stop Ponce de Leon	6:36:30	6:36:32	0	1	0	5
StopA3 Walgreens	6:37:15	6:37:28	0	1	0	4
Stop A3	6:38:14					4
Stop In front of Edif. Lexmark	6:39:16	6:39:31	5	0	0	9
Stop Amelia	6:40:19					9
Stop Banco Popular/Fed. Express	6:43:05					9
Stop in front of Terminal San Patricio	6:43:27	6:43:39	0	2	0	7
Stop. Edif Triple S	6:45:07	6:45:18	0	1	0	6
Stop despues de Edif Triple S	6:46:50	6:46:55	1	0	0	7
Stop before Borinquen Towers Plaza	6:47:51					7
Stop in front of a Subway	6:50:25	6:50:30	2	0	0	9
Stop in front of United Losetas Italiano	6:52:xx	5 seg	0	1	0	8
Stop JC Penney	6:55:30	pass				8
Stop Gasolinera Plaza las Americas	6:56:36					8
Stop en Plaza	6:57:04	6:58:30	10	1	0	17
Starbucks	6:59:51	pass				17
Stop	7:02	pass				17
Stop	7:02:25	pass				17
Denny's	7:03:30	pass				17
Stop	7:03:50	pass				17
Stop	7:05:30	pass				17
Stop	7:05:50	pass				17
DIA- Texaco	7:06:20	???	1	0	0	18
MCS	7:07:50	???	0	1	0	17
Sizzler / Doral	7:08:40		0	1	0	16
Rico H/ Mc Donalds/ La Cueva	7:09:40	7:09:48	0	1	0	15
AEE, KFC, BRASA	7:11:30	7:11:34	0	1	0	14
Stop in Ponce de Leon	7:13					14
Stop Esq. Universidad Sta.	7:14:20	pass				14
In front of A.E.E. in Ave. Ponce de Leon	7:15:22	pass				14
Stop in front of UPR	7:16:09	???	0	7	1	7
Stop Under Bridge(Ave. Gandria)	pass					7
Stop	pass					7
Stop Robles Street Perpen. William Jones	7:18:48	pass				7
						7
						7

VIII. Survey: "Survey of Quality of Service Perception of the Bus System in the San Juan Metropolitan Area"

In order to obtain the users perspective and to correlate it with the TCQSM results of LOS, a survey was conducted aiming to get a profile of the users and their perception of the quality of service of the bus system. It also served to find what the is the acceptable LOS for headway-frequency, and serves to identify what the users would find to be a critical LOS, meaning that the person would consider looking for another option of transportation.

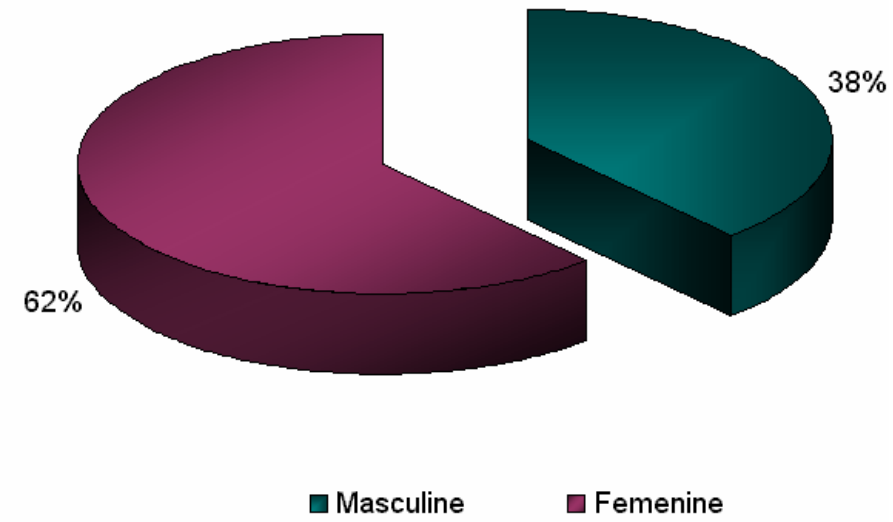
The survey consisted of 19 questions and contained a commentary section. The survey was distributed in bus stops of TU integrated bus routes. It was also handed out in randomly chosen TU stations and in the train itself. With a number of 104 surveys in total, a 10% error margin was achieved for a 95% confidence level. This was obtained by using the equation:

$$e = z_{\frac{\alpha}{2}}\sqrt{\frac{(p\times(1-p))}{n}} = 1.96\sqrt{\frac{0.5\times(1-0.5)}{100}} = 9.8\% \approx 10\%$$

The survey is included in the Appendix A.

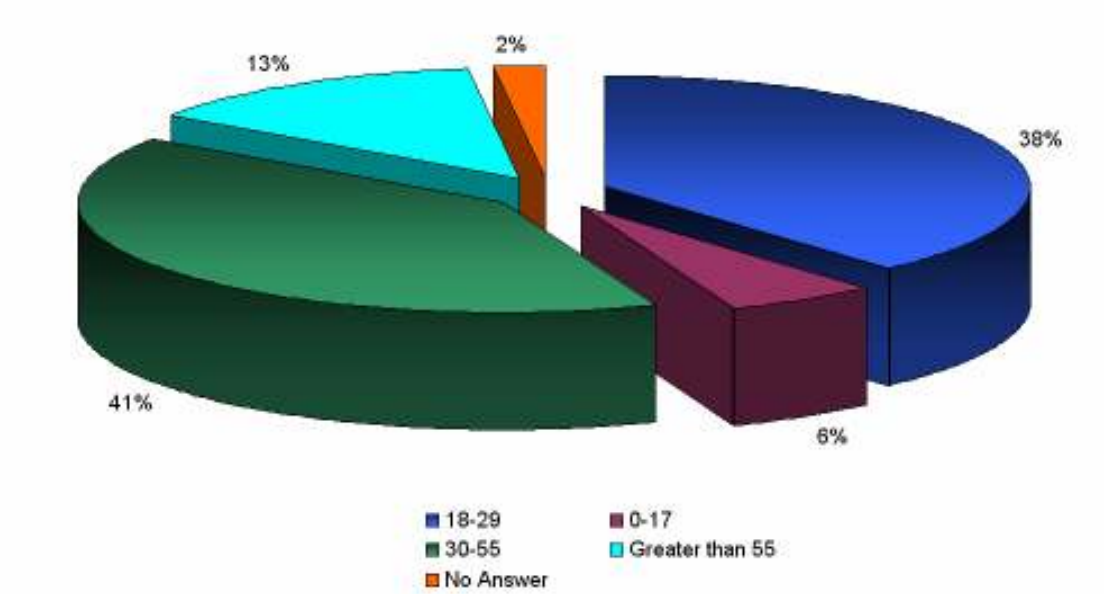
IX. Survey Results and Analysis.

Fig. 8 Results for: Gender Distribution



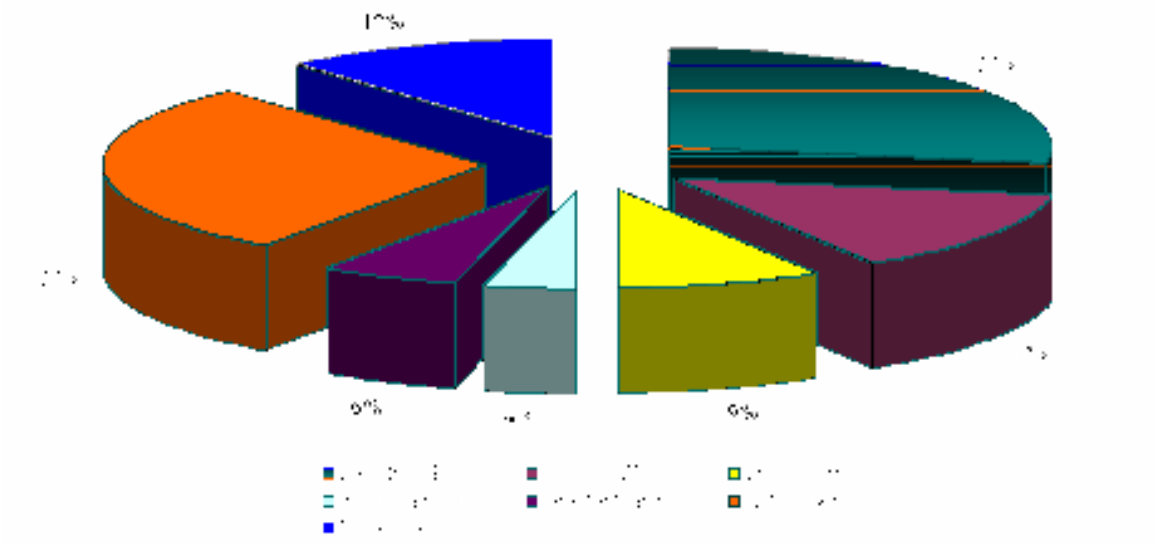
This graph shows that 62 % of the surveyed are women and 38 % are men. Such results tend to indicate that the majority of collective transportation users in SJMA are women.

Fig. 9. Results for: Age Distribution (In years)



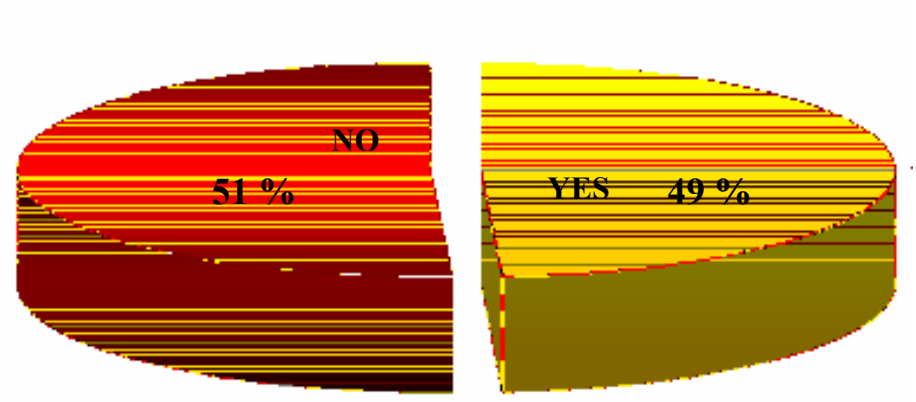
According to results, it can be appreciated that 6 % of surveyed are 17 years old or less. Also, 38 % of surveyed are young adults between the ages of 18 and 29. The majority of potential users are between the ages of 30 through 55 (41%) and of 18 through 29 (38%), meaning 79 % are adults between the ages of 18 and 55, which may comprise the working force. Still, 13% are people over the age of 55 and 2 % did not answer this question.

Fig. 10. Results for: Annual Income



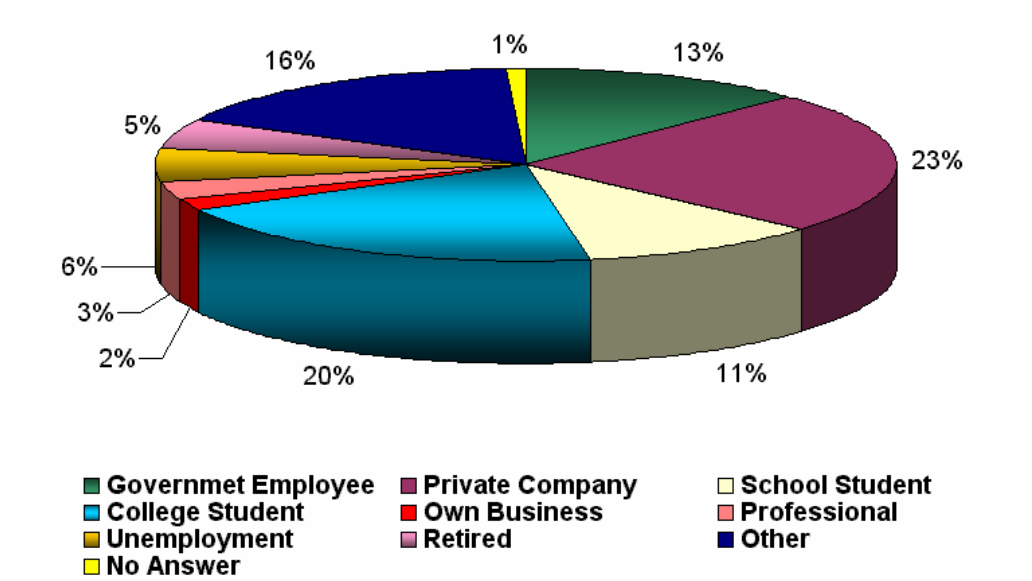
As it can be observed, 28 % of surveyed have an income lower than $10,000. A 13 % have an income within the range of $10,000 to $25,000 while 9% admit to have an income between $26,000 and $35,000. A minority of 4 % have an annual income between $36,000 and $50,000. However, 6% have an income greater than $50,000. Also, 28% do not work while a 12% gave no answer. This means at least 60% of surveyed have some kind of annual income.

Fig. 11 Results for: Do you own an automobile?



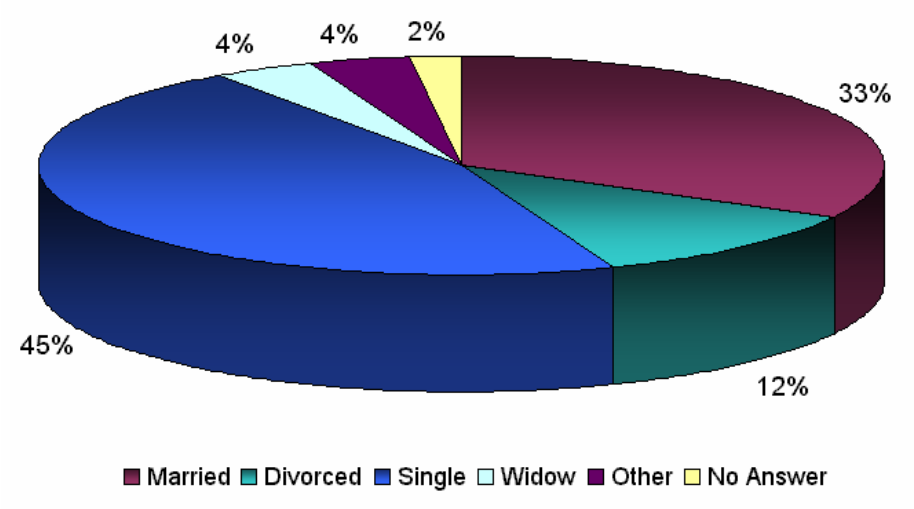
According to data, 49 % of surveyed are automobile owners while 51 % do not own an automobile. 51% could be captive riders.

Fig. 12. Results for: Occupation



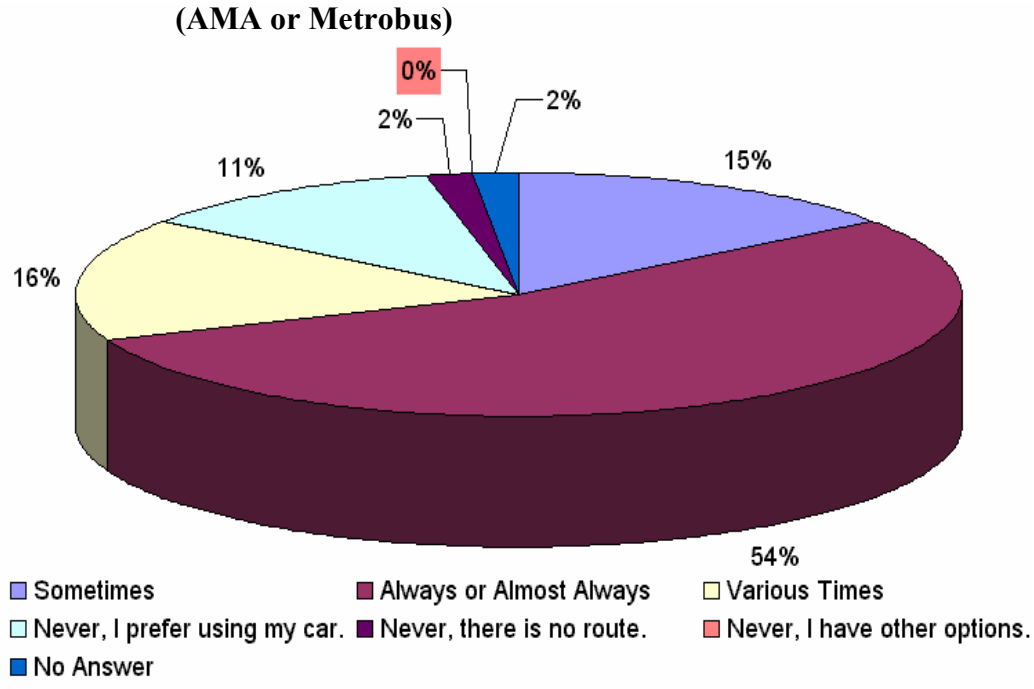
As it can be seen in the graph, 13 % of surveyed is comprised of government employees while 23 % work for a private company. An 11 % are school students and 20% are college students. 2 % are business owners, 3% are professionals (meaning doctors, engineers, etc.), 6 % are unemployed, and 16 % are retired people. Some 16 % classified themselves in the "Other" category, mostly housewives and housekeepers. Only 1% did not answer this question. Therefore, at least 41% of surveyed comprise of the working force and 31% are students.

Fig. 13. Results for: Civil Status



As for the civil status, according to data 33% are married, 12% are divorced, 45% are single, 4% are widows, 4% chose "Other", and 2% did not answer. This meaning 45% have at least been married, an equal 45% are single and 10% fall under another status.

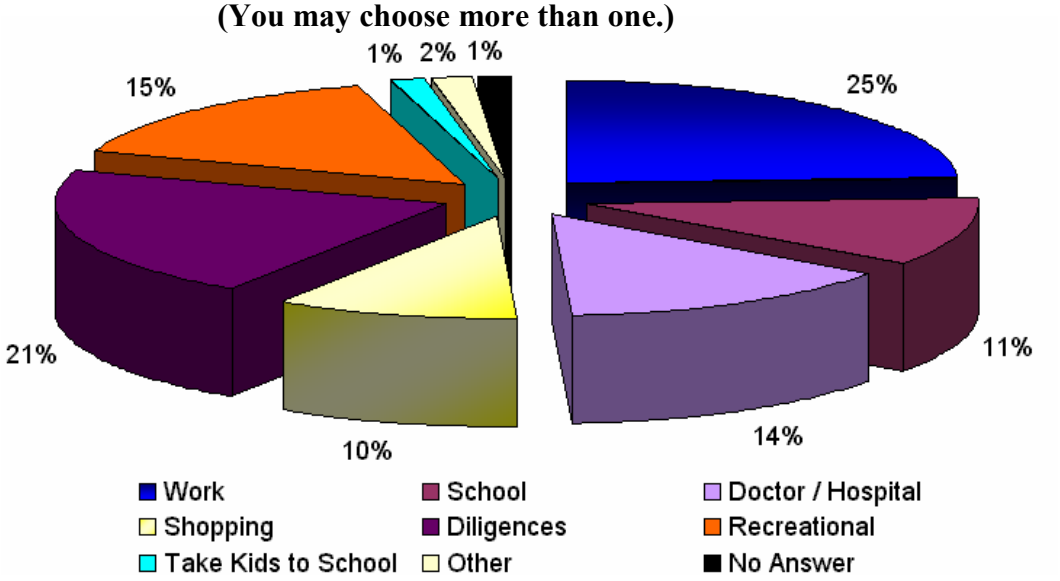
Fig. 14 Results for: How often do you use the bus service per week?



A majority of 54% answered that they use the bus system always or almost everyday. A 16 % answered they use the service various times per week, 15 % use the bus service sometimes. However, 11% never use it because they prefer using their car, 2% never use it because there is no route to his/her destination or near him/her, and 0% answered they never used it because they have other options. Still, 2% did not answer the question. Therefore, 85% use the bus system whether it is from AMA or Metrobus and 13% never use the bus system.

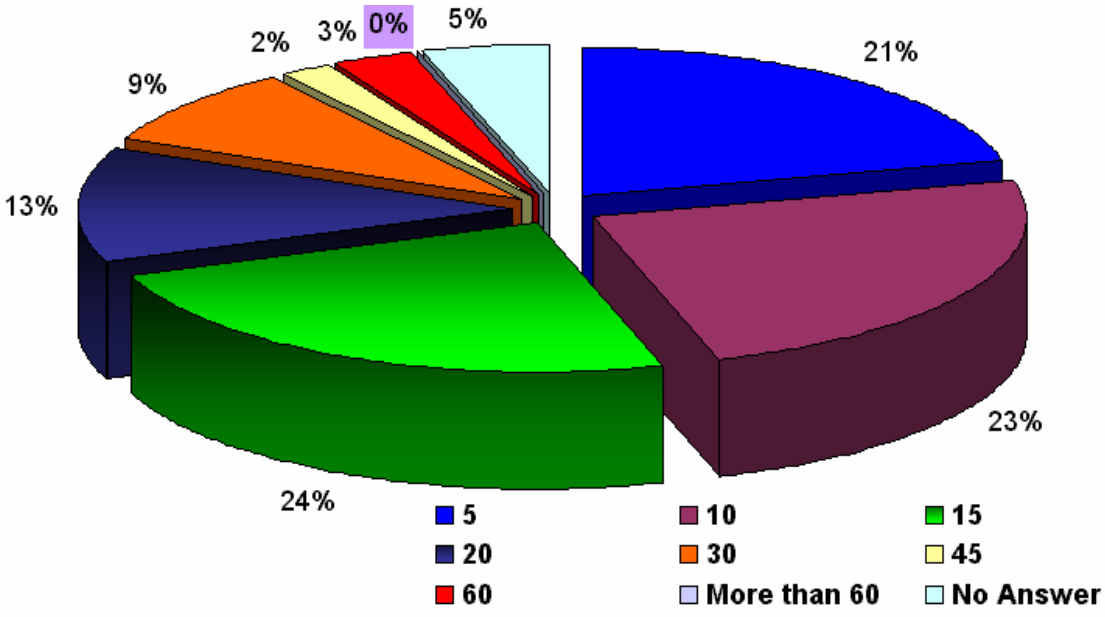
Fig. 15. Results for: What is your main purpose in collective transportation systems?

(You may choose more than one.)



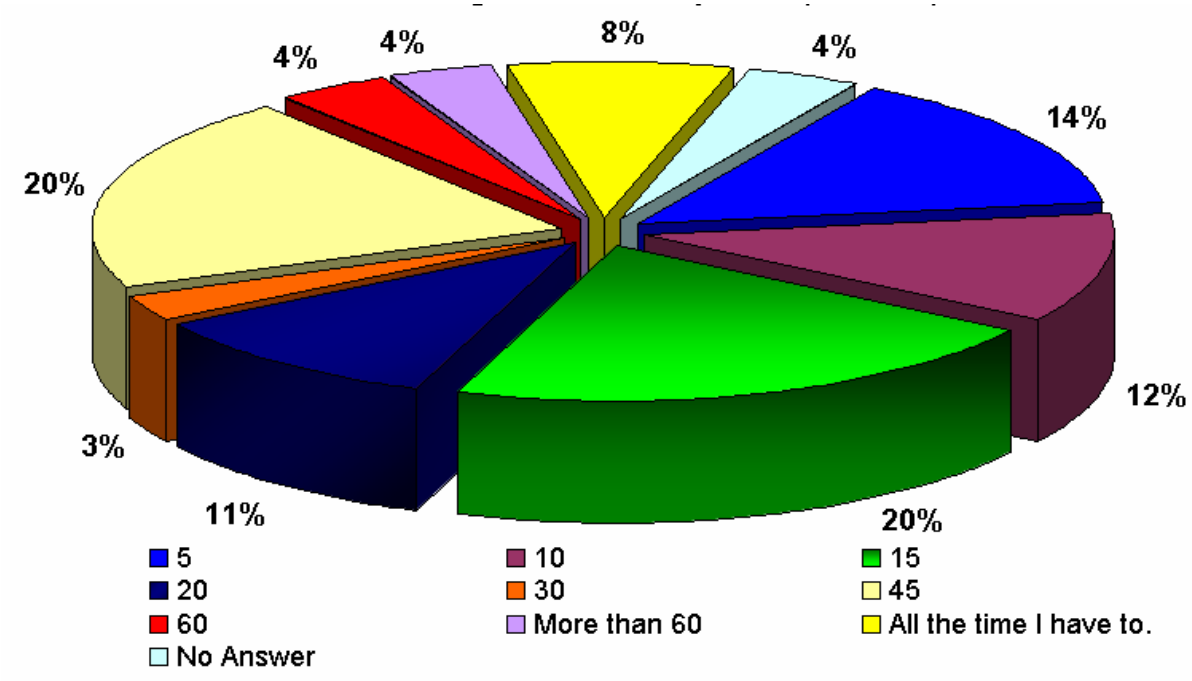
According to data, of the people surveyed 25% chose one of their main purposes of collective transportation to be for going to work, 11% to go to school, 14% use it for medical purposes, 10% use it to go shopping 21% to run diligences, 15% for recreational purposes, 1% to take the kids to school, 2 % for other purposes, and 1% did not answer the question. This means going to work is the main purpose of using collective transportation, followed by running diligences.

Fig. 16. Results for: Up to how much time do you think is acceptable to wait for a bus? (In minutes)



According to data results, 21% think 5 minutes is the acceptable time to be waiting at a bus stop, 23% think it to be 10 minutes, 24% up to 15 minutes, 13% chose 20 minutes, 9% chose half an hour, 2% think it to be 45 minutes, 3% think it to be up to one hour, 0% chose more than 60 minutes, and 5% did not answer the question. Therefore, according to the survey, 24 % believe that waiting up to 15 minutes for a bus is acceptable which is equal to a LOS B. 44 % believe a LOS A is the acceptable quality of service. A 37% only find LOS B as the maximum acceptable waiting time. A 68 % of surveyed do not consider waiting more than 15 minutes as acceptable and an 85 % consider less than LOS B as unacceptable.

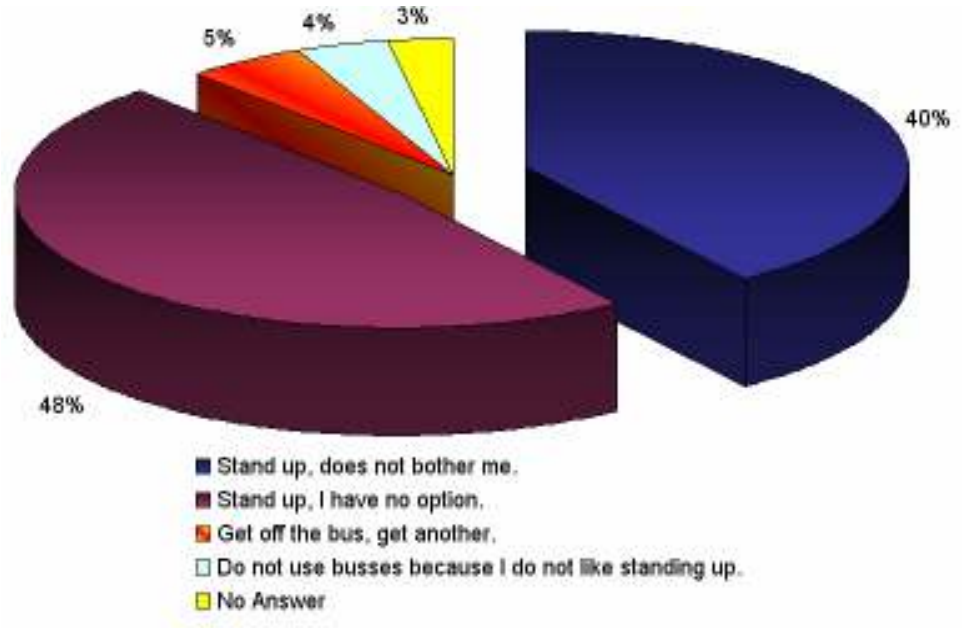
Fig. 17. Results for: Up to how much time are you willing to wait for a bus at your stop before looking for another option? (In minutes)



This question was designed to identify the critical amount of time that people thought it would take them to leave the bus stop or look for another option of transportation. According to the data collected, 14 % believe they would wait up until 5 minutes, 12 % chose 10 minutes, 20 % said 15 minutes before looking for another option, 11 % answered 20 minutes, 3 % thought 30 minutes was

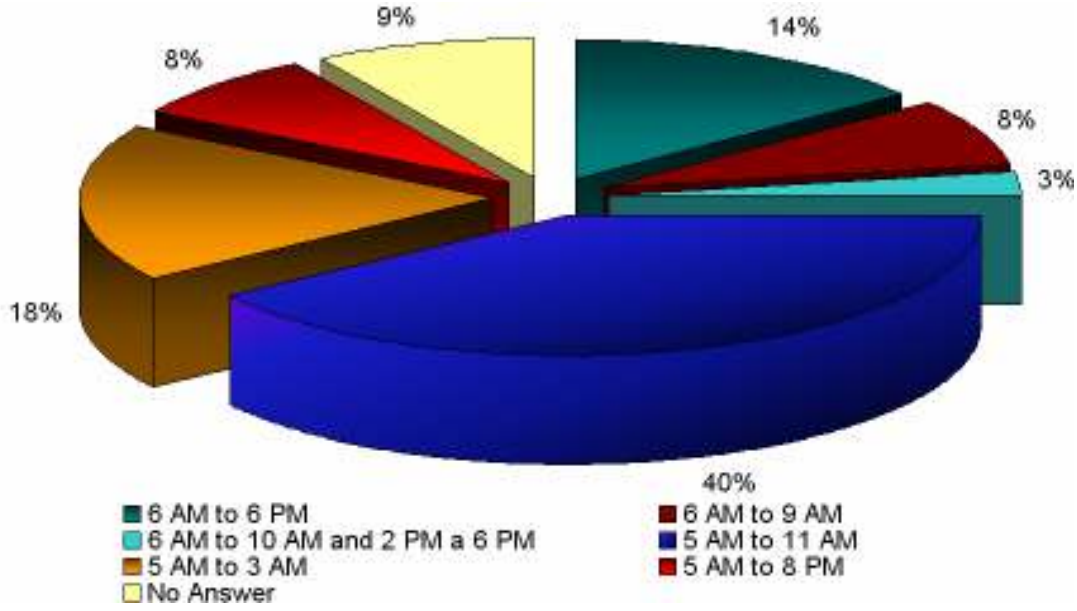
the maximum time they would wait, 20 % chose 45 minutes, 4 % chose 60 minutes, another 4% chose the "more than 60 minutes" option, 8 % answered all the time they have to wait, and a final 4% did not answer the question. Therefore, 46 % will not wait for more than 15 minutes. A 57 % do not want less than a quality LOS B. Also, 8% definitely appear to be captive riders.

Fig. 18. Results for: If when entering a bus all the seats are taken, you…



It can be observed that 88 % are willing to stay standing up in the bus, where 40% expressed they are not bothered by it and 48 % expressed they will stay in the bus because they have no option. 5 % say they will get off the bus and get another one, 4% say they will not use the bus system to avoid having to stay stand up in the bus, and 3% did not answer the question. Therefore, not having available seats is not a critical factor for riders to use the system since 88% would stay inside, as long as there is space.

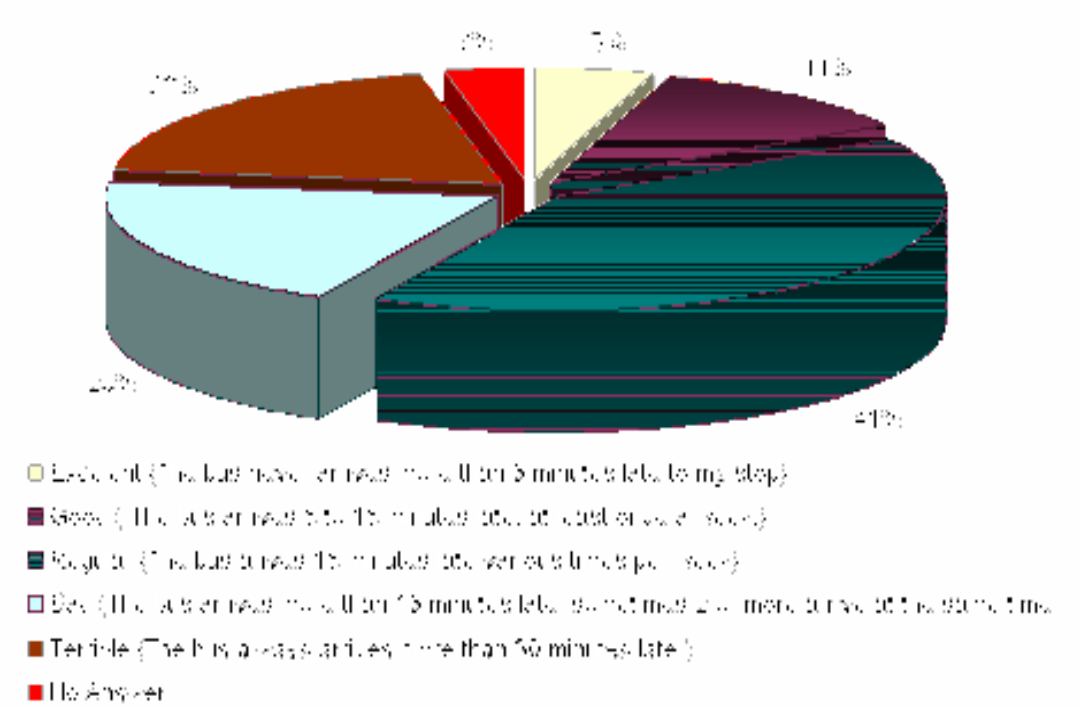
Fig. 19. Results for: What hours of service of busses will satisfy your needs?



As it can be observed, an 8 % expressed that 6 AM to 9 AM service time span will satisfy their needs. While 14 % chose the 6 AM to 6 PM option as the one that meets their needs, a 3% said 6 AM to 10 AM and 2 PM to 6PM would meet their needs. An 8% chose 5 AM to 8 PM as the hours of service that would satisfy their transportation needs, but 40 % will need a 5 AM to 11 PM service. The 5 AM to 3 AM option has an 18 % support. The question was not answered by 9 % of the surveyed.

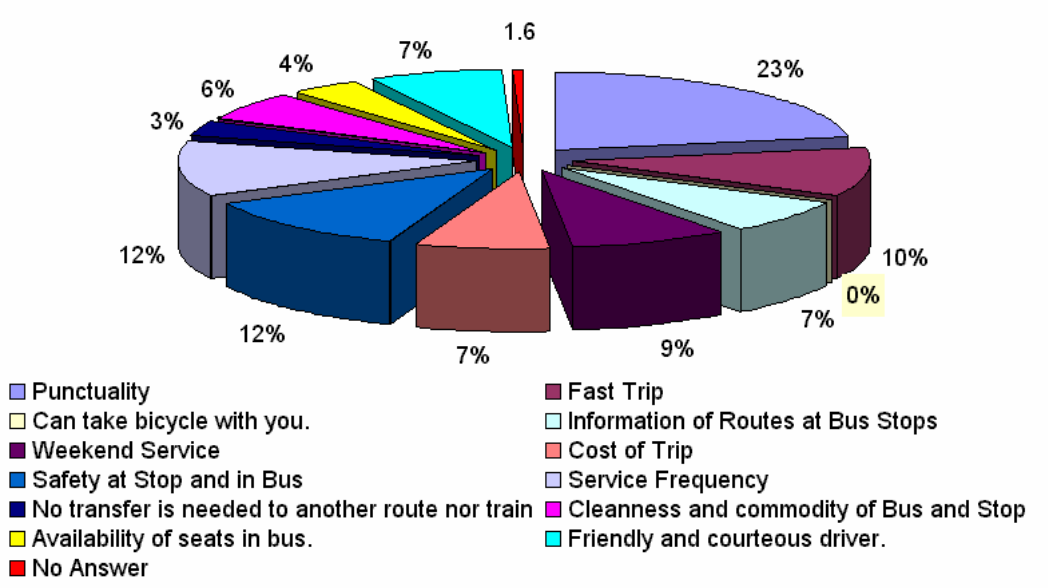
From these results, we get that the most supported time frame (40%) is that of 5 AM to 11PM. This is equal to an 18 hour span of service which is a LOS B for hours of service. Following it, is a desire for LOS A (19 – 24 hour service) with a 18% support, this being the option for a bus service until 3 AM.

Fig. 20. Results for: How would you rate the actual service offered by buses?



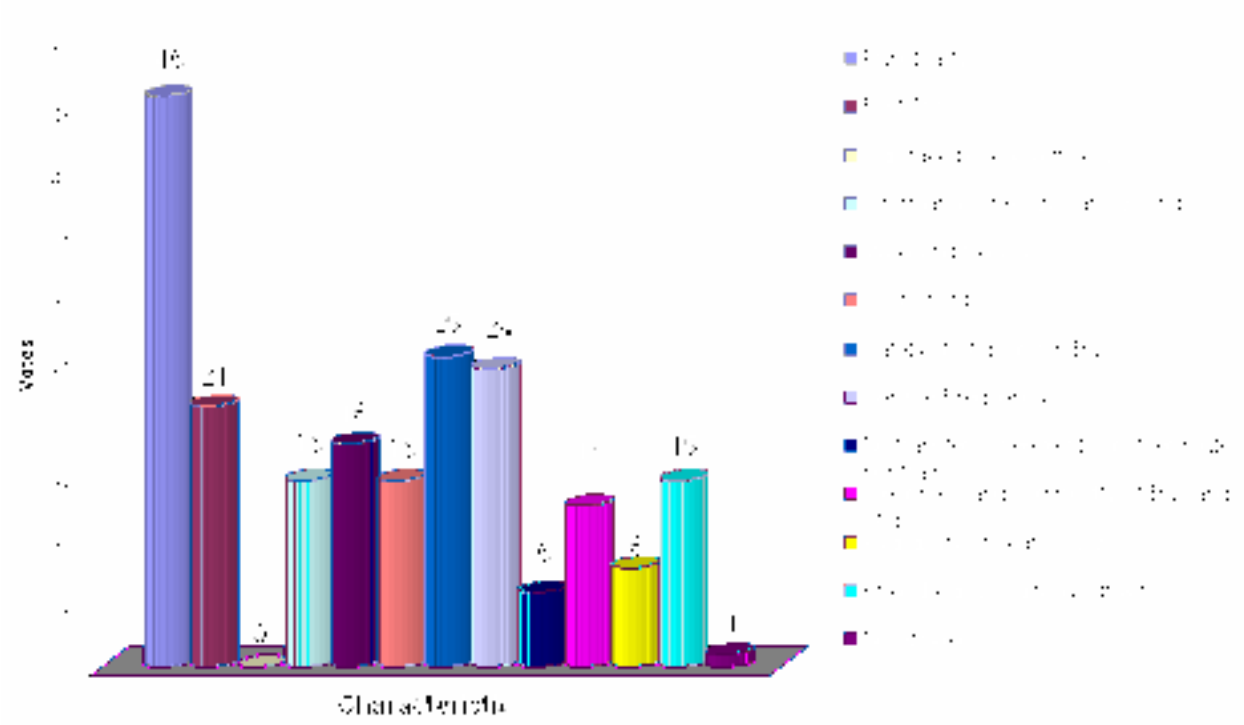
When asking about their perception of the actual service given by busses, 5% rated the service as excellent, 11% thought it to be good, 41 % said it to be regular, 20 % thought of it as bad, and an equal 20% rated it as terrible. A 3% did not answer the question. Take notice that the rating is according to the specifications given in the survey. The dominating rating is that of regular, meaning the bus arrives 15 minutes late various times per week. In addition, 40 % have a perception that the bus service is bad or terrible. This indicates that bunching occurs.

Fig. 21. Results for: Select up to 4 of the following characteristics of bus service with the most priority for you.



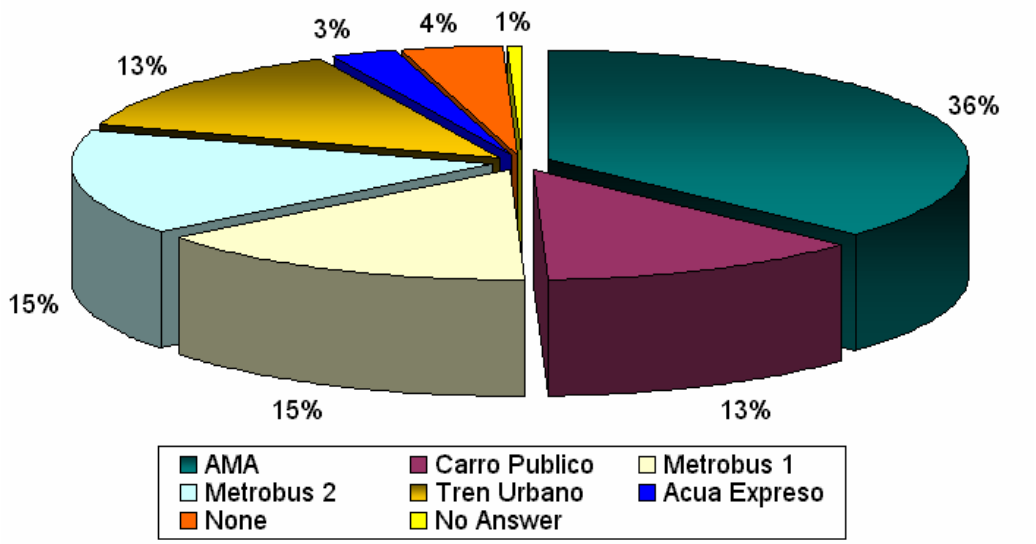
When asked to select up to 4 of the most prioritized characteristics of a bus system, 23% chose punctuality, 10 % answered a fast trip, none (0 %) opted for "can take bicycle with you", 7 % said information of routes at bus stops, 9 % thought weekend service to be a priority, and 7% chose cost of trip. Also, 12% thought of safety at stop and in bus, 12% voted for service frequency, 3% chose that no transfer is needed to another route nor train, 6% answered cleanness and commodity of bus and stop, 4% wanted availability of seats in bus, 7% marked that friendly and courteous drivers was a priority, and 1.6% did not answer the question. This leads to punctuality being the characteristic with the most priority. The following bar graph demonstrates the distribution of the characteristics.

Fig. 22. Results for: Select up to 4 of the following characteristics of bus service with the most priority for you. Bar Graph Distribution.



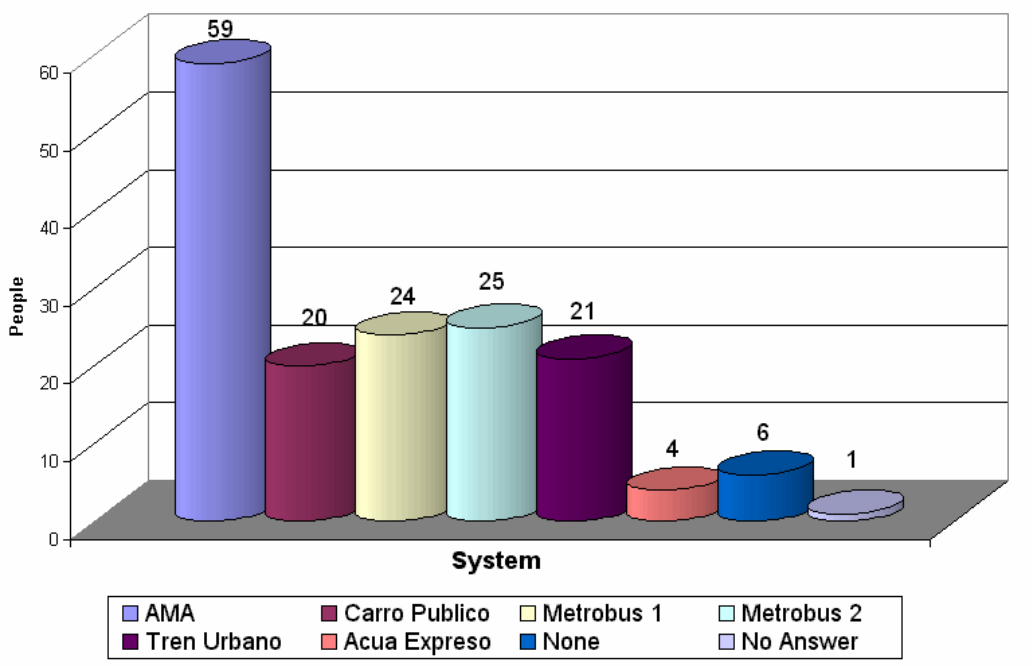
In this graph, it can be appreciated that the four bus service characteristics chosen with the most priority were, in descending order of importance, punctuality, safety at bus and in stop, service frequency, and fast trip. Of these four, punctuality, service frequency, and fast trip, are related to the LOS of quality of service.

Fig. 23. Results for: Which of the following systems of collective transportation have you used or frequently use?



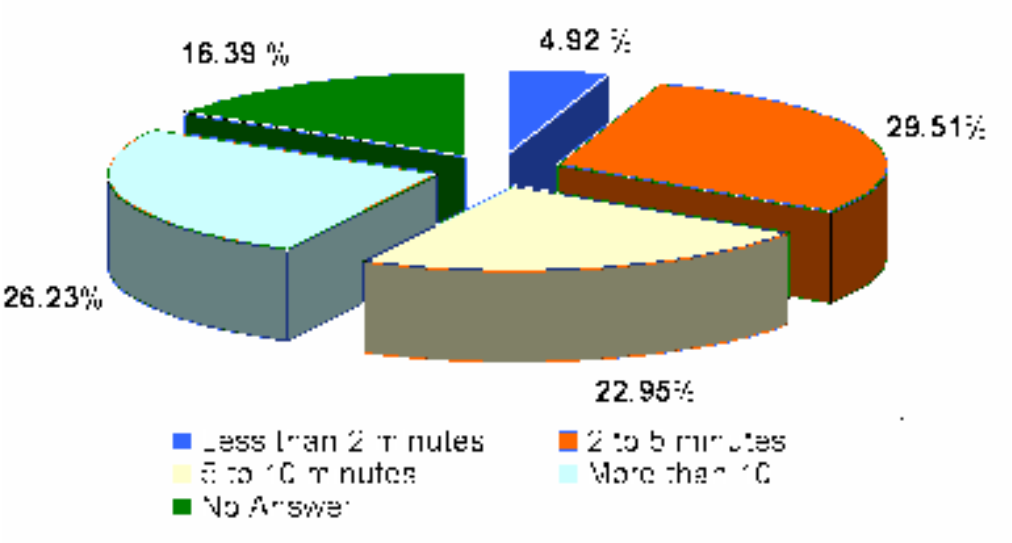
According to the results obtained, AMA is used by 36% of the surveyed, 13% ride Carro Público, 15% use Metrobus 1, 15% take Metrobus 2, 13% utilize Tren Urbano ,and a small 3% travel in Acua Expreso. However, 4% do not use any of these systems and 1% did not answer. It can be observed that Metrobus I and Metrobus II appear to have the same ridership. AMA is the most used system in the SJMA, followed by Metrobus I and Metrobus II, both used by 15%. Carro Publico and TU appear to have the same ridership as well.

Fig. 24. Results for: Which of the following systems of collective transportation have you used or frequently use? Bar Graph Distribution.



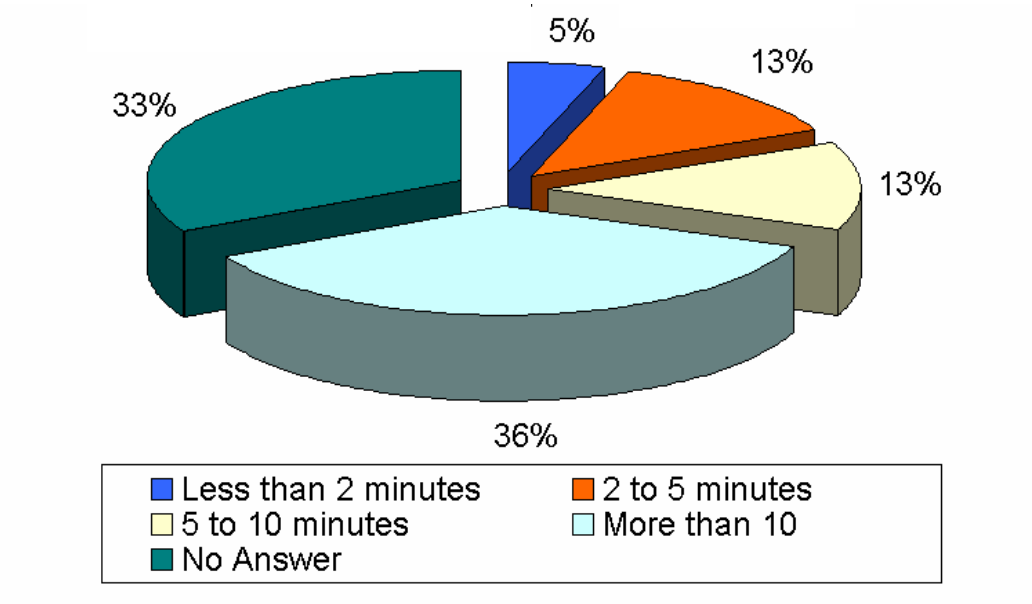
It can be seen that AMA busses are much more used than the other collective transportation systems in the SJMA. Except for Aqua Expreso, the rest of the of the systems seem to be nearly equally used. However, more surveying is recommended.

Fig. 25. Results for: How many minutes must you regularly walk to get to the bus stop of origin?



The data collected resulted in that 4.92% are less than 2 minutes away from the bus stop. Meanwhile, 29.51% are between 2 to 5 minutes away. However, 22.95% must walk between 5 to 10 minutes. In addition, 26.23% must walk more than 10 minutes and 16.39% did not answer the question.

Fig. 26. Results for: How many minutes must you regularly walk reach your point of destiny from your stop?



From the collected data, it was obtained that 5% are less than 2 minutes away from the bus stop. Meanwhile, 13% are between 2 to 5 minutes away. Equally, 13% must walk between 5 to 10 minutes. In addition, 36% must walk more than 10 minutes and 33% did not answer the question. The most traveled time from the bus stop to the point of destiny is more than 10 minutes. Also, 31% are 10 minutes or less away from their stop once they reach their point of destiny.

X. LOS for Data Results

Utilizing Figure 2 to Figure 6 that applies, according to the methodology previously explained, the following results were obtained.

A. Headway – Frequency Level of Service

Table 3. LOS Results for Frequency LOS – Sagrado Corazón Station
March 23, 2006

Route	Frequency (veh./hr)	Actual LOS	Expected LOS
A-9	2	D	A
B-17	1	E	C
B-21	2	D	C
B-41	1	E	C
M1	8	A	A
ME	2	D	A
M2	4	C	A

These results are for data logs taken during the afternoon peak hours of transit, 2:30 PM to 5:30 PM.

Table 4. LOS Results for Frequency LOS- "Domenech Station"*
April 25, 2006

Bus Route	Frequency (veh./hr)	Actual LOS	Expected LOS
A-3	4	C	B
B-17	2	D	C
B-41	1	E	C
ME	<1 (0.4)	F	A
M1	5	B	A

*Located in Ponce de León Avenue, in front of a Subway Restaurant.

These results are for data logs taken during the off-peak hours of transit, from 9:00 AM to 2:00 PM.

For data logs, see Appendix 2.

B. Level of Service for Hours of Service

Table 5. LOS Results for Hours of Service

Ruta	LOS
A-3	B
B-21	B
M-1	B
M-2	B
C-45	C

Hours of Service Level of Service was determined according to the published time table for the routes.

C. Loading / Passenger Area Level of Service

Table 6. LOS Results for Loading/Passenger Area

A-3 ROUTE	
Direction	**Average LOS**
Cataño - Río Piedras	A
Río Piedras-Cataño	F

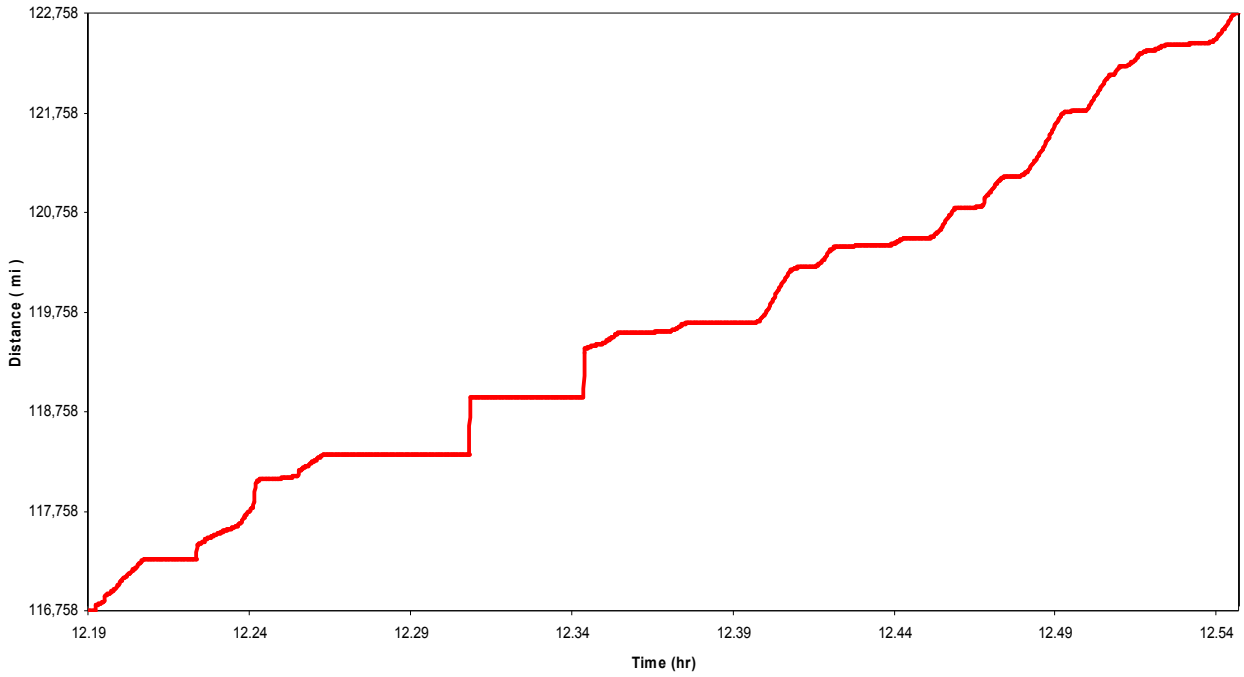
The data for loading capacity was obtained manually. Two trials were logged in the Cataño – Río Piedras direction, and one in the Río Piedras – Cataño direction. The Río Piedras –Cataño trial occurred during peak hours of the afternoon, with much loading of riders, whereas the other two trials in the other direction had much less loading per stop.

D. On Time LOS could not be measured for various reasons:

- On-Time LOS determination was not calculated.
- Only for posted scheduled- time frames.
- A minimum of 20 observations is necessary.
- No AVL bus data was made available in order to prepare time-delay graphs for the bus routes.
- The manual determination of time-delay diagrams was not possible due to various reasons.

Time-Delay Diagrams

Fig. 27. Time Delay Diagram for Metrobus II



This Time- Delay diagram is an approximate example of how it would. It was provided by Coral Torres, Group #2 ATI student. The diagram cannot be used since it has various errors (the steps in the graph).

It was not possible for this researcher to prepare such diagrams due to the lack of availability of AVL data of AMA bus routes. The use of a Global Positioning System (GPS) was tried but due to lack of signal and noise in the signal, such data could not be obtained. The need for an external antenna was a limiting factor. The GPS unit utilized was a Geo Explorer 3, from Trimble. Only 8 points were collected but were in a traffic jam.

XI. Conclusions

- Among all the routes evaluated, M-1 is the route with the best LOS for frequency and headway (LOS A) and is living up to it's expected LOS for headway-frequency and for hours of service. It has a LOS B for hours of service. According to results, M-I is offering a good quality of service.
- The selected AMA bus routes, A-3 and B-21, are not yielding the expected headway / frequency LOS. Its routes are under the expected (published) level of service (LOS B). It resulted in LOS of C and E, respectively, for headway – frequency quality of service. These routes are not living up to users' expectations since according to survey, 57% of users and potential users want nothing less than what is equivalent to a LOS C for headway- frequency, where LOS C is found to be the critical LOS for users to abandon the bus stop. As for hours of service, it is living up to most of the user's expectations since according to survey; LOS B is equivalent to what most users want. However there is a big percent that long for the equivalent to LOS A. Other AMA routes yielded LOS E for headway-frequency LOS. As for the passenger load-area LOS, the A-3 route gave LOS A in one direction and LOS F in another direction. However, more ride check data is needed in order for results to be more representative. Still, according to survey, this LOS is not so important to users.
- M-E route is under the expected headway / frequency LOS. The expected LOS is LOS A, but is yielding LOS F. This route should be evaluated more thoroughly.
- According to survey, SJMA habitants want at least a LOS B headway and consider LOS C as the critical LOS to abandon the service..
- A late-night (11 PM) to all day service is wanted, Hours of Service. Actual LOS B gives hours of service until 10 PM. The time span should be expanded.
- Loading passenger areas LOS not so critical since the majority chose to stay in bus.
  It is among the last priorities of users.

XII. Suggestions of Future Research

This project evaluated LOS for selected bus routes and opens a gateway to suggest new research studies. It is suggested to analyze the necessity of adding more buses and increase headways to connecting routes to TU (A-3 and B-21). Study and evaluate the LOS competence (capacity, seating facilities, stop identification, route information) of bus stops.

It is suggested to use First Transit (M-1) service as benchmark for AMA routes because it offered a very good frequency- headway LOS.

XIII. Tasks Performed

	2005																2006															
ACTIVITY	October				November				December				January				February				March				April				May			
Literature Review																																
Interviews : AMA/ATI																																
Hand In Proposal			26																													
Proposal Presentation			29																													
Progress Report									3																							
Bus Data Collection- On Site							23										9						23				25					
Survey Preparation																																
Survey																																
Analysis of Survey																																
Analysis of Results																																
Poster Preparation																																
Poster																													6			
Preparations Final Report																																
Final Final Report																														16		

Yellow- Proposed Green- Done

XIV. References

1- Luyanda, F.; (August 2005); **Integración del Transporte Público**; ATI Presentation

2- Rivera Medina, V., (2004);**The Elderly and Handicapped population and their potential as a market for the Tren Urbano**

3- Ryus, P; Ausman, J; Teaf, D; Cooper, M; Knoblauch, M., (2000), **Development of Florida's Transit Level-of-Service Indicator.** pp. 123-129. TRB Publications.

4- Arroyo Miranda, H.; (2004); **La Percepción de los Usuarios Potenciales para el Desarrollo de Estrategias de Mercadeo para Tren Urbano y ATI**

5- Estrella Colon, M.; (2001); **Analysis to Identify and Evaluate Strategies to Increase Urban Rail Transit Ridership**

6- Chu X.; **Ridership Models at the Stop Level**; National Center for Transit Research, http://www.nctr.usf.edu

7- Transportation Research Board; (2000); **Highway Capacity Manual 2000**

8- Lacourt, M.; (2004); **Bayamon Station and its Surroundings: Desirable Characteristics Needed to Attract Non-Metropolitan Potential Riders**

9- Transportation Research Board; (January 1999); **Transit Capacity and Quality of Service Manual**

10- Torres, C. ;(2006)**Estudio de Viabilidad para Implantación de sistemas Inteligentes de Transportación en la Autoridad Metropolitana de Autobuses**. Professional Development Program.

APENDIX 1

ENCUESTA DE PERCEPCIÓN DE LA CALIDAD DE SERVICIO DEL SISTEMA DE AUTOBUSES EN EL ÁREA METROPOLITANA DE SAN JUAN

Los **objetivos** de esta encuesta son:

1. Obtener un perfil del usuario típico del sistema de autobuses (AMA y Metrobús).
2. Identificar la percepción y la preferencia del usuario acerca de la disponibilidad, eficiencia y calidad de servicio del sistema de autobuses.

Instrucciones: Por favor conteste cada pregunta en el espacio provisto utilizando su juicio y experiencia con el sistema de guaguas. Algunas de las preguntas requieren que marque más de una alternativa.

I – INFORMACIÓN GENERAL

1. **Género** ____ Masculino ____ Femenino
2. **Edad** ____ años
3. ***Estado Civil***

___ Soltero(a) ___ Casado(a) ___ Divorciado(a) ___ Viudo(a) ___ Otro: _____

4. **Ocupación**

___ Estudiante de escuela ___ Empleado(a) de gobierno ___ Negocio propio (mecánico, vendedor, etc.)
___ Estudiante universitario ___ Empleado(a) empresa privada ___ Profesional (abogado, doctor, ingeniero, etc.)
___ Retirado(a) ___ Desempleado(a) ___ Otro (favor indique) _____

5. **Ingreso personal anual**

___ menos de $10,000 ___ $26,000 - $35,000 ___ más de $50,000
___ $10,000 - $25,000 ___ $36,000 - $50,000 ___ No trabajo

6. **¿Cuantas personas viven con usted? (no se incluya en el total):** _____ personas
7. **Nivel escolar (último grado escolar completado)**

___ Escuela elemental o intermedia ___ Grado asociado ___ Escuela graduada
___ Escuela superior o vocacional ___ Bachillerato ___ Otro: _____

8. **¿Tiene automóvil propio?** ____ Sí ____ No
9. **Lugar de residencia:** _____ Pueblo _____ Barrio o sector
10. **¿Cuál de los siguientes sistemas de transporte colectivo ha utilizado o utiliza frecuentemente?**
Puede seleccionar más de uno.

___ AMA ___ Metrobús I ___ Tren Urbano
___ Carros públicos ___ Metrobús II ___ Acuaexpreso ____ Ninguno

11. **¿Con que frecuencia utiliza el servicio de guaguas (AMA o Metrobús)?**

___ NUNCA porque prefiero usar mi auto ___ Algunas veces al año (cuando se daña mi auto)
___ NUNCA porque tengo otra opción (Público, pon, etc.) ___ Varias veces al mes
___ NUNCA porque no hay ruta de guaguas disponible donde vivo o a donde quiero ir ___ Casi o todos los días

12. ¿Cuál(es) es(son) el(los) propósito(s) principal(es) de sus viajes en transporte colectivo? Puede marcar más de una.

___ Ir al trabajo ___ Ir al médico / hospital ___ Hacer diligencias ___ Llevar niños a la escuela
___ Ir a la escuela (univ.) ___ Ir de compras ___ Recreativo ___ Otro: _____

13. ¿Cuántos <u>minutos</u> regularmente tiene que caminar para llegar a la parada de guagua?

ORIGEN DEL VIAJE ____ menos de 2 ____ de 2 a 5 ____ de 5 a 10 ____ más de 10

DESTINO DEL VIAJE ____ menos de 2 ____ de 2 a 5 ____ de 5 a 10 ____ más de 10

II – CALIDAD DE SERVICIO DEL SISTEMA DE AUTOBUSES

14. ¿Hasta cuánto tiempo cree usted que es <u>aceptable</u> esperar por una guagua?

___ hasta 5 minutos ___ hasta 20 minutos ___ hasta 60 minutos
___ hasta 10 minutos ___ hasta 30 minutos ___ más de 60 minutos
___ hasta 15 minutos ___ hasta 45 minutos

15. ¿Hasta cuánto tiempo está usted dispuesto a esperar por que llegue la guagua a su parada antes de buscar otra alternativa?

___ hasta 5 minutos ___ hasta 20 minutos ___ hasta 60 minutos ___ todo lo que tenga que esperar, no tengo otra opción
___ hasta 10 minutos ___ hasta 30 minutos ___ más de 60 minutos
___ hasta 15 minutos ___ hasta 45 minutos

16. Si al entrar al autobús todos los asientos están ocupados, usted:

_____Se queda de pie, no le molesta. _____Se baja de ese autobús y espera por otro.
_____Se queda de pie, pues no tiene otra opción. _____No utilizo el sistema por no estar de pie dentro de la guagua.

17. ¿Cuál horario debe ofrecer el servicio de guaguas para satisfacer sus necesidades?

___ **de 6 a 9 AM** (sólo durante las horas de mayor tráfico en la mañana) ___ **de 5 AM a 8 PM** (hasta temprano en la noche)
___ **de 6 a 10 AM y de 2 a 6 PM** (sólo durante las horas de mayor tráfico en la mañana y la tarde) ___ **de 5 AM a 11 PM** (hasta tarde en la noche)
___ **de 6 AM a 6 PM** (sólo durante el día) ___ **de 5 AM a 3 AM** (hasta la madrugada)

18. Seleccione hasta <u>cuatro</u> características del servicio de guaguas con mayor prioridad para usted.

___ Puntualidad de las guaguas ___ Seguridad en las paradas y guaguas
___ Viaje rápido (menos paradas en la ruta) ___ Frecuencia del servicio (tiempo de espera)
___ Que pueda llevar su bicicleta con usted ___ No se necesite transferencia a otra ruta o al tren
___ Información de rutas disponibles en las paradas ___ Limpieza y comodidad de las paradas y guaguas
___ Servicio durante los fines de semana ___ Disponibilidad de asientos dentro de la guagua
___ Costo del viaje ___ Chóferes de guaguas amigables y corteses

19. ¿Según su experiencia, cómo describe la calidad actual del servicio ofrecido por las guaguas?

___ Excelente (la guagua nunca llega más de 5 minutos tarde a mi parada)
___ Bueno (la guagua llega de 5 a 15 minutos tarde al menos una vez a la semana)
___ Regular (la guagua llega 15 minutos tarde varias veces a la semana)
___ Malo (la guagua llega más de 15 minutos tarde, a veces llegan dos o más guaguas a la vez)
___ Pésimo (la guagua siempre llega más de 30 minutos tarde)

Comentarios: _____
_____
_____.

Muchas gracias por su colaboración

Puede llamar al (787) 265-5695 en el Departamento de Ingeniería Civil y Agrimensura del UPR-RUM para cualquier pregunta o comentario acerca de este estudio.

APENDIX 2

February 9, 2006 Ride Check Boring Log

Description of Stop	Arrival	Departure	In	Out	Standing	Acum.
Unit 20005						
Terminal Cataño	3:23	3:25	9	0	0	9
Stop	3:26	3:26:10	1	0	0	10
Stop Plaza Cataño	3:28	3:28:10	3	0	0	13
Stop	3:29	Passing by	0	0	0	13
Stop In front of Villa Concepcion	Passing by	Passing by	0	0	0	13
Stop Esquina Ponce de Leon	3:31	3:31:05	0	1	0	12
Stop Ponce de Leon Esq. Munoz Rivera	3:31	3:31:15	3	1	0	14
Esquina Walgreens (Amelia)	3:33	Passing by	0	0	0	14
Stop	3:33	Passing by	0	0	0	14
Stop In front of Edif. Lexmark	3:35	3:35:15	0	0	0	14
Stop Packaging Unlimited Inc. Centro de Distribucion Amelia	3:38	Passing by	0	0	0	14
Stop.	3:39 = 4:03:48	Passing by	0	0	0	14
Stop. V. Suarez Co.	4:04:30	4:04:45	0	2	0	12
Stop. Edif Triple S (Roosvelt)	4:06:30	4:06:40	1	1	0	12
Stop Ave. Roosvelt Front of Subway	4:07:51	4:08:06	1	1	0	12
Stop Cerca Casa Knuecas	4:08:52	4:09:00	0	2	0	10
Stop In front of Texaca y Fambi	4:10:15	pass	0	0	0	10
Stop Perpendicular Constitucion en Roosvelt	4:10:50	pass	0	0	0	10
In front of BBVA Mortage en Ave. Roosvelt	4:11:27	4:11:34	1	0	0	11
Stop Ital Ceramics	4:12:28	pass	0	0	0	11
Front of Correo near Roberto Clemente	4:13:18	Passing by	0	0	0	11
Ave. Plaza las Americas	4:16:28	4:16:51	1	4	0	8
Stop Plaza las Americas Esquina Gulf	4:17:45	4:18:10	5	0	0	13
Stop. de Espalda a Sears	4:19:20	4:19:30	2	0	0	15
Stop Cerca de Starbucks Café	4:21:37	pass	0	0	0	15
Stop	4:22:36	4:23:09	4	0	0	19
Stop en calle "Ciudad San Germán"	4:23:39	4:23:55	0	1	0	18
Stop	4:27:55	4:28:05	0	3	0	15
Stop A-3?? …check			0	0	0	15
Stop Dunkin Donuts	4:30:00	4:30:11	2	0	0	17
Stop Centro Transf. Hato Rey	4:30:50	4:31:00	0	4	0	13
Stop	4:31:50	4:31:58	0	1	0	12
Stop en Ave. Ponce de Leon	4:32:28	pass	0	0	0	12
Stop en Ave. Ponce de Leon	Passing by		0	0	0	12
In front of A.E.E. en Ave. Ponce de Leon	4:33:19	4:33:45	0	2	0	10
Stop Esq. Ponce de Leon (near Piñero Sta.)	4:34:00	pass	0	0	0	10
Stop	4:37:47	4:38:00	0	1	0	9
Stop	4:38:50	pass	0	0	0	9
Stop NO A-3	4:39:18	4:39:28	1	0	0	10

Stop	Passing by		0	0	0	10
Stop Bajo Puente Ave. Gandria	4:40:10	4:40:23	0	3	0	7
Stop Ave. Gandria	4:41:00	4:41:10				7
Stop Justo before de Terminal	4:42:30	4:42:39	0	4	0	3
Terminal Rio Piedras	4:43:28		0	3	0	0
Coordenadas R. Piedras						
18^{0}24'7.075"N						
66^{o}02'41.981"W						

Ride Check Log – February 9, 2006

Unit20043 (40 seats)	Arrival	Departure	IN	OUT
Terminal Rio Piedras		4:59:16	18	0
Stop Univ Rio Piedras	5:02:38	5:03:25	6	0
Stop Univ Rio Piedras	5:03:56	5:04:31	6	0
Stop Univ Rio Piedras Entrada	5:05:18	5:05:38	2	0
Stop Sta. Universidad	5:06:16	5:06:20	1	0
Stop A3	5:07:30	5:08:05	5	0
Stop Cerca Parking Est. Piñero	5:09:25	5:09:30		
Stop Cerca Est. Piñero Ave. Muñoz Rivera	5:10:13	5:10:29	3	0
Stop In front of Subway	no pude tomar		3	0
Stop A3	5:12:10	5:12:18	2	0
Stop Luis Muñoz Rivera (Pegado a Oficinas PNP)	5:12:50	5:12:59	0	1
Stop A-3 before de American International Plaza	5:15:25	5:17:05	5	0
Stop	5:17:57	5:18:36	5	0
Stop before de Denny's	5:19:29	5:20:14	3	0
Stop	5:20:56	5:21:38	0	2
Stop	5:22:30	5:22:37	1	1
Stop	pass		overcapacity	
Stop	5:28:55	pass	overcapacity	
Stop	5:34:08	5:35:00	-	-
Stop	5:37:41	5:37:49	-	-
Stop (Pto #8 GPS en (A3 TAPON)	5:40:35	5:40:45	-	-
Stop Roosevelt Perpendicular Calle 19	5:43:00	5:43:10	-	-
Stop A3 Cafeteria La Ceiba	5:44:49	5:44:53	-	-
Stop before de Triple S	5:47:06	5:47:11	0	1
Stop Triple S	5:47:49	pass		
Stop Mc Donalds	5:49:35			
Stop San Patricio	5:51:13	5:51:31		
Stop Edif. Buchanan	5:53:19	pass		
Stop A3 Buchanan	5:55:29	pass		
Stop In front of a Walgreens	6:00:00	pass		
Stop Ave. Ponce de Leon Beginning	pass			
Stop A3 Ave Ponce de Leon	pass			
Stop A3	pass			
Stop A3 Calle Paparra Perpendicular Wilson St.	6:04:43	6:04:49		
Stop A3 Stop –you can see the sea	6:05:47	6:05:54	0	8
Stop A3 Cataño next to sea	6:06:36	6:06:48	Asking something.	
Stop A3	6:07:48	6:07:55	0	2
Terminal Cataño	6:15:00			
Coordinates Terminal- Cataño	taken 5:56 pm cell phone			
66°07'29.815"				
18°27'0.615"				