ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Hybrid Mass Transportation: A Portland Area Case Study Using QFD

Course Title: Management of Engineering and Technology
Course Number: EMGT 520 / 620
Instructor: Dr. Tugrul Daim
Term: Winter
Year: 2009
Author(s): Nick Wallace, Naresh Bokka, Brian Muchilwa, Majed Ah, Huang Chaio Yu

Abstract

Mass transportation has been growing over time, but it is not being utilized to its full potential. Using Portland as the case study we would try to develop a system that would help increase the ridership of the existing transport system. The main problem we are addressing is that the train or Trimet is not able to serve the passengers who live or work far away from the max stations. There could be many reasons why someone would not want to use public transportation, including rush at the peak hours, safety and other problems. So, in this paper we have developed a framework to design a system that relys on what the customer needs are using the QFD model.

Our task is to implement an innovative transport system, which consists of multiple riders with a custom pickup and drop off solution with the goal of increasing mass transport usage.

The project supports the public transportation mission to work cooperatively to provide safe, reliable and efficient movement of people. In this case we are trying to improve upon the present transportation solutions there in the market based on the user suggestions through surveys by implementing QFD. The solution to increase transit ridership is to provide them a transport solution which would take them from where they are to where they want to go at the time they want to go with high speed of travel and with a very high frequency with reliability in a safe and healthy environment.

The goal for the team was to develop and test a framework for developing a hybrid transport system. One of the concerns that we wanted to address was that the current transport systems suggested a need for a ‘transition’ or radical systemic change towards sustainable transport [18]. Due to the potentially radical nature of hybrid mass transport systems, the slow moving pace of innovation in the transportation industry, and the high-cost, high-risk nature of transportation capital projects, we wanted to ensure that the framework produces value propositions that are likely to succeed.
Various tools were adopted in the development of a framework for capturing value the first being the gap analysis tool. Another tool used was the technology acceptance model (TAM) proposed for acceptance of information technology [19]. (Appendex 13) The TAM itself, is a derivative of the theory of reasoned action, was used in the framework because of the proposed hybrid systems inherent reliance on information systems. We also utilized the quality function development process (QFD), a quality tool and planning method developed to integrate customer requirements into product design [20].
The framework was used in a case study of the Portland metro area to determine the viability of such a system in the region.

The mission of mass transit is to increase the mobility of the residents, by paying more attention to transport requirements for people who are able to provide their own transport. Transit users are divided into 2 groups:

1) Transit Dependent Users: This group consists of old and physically challenged people and also by people who do not have access/ability to drive an Automobile.
2) Choice Riders: This Group consists of People having access and ability to drive an automobile.

Although in the real world, there are many shades to a pure transit dependent and pure choice rider. There are many factors that come into play like availability, quality and price for a person to be a pure transit dependent or a choice rider.

As per APTA (American Public Transportation association) [7] a public transportation rider in Portland, can save up to $8,988 annually by taking public transit instead of driving based on march 5, 2009 gas prices and the unreserved parking rate. In addition to the annual transit saving, commuters riding public transit are eligible to receive a maximum transit benefit of $230 per month increased from $120 per month from the employer. The change is a part of the economic stimulus package passed by congress and signed into law by president Obama. APTA's "Transit saving Report" calculates this month's savings for the public transit users in Portland at $749 per month based on the gas price of $1.933 as reported by AAA are still $1.245 lower than last year. Given below is the report replicated from the article published in form of table" Top Twenty Cities – Transit Saving Report"

Top Twenty Cities – Transit Savings Report

	City	Monthly Savings	Annual Savings
1	Boston	$1,036	$12,428
2	New York	$1,032	$12,390
3	San Francisco	$960	$11,516
4	Chicago	$875	$10,497
5	Philadelphia	$861	$10,333
6	Seattle	$856	$10,274
7	Honolulu	$836	$10,033
8	Washington DC	$794	$9,530
9	San Diego	$772	$9,268
10	Minneapolis	$766	$9,198
11	Cleveland	$755	$9,064
12	Portland	$749	$8,988
13	Denver	$734	$8,811
14	Baltimore	$720	$8,635
15	Los Angeles	$701	$8,416
16	Miami	$685	$8,222
17	Dallas	$681	$8,169
18	Las Vegas	$675	$8,105
19	Atlanta	$669	$8,033
20	Pittsburgh	$630	$7,556

Methodology involved here is as follows: APTA calculates the average cost of taking public transit by determining the average monthly transit pass of local public transit agency across the country. The assumption is that a person making a switch to public transportation would likely purchase an unlimited pass on the local transit agency, typically available on a monthly basis. APTA compares the monthly average transit fare to monthly average cost of driving. The cost of driving is derived from 2008 AAA cost of driving formula. AAA cost of driving consists of cost of gas, maintenance and gas. Fixed cost includes insurance, license registration, depreciation and finance charges. APTA also has a website where one can calculate individual saving with or without car ownership.

So basically what transit can do is provide transit to transit dependent. If a certain choice rider wants to use transit, and it's good for them, we certainly should not push them away. However, the worst thing about transit for the choice rider is that it cost more to use transit than his own vehicle, unless he is provided everything he wants in transit system. In order to attract a choice rider, he/she must be presented with a transit option that goes from where he/she is to where he/she wants to go, when he/she wants to go, at a high speed of travel, with high trip frequency, in a comfortable environment, and with a very high reliability.

We studied several different existing systems to become more knowledgeable on the possibilities of a hybrid transport system. The following sections are brief summaries of the systems that we researched.

1) Dial a Bus (Demand – Activated Bus System) :

A major failing of the public urban transportation today is its inability to provide adequate services in lower density areas. In some parts of the urban area or small city the travel demand is too small to support any kind of transit operation hence is economically infeasible. Rail systems are expensive and technological not suited for low volume of demand. Ordinary buses cannot maintain frequency for such low volume of travel demand. Thus what is needed is a dynamic public transit system responding to needs of the areas. A system whose routes and schedules are both flexible and ubiquitous.

The Dial a Bus is a hybrid between an ordinary taxi and a bus. It would pickup passengers at their doors or nearby bus stops shortly after they have telephoned for the service. The computer would know the location of the bus, where it is headed and how many people are travelling on it. The system would select the right kind of vehicle and dispatch it to the caller based on some optimal routing program which had been devised for the system.

A Dial-a-Bus with its position established by automatic vehicle monitoring can be routed by a computer and a communication link to collect passenger who have called for the service. With its operational flexibility, Dial-a-Bus system could be programmed to give different levels of service for different fares.

Major Advantages of Dial-a-Bus are
-Handle door to door demand at the time of demand. This would make it capable of doing more off peak business than does the conventional transit
-It would reduce dependence on automobiles

Dial-a-Bus would be more efficient if it had automatic monitors to report each vehicle location to the dispatchers at frequent intervals. The cost of such a system depends on many variables. These include the nature of street system, the speed, the distribution of demand and the size of the area served. So the most uncertain of these variables are travel demands and no of trips per hour per square mile.

Dial-a-Bus system would be most efficient at demand density of 100 trips per square mile per hour – A level barely practicable for the conventional bus service.

2) Van Pooling Service: (e.g.: TMA group in Franklin Tennessee)

The second option is Van pooling services for the choice riders of the transit system. Like the TMA group there are many groups which offer comprehensive services and resources to commuters who wish to van pool, whether or not their existing employer’s have an existing van pool program in place.

Van pools are group of five to fourteen commuters who share the ride to work, one of the commuter is the driver, rider share the monthly fare of the van. The monthly fare covers insurance, maintenance and depreciation. An additional savings is incurred by tax free gasoline. Each van pool sets its own route and schedule. Most Vans have common meeting points, which reduce the overall travel time and expense.
A lot of individuals like the idea of sharing commute, but are worried about being stranded with the ride in case of unplanned emergency. The emergency ride home program provides a free ride home using taxis(trips up to 25 miles) and rental cars for registered participants who van pool a minimum of three times per week and have an unplanned emergency.

The TMA group assists in all phases of process including determining the feasibility of starting a van pool, coordinating van pool information and assisting in recruiting passengers.

3) Smart Car Sharing:

Through car sharing, individual can have access to a shared fleet of vehicles owned by an agency for multiple uses throughout the day without the cost and responsibility of ownership. Shared vehicles are available at transit stations, neighborhoods, campuses, employment centers and resorts. Car sharing can be thought of as organized short term car rental. Shared-use cars provide instant and convenient access to destinations that are not conveniently accessible by transit. The goal of car sharing is to reduce traffic congestion, air pollution and government spending. Car sharing fleet of vehicles could also be made up of ultra low emission, energy efficient cars. Sharing vehicles would lessen the demand for parking space.

Advances in smart technologies have many benefits for both public transportation agencies and private firms managing fleets. There are several smart technologies bundled into such a smart system. One of the important technologies is Automatic Vehicle Location (AVL) which use global positioning system to locate the vehicle and also Advanced Traffic Management System (ATMS). Smart cards or keys containing memory and a microprocessor allow access to the reserved vehicle and relay the billing and reservation information to the vehicle and ATMS.

4) Curitiba's Bus System is Model for Rapid Transit [10]

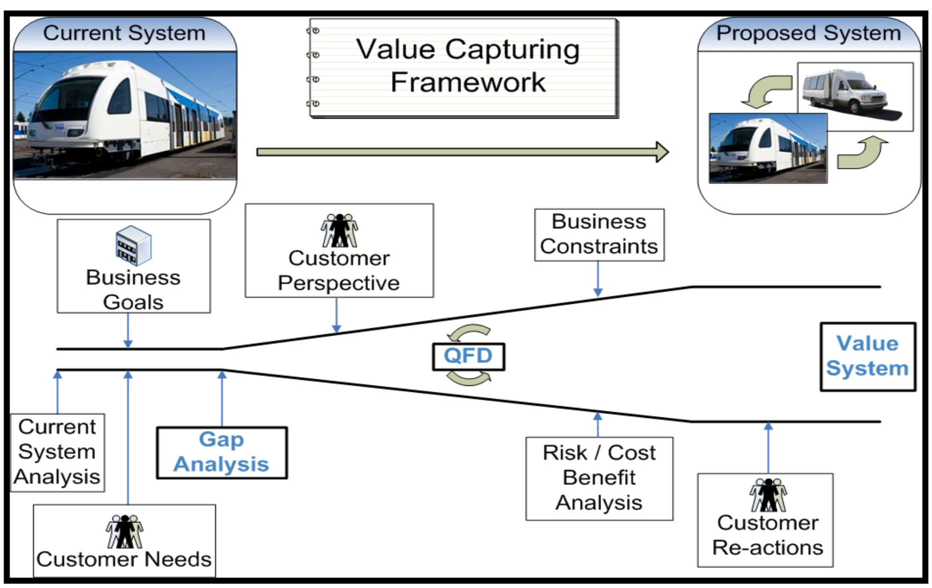
The popularity of Curitiba’s BRT has affected a modal shift from automobile travel to bus travel. Based on 1991 traveler survey results, it was estimated that the introduction of the BRT had caused a reduction of about 27 million auto trips per year, saving about 27 million liters of fuel annually. In particular, 28 percent of BRT riders previously traveled by car. Compared to eight other Brazilian cities of its size, Curitiba uses about 30 percent less fuel per capita, resulting in one of the lowest rates of ambient air pollution in the country. Today about 1,100 buses make 12,500 trips every day, serving more than 1.3 million passengers—50 times the number from 20 years ago. Eighty percent of travelers use the express or direct bus services. Best of all, Curitibanos spend only about 10 percent of their income on travel—much below the national average.

Curitiba's bus system is composed of a hierarchical system that includes a range of services from small feeder minibuses to conventional buses. The backbone of the bus system is composed of express buses operating on five main arteries leading into the city center. This backbone, aptly described as Bus Rapid Transit, is characterized by the following features:

- Integrated planning
- Exclusive bus lanes
- Signal priority for buses
- Pre-boarding fare collection
- Level bus boarding from raised platforms in tube stations
- Free transfers between lines (single entry)
- Large capacity articulated and bi-articulated wide-door buses
- Overlapping system of bus services

Even with one automobile for every three people, one of the highest automobile ownership rates in Brazil, around two thirds of Curitiba's inhabitants use transit daily to commute to work. Curitiba enjoys one of the lowest rates of ambient air pollution in Brazil, and uses about 30 percent less fuel per capita when compared to other Brazilian cities.

Value Capturing Framework



The first third of the chart are steps to develop the gap analysis. This has to do with gathering customer perspective. As stated by William W. Scherkenbach, “The purpose of QFD is to deploy the quality necessary to satisfy and even delight the customer. Thus, obtaining the voice of the customer is the focal point of the QFD process.” [11] We centered our research and objectives on using customer generated data as well as expert generated data.

The first step was to develop a gap analysis of the proposed system. (Appendix 1) As a team of experts, we brainstormed in two categories: current system capabilities and customer and business needs. We found in the current system capabilities, that the system was working well and designed well, but the system was too rigid to meet the needs of a much larger customer demographic. By examining the current system capabilities, we were able to design features that took advantage of the current technologies out there. For example, DHL delivery service has existing software that is used for route optimization, and we could also count on the fact that a large percentage of the population has access to a cellular phone that could be used for online and text ride setup. By analyzing these current capabilities, we were able to add features to our system without having to develop new technologies.

We also brainstormed customer and business needs so the new system will be designed to solve the current unfulfilled needs. From the customer side, we looked at what the new system’s features would need to be for us to want to use the system. For instance, the system needs to be reliable, flexible, and robust enough for us to consider taking mass transit over personal transportation. We also require short waiting times and a user friendly system for pick-up reservation. From the business perspective, we need the new system to integrate easily into the current system. We also want the new system to increase the number of users on the current system and increase the MAX line profits.

By cross analyzing the needs and the capabilities, we came up with the gaps or features that would be required to implement the new system. By using the gap analysis tool we were able to pin point the features that were necessary and eliminate spending time and money on developing features that would not create much value for the system.

The next step is to capture customer perspective. The purpose of the customer perspective is to look at the features that our experts have come up with and gather customer opinion about how important each feature is. We took two approaches to come up with an accurate customer opinion. We gathered data from typical users of mass transit’s current system as well as data from non-typical users. We formatted a single survey to capture the customer’s preference and valuation of the different features. (Appendix 2) The survey consisted of about twenty questions that were meant to be answered in about 5 minutes. The first group of participants was students at PSU. This was the group of non-typical transit riders. Their answers varied greatly, and gave us a good idea of how well the idea would be picked up on by potential riders. The second set of surveys was gathered from typical users of the MAX system. We went on site to the Beaverton Transit Center and surveyed people as they waited for the MAX and busses. We received exceptional results and encouragement from these users because the

Beaverton Transit Center is a different type of station that does not provide for park and ride. So these users are required to get a ride, walk, or take a bus to get to the station. Many of these users desired a system like what we were proposing, and they had great input on what features were important or not.

After we gathered the survey data, we broke down the results into spreadsheets to be used in the house of quality (HOQ) section of the process. (Appendix 3)

Building the Hybrid Transport System HOQ

The customer needs from the survey data were combined with the customer needs data produced by the group of experts. The survey needs represented the stated needs while the expert's needs represented the customers unstated needs. It was important to include the unstated needs because some needs may be perceived as obvious and may not come up in a survey but are critical to the success of the service. These unstated needs were categorized according to the technology acceptance model (TAM)'s perceived ease of use and perceived usefulness. (Apendix 4) Simple range based scoring, one to five scale, was used to determine the importance of the needs criteria from the VOC. Range based scoring is an effective way of quickly getting user preferences which was essential when surveying commuters. The method, however, assumes linearity, which may sometimes dull the responses. In our case, we thought it more suitable than pair-wise comparisons in capturing the essence of the VOC. For each of the customers stated criteria evaluated, the importance was calculated as:

$$importance = 1/N\sum_{i=1}^{5} i*n$$

Where
i = criteria score
n = criteria score count
N = survey sample size (26 for regular and 23 for non-regular users)

The values created represent the merit due to each need criterion. The unstated needs identified by the focus group were also scored on the same scale. The average of the scores from the unstated needs, generated by the expert group, were assumed to be of equal importance for the two groups of users. The needs were then weighted and non-regular users given a 20% stronger voice. This was done because the goal of the exercise was to increase the user base by capturing the VOC. The importance to the customer was then calculated as a proportional score of the two user groups. (Appendix 5) The hybrid transport system was benchmarked against the alternatives according to how well the needs identified in the VOC are met. The alternatives used were Trimet, private vehicle or taxi, and car pooling systems. Targets were set and each alternative assessed for compliance on a scale of 1 to 5, with 5 being full compliance down to 1 for no compliance. (Appendix 7) The VOC needs, defined as the "what's" in conventional QFD, were addressed by the critical to quality (CTQ) criteria, defined as the "how's", identified by the focus group. The CTQ were a combination of specifications that encompasses the system level feature sets to be deployed to meet the user needs. The calculation for the percent importance for each component was calculated using the formula shown below [13]

$$\%Ix = 100\sum_{i=1}^{n}\ [(\%Cx_i)(\%I_i)$$

$$Where$$

$$\%Ix = impor\tan ceof\, component x$$

$$\%Cx_i\ =\ percentimopr\tan ceof\, component x to\, function i$$

$$\%I_i\ =\ percentimpor\tan ceof\ \ function i$$

These feature sets were also benchmarked and assessed for target compliance for the different alternatives. (Appendix 8)

Correlations and Interactions

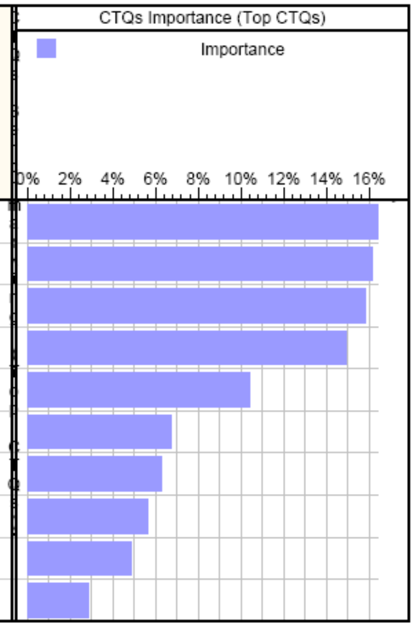
The next step was to fill out any correlations between the "what's" and the "how's". The correlations were scaled from of 9 down to 0 with 9 being strong correlation, 3 being some correlation, 1 being possible correlation and 0 being negative correlation. (Appendix 10) The interactions between the CTQ's resulting from their optimization were also captured and used to form the roof of the house. The interactions were scaled from -3 to 3 for negative to positive interactions. An example is a positive interaction in vehicle size and the wait times; increasing vehicle size leads to more stops and therefore increased wait time. (Appendix 9)

Results

The results of the exercise are captured in the house of quality. (Appendix 11) The VOC section of the house shows the needs ranked by importance. This is helpful in communicating the high impact areas that need to be addressed if the hybrid system is to be accepted by the users. For the Portland metro area, making mass transit easier to access was found to be the most important need to be addressed followed by providing a safe feeling and being eco friendly. The house of quality also shows the CTQ's ranked by order of importance in meeting the customer's needs. The CTQ's most critical to the success of the Portland hybrid transport system are shown below.

Top CTQ's by Importance

CTQs	Optimization	Importance	Target score	Measure
2.1 Vehicle size	○	16.39%	10	# Seats
2.2 Reservation systems	↑	16.15%	3	score
1.5 Intergation	↑	15.82%	95	Percentage
1.4 Radius	○	14.91%	5	Miles
1.1 Wait time	↓	10.42%	8	Minutes
2.3 Payment systems	↑	6.70%	2.4	score
1.2 Delivery time	↓	6.28%	6.4	Minutes
3.1 Personal safety	↑	5.59%	5	score
1.3 Accuracy	↑	4.87%	100	Percentage
3.2 Data Safety	↑	2.86%	5	score



Optimizing the vehicle size is the most important factor in meeting the customer needs. This will close the biggest gap in customer satisfaction. The modes of making reservations are the next important factor. In the survey, nearly half of potential customers surveyed preferred online reservations. (appendix 1,2,3)

The next section of our process will take the outputs from the QFD HOQ process and perform a few final checks on it. We will take the features list from the HOQ and analyze that by checking to see if they are feasible. This is a highly important part of the QFD process. Professor Brent Flyvbjerg from Denmark, stresses the importance of accurate forecasting and feasibility studies [12]. He mentions that almost all transportation projects are over estimated for demand. We use his advice to put together a detailed analysis of the costs and risks of each feature, and analyze the business constraints before proposing the next set of features. We look at each feature and first look at the risk per benefit and cost benefit, to see if the feature is worth adding to the proposed system. If the costs come in way too high or the risk effects the reliability of the system too greatly, the feature might have to be scrapped or reworked. On the same note, if a feature will be affected by too many business constraints, it will have to be re-analyzed. For example, one of our features was to limit the number of stops on the mini-bus. If we determine that it will take too many resources to cut back on stops, that feature will have to be altered to make the system more efficient.

The final step is to gather more customer data. This time we will be asking the customers to evaluate the system after it has gone through the QFD process. This will consist of more detailed questions about the specific features and how helpful they will be. We are trying to find out if the new system will meet the requirements of the consumer even after it has been re-scoped. For instance, we will look at determining if a scrapped feature will affect the overall performance of the system and if the customer will still be interested in the final product. This data will be gathered by more surveys and interviews from potential users, experts, and stakeholders.

By following the value capturing framework process, we were able to get a list of the features needed for integrating a hybrid system to accompany the traditional bus and max lines. One benefit to developing a framework is that it can be used in different metropolitan areas to develop similar systems, but where there would be different system requirements. For example, you can gather survey data from consumers in Phoenix. Then you can follow our steps to input the data into the HOQ and you will have an outcome that is suitable for that city.

Another benefit to following the framework is that you can count on better forecasting accuracy, by having multiple experts and system consumers adding valued information to the system. The definition of value is getting a lot for very little and by following the QFD process you maximize the amount of value you can get from a system.

Appendix

Section 1.
Gap Analysis

Needs

- Minimize stops, waits, and effort to get to commute
- Reliability/Robustness
- Easily incorporate with current system
- Flexibility (Easy to modify routes, schedules, coverage areas)
- Approval by relevant authorities
- Economical feasibility
- User Friendly
- Personal
- Feel safe

Capabilities

- Route optimization systems and software
- Existing infrastructure and facilities like the Max
- The public access to communication technologies like the internet, cell phones
- Public awareness of gaps

Gaps

- Candidate Systems are not fully tested or proven
- Current systems are too rigid
- Higher capacity systems
  - Economic crisis (limited resources)
- Fewer commuters (limited revenues)
- Learning Curve with new systems
- Personal
- Lack of trust in public transport systems

Section 2.
Survey Questions

Mass Transit Survey

We are proposing a system that would increase the amount of people that would use public transportation We would have a system made up of mini busses that would pick up passengers closer to their homes and deliver them to the nearest MAX station and vice versa.

1. How far do you have to travel to get to the MAX from home?
2. Would you prefer to use Cash, Credit, or Pre-paid card?
3. If you had to make a reservation for pickup would you prefer to:
   a. Reserve online b. Send SMS(text) c. Make a call
4. What is the longest amount of time you would allow to be on the mini bus? 10min 20min 30min
5. What is more important, spending less time on the bus or paying less?

On a scale of 1 being very un-important and 5 being very important, How important is:

1. Walking less to get to a bus stop?
2. Having a user friendly system for pickup?
3. Having a short ride on the mini bus?
4. Paying less for a ride?
5. Not having to drive to a park and ride?
6. Not having to drive on the highways? (Not having to drive at all)
7. Being eco-friendly?
8. Finding an easy way to get to mass transit?

Does the existing system meet your travel needs today?

1-Yes 2-No

How likely are you to recommend using this transit system to a friend or colleague?

1-Not at all likely 2-Neutral 3-Extremely likely.

On average, how often do you ride the max?

1. 5 days a week
2. 2-4 days a week
3. Once a week
4. Once or twice a month
5. Less than once a month

Section 3.
Survey Results

Non typical transit user 23 persons surveyed

	Mass Transit Survey		Far way	<1 mile	2mile	3mile	>4miles	Total
1	How far do you have to travel to get to the MAX from home?		2	13	3	2	3	23
			Cash	Credit	Prepaid	Free		
2	Would you prefer to use Cash, Credit, or Pre-paid card?		4	10	8	1		23
			Online	SMS	Call	Free		
3	If you had to make a reservation for pickup would you prefer to:		12	2	8	1		23
	a. Reserve online b. Send SMS(text) c. Make a call							
			<10 min	20 min	30 min	NA		
4	What is the longest amount of time you would allow to be on the mini bus? 10min 20min 30min		9	8	4	2		23
			Less time	Pay Less	NA			
5	What is more important, spending less time on the bus or paying less?		14	6	3			23
	On a scale of 1 being very un-important and 5 being very important, How important is:							
	Scale	1	2	3	4	5		Total
1	Walking less to get to a bus stop?	2	2	2	6	11		23
2	Having an user friendly system for pickup?	2		5	9	7		23
3	Having a short ride on the mini bus?	1	4	3	7	8		23
4	Paying less for a ride?	2	3	6	6	6		23
5	Not having to drive to a park and ride?	6	4	3	5	5		23
6	Not having to drive on the highways? (Not having to drive at all)		3	4	5	11		23
7	Being eco-friendly?	1	3	7	6	6		23
8	Finding an easy way to get to mass transit?	1	1	4	12	5		23
			Yes	No				
	Does such a system meet your travel needs today?		10	13				23
	1-Yes 2-No							
	How likely are you to recommend using this transit system to a friend or colleague?	Not Likely	Neutral	Likely				
	1-Not at all likely 2-Neutral 3-Extremely likely.	1	15	7				23
	On average, how often do you ride the max?	Points						
	1. 5 days a week	3						
	2. 1-4 days a week	2						
	3. Once a week	3						
	4. Once or twice a month	3						
	5. Less than once a month	12						
	Total	23						

Typical Transit users 26 persons surveyed

Mass Transit Survey

	Mass Transit Survey		Far way	<1 mile	2mile	3mile	>4miles	Total
1	How far do you have to travel to get to the MAX from home?		2	16	6		2	26
			Cash	Credit	Prepaid	Free		
2	Would you prefer to use Cash, Credit, or Pre-paid card?		7	2	17			26
			Online	SMS	Call	Free		
3	If you had to make a reservation for pickup would you prefer to:		8	6	12			26
	a. Reserve online b. Send SMS(text) c. Make a call							
			<10 min	20 min	30 min	NA		
4	What is the longest amount of time you would allow to be on the mini bus? 10min 20min 30min		13	8	5			26
			Less time	Pay Less	NA			
5	What is more important, spending less time on the bus or paying less?		12	14				26
	On a scale of 1 being very un-important and 5 being very important, How important is:							
	Scale	1	2	3	4	5		Total
1	Walking less to get to a bus stop?	4	3	5	5	9		26
2	Having an user friendly system for pickup?	2		4	4	16		26
3	Having a short ride on the mini bus?	6	2	8	2	8		26
4	Paying less for a ride?	4		7	3	12		26
5	Not having to drive to a park and ride?	7	2	4	5	8		26
6	Not having to drive on the highways? (Not having to drive at all)	5	1	4	2	14		26
7	Being eco-friendly?			4	5	17		26
8	Finding an easy way to get to mass transit?			2	7	17		26
			Yes	No				
	Does the existing system meet your travel needs today?		22	4				26
	1-Yes 2-No							
	How likely are you to recommend using this transit system to a friend or colleague?	Not Likely	Neutral	Likely				
	1-Not at all likely 2-Neutral 3-Extremely likely.		7	19				26
	On average, how often do you ride the max?	Points						
	1. 5 days a week	14						
	2. 1-4 days a week	7						
	3. Once a week							
	4. Once or twice a month	3						
	5. Less than once a month	2						
	Total	26						

Section 4.

Customer needs

VOC		
1 Customer Stated Needs	1.1 Walking less to get to a bus stop	
1 Customer Stated Needs	1.2 Having an user friendly system for pickup	
1 Customer Stated Needs	1.3 Having a short ride on the bus	
1 Customer Stated Needs	1.4 Paying less for a ride	
1 Customer Stated Needs	1.5 Not having to drive to a park and ride	
1 Customer Stated Needs	1.6 Not having to drive at all	
1 Customer Stated Needs	1.7 Being eco-friendly	
1 Customer Stated Needs	1.8 Finding an easy way to get to mass transit	
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.1 Reliabe
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.2 Easily incorporate with current systems
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.3 Flexibility (Easy to modify routes, schedules, coverage areas)
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.4 Walking less to get to a bus stop
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.5 User friendly system for payment
2 Customer Unstated Needs	2.2 Usefulness	2.2.1 Minimimal Waits Stops
2 Customer Unstated Needs	2.2 Usefulness	2.2.2 Comfortable ride
2 Customer Unstated Needs	2.2 Usefulness	2.2.3 Safe feeling

Section 5.

Score by User groups: Regular and Non-regular

Voice of the customer		User Group 2	Regular	Non-regular	Weight	Weight %	% importance
Weight			1.0	1.2			
1 Customer Stated Needs		1.1 Walking less to get to a bus stop	3.46	3.96	0.14	6.2%	5.9%
		1.2 Having an user friendly system for pickup	4.23	3.83	0.15	6.6%	6.4%
		1.3 Having a short ride on the bus	3.15	3.74	0.13	5.7%	5.5%
		1.4 Paying less for a ride	3.73	3.48	0.13	5.9%	5.7%
		1.5 Not having to drive to a park and ride	3.19	2.96	0.11	5.1%	4.9%
		1.6 Not having to drive at all	3.73	4.04	0.14	6.5%	6.2%
		1.7 Being eco-friendly	4.50	3.57	0.15	6.6%	8.6%
		1.8 Finding an easy way to get to mass transit	4.58	3.83	0.15	6.9%	8.9%
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.1 Reliabe	4.00	4.00	0.15	6.6%	8.0%
		2.1.2 Easily incorporate with current systems	4.00	4.00	0.15	6.6%	5.1%
		2.1.3 Flexibility (Easy to modify routes, schedules, ..	3.80	3.80	0.14	6.3%	6.0%
		2.1.4 Walking less to get to a bus stop	3.71	3.71	0.14	6.1%	5.9%
		2.1.5 User friendly system for payment	3.50	3.50	0.13	5.8%	4.5%
	2.2 Usefuln...	2.2.1 Minimimal Waits Stops	3.00	3.00	0.11	5.0%	4.8%
		2.2.2 Comfortable ride	4.00	4.00	0.15	6.6%	4.8%
		2.2.3 Safe feeling	4.50	4.50	0.16	7.4%	8.9%

Section 6.

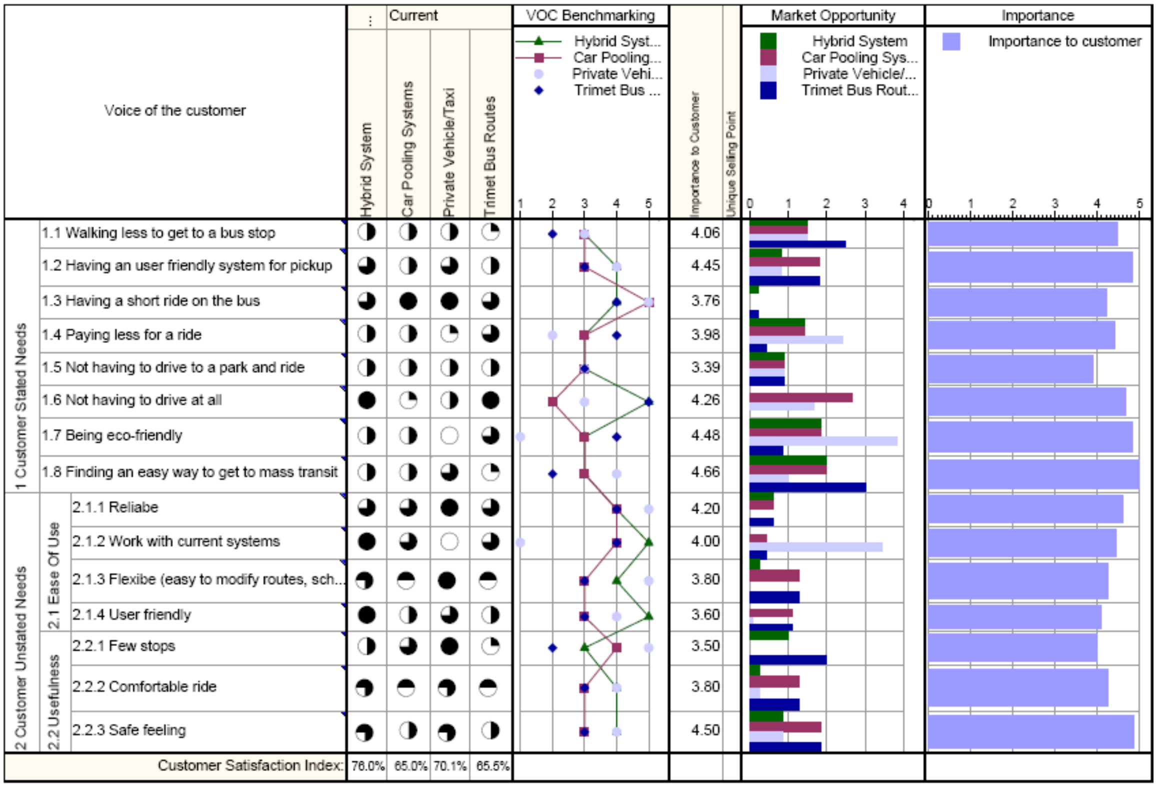
Critical to Quality

CTQs		Specification Data		Optimization	Specification Range	
		Measure	Data Type		Ideal Value	Marginal value
1 Performance	1.1 Wait time	Minutes	cont	↓	10	15
	1.2 Delivery time	Minutes	cont	↓	8	15
	1.3 Accuracy	Percentage	cont	↑	100	95
	1.4 Radius	Miles	cont	○	10	15
	1.5 Intergation	Percentage	disc	↑	95	90
2 Comfort	2.1 Vehicle size	# Seats	disc	○	8	15
	2.2 Reservations	Preferred modes	disc	↑	3	2
	2.3 Payment Syste...	Preferred modes	disc	↑	3	2
3 Safety	3.1 Personal safety	Percentage	cont	○	100	99.7
	3.2 Data Safety	Percentage	cont	○	100	99

CTQs Optimization		
Optimization		
↑	1.00	maximize
○	0.00	exact
↓	-1.00	minimize

Section 7.

VOC Benchmark



Section 8.

House of quality correlations “What’s” Vs “How’s”

Hybrid Transport System QFD

⊙ 9.00 strong correlation
○ 3.00 some correlation
△ 1.00 possible correlation
\- 0.00 (possible negative correlation)

			1 Performance					2 Comfort			3 Safety		
			1.1 Wait time	1.2 Delivery time	1.3 Accuracy	1.4 Radius	1.5 Intergation	2.1 Vehicle size	2.2 Reservation systems	2.3 Payment systems	3.1 Personal safety	3.2 Data Safety	Number of significant relationships
1 Customer Stated Needs	1.1 Walking less to get to a bus stop				⊙	⊙		⊙					3
	1.2 Having an user friendly system for pickup						○		⊙		○	○	4
	1.3 Having a short ride on the bus		○	⊙			△	⊙					3
	1.4 Paying less for a ride					○	○	-		△			2
	1.5 Not having to drive to a park and ride						△				△		0
	1.6 Not having to drive at all		⊙	○		⊙	⊙				△		4
	1.7 Being eco-friendly		△				△	⊙					1
	1.8 Finding an easy way to get to mass transit		△			⊙	⊙		⊙	○		△	4
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.1 Reliabe	○		-		○		○				3
		2.1.2 Work with current systems	⊙	○			⊙	△	○	○			5
		2.1.3 Flexibe (easy to modify routes,..	△			△			⊙	○			2
		2.1.4 User friendly							⊙	⊙			2
	2.2 Usefulness	2.2.1 Few stops	△	○	△	⊙		⊙					3
		2.2.2 Comfortable ride					△	⊙					1
		2.2.3 Safe feeling			○		△		△		⊙	○	3
Significant relations			4	4	2	5	6	5	6	4	2	2	

Section 9.

CTQ Interactions

Coulumns: Causes >>

<< Rows: Effects

CTQ Interaction Matrix

- ++ 3 positive effect
- \+ 1 possible positive effect
- \- -1 possible negative effect
- -- -3 negative effect

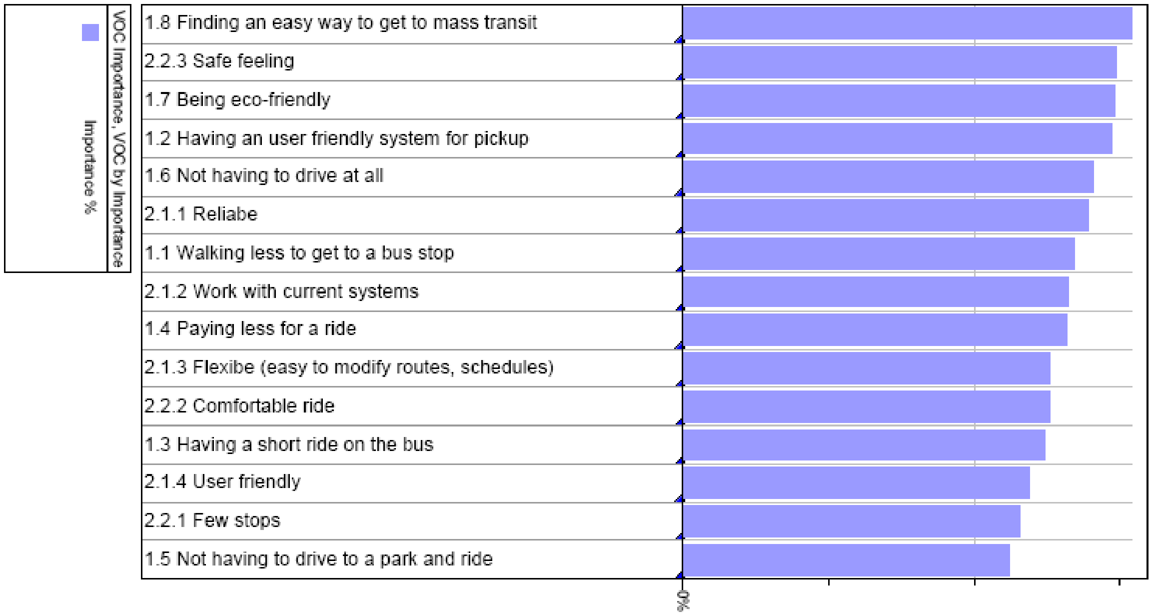
		Optimization	1 Performance: 1.1 Wait time	1.2 Delivery time	1.3 Accuracy	1.4 Radius	1.5 Intergation	2 Comfort: 2.1 Vehicle size	2.2 Reservation systems	2.3 Payment systems	3 Safety: 3.1 Personal safety	3.2 Data Safety	Positive effects	Negative effects	Decoupling Sequence (Design Structure Matrix)
	Optimization		↓	↓	↑	◯	↑	◯	↑	↑	↑	↑			
1 Performance	1.1 Wait time	↓												0	1
1 Performance	1.2 Delivery time	↓	++										1	0	2
1 Performance	1.3 Accuracy	↑	+										1	0	3
1 Performance	1.4 Radius	◯	--											1	4
1 Performance	1.5 Intergation	↑	++										1		5
2 Comfort	2.1 Vehicle size	◯	++	-		+							2	1	6
2 Comfort	2.2 Reservation systems	↑					++						1	0	7
2 Comfort	2.3 Payment systems	↑					+						1	0	8
3 S...	3.1 Personal safety	↑			+			-					1	1	9
3 S...	3.2 Data Safety	↑			+				-				1	1	10
	Positive factors		4		2	1	2		0		0	0			
	Negative factors		1	1	0	0		1	1			0			

Section 10.
Significant Relations

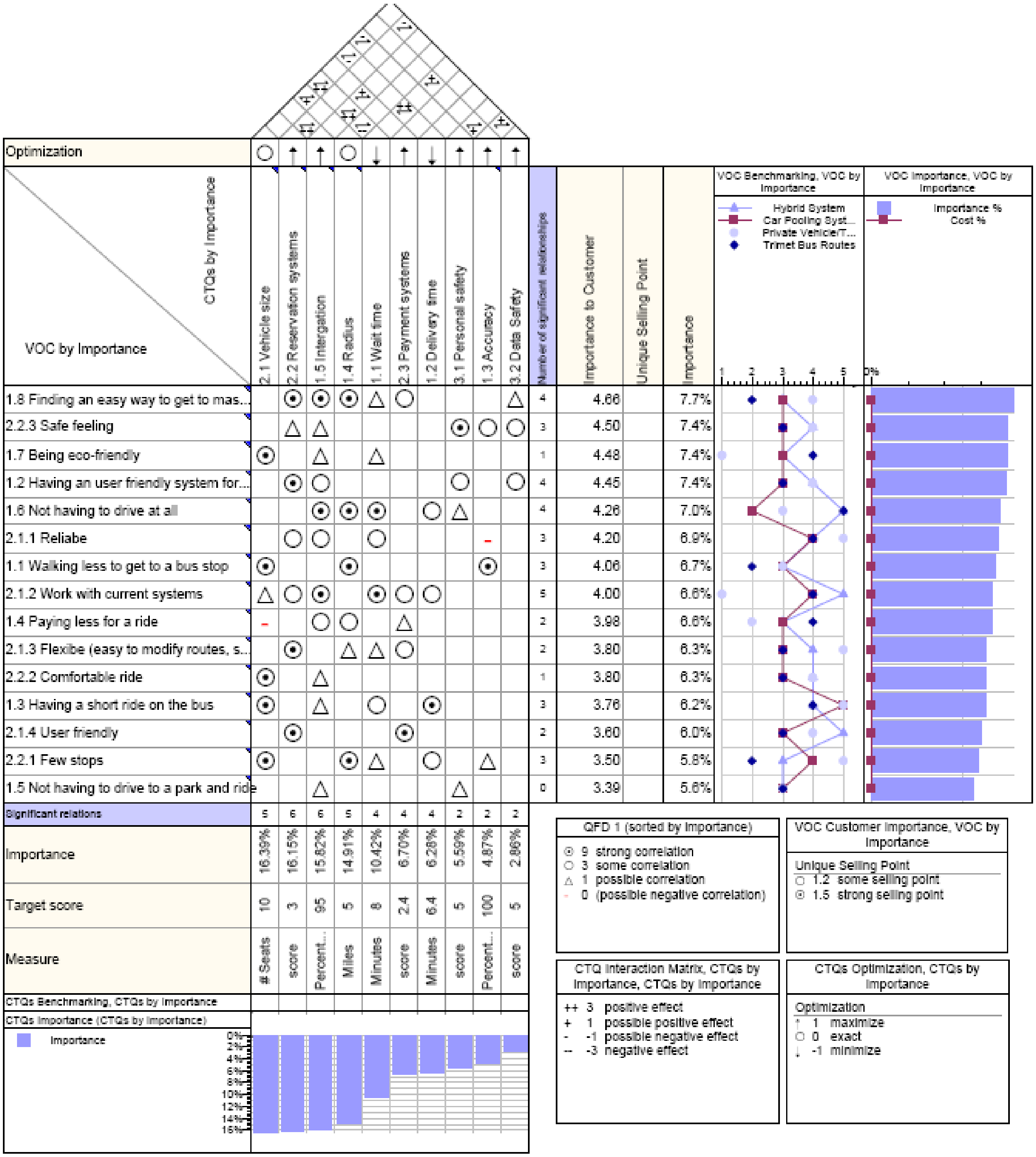
Hybrid Transport System QFD			1 Performance					2 Comfort			3 Safety		
⊙ 9.00 strong correlation ○ 3.00 some correlation △ 1.00 possible correlation - 0.00 (possible negative correlation)			1.1 Wait time	1.2 Delivery time	1.3 Accuracy	1.4 Radius	1.5 Intergation	2.1 Vehicle size	2.2 Reservation systems	2.3 Payment systems	3.1 Personal safety	3.2 Data Safety	Number of significant relationships
1 Customer Stated Needs	1.1 Walking less to get to a bus stop				⊙	⊙		⊙					3
	1.2 Having an user friendly system for pickup						○		⊙		○	○	4
	1.3 Having a short ride on the bus		○	⊙			△	⊙					3
	1.4 Paying less for a ride					○	○	-		△			2
	1.5 Not having to drive to a park and ride						△				△		0
	1.6 Not having to drive at all		⊙	○		⊙	⊙				△		4
	1.7 Being eco-friendly		△				△	⊙					1
	1.8 Finding an easy way to get to mass transit		△			⊙	⊙		⊙	○		△	4
2 Customer Unstated Needs	2.1 Ease Of Use	2.1.1 Reliabe	○		-		○		○				3
		2.1.2 Work with current systems	⊙	○			⊙	△	○	○			5
		2.1.3 Flexibe (easy to modify routes,..	△			△			⊙	○			2
		2.1.4 User friendly							⊙	⊙			2
	2.2 Usefulness	2.2.1 Few stops	△	○	△	⊙		⊙					3
		2.2.2 Comfortable ride					△	⊙					1
		2.2.3 Safe feeling			○		△		△		⊙	○	3
Significant relations			4	4	2	5	6	5	6	4	2	2	

Section 11.

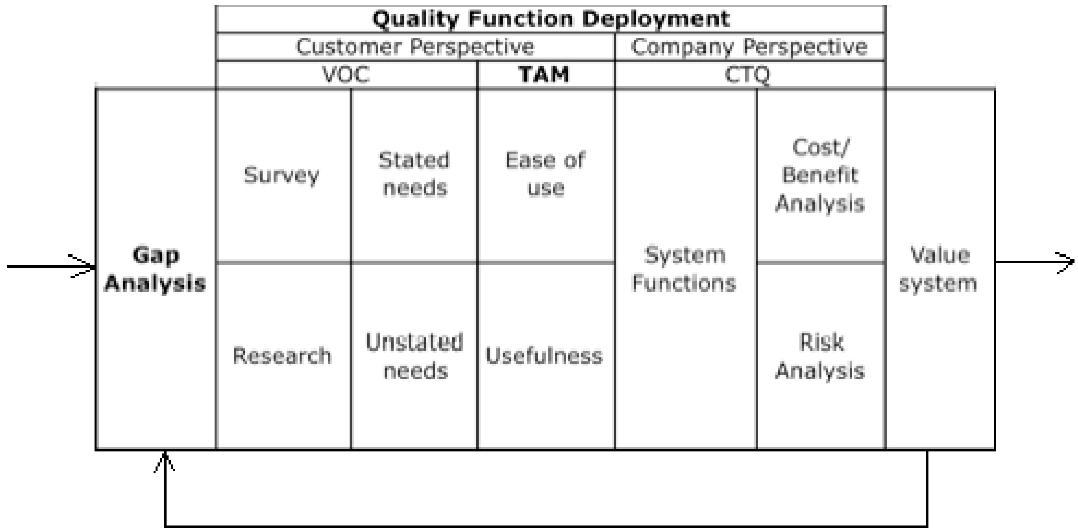
VOC ranked by importance



Section 12.
House of Quality



Section 13.
Framework detail



KEY: VOC= voice of the customer, CTQ = critical to quality, TAM= technology acceptance model

References

[1]http://www.regionalserviceplanning.org/maintenance/presentations/maintenance_initiatives.pdf
[2] http://www.publictransportation.org/contact/stories/
[3] http://www.qfdi.org/what_is_qfd/what_is_qfd.htm
[4] http://cdnet.stpi.org.tw/techroom/analysis/pat_A106.htm
[5] Quality Function Deployment (QFD): Integration of Logistics Requirements into Mainstream System Design Author: Dinesh Verma, Rajesh Chilakapati, Benjamin S. Blanchard. Virginia Tech
[6] "http://www.texaspolicy.com/pdf/2000-veritas-1-2-transit.pdf - The Future of Mass Transit in the United States: Can We Get There From Here? by Thomas A. Rubin, CPA, CMA, CMC, CIA, CGFM, CFM (Senior Policy Analyst, Texas Public Policy Foundation).
[7] http://www.publictransportation.org/facts/ "American Public Transportation Association"
[8] http://faculty.washington.edu/jbs/itrans/tomtrans.htm "Tomorrow's Transportation: New Systems for the Urban Future -Secretary of the Department of Housing and Urban Development (Robert Weaver) in 1968"
[9]
http://www.tmagroup.org/van_pool.php?PHPSESSID=9a81d52247102fc4d3001c71a44f3e45
"TMA Group in Franklin Tennessee"
[10] http://www.urbanhabitat.org/node/344 "Curitiba's Bus System is Model for Rapid Transit By Joseph Goodman, Melissa Laube, and Judith Schwenk"
[11] The Deming Route to Quality and Productivity: Road Maps and Roadblocks. Author: Scherkenback, W. W. (1986), CEE Press Books, Continuing Engineering Education Program, George Washington University, Washington, DC, USA.
[12] How (In)accurate Are Demand Forecasts in Public Works Projects? The Case of Transportation Authors: Bent Flyvbjerg, Mette K. Skamris Holm, and Søren L. Buhl. Journal of the American Planning Association, Spring 2005, Vol. 71, No. 2. http://flyvbjerg.plan.aau.dk/Traffic91PRINTJAPA.pdf
[13] Value, Its Measurement Design & Management Author: M. Larry Shillito and David J. De Marle 1992
[14] "Mobile phone location and its impact on intelligent transport systems- Yilin Zhao, Senior member IEEE".
[15] National association of realtors and smart growth America 2007 Growth and Transportation survey.
[16] Analyzing a Quality Function Deployment (QFD) Matrix: An Expert System Based Approach to Identify Inconsistencies and Opportunities - Dinesh Verma, Rajesh Chilakapati
[17] AUTOMATED BUS DISPATCHING, OPERATIONS CONTROL AND SERVICE RELIABILITY: ANALYSIS OF TRI-MET BASELINE SERVICE DATE James G. Strathman Kenneth J. Dueker Thomas Kimpel Rick Gerhart Ken Turner Pete Taylor Steve Callas David Griffin Janet Hopper

[18] Nykvista Björn , and Lorraine Whitmarshb Lorraine(2006) A multi-level analysis of sustainable mobility transitions: Niche development in the UK and Sweden
[19] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319-339
[20] Akao, Y. (1990), Quality Function Deployment: Integrating Customer Requirements into Product Design, Productivity Press, Cambridge, MA, English translation (originally published as, Hinshitutenkai katsuyo no jissai, Japan Standards Association),