

DOI: <https://doi.org/10.57125/FEL.2024.12.25.14>

How to cite: Zidani, O., Alouat, M., & Tabti-Talamali, A. (2024). Using Correspondence Factor Analysis (CFA) to assess the quality of public transport services. A case study: Public transport in the Province of Boumerdes, Algeria. *Futurity Economics&Law*, 4(4). 239-258. <https://doi.org/10.57125/FEL.2024.12.25.14>

Using Correspondence Factor Analysis (CFA) to assess the quality of public transport services. A case study: Public transport in the Province of Boumerdes, Algeria

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Received: August 3, 2024 | **Accepted:** November 10, 2024 | **Available online:** November 29, 2024

Abstract: This study aims to analyse passenger expectations in terms of service quality and to propose improvements to increase the attractiveness of public transport in the Province of Boumerdes (specifically in the Municipalities of Boumerdes, Bordj Menaiel, Ouled Moussa, and Dellys). This analysis has helped identify the aspects of the service that most influence user satisfaction, providing a solid basis for decisions to optimise the quality of public transport in the Province. The study is based on a model using evaluation indicators that comply with the NF EN 13816 standard, which is specific to the quality of passenger transport. A field survey was carried out to gather the views of public transportation users. Random sampling was used, with 1093 respondents showing a representative distribution of the different municipalities in the province of Boumerdes. Several statistical analysis

tools were used to process and analyse the questionnaire data, including Excel, SPSS, and R, as well as the CFA method (Correspondence Factorial Analysis). This rigorous methodological approach allows an in-depth and reliable analysis of user satisfaction and the quality of public transport services in the Province. The study's results revealed significant differences in satisfaction regarding quality dimensions and a relation between the modalities of qualitative service quality variables used in the study area.

Keywords: Public transport, quality of transport services, service quality assessment, NF EN 13816 standard, correspondence factorial analysis (CFA), transport user satisfaction.

Introduction

Transport is a fundamental link that connects all the players in the sector, including public transport, which is considered to be an essential tool for the country's development (Ceder, 2021; Jaramillo et al., 2022), thanks to the many beneficial services it offers, whether for the transport of passengers or goods.

The development of public transport depends on improving the quality of transport services in general, which is seen as the ability to satisfactorily meet users' expectations (Abdullah et al., 2022; FNAUT, 2013, p. 13).

Service quality indicators are defined by AFNOR standard NF EN 13816 (Amara et al., 2024; Barabino et al., 2020). This standard defines all the quality indicators for passenger transport services, applicable to all modes of transport (Wawryszczuk et al., 2023). It is considered a necessary management tool in the transport sector, clarifying the distribution of responsibilities and optimising the involvement and coordination of all actors involved in the production of services (Baccelli & Morino, 2020). It also helps to improve the quality of transport services, effectively monitor commitments made and increase the value of passenger transport while providing a standardised framework for assessing and comparing the performance of different transport service providers (Lahlou & Chahli, 2015, p. 185).

Our study is concerned with evaluating service quality in the province of Boumerdès, located in the north of Algeria. We will use an approach based on the service quality indicators defined by AFNOR and conduct a user satisfaction survey (Amarasekara & Marasinghe, 2020). The data collected will be analysed using statistical tools, in particular, the Chi-square test (Tavares et al., 2021) and Correspondence Factorial Analysis (CFA) (Atombo & Wemegah, 2021; Girma et al., 2022), to determine any relationships between two qualitative variables (de Oña, 2022): the first representing geographical areas and the second selected questions reflecting user opinion. This approach will allow us to make a rigorous assessment of service quality and identify potential areas for improvement based on the specific geographical characteristics of the Province.

Research Problem

Preliminary studies on Algeria's transport sector primarily focus on quantitative aspects like multimodal planning, infrastructure capacity, and modal split analysis. However, qualitative dimensions such as service reliability, passenger comfort, and user experience are often underexplored. This study addresses this gap by examining the quality of terrestrial passenger transport services and identifying operational inefficiencies and service gaps. By focusing on these qualitative indicators, the research seeks to contribute to a more user-centric and efficient transportation system. This study examines how transport operators' service quality in Boumerdes, Algeria, affects user satisfaction. It also explores how public transport services are evaluated, focusing on methods and indicators for qualitative assessment.

Research Focus

The study's main objective was to assess the quality of service in public land transport and measure passenger satisfaction in the study area zones of the Province of Boumerdes. The authors

focused on analysing the data from the satisfaction survey conducted in 2024 and determining the modalities of the quantitative variables used to examine the relationship between them using the Correspondence Factorial Analysis (CFA) method.

Research Aim and Research Questions

This study aims to understand the concepts related to the quality of the public transport service in the Province of Boumerdes and its evaluation methods while exploring the concepts related to the quality of the service and its measurement methods. It will seek to clarify the influence of the quality of the transport service on customer satisfaction by analysing the data from the satisfaction survey carried out in the field. The study will also seek to identify and analyse the relationship between the modalities of two qualitative variables using the Correspondence Factorial Analysis (CFA) method. Finally, the final objective is to identify the main results that will make it possible to propose a series of recommendations to improve the quality of public transport services to increase customer satisfaction and loyalty. The following problem statement guides the study:

1. Does the quality of service offered influence the achievement of user satisfaction in the Province of Boumerdès - Algeria?
2. How was the CFA method applied in this research?
3. According to the study, what factors influence the perception of the quality of public transit services?

Literature Review

Documentary analysis was essential for our study on evaluating service quality (Redman et al., 2013). It enabled us to situate our research in Algeria's specific context, identify the quality of service indicators most relevant to our context, and define a sound theoretical framework for analysing the data from our satisfaction survey.

Improving the quality of service is a very useful way of improving public transport (Oeschger et al., 2020), as it not only attracts more passengers but also reduces travel problems.

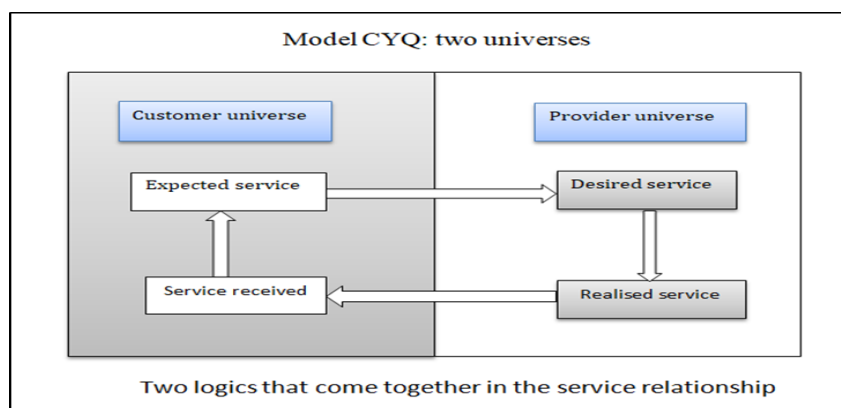
According to Loi No.°13/01 (2001), land transport is any activity by which a natural or legal person transports persons or goods from one point to another by road or rail using an appropriate vehicle. Transport is often defined as an intermediary service and a means to an end without being an end. In public transport, the main objective is to move people or goods from one point to another.

The quality of passenger transport services in Algeria is based on urban and non-urban public transport services (Loi No.°13/01, 2001). Article 28 states that within the urban transport perimeter, public transport shall be provided by equipped vehicles running on roads or mobile means on their own tracks. Urban public transport aims to limit the use of private cars, thereby reducing urban congestion and pollutant emissions. Article 33 states that non-urban public transport must provide connections of national interest and local interest between neighbouring municipalities and local interest within a city. The latter is essential in serving rural areas and facilitating interurban travel.

The same law classifies urban public transport services as regular public services that follow a specific route, timetable, and frequency that are published in advance. Generally, transport service quality is the degree of conformity of all the characteristics of a service to satisfy objectively or subjectively the needs and expectations of users for a market segment and at a reasonable price (Christophe, 2004, p. 140).

Figure 1

The Service Quality Cycle



Source: Averous and Averous (1998, p. 4).

To ensure the desired quality of service, the process is as follows:

- The service provider defines the 'desired service';
- It adapts its structures to deliver the 'realised service';
- This delivered service becomes the 'perceived service' for the customer;
- The customer's perception, in turn, influences the 'expected service' for future interactions.

Evaluation of service quality is essential for achieving these objectives. Numerous studies have proposed a survey assessing public transport user satisfaction in Algiers using the SERVQUAL method (Mimoune & Chabane, 2024). The survey, with a sample of 1704 respondents, sheds light on users' perceptions of the services' quality. The results show that services do not always meet users' expectations, with significant differences between residents in different regions of Algiers.

Service Quality Indicators

Quality of service in public transport is a multidimensional concept (Boulkaibet et al., 2020) based on evaluating key indicators (Errampalli et al., 2020). These indicators allow customers to assess the quality of the transport service (perceived quality) (Tumsekcali et al., 2021). To define these indicators, the French standardisation bodies, in particular AFNOR, rely on the work of the French National Institute for Transport and Safety Research (INRETS). The NF EN 13816 standard defines a set of quality indicators for passenger transport services applicable to all modes of transport (Meudic, 2022); it is a valuable management tool that makes it possible to clarify the distribution of responsibilities and to identify all the players involved in the production of the service.

According to this standard, AFNOR defines eight categories of quality indicators for public transport services, as follows (Norme européenne NF EN 13816, 2002, p. 8):

- **Service offer:** This dimension includes indicators relating to the variety of services offered, frequency of services, vehicle capacity and geographical coverage of the network.
- **Accessibility:** This dimension assesses the ease of access to stops and stations, the availability of information on timetables and routes, and the adaptation of infrastructure to people with reduced mobility.
- **Information:** This dimension concerns the quality and accessibility of information provided to users, particularly timetables, fares, routes, connections, and service disruptions.
- **Time:** This dimension measures the punctuality of services, journey times and waiting times at stops and stations.

- **Customer focus:** This dimension assesses the quality of reception and service provided to users, the courtesy and availability of staff and the extent to which complaints and suggestions are taken into account.

- **Security:** This dimension concerns the safety of users and property during journeys, the quality of vehicle and infrastructure maintenance, and the implementation of accident prevention measures.

- **Comfort:** This dimension assesses user comfort during the journey, particularly vehicle cleanliness, air conditioning, lighting, and the presence of comfortable seats.

- **Environmental impact:** This dimension measures the environmental impact of public transport, particularly greenhouse gas emissions, noise pollution, and energy consumption.

An analysis of the literature on quality of service in public transport reveals several significant gaps (Dong et al., 2021), as most studies focus on urban contexts, neglecting the specific features of rural areas such as Algeria. In addition, there is a lack of research integrating the perspectives of both users and transport operators, which limits the overall understanding of quality issues. Furthermore, few studies have examined the impact of socioeconomic factors on perceptions of service quality. Finally, existing evaluation methods often fail to consider the variability of user expectations across different population segments. These shortcomings underline the need for an in-depth, contextualised study of public transport service quality to provide new, relevant knowledge for improving transport provision in our country.

Materials and Methods

Presentation of the Study Area

The Province of Boumerdès is coastal in central Algeria; it covers an area of 1,456.16 km² and has around 100 km of coastline. It was created following the promulgation of law no. 84-09 of 4 February 1984 on administrative-territorial division, and currently has 9 Dairas (each grouping several municipalities). The Province comprises a total of 32 municipalities (ONS, 2020).

The Province of Boumerdès is bordered to the north by the Mediterranean Sea, to the east by the Province of Tizi Ouzou, to the south-east by the Province of Bouira, to the south-west by the Province of Blida and to the west by the Province of Algiers. The study area comprises four geographical zones (Municipalities: Boumerdes, Bordj Menaiel, Ouled Moussa and Dellys).

According to the 2008 census, the population was estimated at 801,068 and is expected to reach 1,021,018 by 2020 (ONS, 2020).

The population data for the four geographical areas selected for our study, according to statistics for 2020, are as follows: The Municipality of Bordj Menaiel is located on the southern coast of the Province of Boumerdes and is one of the most densely populated municipalities in the Province, with 81,245 inhabitants. The Municipality of Boumerdes, the capital of the Province, has a population of 54,124 inhabitants. The Municipality of Dellys, on the east coast of the Province of Boumerdes, has a population of 39,867 inhabitants, and the Municipality of Ouled Moussa, on the west coast of the Province of Boumerdes, has a population of 65,257 inhabitants.

Study Population and Sample

The sample consisted of 1,093 public transport users in the Province of Boumerdes. The classification was based on the province's geographical areas (Municipalities) and the number of bus stations and bus stops.

The satisfaction survey was carried out among users of transport services (public and private) to gain a better understanding of the level of service provided (Wang et al., 2021).

The quality of public transport in the Province of Boumerdes was assessed using a questionnaire based on a satisfaction survey to obtain primary data based on evaluation indicators that comply with the NF EN 13816 standard on the overall quality of public passenger transport.

Our questionnaire is structured and consists mainly of closed questions (Moslem et al., 2020; Przybylowski et al., 2021), where the answers are predetermined. It follows a rigid format, making quantifying and analysing statistically easy. The questionnaire includes several multiple-choice questions and Likert scales, which enable responses to be standardised and analysed efficiently.

The questionnaire has 02 parts: The first contains data on the general criteria of the study sample (gender, age, level of education, occupation, ticket price...), while the second contains data on the detailed criteria in the form of questions representing the different dimensions of the study variables (service provision, accessibility, duration, comfort etc.). Likert scale was used to measure responses to questionnaire items, as shown in Table 1 (Mimoune & Chabane, 2024; Sukhov et al., 2021).

Table 1

Likert Scale Levels

Response	Not at all satisfied	Not satisfied	Neutral	Satisfied	Very Satisfied
Code	PTS	PS	N	S	TS
Ranking	1	2	3	4	5

Source: Authors' elaboration.

Table 1 shows that if the customer is not satisfied at all, it corresponds to score 01 and so on for the remaining responses.

Reliability and validity of the study tool: The questionnaire was submitted to professors specializing in quality and transport, and their comments and suggestions helped to refine the questionnaire's content, making it more relevant and appropriate to the study's objectives.

Stability of the study tool: To assess the reliability of the survey instrument, Cronbach's alpha coefficient (Hayes & Coutts, 2020; Kennedy, 2022) was calculated at 0.82, which is above the threshold of 0.60 and is generally considered acceptable for research. This value indicates good internal consistency of the questionnaire items, suggesting a high degree of stability.

We want to study the possible relation between the modalities of two qualitative variables. To do this, we have chosen four modalities of geographical areas:

- Zone 01 : Municipality of Bordj Menaiel ;
- Zone 02: Municipality of Boumerdes;
- Zone 03: Municipality of Dellys;
- Zone 04: Municipality of Ouled Moussa.

The three types of questions chosen (user opinions) are:

- Is public transport regularly available;
- Do transport operators respect time slots;
- The price of the ticket.

The satisfaction survey was carried out using a Likert scale (very satisfied, satisfied, not very satisfied, not at all satisfied, neutral), after which we tried to identify any transport problems and propose solutions.

We will perform the Chi-square test (Harerimana & Mtshali, 2020; Tavares et al., 2021). This test analyses the relationship between two qualitative variables, X (geographical area) and Y (Passenger ratings and opinions). It is assumed that X has p modalities and Y has q modalities.

To study this relation, we draw a sample of size n and construct a contingency Table 2 (Leclerc, 1975), also known as a cross-tabulation table (Lebart, 1989).

Table 2

Contingency Table

X/Y	y_1	...	y_q	Total
x_1	n_{11}	...	n_{1q}	$n_{1.}$
\vdots			\vdots	\vdots
x_p	n_{p1}	...	n_{pq}	$n_{p.}$
Total	$n_{.1}$...	$n_{.q}$	n

Source: Authors' elaboration.

Where

$x_1 \dots x_p$: Modalities of the variable X

$y_1 \dots y_q$: Modalities of the variable Y

Associated number of modality i of variable X and modality j of variable Y

$n_{i.}$ =: Sum of the jth row: marginal effect size of modality i of variable X

$n_{.j}$ =: Sum of the ith column: the marginal size of modality j of variable Y

n =: Total Workforce

Steps in constructing the chi-square test (Kwan et al., 2020; Shankar, 2019).

1) Define the assumptions H_0 and H_1

$$\begin{cases} H_0: X \text{ and } Y \text{ are independent} \\ H_1: X \text{ and } Y \text{ are not independent} \end{cases}$$

2) Choose the significance level of the test α :

$$\alpha = P(\text{reject } H_0 / H_0 \text{ is true}) \text{ (Error of the first kind).}$$

3) Calculate the theoretical workforce under H_0 .

As mentioned above, the theoretical numbers represent the numbers that would have been obtained if the variables X and Y were independent and are calculated as follows:

$$T_{ij} = \frac{n_{i.} \times n_{.j}}{n}$$

4) Define a decision variable (or statistic) D.

This statistic measures the difference between observed and theoretical headcount.

$$D = \sum_{i=1}^p \sum_{j=1}^q \frac{(n_{ij} - T_{ij})^2}{T_{ij}}$$

Law of D:

If H_0 is true and $T_{ij} \geq 5$ and $n \geq 50$ then

$$D \sim \chi^2_{(p-1)(q-1)}$$

D is a random variable, and its realisation over a sample is equal to d

5) Determining the critical value:

Critical value d_0 is the quantile of order $1 - \alpha$ from a chi-square law to $(p-1)(q-1)$ degrees of freedom.

6) Setting the decision rule:

We reject the hypothesis H_0 if $d > d_0$

Otherwise, we do not reject hypothesis H_0 and consider X and Y independent.

In this case: p – value = $P(D > d)$

We will reject H_0 if p – value $< \alpha$

We will choose a significance level of $\alpha = 5\%$

Apply the Procedure in R for our Case

The Chi-square test only allows us to indicate a relation (link) between two qualitative variables. To study the relation between the modalities of the two variables, we add a CFA (Correspondence Factorial Analysis) to this test. CFA is a statistical technique used to analyse categorical data (de Oña, 2022; Hamerska et al., 2022). It allows the visualisation of relations between categories of different variables and the identification of underlying structures in the data (Gamboa-Rosales et al., 2020). CFA is used to study contingency tables and to identify any links between the terms of two selected qualitative variables (the terms of the zones and the terms of the selected questions (user’s opinions)).

Research Results

For our case study, we will construct three contingency tables, followed by the chi-square test, and finally determine the relation between the modalities using CFA. We will be working with ‘R’ software and Excel, and the results will be represented as follows/

The first case: Relation Between Geographical Area and Public Transport Regularly Available

Table 3 shows users' (travellers) opinions on the availability of public transport in different geographical areas. The opinions are grouped into five categories: neutral (N), Not Satisfied (PS), not at all Satisfied (PTS), Satisfied (S), and Very Satisfied (TS). The aim of this analysis is to assess the availability of public transport in each geographical area.

Table 3

Cross-Tabulated Data Between Modalities (Geographical Area / Public Transport Regularly Available)

Number of geographical areas	Column labels					General total
	Line labels	N	PS	PTS	S	
Bordj Menaïel	35	130	152	62	7	386
Boumerdes	85	195	129	55	14	478
Dellys	39	41	37	36	4	157
Ouled Moussa	7	29	23	12	1	72
General Total	166	395	341	165	26	1093

Source: Authors’ elaboration.

Table 3 represents the satisfaction of users regarding the availability of public transport in the four zones; in Bordj Menaïel, there is a high level of dissatisfaction, with 73% of dissatisfied (39% not at

all satisfied and 34% not satisfied), 9% of neutrals and only 18% of satisfied, while in Boumerdès, the trend remains negative with 68% of dissatisfied (27% not at all satisfied and 41% not satisfied), 18% neutral and 14% satisfied, in Dellys, opinions appear more balanced with 50% dissatisfied (24% not at all satisfied and 26% not satisfied), 25% neutral and 25% satisfied. In contrast, in Ouled Moussa, dissatisfaction predominates, with 72% dissatisfied (32% not at all satisfied and 40% not satisfied) and only 10% neutral.

To carry out the chi-square test, we use a function supplied as standard with the R software: the **chisq.test** function (Okoye & Hosseini, 2024). Note that **Z1** represents our data in Table 3.

```

chisq.test(Z1)

Pearson's Chi-squared test

data: Z1

X-squared = 57.109, df = 12, p-value = 7.555e-08

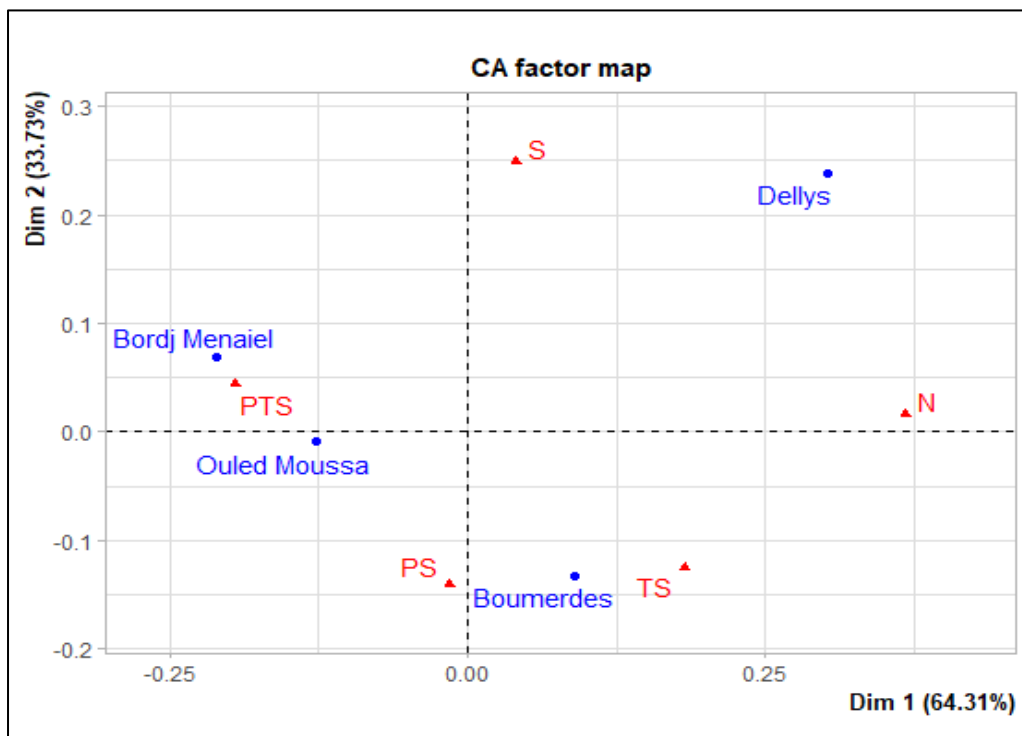
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We note that the p-value = 7.555e-08 is less than 0.05. We reject the hypothesis of independence H_0 , and we conclude that the threshold $\alpha \geq 5\%$ that there is a relation (link) between the 'geographical area' and the assessment of whether public transport is regularly available. As the Chi-square test confirmed the existence of a relation between the terms 'geographical area' and "public transport regularly available", we will conduct a CFA to refine our analysis.

We will do a CFA to visualise the nature of the link (Figure 2). We've chosen the "FactoMineR package" dedicated to multidimensional data analysis (Lê et al., 2008). We will use the CA() function on R to do this.

Figure 2

The AFC Graph of (Geographical Area / Public Transport Regularly Available)



Source: Authors' elaboration using R.

We have only interpreted the first axis in all cases, as it contains most of the initial information.

Axis 01: This axis explains 64.31% of the total inertia, with the Boumerdès geographical area on the positive side and the Bordj Menaïel and Ouled Moussa geographical areas on the opposing side. The TS mode on the positive side of the axis is opposite to the PTS mode on the opposing side.

It should be noted that we have not interpreted the Dellys, S, and N modalities because they are far from each other. This implies that there is no relation between them, and the same applies to the PS modality.

Table 4 and Table 5 show the breakdown for Axis 01.

Table 4

Modalities of Geographical Areas

Axis 01 positive	Axis 01 negative
Boumerdes	Bordj Menaïel Ouled Moussa

Source: Authors' elaboration.

Table 5

Modalities of Questions Chosen (User Opinions)

Axis 01 positive	Axis 01 negative
TS	PTS

Source: Authors' elaboration.

The correspondence factor analysis (CFA) graph defines the relationship between geographical areas and travellers' assessment of the availability of public transport to determine the quality of service and disruption of public transport. The graph shows that the Bordj Menaïel and Ouled Moussa modalities are close to each other, which means that the two modalities have the same characteristics regarding public transport availability. We can, therefore, see that the Bordj Menaïel and Ouled Moussa modalities and the PTS are close to each other in the cloud, indicating a similarity in their perception of transport availability.

The Second Case: The Terms are "Geographical area" and "Do operators respect the time slots?"

The following table presents the cross-tabulated data for the two categories.

Table 6

Cross-tabulated data between modes (geographical area / do transport operators respect time slots)

Number of geographical areas Line labels	Column labels					General total
	N	PS	PTS	S	TS	
Bordj Menaïel	79	92	124	78	13	386
Boumerdes	107	174	128	61	8	478
Dellys	40	37	24	47	9	157
Ouled Moussa	8	22	15	17	10	72
General Total	234	325	291	203	40	1093

Source: Authors' elaboration.

Table 6 shows the satisfaction of users regarding the respect of timetables by transport operators reveals significant variations between the zones; in Bordj Menaïel, the perception is mainly negative with 56% dissatisfied (32% not at all satisfied and 24% not satisfied), 20% neutral, and only 23% satisfied, similar trend in Boumerdès where 63% are dissatisfied (27% not at all satisfied and 36% not

satisfied), 22% neutral and 15% satisfied; on the other hand, Dellys has a more balanced profile with 39% dissatisfied (15% not at all satisfied and 24% not satisfied), 25% neutral and 36% satisfied. In comparison, Ouled Moussa has a mixed distribution with 52% dissatisfied (21% not at all satisfied and 31% not satisfied), 11% neutral and 38% satisfied.

To perform the chi-squared test, we use a function that comes standard with the R software: the **chisq.test** function. Note that **Z2** represents our data table (Table 2).

```

chisq.test(Z2)

Pearson's Chi-squared test

data: Z2

X-squared = 80.538, df = 12, p-value = 3.259e-12

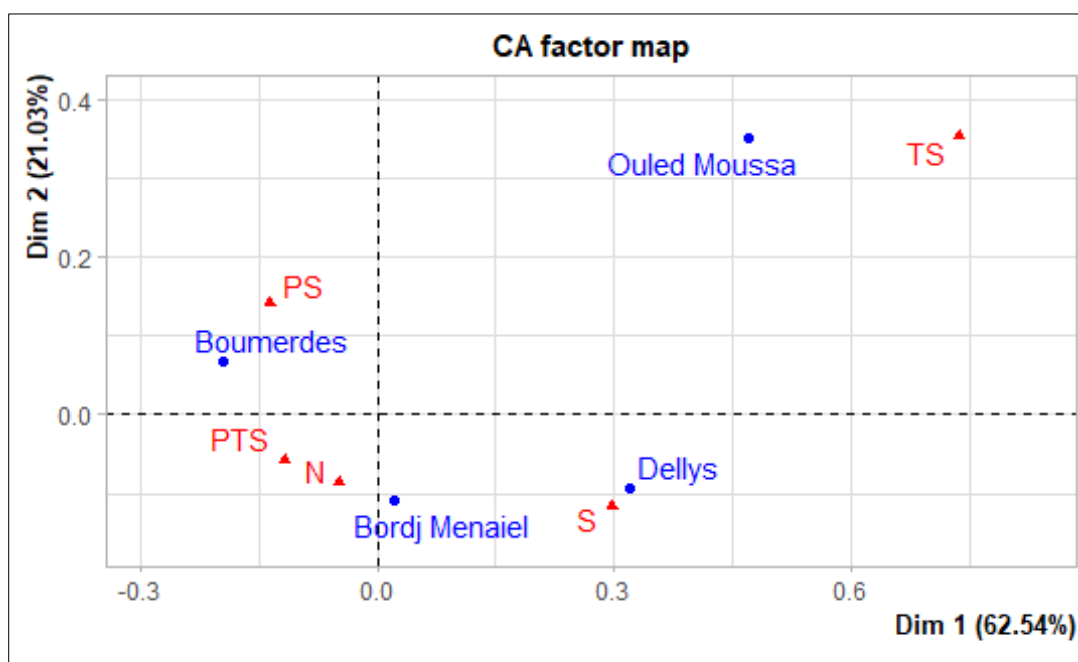
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We find that the p-value = 3.259e-12 is less than 0.05, so we reject the hypothesis independence H_0 , and we conclude that the threshold $\alpha \geq 5\%$ H_1 that there is a link between the geographical area' and the assessment of "compliance with time slots by transport operators". As the Chi-square test confirmed the existence of a relation between "geographical area and compliance with time slots by transport operators" conditions, we will conduct a CFA to refine our analysis.

We will carry out an AFC to visualize the nature of the relation (Figure 3). We have chosen to use the FactoMineR package (dedicated to multidimensional data analysis). To do this, we'll use the CA() function on R.

Figure 3

The AFC Graph of (Geographical Area / Do Transport Operators Respect Time Slots)



Source: Authors' elaboration using R.

Axis 1: This axis accounts for 62.54% of the total inertia, with the geographical area of Dellys on the positive side and the geographical area of Boumerdes on the negative side of the axis. The (S) modality on the positive side opposed the PS modality on the negative side of the axis. It is essential to highlight that we did not interpret the modalities of Ouled Moussa, TS because they are far from each other, which implies the absence of a relation between these modalities, as well as the modality of Bordj Menaiel.

Table 7 and Table 8 show the breakdown for Axis 1.

Table 7

Modalities of Geographical Areas

Axe01 positive	Axe01 negative
Dellys	Boumerdes

Source: Authors' elaboration.

Table 8

Modalities of Questions Chosen (User Opinions)

Axe01 positive	Axe01 negative
S	PS

Source: Authors' elaboration.

The Correspondence Factor Analysis (CFA) graph defines the relationship between geographical areas and operators' perceptions of on-time performance. It can be used to assess service quality and identify disruptions in public transport. Analysis of the graph shows, on one hand, proximity between the Dellys modality and the S (satisfied) modality in the cloud, suggesting a relatively positive perception of timetable adherence by transport operators. On the other hand, the proximity of Boumerdes and PS reflects a negative perception of punctuality.

The Third Case: Determine the Relation Between "Geographical Area" and "Ticket Price".

The following table shows the cross-tabulated data for the two modalities.

Table 9

Cross-Tabulated Data Between Modes (Geographical Area/Ticket Price)

Number of geographical areas Line labels	Column labels			General Total
	Affordable price	High price	Too expensive	
Bordj Menaïel	220	125	41	386
Boumerdes	293	144	41	478
Dellys	123	26	8	157
Ouled Moussa	45	23	4	72
General Total	681	318	94	1093

Source: Authors' elaboration.

Table 9 represents the price perceptions in the four geographical areas and reveals variable trends; in Bordj Menaïel, 57% of the opinions consider the price affordable, 32% find it expensive and 11% too expensive, while in Boumerdes, similar perceptions are observed with 61% of views "Affordable price", 30% "Expensive" and 9% "Price too expensive"; in Dellys, the distribution of opinions is more contrasted with 78% of "Affordable price", 17% "Expensive" and 5% "Too expensive", and finally in Ouled Moussa, the dominant perception is also that the price is affordable at 63%, followed by 32% of "Expensive price" and 6% "Price too expensive".

To perform the chi-squared test, we use a function that comes standard with the R software: the **chisq.test** function. Note that **Z3** represents our data table (Table 2).

```
chisq.test(Z3)
```

Pearson's Chi-squared test

data: Z3

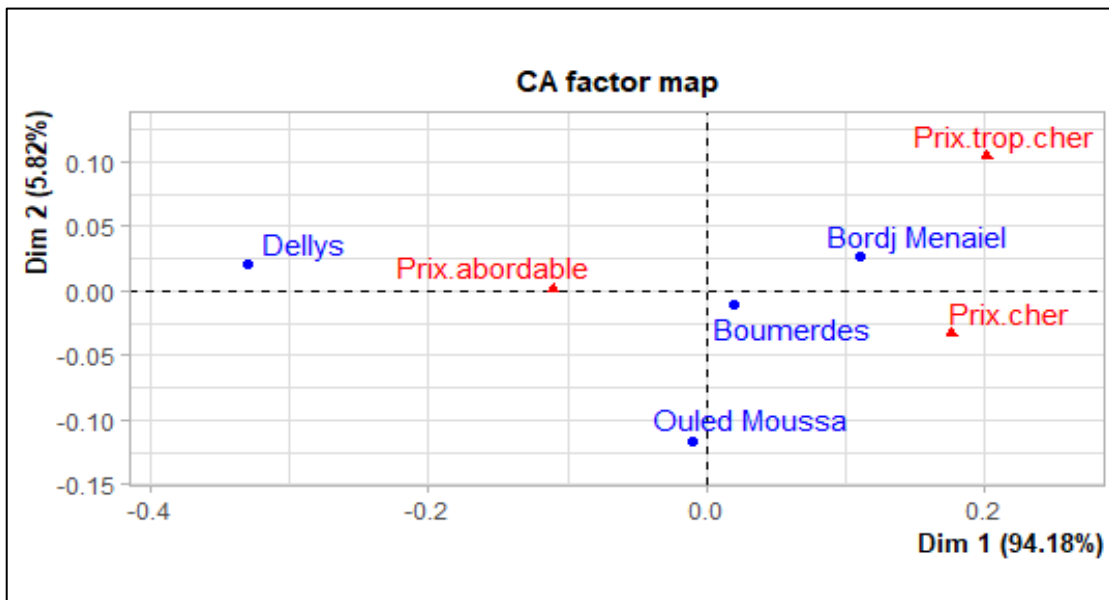
X-squared = 23.449, df = 6, p-value = 0.0006593

We find that the p-value = 0.0006593 is less than 0.05, so we reject the hypothesis of independence H_0 , and we conclude that the threshold $\alpha \geq 5\%$ that there is a link between the 'geographical area' and the assessment of the 'price of the ticket'. The Chi-square test confirmed a relation between the categories of 'geographical area and ticket price'. Consequently, we will perform a CFA to refine our analysis.

We will do an AFC to visualise the nature of the link (Figure 4). We've used the FactoMineR package (dedicated to multidimensional data analysis). For this purpose, we will use the CA() function on R.

Figure 4

The AFC Graph of (Geographical Area/Ticket Price)



Source: Authors' elaboration using R.

Axis 01: This axis explains 94.18% of the total inertia and pits the Boumerdes and Bordj Menaiel geographical area on the positive side of the axis against the Dellys geographical area on the opposing side. The modality (expensive price, price too expensive) is on the positive side (affordable price) as opposed to the negative side of the axis. It is important to note that we did not interpret the Ouled MOUSSA price modalities as too expensive because they are far from the other modalities, suggesting no relation between them.

Table 10 and Table 11 show the breakdown for Axis 1.

Table 10

Modalities of Geographical Areas

Axe01 positive	Axe01 negative
Boumerdes	Dellys
Bordj Menaiel	

Source: Authors' elaboration.

Table 11*Modalities of Questions Chosen (User Opinions)*

Axe01 positive	Axe01 negative
Expensive price	Affordable price

Source: Authors' elaboration.

The Correspondence Factor Analysis (CFA) graph defines the relationship between geographical areas and the ticket price rating to determine the quality of service and disruption in public transport. The analysis of the graph reveals proximity between the Boumerdes and Bordj Menaiel modalities, indicating similarity in their ticket price characteristics. This suggests that factors influence ticket prices, such as administrative activity, given that Boumerdes is the Province's capital, Bordj Menaiel is the capital of the Daira and their significant commercial activities.

Discussion

The aim of our study was to analyse the quality of public transport service and determine user satisfaction by analysing the data from the satisfaction survey carried out in the field and the relationship between geographical areas and the variables selected. Finally, the objective was to identify the main results aimed at improving the quality of the public transport service in order to increase user satisfaction.

Previous studies have shown, for example, in the study of Mimoune and Chabane (2024), that user satisfaction in public transport in Algiers indicates that most users are classified into the 'dissatisfied' and 'neutral' categories. The results highlight critical problems, notably the lack of friendliness of drivers, contributing to a negative perception of service quality. Previous research has also shown that service quality, measured by variables such as comfort, punctuality and pricing, plays a vital role in passenger experience (Abdullah et al., 2021). Based on these studies, we proposed our first research question. We obtained in the results the existence of a relationship between the modalities of the geographical areas and the modalities of the selected questions (users' opinions), which indicate that the majority of passengers are not satisfied with the availability of public transport and with the punctuality (respect of time slots) of transport operators. This could be explained by factors linked to degraded or non-existent infrastructure and problems with transport organisation. As well as an inadequate transportation service for the population's needs. On the other hand, most opinions on 'affordable prices' are expressed by the population's satisfaction with the prices charged by transport operators, which the government generally sets. Contrary to the study of Amara et al. (2024), whose results show a positive correlation between transport service quality indicators and customer satisfaction for the services offered by the SNTF in Annaba, as well as Deepa et al. (2021), whose results show that the service provided has a positive influence on passenger satisfaction and confidence.

For the second research question, which concerns the application of the research method, we chose Correspondence Factor Analysis (CFA). This is a statistical technique used to analyse categorical data. In our case, it makes it possible to study contingency tables and establish possible links between the modalities of two selected qualitative variables (the modalities of the zones and the modalities of the questions chosen concerning users' opinions), as documented in previous studies de Oña (2022) used a confirmatory factor analysis model to assess the quality of service perceived by public transport users, which made it possible to estimate the relationships between latent factors (such as quality of service) and observed indicators (such as punctuality, frequency, comfort, etc.). The results indicate that the most critical attributes for public transport users are punctuality and frequency, while cost, safety and cleanliness are perceived as less necessary. As for Hamerska et al. (2022), their CFA results showed that all dimensions were significantly related to perceived service quality, which can guide service managers in improving their offerings to meet user expectations. Similarly, using CFA enabled us to define the relationship between geographical areas and the three modalities of the questions. The

relationship between the first and second modalities (availability and adherence to opening times) and their similarities suggest possible associations between these variables depending on the characteristics of each zone. The third modality, relating to ticket prices, also shows similarities, which suggest possible associations between these variables.

Regarding the third research question, based on previous research findings, Atombo and Wemegah's (2021) study aims to identify service quality factors that predict passenger satisfaction and use of public transport. Focusing on the Ghanaian context, they determined that expectation factors, such as availability, safety and reliability, are the most significant for passenger satisfaction. Wawryszczuk et al. (2023) determine the factors influencing the quality of comfort in transport, such as air temperature, humidity, vibrations and air quality. In their work, Dong et al. (2021) indicate that several factors influence the quality of public transport, such as the perception of safety, information and communication, psychological distance and safety measures. These factors show that the quality of the public transport service is strongly influenced by the perception of safety, effective communication and the safety measures put in place. The study identified several factors that come into play when assessing the quality of service, namely location (geographical area), regularity and availability of transport, and ticket price. The results for the first factor indicate that the majority of passengers are not satisfied with the availability of public transport, which could be explained by other factors linked to the deterioration in the quality of infrastructure, as in the case of Municipality of Ouled Moussa, as well as transport services that do not meet passenger expectations. Similarly, for the second factor, the results indicate that most passengers are unsatisfied with transport operators' failure to keep to timetables. Significant variations between zones could be explained by other factors linked to problems with the organisation of transport and the punctuality of drivers. In contrast to the first two factors, for the third factor concerning the ticket price, the study found that passengers were satisfied with the prices charged by transport operators, which the government generally sets. Finally, the fourth factor, geographical area, plays a vital role in the distribution of population and infrastructure, influencing the results of the different modalities studied.

Limitations of the Study

Although the study was carried out using a global approach, several limitations restrict the generalizability of its results. These include the constraint of geographical concentration on the Province of Boumerdès in Algeria, which may influence the generalizability of the results to other regions of the country, particularly those with different socioeconomic, cultural, or infrastructure contexts. In addition, using the AFNOR NF EN 13816 standard could limit comparability with studies using other standards or service quality indicators.

The satisfaction survey, targeting mainly current public transport users, neglects non-users expectations, which limits understanding of the barriers to adopting these services. In addition, the study may not completely account for all the factors involved in assessing service quality and comes up against methodological constraints, such as the content of the data collected. Limitations relating to statistical models, sample size and study duration must also be considered when interpreting the results.

To overcome these limitations, future research could broaden the scope of the study for a more comprehensive comparison, include the perspectives of non-users of public transport, and complement the quantitative analysis with qualitative methods. This approach would provide a more nuanced understanding of users' perceptions and strengthen the validity and generalisability of the results obtained.

Conclusion and Recommendations

In conclusion, our study focuses on assessing the quality of public transport services in the study area located in the Province of Boumerdes. The data analysis reveals a predominant dissatisfaction

among users, particularly regarding the availability of transport and the use of advanced statistical methods, notably Correspondence Factorial Analysis (CFA). This made it possible to identify significant correlations between geographical areas and various aspects of the service, such as punctuality and fares.

These results underline the importance of a user-centred approach to evaluating and improving transport services and the need to tailor services to the specific needs of each area, taking into account the evolving expectations of transport users.

To make progress, it is recommended that regular assessments of user satisfaction be carried out, practical statistical tools be used, and recognised standards such as NF EN 13816 be used as a basis. These approaches will effectively guide future decisions and continuously improve the quality of the service, thereby helping to increase the satisfaction and loyalty of public transport users.

Transportation operators must recognise the critical importance of evaluating their services' quality from their passengers' perspective (Bellizzi et al., 2020). This involves regularly measuring passenger satisfaction and adapting to evolving needs and expectations. To achieve this, operators should employ statistical methods and data analysis, using public transportation service quality standards as a decision-making framework. Operators should prioritise the service delivery process and ease of access, making decisions focused on assisting passengers, providing comprehensive information about available services, and adhering to schedules (Deepa et al., 2021).

Suggestions for Future Research

The study of the quality of public transport service in the Province of Boumerdes in Algeria could consider several complementary avenues of research. For example, a survey carried out over several years would enable us to observe changes in user satisfaction and the effectiveness of improvements to the service offered.

At the same time, a comparative analysis with other Algerian regions or similar cities in different countries would offer exciting insights into best practices and evaluate the impact of new technologies, such as mobile applications for real-time transport monitoring.

Using statistical models to predict user satisfaction according to various indicators would also be helpful and could complement these analyses. Furthermore, an environmental study examining the ecological impact of different service improvement options would be relevant in the current context of climate concerns.

Finally, it would be essential to broaden the investigation's scope by analysing why some residents do not use public transport and what might encourage them to do so. A specific assessment of accessibility for people with reduced mobility or special needs would help to make the service more inclusive. A study of the possibilities for multimodal integration, combining public transport with other modes and these various lines of research, would provide optimum public transport management in the Province of Boumerdes.

Acknowledgements

None.

Conflict of Interest

None.

Funding

The Authors received no funding for this research.

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