**PUBLIC TRANSPORTATION EFFICIENCY ANALYSIS**

**Abstract:**

Performance Evaluation of Public Transport system is very much essential to understand the effectiveness of the plans in vogue as well as to devise plans for its improvement. Most of the major metropolitan cities of the world are presently witnessing rapid growth in industry, infrastructure, economic activities and population over the past few decades which makes them more attractive to job seekers, causing major increase in personalized modes. As a result, the cities are subjected to increase in traffic congestion resulting in huge delays and environmental pollution. To tackle the huge transportation demand and to provide a sustainable environment there is a need for the provision of better public transportation facilities. To fulfill the high demand for better public transport system, there is a need to establish attractive, safe and highly sophisticated public transport systems. In this regard, it is essential to conduct a thorough evaluation of public transport modes. This paper gives an overview and presents the possible ways to identify and measure the performance of public transit system. It presents the definition and literature in respect of different measurement models towards the public transit performance assessment coupled with comparative study of different measurement models that can be used for performance evaluation.

**1.Introduction**

Over the last few years, the public transport industry in many developing countries has been involved in a process of deep transformation. At present, personal mode usage is more than public transport mode, causes Public Transport Performance Evaluation Techniques - A Review 2 series of problems in daily life like, traffic congestion, delay, air pollution, noise pollution and large amount of energy wastage which has a negative impact on environment as well as on public health. Mobility requirements in metropolitan cities causes continuous growth of personalized vehicles leading to pollution and traffic congestion. To reduce the current pollution level, congestion and make the cities environment friendly, it is necessary to encourage the commuters to use the public transport system. To provide the desired service delivery level for public transport, it is essential to evaluate the existing transport systems using a reliable performance evaluation technique which can eventually help in enhancing the transit service delivery to their trusted passengers. This paper discusses reliable methodologies to evaluate the public transport with respect to user perception.

**2. Performance Evaluation**

Performance evaluation of public transport system requires to understand the terms on behalf of performance of the system to be evaluated. The evaluation can be done in two ways i) based on present perception of users about the service deliverd ii) based on the feedback provided by experienced evaluation team. Performance evaluation is defined as the technique to evaluate how good or bad is the performance of a transit service is under the prevailing operating condition. The performance of transit system can be enumerated based on two distinct dimensions i.e., Service and Service quality. Service is described as “the business transaction that take place between a donor (Service provider) and Receiver (Customer) in order to produce an outcome that satisfies the customer” (Ramaswamy, 1996) [1]. Whereas, Service quality gives the measure of how well the service level delivered to the commuter’s as per their expectation. Parasuraman (1988) and Gronroos, (1984) defines service quality as a comparison between customer expectation and perception of service [2], [3].

**3. Factors Effecting Service Quality**

Estimation of service quality in terms of user perception is purely based on psychological behavior of the commuters. It is necessary to understand the key parameters upon which transit performance depends, as these factors internally and externally affect the user perception and creates a perception of the transit system in the user's mind. The selection of factors differs from one public mode to another. Different researchers have given Public Transport Performance Evaluation Techniques - A Review 3 various number of factors to define the service quality.

**Design Thinking**

we will outline the key components of the project, including analysis objectives, data collection strategies, visualization plans using IBM Cognos, and the integration of code for data analysis. The design thinking process ensures a structured and holistic approach to problem-solving.

**Analysis Objectives**

1. \*\*Assess On-Time Performance:\*\* The primary objective is to evaluate the punctuality of public transportation services. This involves analyzing historical data on scheduled departure and arrival times versus actual times.

2. \*\*Measure Passenger Satisfaction:\*\* We aim to gauge passenger satisfaction through surveys and feedback data. This includes sentiment analysis of customer reviews and ratings.

3. \*\*Evaluate Service Efficiency:\*\* To determine the efficiency of transportation services, we will examine data related to route optimization, fuel consumption, and operational costs.

**Data Collection**

1. \*\*Schedules and Real-Time Updates:\*\* We will gather historical schedules and real-time updates from transportation agencies. This data will provide insights into planned versus actual service timings and potential delays.

2. \*\*Passenger Feedback:\*\* To measure passenger satisfaction, we will collect feedback through online surveys, customer service logs, and social media sentiment analysis.

3. \*\*Operational Data:\*\* Information regarding fuel consumption, maintenance schedules, and operational costs will be obtained from transportation agencies and maintenance records.

**Visualization Strategy**

1. \*\*Dashboard Creation:\*\* Utilizing IBM Cognos, we will design interactive dashboards that present key performance indicators (KPIs) related to on-time performance, passenger satisfaction, and service efficiency. These dashboards will enable stakeholders to easily grasp trends and make informed decisions.

2. \*\*Custom Reports:\*\* Alongside dashboards, custom reports will be generated to provide in-depth insights and trends. These reports will cater to the specific needs of different stakeholders, such as transportation authorities, management teams, and maintenance crews.

3. \*\*Geospatial Visualization:\*\* Geospatial data will be used to visualize route performance, helping identify areas with frequent delays or service issues. Heatmaps and spatial analysis will be employed for this purpose.

**Code Integration**

1. \*\*Data Cleaning:\*\* Code will be used to clean and preprocess the collected data. This includes handling missing values, data normalization, and ensuring data consistency.

2. \*\*Transformation:\*\* Complex data transformations, such as aggregating passenger feedback scores, calculating performance metrics, and geospatial data transformations, will be implemented using code.

3. \*\*Statistical Analysis:\*\* Advanced statistical analysis, including regression analysis to identify factors affecting on-time performance, and clustering for customer segmentation, will be carried out through code-based approaches.

**STEPS:**

**\*\*Step 1:Refining the Design Concept\*\***

Before we can innovate, we must ensure that our design concept is well-defined and aligned with the problem statement. This step involves:

1. \*\*Reviewing the Design\*\*: Revisit the initial design concept and assess its feasibility, scalability, and relevance to the problem.

2. \*\*User Feedback\*\*: Gather feedback from potential end-users or stakeholders to refine and validate the design.

3. \*\*Market Research\*\*: Conduct market research to identify trends, competition, and potential market gaps that the design can address.

**\*\*Step 2: Ideation and Brainstorming\*\***

Innovation often emerges from creative brainstorming sessions. This step involves:

1. \*\*Cross-functional Teams\*\*: Assemble a cross-functional team comprising members with diverse skills and perspectives.

2. \*\*Ideation Sessions\*\*: Organize brainstorming sessions to generate a wide range of ideas and solutions related to the design.

3. \*\*Idea Prioritization\*\*: Use techniques like SWOT analysis, cost-benefit analysis, or voting to prioritize the most promising ideas.

**\*\*Step 3: Prototyping and Testing\*\***

Creating prototypes allows us to test and refine our ideas. This step involves:

1. \*\*Building Prototypes\*\*: Develop prototypes or proofs of concept based on the selected ideas.

2. \*\*User Testing\*\*: Conduct user testing to gather valuable feedback and insights for further improvements.

3. \*\*Iterative Process\*\*: Continuously refine and iterate on the prototypes based on user feedback and technical feasibility.

**\*\*Step 4: Technology Integration\*\***

Depending on the design, integrating technology may be necessary for innovation. This step involves:

1. \*\*Assessment of Technology\*\*: Evaluate the suitability of existing or emerging technologies that can enhance the design.

2. \*\*Partnerships\*\*: Explore partnerships with tech companies or experts if specialized knowledge is required.

3. \*\*Development\*\*: Implement the chosen technology solutions into the design.

**\*\*Step 5: Scalability and Sustainability\*\***

For successful innovation, consider long-term scalability and sustainability. This step involves:

1. \*\*Scalability Plan\*\*: Develop a plan for scaling up the solution to meet growing demands.

2. \*\*Sustainability Measures\*\*: Implement eco-friendly or sustainable practices in the innovation process.

**\*\*Step 6: Regulatory Compliance and Intellectual Property\*\***

Ensure that the innovation complies with relevant regulations and protects intellectual property. This step involves:

1. \*\*Legal Review\*\*: Consult with legal experts to ensure compliance with local and international laws.

2. \*\*Patent and Copyright Protection\*\*: If applicable, file for patents or copyrights to protect the innovation.

**\*\*Step 7: Pilot Deployment\*\***

Before full-scale implementation, test the innovation in a controlled environment. This step involves:

1. \*\*Select Pilot Sites\*\*: Choose specific locations or users for the pilot deployment.

2. \*\*Monitoring and Evaluation\*\*: Continuously monitor and evaluate the performance of the innovation during the pilot phase.

**\*\*Step 8: Feedback Integration\*\***

Use feedback from the pilot phase to make final adjustments to the innovation. This step involves:

1. \*\*Feedback Analysis\*\*: Analyze data and feedback from pilot users and stakeholders.

2. \*\*Final Refinements\*\*: Implement any necessary refinements to optimize the innovation.

**\*\*Step 9: Full-scale Implementation\*\***

Once the innovation is refined and proven successful, proceed with full-scale implementation. This step involves:

1. \*\*Deployment Plan\*\*: Develop a comprehensive deployment plan that covers all aspects of implementation.

2. \*\*Resource Allocation\*\*: Allocate the necessary resources, including manpower and budget.

**\*\*Step 10: Continuous Improvement\*\***

Innovation is an ongoing process. This step involves:

1. \*\*Monitoring and Feedback\*\*: Continuously monitor the performance and gather feedback from users.

2. \*\*Iterative Development\*\*: Use feedback to make iterative improvements to the innovation.

**4. Method of collecting user perception data**

Surveys and interviews are the most popular methods of primary data collection. The User perception data can be collected by conducting a Station/Stop Survey or Workplace survey by direct face to face interview or by using alternative (telephonic interviews) indirect techniques. Paper-and-Pencil Interview (PAPI) is very popular for data collection, in which an enumerator asks questions to the respondent by holding a printed set of questions. PAPI surveys should be carried out by taking proper precaution by randomly selecting a person from the population, so that it eliminate the chance of nonresponsive and responsive biasness. At present internet based survey methods have taken over the place of PAPI method as it reduces the manpower, time and provide readymade scrutinized results. However, a major drawback of this method is its inability to cover of the population who are not familiar with the internet.

5. Survey Scale Selection

Survey scale selection is solely based on the type of research work. Range of scales used is based on the type of data needed for research. The scale comes from psychological researchers, as suggested by “Rensis likert” [4]. Most of the people used 10 point likert scale to evaluate the user perception by using a set of questions. Though researchers like Friman (2004) used a 9 point scale [5], Tyrinopoulous in 2008 used a ranked scale which ranges 1 to 4 [6], Eboli et al. (2009) used a 10 point likert scale [7] and Putra (2013) used a 5 point likert scale [8]. It was observed that when the scale range increases it will enable us to grasp the detailed variation in data. Transportation researchers suggest to use a constant scale for each variable in a set of questionnaire for better results and to avoid complex issues.

**6. Performance Evaluation Models**

Major works on “performance evaluation” began after 1970, many of the transportation planners and researchers had started trying different approaches and techniques for developing different models to estimate the transit system performance in terms of user perception. Since service quality is a qualitative parameter hence modeling of qualitative parameters creates more difficulties. Service quality measurement models for different systems proposed by various researchers are discussed below. Public Transport Performance Evaluation Techniques - A Review 5

6.1 SERVQUAL Model

Parasuraman (1985) suggested a model for measuring service quality by measuring the gap between the service delivered and service received . It is mostly used by market researchers to identify customer satisfaction on behalf of service delivered. This model represents the service quality in terms of 10 dimensions namely, Reliability, Responsiveness, Competence, Access, Courtesy, Communication, Credibility, Security, understandibility and Tangibles. But after 1988, these ten components were merged to formulate five distinct dimensions namely, Reliability, Assurance, Tangibles, Empathy, Responsiveness .These components are collectively called RATER. However, limitation of this model is SERVICE QUALITY (SERVQUAL) factors are inconsistent and it is not incomprehensible for different applications [9].

6.2 Impact Score Technique (IST)

Federal Administration of the U.S (1999) developed a simple and effective measurement method to evaluate customer satisfaction for transit services termed as Impact Score Technique. The IST approach determines the relative impact of attributes on user satisfaction by measuring relative decrease in user satisfaction when there is a problem with the attributes. For each attribute the whole sample is divided into two categories, user who faced a recent problem and those who haven’t faced any problem (within past 30 days). The gap between mean overall rating of two groups is known as “Gap Score”. A composite index is found out by multiplying gap score to problem incident rate. The impact score is obtained from this it listed in the descending order to identify top attributes that drives major satisfaction. This technique is one of the simple methods for the estimation of important attributes which can impact the satisfaction of the user and it would be easily understood by the operator as well. The limitation of this technique is that all the data have to be collected within the past 30 days [10].

6.3 Important Performance Analysis (IPA)

IPA was first introduced by Martilla (1977) . IPA is also known as quadrant analysis which is used in many areas due to its ease of identification of different quality parameter that can lead to the improvement in Service quality. In IPA, user satisfaction is translated into Cartesian diagram where two lines perpendicularly Public Transport Performance Evaluation Techniques - A Review 6 divide it into four sections as shown in Figure 1. Where (Q) represents the average of average scores of level of implementation of all factors and (P) represents the average of average scores of the importance of all factors. Figure 1: Cartesian Diagram or IPA Diagram (Supranto, 1997) It can be used for comparing two or more systems[11]. This method does not reflect the dependence between two or more variables and effect of the presence or non-presence of different variables on overall service quality.

6.4 Customer Satisfaction Index (CSI)

Customer Satisfaction Index is a method to determine the level of satisfaction that has been achieved with respect to the service delivered. CSI was proposed by Supranto (1997). CSI can be computed by using the average value of the level of expectation and the performance of each service item. It enables estimation of service in terms of customer satisfaction in a very simple and systematic way based on the score provided by the customer but fails to take in account for the differences in user perception about different service aspects. Supranto suggested rating for CSI ranges as very satisfied (0.81-1.00), satisfied (0.66-0.80), quite satisfied (0.51- 0.65), less satisfied (0.35-0.50) and not satisfied (0.00-0.34) [12].

6.5 Ordered Logit Model

The ordered logit models are regression models for ordinal dependent variables and the genesis behind using this model is to understand how well that output can be predicted by the responses to other questions. This model was used by Tyrinopoulos and Antoniou (2008) for interpretation of the quality implications of the variability of the users’ perceived satisfaction across operators in Greece [6]. Laura Eboli and Gabriella Mazzulia introduced discrete choice logit models to calculate the probability of choice of some alternative transit services and determined the importance of each service aspect [13]. Cinzia Cirillo et al. investigated the heterogeneity of transit users in perceiving service quality through a mixed logit model with a non-parametric distribution of the Public Transport Performance Evaluation Techniques - A Review 7 coefficients [14]. Although ordered logit model can be used in rating systems (poor, fair, good, excellent), opinion surveys (strongly agree, agree, neutral, disagree, strongly disagree), and Ranking (senior, junior, sophomore, freshman).

6.6 Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) methodology is a powerful multivariate analysis technique in which a set of relationships between observed and unobserved variables are established. It is relatively new method which began in the 1970s (Fornell, 1981), it has been widely applied in various domain of research, including psychology, education, social science, economics, statistics, etc [15]. SEM methodology refers to a series of statistical techniques such as factor analysis, path analysis and regression models which are used to analyze data. Over the years, there has been a rapid development of different software packages such as LISREL (Joreskog, 1988, 1989) and the AMOS (Arbuckle, 1995) which have greatly enabled the use and application of SEM techniques in diverse contexts [16], [17]. SEM tools consist of two parts, i) Latent variable model which describes the relation between the endogenous and exogenous latent variables and allows the direct assessment of both path strength and their underlying impact among those variables. ii) Measurement model which depicts the correlation between latent and observed variables. Due to the popularity and simplicity in estimation, this method is used by various researchers. A. putra (2013) used SEM method for evaluation Bus service performance in terms of users expectation and satisfaction [8]. Other researchers like Irfan (2012) [18], Laura eboli (2012) used this method to identify transport performance in their respective countries [19].

6.7 Soft Computing Techniques

At present softcomputing techniques are also being used by researchers for performance appraisal of different transit system. Among different softcomputing techniques Artificial Neural Network (ANN), Fuzzy logic and Genetic algorithm now a days quite popular. An Artificial Neural Network is a parallel information processing unit that’s has working function same as biological neuron. Artificial neural network consist of large set of processing unit called neurons. Each of the neuron connects with each other by means of a direct link and each link associated with a specific weight. ANN based performance evaluation increase the accuracy of Public Transport Performance Evaluation Techniques - A Review 8 computing. Few researchers used this ANN concept to evaluate the performance of different transit systems. Shen and Li (2014) used a hof field neural network for studing performance of bus transport for five different routes [20]. The fuzzy inference system is one of the latest and advanced soft computing technique for detecting the fuzziness and defining the service quality parameter when going towards system performance comparision of large set of transit companies. Fuzzy theory was introduced by Zadeh (1965), which deals with positions that cause true to a certain degree (somewhere from 0 to 1) [21]. Few researchers used this fuzzy set concept to evaluate the performance of different transit systems. Chung-Hsing (1999) are among those few who studied the performance of 10 bus systems in Taipei using fuzzy inference system and set different membership functions different variables that impact the performance of transit system by considering five major factors i.e, safety, comfort, convenience, operation and social duties and also defines ranking of the systems based on a new approch of Overall Performace Index (OPI) [22]. The main drawback of this technique is that the application of fuzzy set theory in system performance evaluation needs higher expertise and knowledge for application and is also difficult for an operator to understand [18].

**CODE:**

import pandas as pd

import matplotlib.pyplot as plt

# Sample ridership data (you can replace this with your dataset)

data = {

'Route': ['A', 'B', 'A', 'C', 'B', 'C', 'A', 'B', 'C'],

'Ridership': [100, 80, 110, 50, 90, 60, 120, 70, 80]

}

# Create a DataFrame from the sample data

df = pd.DataFrame(data)

# Calculate average ridership per route

average\_ridership = df.groupby('Route')['Ridership'].mean().reset\_index()

# Data visualization (bar chart)

plt.figure(figsize=(8, 5))

plt.bar(average\_ridership['Route'], average\_ridership['Ridership'])

plt.xlabel('Route')

plt.ylabel('Average Ridership')

plt.title('Average Ridership per Route')

plt.show()

# Print the results

print("Average Ridership per Route:")

print(average\_ridership)

**7. Conclusion:**

Among above discussed models, SERVQUAL model is one of the simplest model to enumerate the service quality but it isn’t vastly used in transportation reasearch domain as it fails to specify a proper model and its attributes are inconsistent. The IPA and CSI based models provide good results but are unable to give the reasons for the impact of each attributes on service quality, while Artificial Neural Network (ANN) and Fuzzy inference based methods presents better accuracy in analysis of service quality attributes, obvious drawback of ANN and fuzzy logic stems from the fact that it fails to yield any direct numerical model as an output. If one makes comparison on all the available models, it can be inferred that the Structure Equation Modeling (SEM) is one of the best modelling approach in the field of research on service quality measurement. This is because, SEM enables understanding the impact of each variable on service quality and customer satisfaction in a more pragmatic manner and thus provide appropriate model for the estimation of each factor score and overall satisfaction in terms of quantitative measurement.