

## Article

# Evaluating Passenger Satisfaction in the Valparaíso Railway Service: An Exploratory Study Based on Critical Experience Attributes

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## Abstract

Passenger satisfaction is a key component of sustainable urban mobility, influencing public transport use, customer loyalty, and the attractiveness of railway systems. However, evidence from Latin American commuter rail services remains limited. This study evaluates the satisfaction of frequent users of the Limache–Puerto railway service operated by EFE Valparaíso in Greater Valparaíso, Chile, based on measurements conducted between 2024 and 2025. Using 400 surveys administered on station platforms and onboard trains, the analysis assessed overall satisfaction, Net Promoter Score (NPS), and experience attributes related to safety, predictability, cleanliness, information provision, comfort, and crowding. A repeated cross-sectional quantitative design with quota sampling was employed to compare successive measurement waves. Results indicate that passengers highly value the service’s speed and efficiency. Although NPS experienced a temporary decline during 2025, the final measurement remained comparable to the 2024 baseline. Key concerns included perceived platform safety, peak-hour crowding, onboard environmental conditions (temperature and odors), and service frequency in critical segments. Mentions of informal vendors decreased, whereas concerns regarding criminal incidents and passenger flow difficulties increased. The findings highlight the need for targeted interventions in safety, crowding management, environmental quality, and communication during disruptions. This pilot operational monitoring study proposes a practical framework for evaluating passenger satisfaction and NPS through repeated measurements, providing evidence to support service management and sustainable railway planning.

**Keywords:** satisfaction; Net Promoter Score; quality service; attributes; passenger; railway; Valparaíso; Chile



Academic Editor: Marilisa Botte

Received: 11 June 2026

Revised: 8 July 2026

Accepted: 14 July 2026

Published: 21 July 2026

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## 1. Introduction

### 1.1. Background

Railway systems play a fundamental role in promoting sustainable urban mobility by providing efficient, reliable, and environmentally friendly transport alternatives to private vehicles. As metropolitan areas continue to expand, the quality of service delivered by urban and suburban railways becomes increasingly important because it influences

passenger satisfaction, travel demand, customer loyalty, revenue generation, and the long-term attractiveness of public transport systems [1]. In this context, understanding how passengers perceive service quality is essential for improving operational performance and encouraging a modal shift toward more sustainable transportation options.

In Latin America, commuter railway systems operate under a set of challenges that differ from those commonly reported in Europe, North America, and parts of Asia. Many metropolitan regions have experienced rapid urban growth, increasing travel demand, and suburban expansion, often outpacing investments in transport infrastructure. As a result, railway operators frequently face capacity constraints, peak-hour overcrowding, aging infrastructure, funding limitations, and operational reliability issues. In addition, socioeconomic inequalities and high levels of public transport dependency mean that rail services play a critical role in providing access to employment, education, and essential services for large segments of the population. These conditions create a complex operating environment in which service quality, safety, comfort, and reliability become particularly important determinants of passenger satisfaction and system attractiveness [2].

Despite the strategic role of commuter railways in supporting sustainable mobility in Latin American cities, empirical research on passenger satisfaction remains relatively limited compared with the extensive literature available for railway systems in Europe and North America. Existing studies have predominantly focused on operational performance, infrastructure development, or travel demand, while comparatively less attention has been given to understanding how passengers evaluate service quality and how these perceptions influence satisfaction, loyalty, and willingness to recommend railway services. Consequently, there is a need for context-specific evidence that captures the unique operational and socioeconomic characteristics of Latin American railway systems and supports user-centered transport planning and management [3].

In the case of Valparaíso, Chile, the Limache–Puerto railway service, operated by EFE Valparaíso, constitutes the backbone of public transport in Greater Valparaíso, Chile, connecting the municipalities of Valparaíso, Viña del Mar, Concón, Quilpué, and Villa Alemana through a highly utilized electrified rail corridor. The system supports a substantial share of daily commuting trips associated with employment, education, and access to metropolitan services, making it a critical component of regional mobility, accessibility, and territorial equity.

Given its strategic importance, the systematic evaluation of passenger satisfaction provides valuable information regarding the strengths and weaknesses of the service. Frequent users, defined in this study as passengers making four or more trips per week, represent a particularly relevant population because they account for a large proportion of total demand and are continuously exposed to operational conditions, service disruptions, and infrastructure constraints. Consequently, their perceptions offer a detailed understanding of how operational performance translates into user experience.

## 1.2. Justification of the Study

The evaluation of passenger satisfaction has become a major research topic in transportation studies. Previous research has demonstrated that service quality perceptions are influenced by both objective operational characteristics and subjective experiential factors [4–7]. Operational attributes such as service frequency, travel time, punctuality, accessibility, and reliability have consistently been identified as important determinants of passenger satisfaction. At the same time, qualitative dimensions including personal safety, comfort, cleanliness, crowding, and information provision significantly influence how users evaluate public transport services.

Several studies have emphasized that service quality should be understood as a multidimensional construct in which different attributes jointly shape overall evaluations of transport systems [5]. In railway environments, passenger satisfaction has been associated with travel comfort, station quality, environmental conditions, onboard experience, and perceived security [6,7]. More recently, researchers have highlighted the importance of passenger experience during service disruptions, showing that communication quality and incident management can strongly affect customer perceptions even when average operational performance remains stable [8].

Passenger loyalty has also been extensively studied in railway systems using Structural Equation Modelling (SEM), which has enabled researchers to identify the direct and indirect relationships between service quality, perceived value, satisfaction, trust, and behavioural intentions. These studies generally conclude that service quality influences loyalty both directly and indirectly through passenger satisfaction, reinforcing the strategic importance of maintaining high-quality service standards [9]. Moreover, using SEM, researchers identified the direct and indirect effects of service quality attributes on satisfaction, loyalty, and behavioral intentions in railway systems [10]. In the railway sector, the quality of service is a fundamental determinant of system performance, shaping passenger perceptions, travel behavior, operational revenues, and future infrastructure investments [11]. Particular attention should be paid to service attributes such as safety, punctuality, frequency, and accessibility, as these are fundamental determinants of passengers' perceptions of service quality [12].

In addition to traditional satisfaction indicators, increasing attention has been devoted to the Net Promoter Score (NPS) as a measure of passenger advocacy and willingness to recommend a service. While overall satisfaction reflects a retrospective evaluation of service performance, NPS captures a broader behavioural dimension associated with loyalty, positive word-of-mouth, and future support for the service [13]. Consequently, satisfaction and NPS should be viewed as complementary rather than interchangeable indicators. A passenger may report being satisfied with a service while simultaneously exhibiting a lower willingness to recommend it due to recent disruptions, safety concerns, or other emotionally salient experiences.

### *1.3. Importance for Sustainability*

Passenger satisfaction is not only an operational performance indicator but also a key component of sustainable urban mobility policies. According to the literature, travellers' continued use of public transport depends on their perceived quality of service, including reliability, safety, comfort, accessibility, and the overall travel experience [5,6]. Improvements in these attributes increase the attractiveness and competitiveness of public transport relative to private vehicles, thereby strengthening passenger retention and encouraging voluntary modal shift among potential users. Although modal choice is influenced by multiple factors—including travel time, cost, land-use patterns, and car ownership—service quality remains one of the principal determinants of users' willingness to maintain or increase their use of public transport. Consequently, systematic monitoring of passenger satisfaction provides transport operators and public authorities with valuable evidence for identifying service deficiencies that may undermine public transport attractiveness and, ultimately, the achievement of broader sustainability objectives [7,8].

This relationship is directly aligned with Sustainable Development Goal (SDG) 11.2, which aims to provide access to safe, affordable, accessible, and sustainable transport systems for all by improving road safety, expanding public transport, and meeting the needs of vulnerable populations. Achieving this objective requires not only expanding infrastructure and service supply but also ensuring that public transport remains attractive

and capable of retaining existing users while encouraging new ones. Passenger satisfaction monitoring therefore represents an important management instrument for evaluating whether operational improvements are contributing to these policy objectives.

The relevance of passenger satisfaction monitoring is particularly evident in Chile, where the decarbonisation of the transport sector constitutes a national policy priority. Chile's Long-Term Climate Strategy and its Nationally Determined Contribution (NDC) under the Paris Agreement identify sustainable urban mobility, the strengthening of public transport systems, and the electrification of transport as essential measures for reducing greenhouse gas emissions [1]. While investments in railway infrastructure and rolling stock contribute to improving the environmental performance of the transport system, their long-term effectiveness depends on maintaining high levels of passenger acceptance and continued public transport use. In this context, monitoring user satisfaction provides complementary evidence for assessing whether operational improvements translate into a more attractive railway service capable of supporting national climate and sustainable mobility objectives.

#### 1.4. Objectives

Despite the growing body of literature on railway service quality and passenger satisfaction, most empirical studies have been conducted in Europe, North America, and Asia. Comparatively little evidence exists regarding commuter railway systems in Latin America, where public transport networks often operate under different institutional, operational, and socio-economic conditions [14].

Furthermore, although passenger satisfaction and loyalty have been widely investigated, relatively few studies have simultaneously examined overall satisfaction and NPS within the context of urban and suburban rail systems. Existing research frequently focuses on one indicator or the other, limiting the understanding of how operational conditions influence both service evaluations and behavioural intentions. Consequently, there remains a need for empirical evidence exploring the relationship between satisfaction, recommendation behaviour, and service quality attributes in Latin American railway systems.

The Limache–Puerto railway service provides a particularly valuable case study because it combines recent infrastructure and operational improvements with exposure to several high-visibility disruptions, including signalling failures, power outages, operational restrictions associated with tsunami warnings, and track incidents. These conditions create an opportunity to examine how passenger perceptions evolve under changing operational circumstances.

The main objective of this study is to evaluate the level of satisfaction and its determinants among frequent users of the Limache–Puerto railway service during the 2024–2025 measurement period.

Specifically, the study seeks to:

1. Assess overall passenger satisfaction and Net Promoter Score (NPS) across multiple measurement periods.
2. Identify the service attributes that most strongly influence passenger perceptions.
3. Examine changes in user evaluations over time.
4. Explore the relationship between operational conditions, service disruptions, satisfaction, and recommendation behaviour.
5. Generate evidence to support decision-making aimed at improving passenger experience and service quality.

### 1.5. Methodological Approach and Study Contribution

Evaluating passenger perceptions in operational railway environments presents important methodological challenges due to high passenger volumes, limited interaction times, and rapidly changing service conditions. For this reason, the study adopts a repeated cross-sectional quantitative design based on quota sampling, allowing the collection of standardized information from frequent users across different measurement periods.

This methodological approach is particularly suitable for monitoring user perceptions in public transport systems because it facilitates temporal comparisons while capturing the perspectives of passengers who regularly experience the service. Previous transport studies have successfully employed similar survey-based approaches to assess service quality, user satisfaction, and travel experience under real-world operating conditions [15].

Although the design does not permit causal inference or full population generalization, it provides a practical and robust framework for identifying trends, monitoring performance indicators, and supporting operational decision-making.

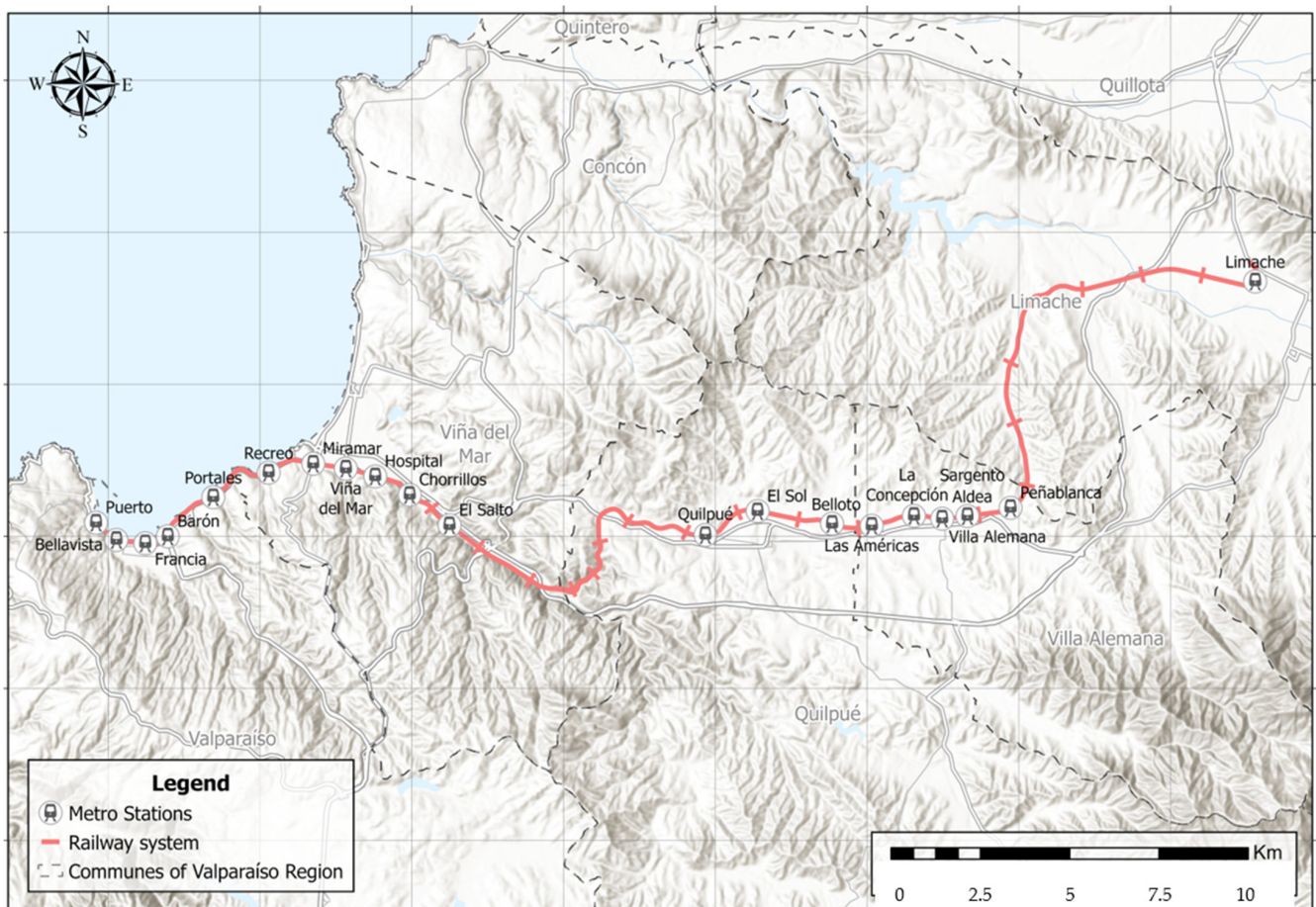
This study contributes to the literature in several ways. Unlike studies primarily aimed at developing behavioural models of passenger loyalty or testing causal relationships among latent service quality constructs, the present research is positioned as a pilot operational monitoring study. Its primary contribution lies in demonstrating a practical and repeatable framework for monitoring passenger satisfaction and Net Promoter Score (NPS) in a commuter railway system through successive measurement waves. By integrating overall satisfaction, NPS, and critical experience attributes into a single monitoring framework, the study provides operational evidence that can support continuous service evaluation and evidence-based decision-making. The proposed approach is particularly suitable for railway operators requiring timely, standardized, and easily interpretable indicators for service management while simultaneously contributing empirical evidence from a Latin American commuter railway context that remains underrepresented in the international literature.

This paper is structured as follows. Section 2 presents the study area and methodological framework. Section 3 describes the results of the passenger satisfaction analysis. Section 4 discusses the findings and their implications for railway management and policy. Finally, Section 5 summarizes the main conclusions and future research directions.

## 2. Materials and Methods

### 2.1. Case Study

The study is conducted along the Limache–Puerto railway corridor, operated by EFE Valparaíso in the Valparaíso Region of Chile [1] (see Figure 1). The Limache–Puerto railway service constitutes the backbone of the public transport system in Greater Valparaíso, connecting the municipalities of Limache, Villa Alemana, Quilpué, Viña del Mar, and Valparaíso through a 43 km electrified corridor. The system plays a strategic role in regional mobility, supporting daily commuting trips associated with employment, education, and access to services. During weekdays, passenger demand is concentrated during the morning and afternoon peak periods, reflecting the predominance of work- and study-related travel patterns. The service operates with multiple-unit trains serving 20 stations along the corridor. Train frequencies vary throughout the day, with shorter headways during peak periods and lower frequencies during off-peak hours. The line accommodates a substantial number of daily passengers, making it one of the most heavily utilized public transport services in the metropolitan area. As a result, stations located in central urban areas and major transfer nodes experience significant passenger concentrations during peak periods.

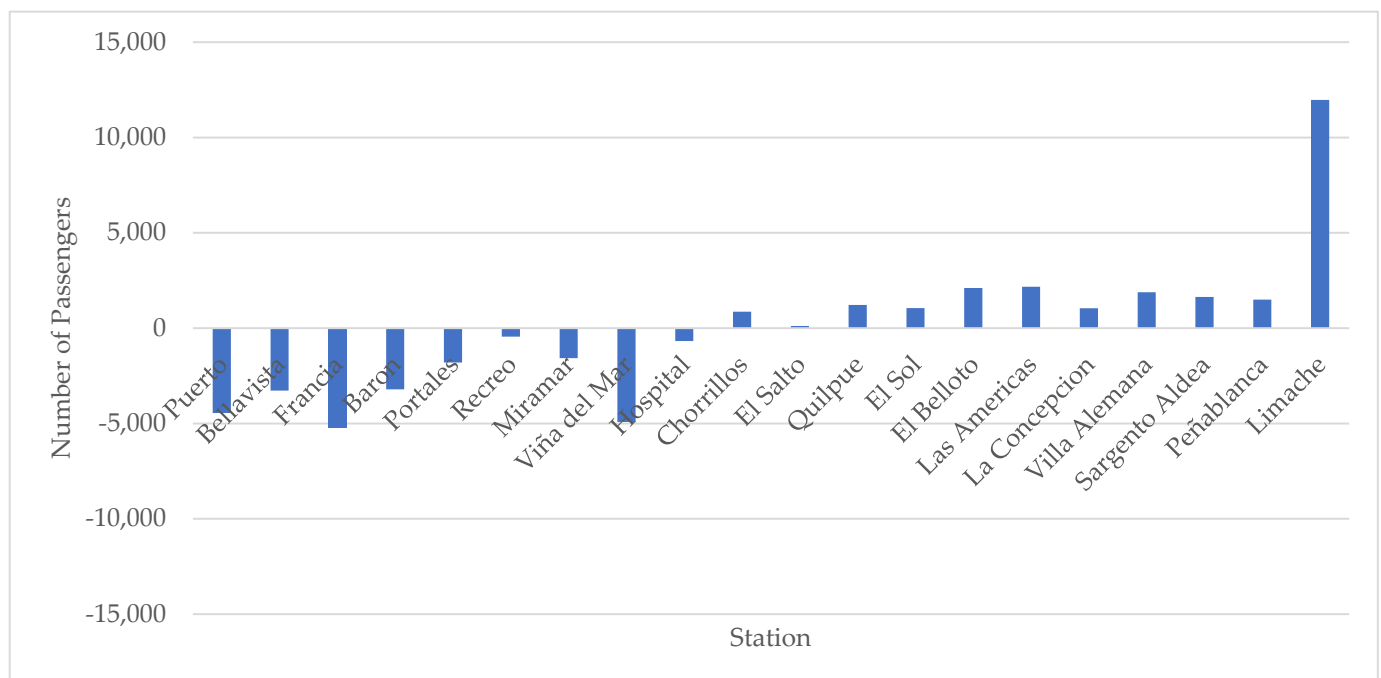


**Figure 1.** Diagram of the EFE Valparaíso Limache–Puerto corridor, illustrating the network configuration and station distribution.

The infrastructure consists of an electrified railway with overhead catenary, enclosed stations with access control, level boarding platforms, and passenger information systems both on platforms and on board. Stations include basic safety equipment (CCTV, staff presence), standardized signage, and universal accessibility features in most facilities. The rolling stock consists of electric trains with high acceleration and braking capabilities, designed for suburban traffic with high passenger turnover, interior layouts optimized for peak-hour flows, and door systems controlled from the cab. System access is enabled through contactless electronic fare payment and distributed loading points, allowing rapid validation and reducing dwell times on platforms.

Passenger crowding constitutes one of the principal operational challenges of the Limache–Puerto railway service. The railway service carries approximately 70,000 passengers per weekday and operates at headways ranging from 6 to 10 min during peak periods [1]. During morning and afternoon peak periods, demand is concentrated in specific stations and train services, generating high passenger densities on platforms and inside train cars. These conditions can affect passenger comfort, boarding and alighting processes, perceived safety, and overall travel experience. Although the service has benefited from investments in rolling stock, station infrastructure, and operational improvements in recent years, peak-period demand continues to place pressure on available capacity. Consequently, crowding emerged as one of the most frequently reported concerns among survey respondents and represents an important factor when interpreting satisfaction and Net Promoter Score (NPS) results.

The service exhibits distinctly bimodal demand patterns, with concentrated flows during AM and PM peaks and lower usage on weekends. Figure 2 shows the passenger demand at each station. For instance, during the AM peak hour, from the total number of passengers who board at Limache station (around 12,000 passengers), about 5000 passengers alight at Francia station (see Figure 2). The figure represents passenger boarding and alighting volumes by station during the morning peak period. Positive values correspond to passenger boardings, whereas negative values represent passenger alightings. In these critical windows of AM and PM peak hours, offered capacity (frequency and hyper-frequency with coupled trains on certain segments) experiences pressure due to crowding on platforms and on board. Service reliability is periodically affected by external and internal contingencies (track incidents), adverse weather impacting the catenary, isolated power failures, vandalism of rolling stock, and civil-protection alerts requiring contingency management, degraded operation, and adequate communication to users. Simultaneously, the travel experience is shaped by contextual factors such as perceived safety in station environments, intermittent informal commerce, and environmental conditions within high-turnover train cars.



**Figure 2.** Passenger demand at each station in EFE Valparaíso Limache–Puerto corridor.

Consequently, the corridor constitutes a mature urban-suburban railway system with standardized infrastructure and service levels that support daily mobility in the Greater Valparaíso metropolitan area. Its performance is determined by the interaction between installed capacity, peak-hour operational management, exposure to contingent events, and the effectiveness of information and safety systems that structure the passenger experience. This characterization defines the physical and situational framework within which satisfaction and recommendation indicators for frequent users are evaluated.

Detailed operational indicators such as train-specific load factors, passenger densities by vehicle, and real-time occupancy levels were not available for this study. The study relied primarily on passenger satisfaction surveys conducted by EFE Valparaíso and complementary operational information regarding service characteristics. Therefore, the assessment of crowding is based on passengers' reported experiences and perceptions rather than on objective occupancy measurements. While subjective perceptions of crowding

are highly relevant for understanding user experience and service quality, future research could benefit from integrating passenger satisfaction data with operational indicators such as automatic passenger counts, train occupancy rates, platform densities, and passenger flow measurements. Such integration would provide a more comprehensive understanding of the relationship between service conditions and passenger satisfaction.

## 2.2. Importance of the Method Used

Evaluating the satisfaction of frequent users of the Limache–Puerto train service is highly relevant for urban mobility in Greater Valparaíso due to both structural and management-related reasons. First, the railway corridor functions as the backbone of the metropolitan transport system, connecting residential, educational, and employment hubs with port and commercial nodes—an aspect consistent with evidence showing that rail-based systems play a structuring role in metropolitan accessibility [16]. Therefore, the perception of quality—captured through overall satisfaction, NPS, and experience attributes—serves as an early indicator of systemic performance and of the railway mode’s ability to retain and attract demand during high-pressure periods [4,17].

Second, evidence on travel experience enables service supply and operations to align with real usage patterns [18]. Identifying gaps in frequency, crowding, perceived safety, and information during contingencies guides cost-effective interventions that improve reliability and reduce generalized travel costs [19], strengthening the competitiveness of rail transport relative to private cars and informal modes [14].

Third, the study provides inputs for public policy goals in sustainability, equity, and safety. A service valued for its speed and predictability encourages modal shift toward lower-emission alternatives [20]; at the same time, disaggregated analysis by time period and station allows prioritization of investments in vulnerable areas, supporting more equitable accessibility outcomes [21], especially in developing countries [22].

In a system exposed to climatic, operational, and public-order contingencies, managing user experience becomes a critical component of resilience [23]. Monitoring satisfaction and NPS reveals the sensitivity of word-of-mouth to disruptive events [13] and enables communication and recovery strategies to mitigate loss of trust. When integrated with operational data—such as load profiles, punctuality, and service frequency—this information supports continuous improvement cycles and evaluation of the impact of new fleets, signaling upgrades, and safety programs [24].

From a sustainability perspective, repeated passenger satisfaction monitoring provides an evidence-based mechanism for evaluating whether operational improvements contribute to maintaining the attractiveness and perceived quality of railway services over time. Although the present study does not directly measure environmental outcomes or modal shift behaviour, regular assessment of passenger experience constitutes an important management tool for identifying service deficiencies that may affect users’ continued use of public transport. In this sense, the proposed monitoring framework complements broader sustainability indicators by providing operational information that supports continuous service improvement and passenger-oriented transport planning.

Therefore, the methodological approach adopted in this study prioritizes operational applicability over behavioural modelling. Repeated cross-sectional monitoring provides a practical mechanism for identifying temporal changes in passenger perceptions and evaluating the operational consequences of service disruptions, infrastructure improvements, and management interventions. Unlike more complex causal modelling approaches, such as Structural Equation Modelling (SEM), the proposed framework emphasizes simplicity, repeatability, and rapid implementation, making it particularly appropriate for operators conducting periodic customer satisfaction programmes. Consequently, the study should be

interpreted as a methodological contribution to operational passenger satisfaction monitoring rather than as a behavioural model explaining causal relationships between service attributes and passenger loyalty. Moreover, measuring and explaining satisfaction in the Limache–Puerto service thus transcends the subjective dimension of travel and provides an empirical foundation for tactical and strategic decisions that directly affect the efficiency, sustainability, and equity of the urban mobility system in Greater Valparaíso.

### 3. Results

#### 3.1. Application of the Method

##### 3.1.1. Survey Application

For each survey wave, a target sample of 400 valid questionnaires was established, resulting in independent cross-sectional samples for each measurement period, aimed at measuring satisfaction among frequent users of the Limache–Puerto railway service (EFE Valparaíso) during an intermediate assessment conducted in 2024 and 2025. The passenger satisfaction programme comprised three measurement waves per year. During 2024, two preliminary surveys of 138 interviews each were conducted in early April and late August to monitor short-term changes in passenger perceptions. These were followed by a comprehensive survey of 400 interviews conducted in early December 2024. The same survey design was replicated in 2025, with measurements carried out during the corresponding periods. The primary interannual comparison presented in this study focuses on the comprehensive surveys conducted in December 2024 and December 2025, while the interim surveys were used to monitor temporal variations in passenger satisfaction and NPS throughout each year. Differences between survey waves were evaluated using two-proportion tests at the 95% confidence level, considering the survey margin of error ( $\pm 4.9\%$  for the 400-interview surveys under maximum variance assumptions). Cross-sectional designs are widely used in transport satisfaction studies because they enable timely assessments of service quality perceptions within specific operational contexts [4,13]. The unit of analysis consisted of users aged 16 or older, with frequent use defined as four or more weekly trips—an approach consistent with studies focusing on habitual riders, who tend to provide more stable evaluations of service attributes [8].

A non-probabilistic quota sampling strategy was used, a common method in public transport environments where passenger flows and platform access restrict the feasibility of probabilistic sampling [14,25]. The design ensured coverage across time periods (AM/PM peaks and off-peak) and key stations along the corridor. Although statistical inference to the population is not possible, the study estimated a referential sampling error, following best practices for non-probability designs in transit research [26]. Therefore, the quota sampling design was based on operational criteria established jointly with EFE Valparaíso. Quotas were distributed according to station importance, passenger volumes, and time periods (AM peak, PM peak, and off-peak). Because the study was designed as an operational monitoring exercise rather than a probabilistic survey, quotas were intended to ensure adequate coverage of key travel contexts rather than statistical representativeness.

The quota-based design was selected for three reasons. First, studies focusing on specific subgroups, such as frequent riders, benefit from quota controls to ensure adequate representation of relevant user profiles and travel patterns [25]. Second, operational constraints in stations and onboard spaces make directed interview allocation more efficient than probabilistic strategies, which often require higher costs and longer fieldwork to achieve acceptable response rates [26]. Third, maintaining methodological continuity strengthens trend analysis across repeated cross-sectional waves—an established practice in transport performance evaluations [27].

The selection of a cross-sectional quantitative approach with quota sampling responded to the need for rapid, comparable, and management-oriented measurements of user satisfaction during a specific operational period—an approach common in transit performance monitoring [28]. This design enables comparability with previous waves and supports service planning through timely indicators [13].

Fieldwork was carried out on platforms and onboard trains by trained surveyors, using digital questionnaires with logical validations and automated filters to reduce routine measurement errors—an approach aligned with recommendations for improving reliability in satisfaction surveys [29]. Quality controls included random supervision, review of application times, and internal consistency checks.

The survey instrument incorporated validated Likert-type satisfaction scales and the Net Promoter Score (NPS) metric, both widely adopted in transportation research to capture user perceptions, loyalty intentions, and overall service image [27,30]. The battery of attributes—covering safety, predictability, cleanliness, environmental conditions, information, and comfort—reflects internationally recognized dimensions of transit service quality [31,32].

Validated metric scales (satisfaction 1–7, NPS 0–10) were used due to their ability to translate complex perceptions into operational indicators and support comparative analyses—an approach consistent with international literature on rail and bus passenger experience [31,32]. Open-ended items were added to incorporate qualitative nuance without compromising standardization [29].

Data processing involved database cleaning, thematic coding of open-ended items, and scale standardization, consistent with methodological guidelines for transport satisfaction surveys [33]. Analysis proceeded in three stages: descriptive analysis, interperiod comparison, and exploration of differences by time period and station. Because the sampling is non-probabilistic, significance tests were used only as orientation; effect sizes and referential confidence intervals were used to interpret differences, as recommended in non-probability transit studies [34].

With respect to statistical analysis, rotated factor loadings were obtained from the exploratory factor analysis conducted on the passenger experience attributes included in the survey (see Appendix A). The analysis identified five underlying dimensions that collectively characterize users' perceptions of the railway service: Safety, Service Quality and Travel Experience, Travel Time and Travel Conditions, Passenger Information and Accessibility, Complementary Services and Fare Collection, and Intermodal Connectivity. As a result, the relative weights were obtained based on the main factors that affect the satisfaction of passengers. Unfortunately, the original database and outputs provided by the railway operator did not include additional statistics such as KMO values, Bartlett's test results, regression coefficients, or significance levels. Therefore, these indicators could not be retrospectively calculated.

To complement the descriptive analysis, an exploratory multiple linear regression model was used to examine the relationship between the latent service quality dimensions identified through the exploratory factor analysis and passengers' overall satisfaction (see Appendix A). The dependent variable was the overall satisfaction score reported by respondents, while the independent variables corresponded to the composite factors extracted from the exploratory factor analysis. The objective of this analysis was not to establish causal relationships but to provide an initial assessment of the relative contribution of the principal service quality dimensions to overall satisfaction. Consequently, the regression results should be interpreted as exploratory and descriptive, serving to identify broad patterns that may support operational decision-making rather than infer causal effects.

The participation was voluntary, informed consent was obtained from all respondents prior to the survey, and responses were collected anonymously. Therefore, ethical considerations included informed consent, anonymity, and exclusive research use of the data, aligning with international norms for human mobility research [35].

Alternative methodological approaches—probabilistic sampling, longitudinal panels, or purely qualitative designs—were considered and discarded for reasons of feasibility, comparability, and alignment with operational decision-making needs [36]. Mitigation measures were implemented to strengthen validity, including distribution of interviews across demand periods, standardization of scripts, consistency checks, and orientative triangulation with operational data (frequency, punctuality, load), consistent with multi-method validation practices in transit research [24].

Overall, the selected method balances operational rigor, temporal comparability, and logistical feasibility, offering sufficiently robust evidence for decision-making in an urban–suburban railway system subjected to volatile demand and operational contingencies.

### 3.1.2. Data Collection Instrument

The data collection instrument was structured as a standardized questionnaire administered in person using a mobile-assisted system, a method widely recommended in field surveys for its capacity to reduce recording errors, apply automated validations, and improve overall data quality [26,29]. It was designed to consistently measure the satisfaction of frequent users of the Limache–Puerto railway service and its immediate determinants. The construction of the instrument considered criteria of content validity, semantic clarity, and operational brevity, following best practices for public transport satisfaction surveys [4,33]. These design principles minimized respondent burden on platforms and onboard trains while ensuring comparability with previous measurements.

The questionnaire was organized into four modules. The first module screened for eligibility and collected user profile information, in line with recommendations for defining user characteristics clearly in service quality studies targeting habitual riders [8]. The second module assessed overall service evaluation through two central metrics: global satisfaction on a 1–7 ordinal scale and the Net Promoter Score (NPS) on a 0–10 scale, acknowledging their utility in capturing service perception and user loyalty [27,30]. The third module examined key experience attributes using 5-point Likert-type items, a validated approach for measuring dimensions such as safety, predictability, cleanliness, comfort, and informational quality [31,32]. The fourth module included two short open-ended questions that allowed qualitative nuance to complement the quantitative indicators, consistent with mixed-method recommendations for operational environments [29].

In terms of formulation, the instrument prioritized unambiguous items, clear wording, and avoidance of double meanings—criteria fundamental for reliable scale construction [37]. Explicit scale anchors were used to strengthen response consistency, and visible instructions were provided to ensure interviewer neutrality. To reduce ordering effects, blocks of attributes were rotated across interviews within the same time period, following established procedures for mitigating order bias [38].

Pretesting included expert judgment by technical and operational staff to ensure construct relevance and coverage, followed by a cognitive pilot in two stations with different load profiles ( $n \approx 20$ ). These procedures align with recommended validation techniques for evaluating comprehension, clarity, and operational suitability of questionnaires [39]. During fieldwork, quality indicators were monitored (module duration, item nonresponse, and flatlining response patterns) in accordance with professional standards for survey quality assurance [35].

Data processing procedures involved systematic cleaning and standardization, including identification of atypically short interviews, duplicate control, normalization of station and time-period codes, and thematic coding of open-ended responses using an inductive–deductive category system. The identified dimensions were obtained using a factor analysis, which should be interpreted as preliminary operational groupings, consistent with the measurement literature in public transport service quality [33] (see Appendix A).

It is important to note that the objective of the present study was to evaluate the operational and experiential attributes most frequently monitored by EFE Valparaíso within its passenger satisfaction program. Consequently, the survey instrument focused on dimensions directly associated with the travel experience, including safety, predictability, comfort, environmental conditions, information, crowding, and ticket purchasing processes. Therefore, other variables such as the perceived fare value were not considered in this study, but it is widely recognized as an important determinant of public transport satisfaction and loyalty, and it will be considered in further research.

### 3.1.3. Description of the Data Collection Procedure

Data collection was carried out in 2024 and 2025, through in-person interviews assisted by a mobile device on station platforms and onboard trains along the Limache–Puerto railway service. This procedure was designed to maximize coverage of relevant operational scenarios and ensure standardized application under a non-probabilistic quota sampling scheme, a strategy frequently used in public transport environments due to flow variability and limited sampling-frame feasibility [14,25].

Prior to fieldwork, training sessions were conducted for interviewers and supervisors focusing on: eligibility criteria (age  $\geq 16$  and frequent use of four or more weekly trips), neutral approach protocol, verbal informed consent procedures, instructions for literal reading of items and verbatim recording of open-ended answers, operation of the digital questionnaire (logical skips, validations, secure synchronization), and personal safety guidelines in stations and trains. The team received operational manuals and assignment sheets specifying quota targets by station, time period (AM/PM peak and off-peak), and day of the week. Such structured training and standardization align with recommendations for improving reliability and interviewer consistency in field surveys [29,37].

Daily scheduling included staggered shifts to cover peak and off-peak periods on weekdays and weekends. On platforms, interviews were conducted in waiting areas without obstructing passenger flows; onboard, they were administered during travel segments of sufficient duration, avoiding interference with safety procedures. Approaching participants followed a standardized script: study introduction, eligibility verification through filter questions, explanation of confidentiality and voluntariness, and request for consent. When respondents declined, an immediate replacement protocol was applied, respecting time-period quotas and documenting the reason for nonresponse, consistent with best practices in managing nonresponse bias [35].

Case assignment followed a systematic pattern within each quota (approximate intervals between approaches adjusted to passenger density) to reduce selection bias. The digital application incorporated real-time quality controls—range and consistency checks, mandatory fields for critical items, timestamps, and start/end geolocation—reflecting approaches recommended for enhancing data integrity in mobile-assisted surveys [26]. Minimum-duration thresholds were monitored to detect interviews completed too quickly to be valid.

Field supervision combined unobtrusive observations and spot checks of completed forms, followed by daily feedback sessions. Each day concluded with a field committee reviewing quota progress, rejection rates, operational incidents (delays, degraded opera-

tions, high demand), and mitigation measures (reassigning interviewers, reinforcing critical stations, fine-tuning schedules). When contingencies occurred—such as partial service suspensions due to alerts or track incidents—a continuity plan was activated to prioritize operational stations while maintaining time-period distribution, a key practice for preserving comparability across measurement waves [28].

Data were synchronized at the end of each field block through secure connections with end-to-end encryption and server backup. The analytical team conducted daily preliminary cleaning to identify duplicates, flatlining response patterns, and deviations from expected duration norms, issuing control reports to supervisors for immediate corrective action. Full traceability of field adjustments was maintained, and all decisions potentially affecting interpretation were documented, following transparency standards recommended for high-quality survey research [35].

It is important to note that the surveys were conducted during different months of the year, which may indeed introduce seasonal influences, particularly regarding environmental conditions, perceived comfort, lighting conditions, and operational disruptions associated with winter weather. The intention of the study was to compare successive monitoring waves rather than isolate causal effects. Therefore, seasonal effects were not explicitly controlled.

### 3.2. Analysis of Results: Travel Experience

The analysis shows that overall satisfaction among frequent users of the Limache–Puerto train service remains high and stable in the 2025 measurement, whereas the Net Promoter Score exhibits an increase of 1 percentage point compared to 2024, indicating less sensitivity to recent operational contingencies. At the attribute level, the differences are observed in perceived safety, travel-time predictability, and environmental conditions (including reports of unpleasant odors), as well as tensions affecting the pleasantness of the trip associated with peak-hour crowding. In contrast, the presence of informal street vending decreases noticeably, and evaluations of user information and fare/payment processes remain acceptable. Reasons for satisfaction are concentrated mainly on the system's speed and relative efficiency compared with other modes, while the main sources of dissatisfaction continue to be safety in station environments, peak-hour frequency, and crowding. The negative variation in NPS suggests that high-salience events (such as delays, partial operations, and on-track incidents) affect word-of-mouth more strongly than they do general service evaluation.

Figure 3 shows overall satisfaction with the trend for the 2018–2025 comparison, displaying the temporal evolution of the proportions of satisfied users (6–7), dissatisfied users (1–4), and net satisfaction. Between 2024 and 2025, overall satisfaction remains stable, with August 2025 showing levels comparable to April 2025 (a variation close to  $\pm 2$  percentage points, not significant within the sampling margin). Aggregate satisfaction remains within historically high thresholds for the service, although emerging tensions in specific dimensions suggest potential erosion if these issues are not addressed.

In Figure 4, the evolutionary NPS (2018–2025) is presented using a 0–10 scale, with promoters (9–10), neutrals (7–8), and detractors (0–6). The metric is based on the question: “If someone close to you had to make a trip similar to yours, would you recommend the service?”, where 0 means “I would definitely not recommend it” and 10 means “I would definitely recommend it.”

In August 2025, the NPS decreases by 7 percentage points compared with April 2025 (−13% relative). Willingness to recommend is more sensitive than overall satisfaction to short-term variations and perceptions of risk/reliability; its decline signals a potential

weakening of loyalty if operational frictions persist. However, at the end of 2025 the NPS increased, reaching a score of 49.

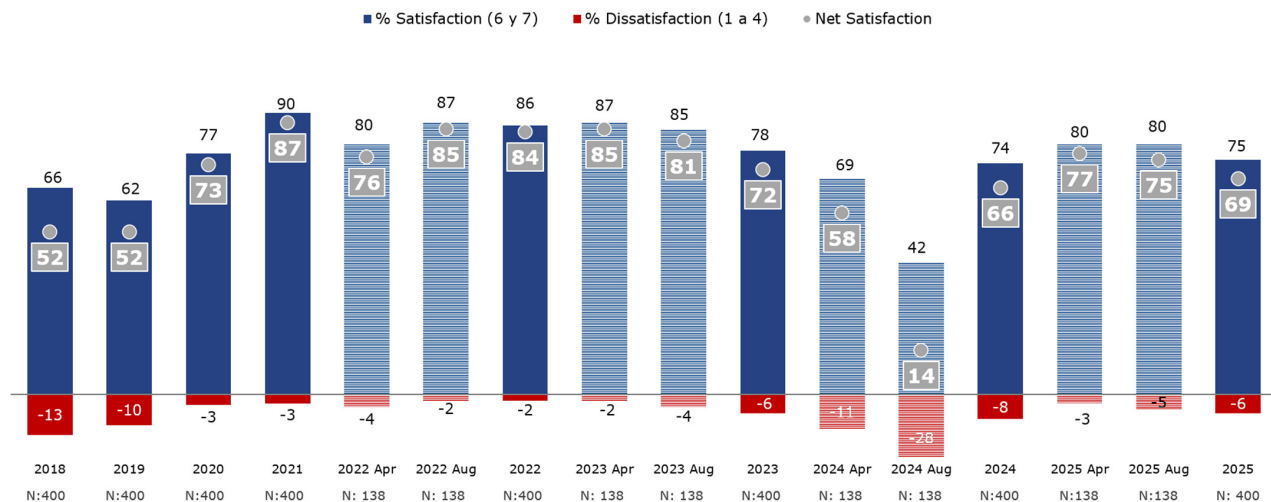


Figure 3. Overall Satisfaction with the Service (N = sample size).

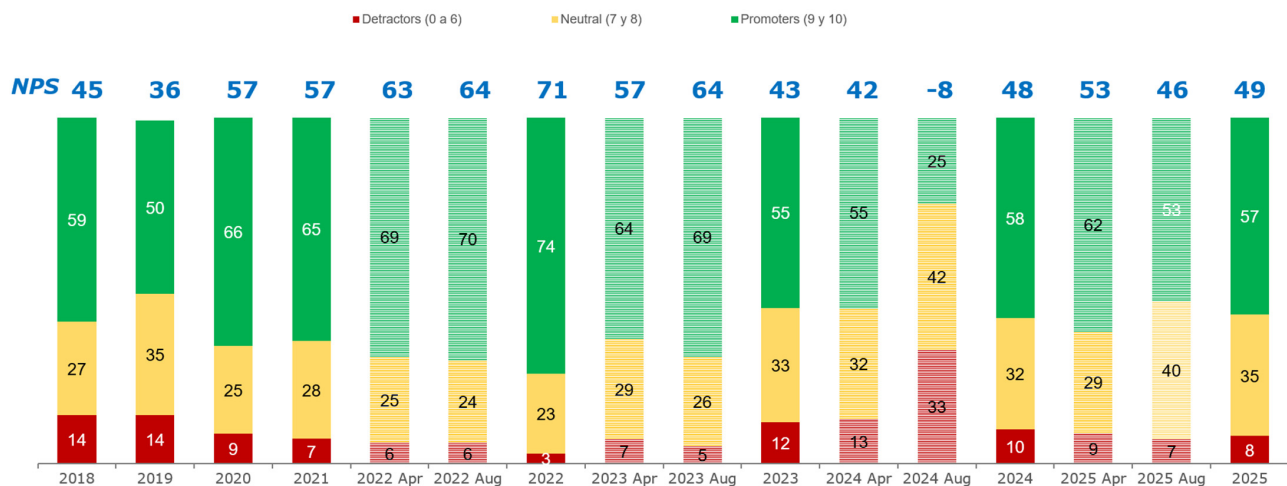


Figure 4. Evolution of satisfaction based on NPS (Would you recommend other passengers to use the service?).

In Figure 5. Reasons for overall satisfaction, the positive (promoters), neutral and negative (detractors) factors between 2024 and 2025 are highlighted. The core value proposition—speed—is strengthened, while the main operational “pain point” shifts from general safety concerns toward capacity and frequency management during peak hours.

From Figure 6, which presents the experience attributes for 2024–2025 (safety/certainty, environmental conditions, staff, information, loading, payment, waiting/boarding, travel experience, and station environment), the matrix shows item-level variations across the three measurement points.

Declines are observed in:

- Safety regarding accidents and safety while waiting on the platform.
- Ease of predicting travel times (moderate decline).
- “Pleasantness of the trip”, affected by interpersonal distance, temperature, and smell.

Indicators that remain stable or improve include:

- Items related to user information and loading/payment channels, which show consistently stable performance—an important interpretive signal.

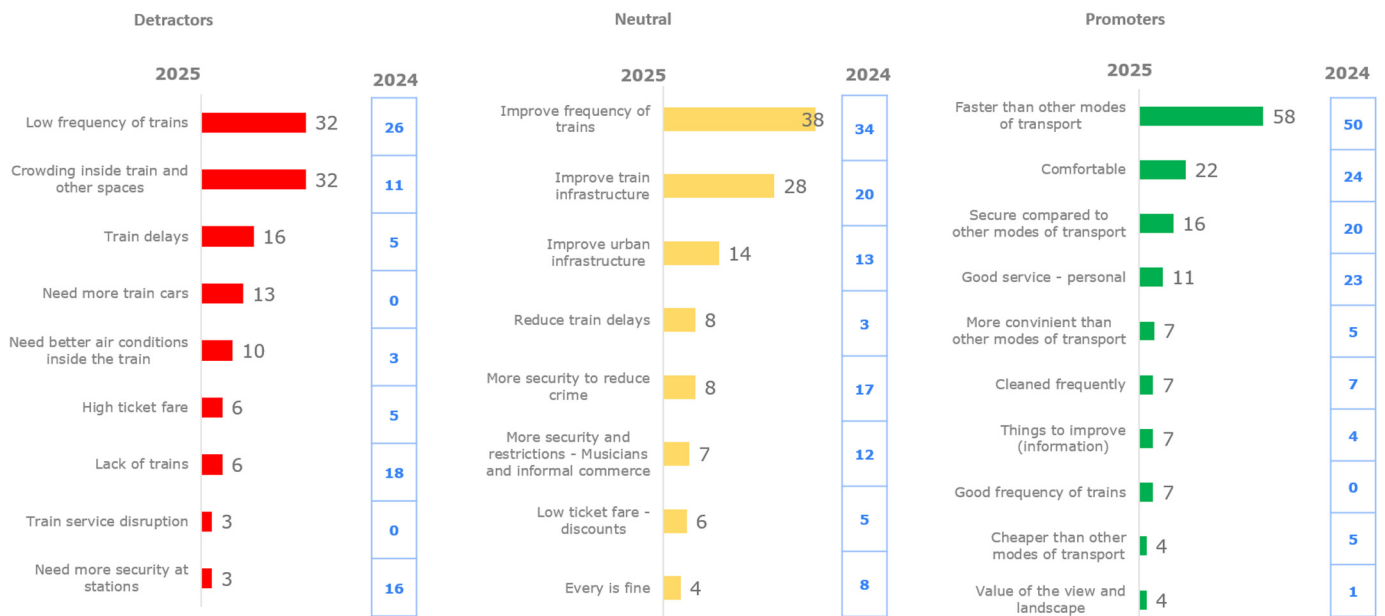


Figure 5. Reasons for overall final satisfaction.

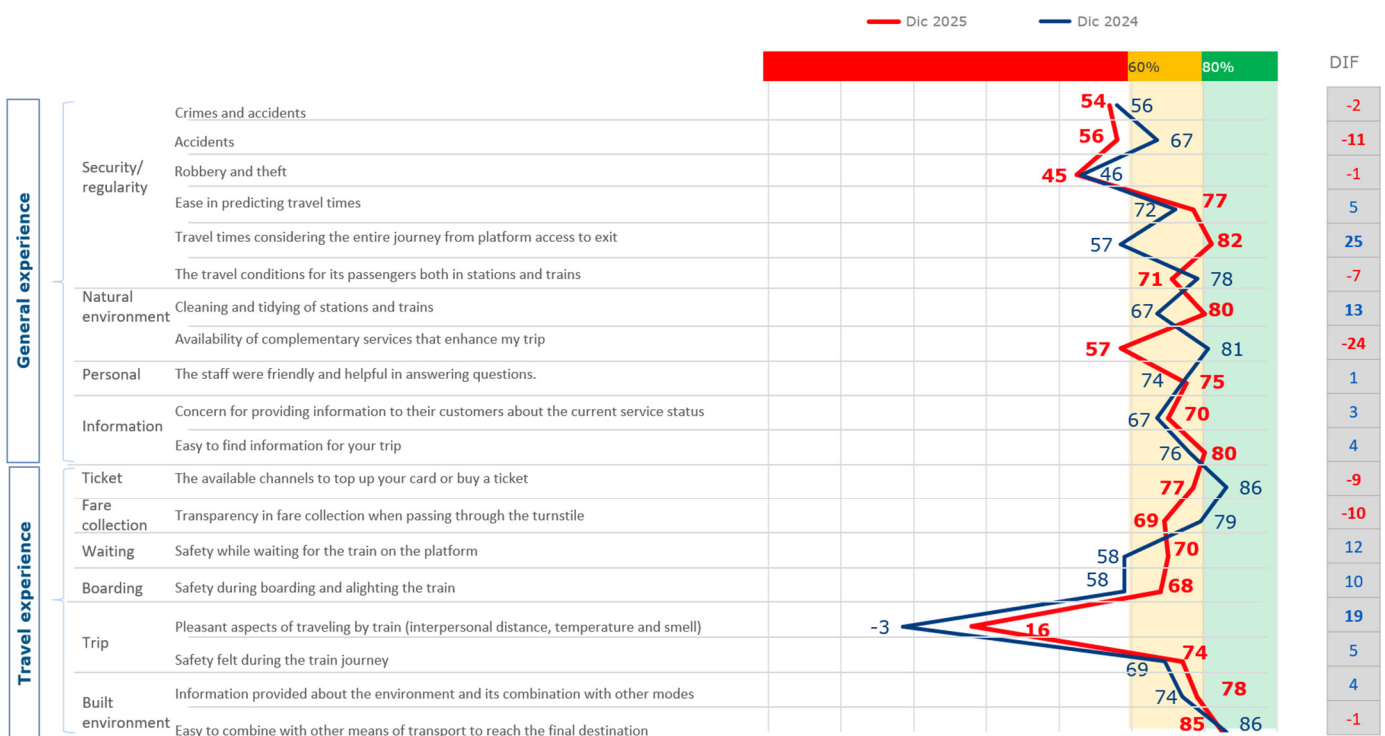


Figure 6. Experience attributes considering the difference (DIF) between 2024 and 2025.

Overall, the main friction points concentrate around the interaction between perceived reliability, peak-hour density, and environmental/spatial conditions.

Table 1 shows the reasons explaining the experience attributes during 2024–2025. Based on a sample of 213 responses, the results indicate that overcrowding during peak hours is by far the most significant factor affecting the travel experience, reported by 71% of respondents. This is followed by issues related to onboard environmental conditions, including problems with air conditioning or temperature (47%) and bad smells (43%), suggesting that comfort inside the train is a major concern. Additionally, one-third of users (33%) noted that the pleasantness of the trip varies depending on the time of day, reinforcing the impact of peak-hour congestion. Social factors, such as the presence of

street vendors, performers, or individuals asking for money, were mentioned by 26% of respondents. In contrast, relatively few participants identified lack of space due to packages (5%), uncomfortable trains (4%), or low security (2%) as key issues, indicating that these are less critical compared to crowding and environmental conditions. In conclusion, peak-hour density remains the main determinant of comfort; discomfort attributable to street vending decreases, but odors and temperature emerge as secondary factors.

**Table 1.** How unpleasant it is to travel by train.

| Reason                                                            | %          | 95% CI     |
|-------------------------------------------------------------------|------------|------------|
| <b>Base</b>                                                       | <b>213</b> |            |
| Crowds/Lots of people during peak hours                           | 71%        | 64.9–77.1% |
| Problems with the air conditioning/temperature                    | 47%        | 40.3–53.7% |
| Bad smells                                                        | 43%        | 36.4–49.7% |
| The pleasantness of the trip depends on the time of day           | 33%        | 26.7–39.3% |
| Street vendors, singers, people asking for money inside the train | 26%        | 20.1–31.9% |
| Lack of space—Many packages                                       | 5%         | 2.1–7.9%   |
| Uncomfortable trains                                              | 4%         | 1.4–6.6%   |
| Low security                                                      | 2%         | 0.1–3.9%   |

Table 2 shows the security reasons when waiting on the platform. Based on a sample of 88 responses, the results show that the most prominent concern is the need for increased security measures, with 77% of respondents highlighting the importance of more guards and/or surveillance cameras. This is followed by issues related to user behavior and crowding, as 33% indicated that people do not respect designated spaces, and 31% pointed to concerns arising from criminal acts that have occurred. Infrastructure-related safety concerns are also relevant, with 23% of respondents mentioning insufficient protection to prevent falls on platforms and the perception that access control is weak (“anyone can enter”). In contrast, only a small proportion (5%) identified dark or isolated areas as a key issue. Overall, the findings suggest that perceived insecurity is driven primarily by the need for stronger formal security presence, complemented by concerns about user behavior, past incidents, and specific infrastructural vulnerabilities. In conclusion, the perception of risk is shaped by crowding, lighting, and access control; recent criminal incidents heighten concern even when direct victimization remains low.

**Table 2.** Safety when waiting for the train.

| Reason                                                         | %         | 95% CI     |
|----------------------------------------------------------------|-----------|------------|
| <b>Base</b>                                                    | <b>88</b> |            |
| More security is needed (guards and/or cameras)                | 77%       | 68.2–85.8% |
| Crowding—They don’t respect the spaces                         | 33%       | 23.2–42.8% |
| For the criminal acts that have occurred                       | 31%       | 21.4–40.6% |
| There is a lack of protection to prevent falls on the platform | 23%       | 14.2–31.8% |
| Anyone can enter                                               | 23%       | 14.2–31.8% |
| There are dark, lonely places                                  | 5%        | 0.4–9.6%   |

Table 3 shows the availability of complementary services that enhance the trip. Based on a sample of 120 responses, the results highlight that the most pressing issue is the lack of accessible toilet facilities, with 62% of respondents indicating that free toilets are needed at stations. This is followed by a broader perception of insufficient complementary services (37%), suggesting a general gap in station amenities. Around one-quarter of respondents pointed to the absence of retail options for quick purchases (23%) and the high cost or limited variety of existing shops (23%), indicating both availability and affordability

concerns. Additionally, 22% noted the lack of additional services at the stations they use, reinforcing the perception of underdeveloped service provision. Finally, 21% emphasized the need for greater control over informal street vending. Overall, the findings suggest that users perceive metro stations as lacking basic and complementary services, with particular emphasis on sanitation, retail availability, and better regulation of commercial activities. In conclusion, toilets and complementary services, such as shops, are needed.

**Table 3.** Availability of complementary services that enhance the trip.

| Reason                                                   | %          | 95% CI     |
|----------------------------------------------------------|------------|------------|
| <b>Base</b>                                              | <b>120</b> |            |
| Toilets not available—Free toilets service               | 62%        | 53.3–70.7% |
| Complementary services are lacking                       | 37%        | 28.3–45.7% |
| There are no shops to buy something on the go            | 23%        | 15.5–30.5% |
| Shops are expensive—Limited commercial supply            | 23%        | 15.5–30.5% |
| There are no additional services at the stations I use   | 22%        | 14.6–29.4% |
| There needs to be more control (too much street vending) | 21%        | 13.7–28.3% |

Table 4 shows the available channels for topping up your card or buying a ticket. Based on a sample of 79 responses, the results indicate that the main issues are related to the condition and availability of ticketing infrastructure, with 53% of respondents reporting that machines are in poor condition or that ticket offices are closed, and 44% expressing the need for more machines, totems, or service points. Operational inefficiencies are also evident, as 34% mentioned crowding and long queues during the ticket purchasing process. In terms of system modernization, 17% highlighted the need for online or app-based ticket payment, while 14% called for new payment methods such as bank cards or onboard top-ups. Additionally, 13% of respondents pointed to poor staff service. Overall, the findings suggest that users face significant barriers in accessing and using ticketing services, driven by infrastructure limitations, congestion, and a lag in the adoption of more flexible and digital payment options. In conclusion, new ticket and cash machines are needed to reduce queues at the concourse area in stations.

**Table 4.** The available channels for topping up your card or buying a ticket.

| Reason                                                                    | %         | 95% CI     |
|---------------------------------------------------------------------------|-----------|------------|
| <b>Base</b>                                                               | <b>79</b> |            |
| The machines are in poor condition—The cash registers are closed          | 53%       | 42.0–64.0% |
| More cash machines/totems/ticket offices are needed                       | 44%       | 33.1–54.9% |
| It gets very crowded/there's a long queue                                 | 34%       | 23.5–44.5% |
| Being able to pay the ticket online or application                        | 17%       | 8.7–25.3%  |
| New forms of payment are needed (bank cards, coins, top-ups on the train) | 14%       | 6.4–21.6%  |
| Poor staff service                                                        | 13%       | 5.6–20.4%  |

It is important to note that Tables 1–4 summarize responses to open-ended follow-up questions that were asked only to respondents who expressed dissatisfaction or concerns regarding specific attributes. Consequently, these questions were not administered to the entire sample of 400 respondents. In other words, percentages exceed 100% because respondents were allowed to provide multiple answers to the open-ended questions.

## 4. Discussion

### 4.1. Summary of the Results

The findings should be interpreted within the scope of a pilot operational monitoring framework rather than a confirmatory behavioural study. The primary objective was not to estimate causal relationships between service quality attributes and passenger behaviour, but to identify operational trends and critical experience dimensions that can inform service management. In this regard, the repeated monitoring approach complements, rather than replaces, explanatory methods such as Structural Equation Modelling (SEM), ordinal regression, or Importance–Performance Analysis (IPA). Whereas these approaches seek to estimate causal pathways or quantify attribute importance, the present framework provides a practical and standardized mechanism for continuously tracking passenger perceptions over time and supporting evidence-based operational decision-making.

The results of this study provide empirical evidence on passenger satisfaction and Net Promoter Score (NPS) dynamics among frequent users of the Limache–Puerto railway service in Greater Valparaíso. Overall, the findings confirm that passengers continue to value core attributes such as travel speed and operational efficiency, which aligns with established literature indicating that perceived service reliability and travel time are among the primary determinants of satisfaction in public transport systems [5,27]. Similarly, the relevance of safety, comfort, and information provision as key drivers of satisfaction is consistent with prior research highlighting the multidimensional nature of service quality in rail and urban transport systems [6,7,13].

The study also confirms the distinction between overall satisfaction and behavioral loyalty indicators such as NPS. While satisfaction levels remained relatively stable across measurement periods, NPS exhibited a temporary decline during 2025 before partially recovering. This divergence is consistent with recent findings suggesting that satisfaction and loyalty represent related but conceptually distinct constructs, where satisfaction reflects cumulative cognitive evaluation of service performance, whereas NPS captures affective response and willingness to recommend the service [3,11]. Similar patterns have been reported in rail contexts where short-term operational disruptions disproportionately affect recommendation behaviour compared to overall satisfaction [15].

A key explanatory factor emerging from the results is the role of operational disruptions and their salience in shaping passenger perceptions. Episodes such as signaling failures, temporary service interruptions, and external events (e.g., emergency alerts) appear to have had a disproportionate impact on NPS evolution. This finding is consistent with evidence that user satisfaction in transport systems is highly sensitive to reliability and service regularity, particularly under conditions of crowding and uncertainty [8,9,32]. Moreover, the literature on transport resilience emphasizes that highly visible disruptions can significantly alter perceived service quality even when average operational performance remains stable [23].

From a Latin American perspective, the results reflect structural conditions described in regional transport studies, where high demand pressure, capacity constraints, and uneven service quality remain persistent challenges [1,2]. These conditions help explain why crowding, platform safety, and environmental comfort emerge as dominant concerns among users. In particular, peak-hour saturation and platform density reinforce findings from accessibility-oriented frameworks, which highlight the importance of balancing supply and demand in ensuring perceived service quality [16,24].

The findings also have broader implications for sustainable urban mobility. The results suggest that maintaining high levels of passenger satisfaction requires more than reliable infrastructure; it also depends on passengers' perceptions of safety, comfort, information provision, and operational resilience during service disruptions. These experiential at-

tributes influence the attractiveness of public transport and therefore represent important elements supporting the long-term sustainability of commuter railway systems. Although the present study did not directly evaluate behavioural outcomes such as modal shift or changes in travel demand, improving these service quality dimensions may contribute to strengthening public transport competitiveness and encouraging continued use of rail services in metropolitan areas.

Finally, the results contribute to the broader literature on public transport service quality in developing contexts. Studies have shown that in systems with high dependency on public transport, perceived service deficiencies in safety, cleanliness, and environmental conditions have amplified effects on satisfaction and loyalty [21,22]. The present study supports this evidence by showing that although the Limache–Puerto service maintains a strong core value proposition in terms of speed and accessibility, experiential factors—particularly crowding, safety perception, and environmental conditions—play an increasingly decisive role in shaping user recommendation behaviour.

Overall, these findings reinforce the need to consider satisfaction and NPS as complementary but distinct indicators of service performance. They also highlight the importance of integrating operational reliability, experiential quality, and disruption management into railway planning strategies, in line with international evidence on sustainable and user-centered transport systems [19,20,30].

Although the present study did not directly evaluate behavioural outcomes such as modal shift intentions or reductions in private vehicle use, the findings have important implications for sustainable transport policy. The attributes identified as most influential in passengers' evaluations—particularly safety, comfort, reliability, crowding, and the provision of information during service disruptions—have consistently been identified in previous studies as important determinants of public transport attractiveness [3]. Persistent deficiencies in these dimensions may reduce passengers' willingness to continue using rail services, whereas improvements may strengthen user confidence, increase customer retention, and enhance the competitive position of public transport relative to less sustainable travel alternatives.

The contribution of passenger satisfaction monitoring to sustainability should therefore be understood as an indirect but important mechanism within a broader policy framework. Satisfaction itself does not reduce greenhouse gas emissions; rather, it provides an operational indicator of the quality of service experienced by passengers. When monitoring identifies critical deficiencies and these are addressed through targeted operational and infrastructure improvements, passenger perceptions may improve, contributing to higher levels of continued public transport use and increasing the attractiveness of rail for potential users. Over time, these behavioural responses may support modal shift away from private vehicles, thereby contributing to reduced transport-related emissions, improved energy efficiency, and progress towards national and international sustainability objectives. Consequently, repeated satisfaction monitoring represents an important evidence-based management tool linking day-to-day operational performance with longer-term sustainable mobility strategies.

#### *4.2. Critical Assessment of the Evidence*

A critical examination of the evidence suggests that the findings are consistent with the operational context observed, but they must be interpreted with caution due to inherent constraints of the study design and fieldwork conditions. First, the non-probabilistic quota sampling approach—while effective for covering peak/off-peak periods and high-turnover stations within a limited timeframe—restricts statistical inference to the subset of frequent users present at the sampled points and times. The absence of random selection

introduces risks of selection bias (e.g., over-representation of peak-hour travelers or specific stations) and nonresponse bias, the magnitude of which cannot be precisely estimated. Consequently, the “referential” confidence intervals and errors reported are indicative rather than equivalent to margins of error from a probabilistic design.

Second, the sample size ( $n = 400$ ) limits the ability to detect small variations between measurements and reduces statistical power for disaggregations by station, time period, or fare type. This increases the likelihood of Type II errors and suggests prioritizing the interpretation of effect sizes over significance tests. Additionally, the cross-sectional nature of the study prevents causal attribution for observed associations (e.g., between crowding, perceived safety, and NPS). Interperiod comparisons reveal trends, but they do not control for structural or seasonal changes in demand and operations.

Third, the close temporal proximity of fieldwork to operational contingencies (delays, partial operations, catenary incidents) elevates the salience of recent events and may upwardly bias the sensitivity of NPS relative to overall satisfaction (recency bias). Likewise, interviewing only on platforms and onboard trains effectively excludes occasional users or those who avoid the most congested stations or time periods, compromising external validity for relevant subpopulations (e.g., weekend or off-peak travelers).

Fourth, although the instrument employed standardized scales (satisfaction 1–7 and NPS 0–10) and a Likert battery for experience attributes, measurement risks persist: anchoring effects across scales, flatlining from respondent fatigue, and common-method variance from collecting all perceptions in a single session. While internal consistency for composite indicators was acceptable, construct-validity issues may remain (e.g., overlap between “travel comfort” and “crowding”). By design, NPS is more volatile and sensitive to short-term conditions than overall satisfaction; its decline should be interpreted as a tactical warning signal rather than evidence of structural deterioration unless supported by convergent indicators.

Fifth, although quality control was conducted through logical validations, time monitoring, and thematic coding of open-ended responses, qualitative coding may introduce interpretative variability, and interperiod comparisons assume semantic invariance that should ideally be verified formally. The multiplicity of contrasts (across attributes and segments) raises the risk of spurious findings due to multiple comparisons if corrections are not applied or if the narrative is not anchored in robust, replicable patterns.

Sixth, another limitation of the present study concerns the availability of detailed statistical outputs associated with the exploratory factor analysis and regression model. The statistical analyses were conducted within the operational monitoring programme developed in collaboration with EFE Valparaíso, and only the outputs required for operational reporting—namely the factor structure, relative importance of the extracted dimensions, and overall explanatory power ( $R^2$ )—were made available to the research team (see Appendix A). Consequently, additional diagnostic statistics commonly reported in academic studies, including KMO statistics, Bartlett’s test, regression coefficients, standard errors, confidence intervals, and multicollinearity diagnostics, could not be incorporated into the manuscript. Although this limits the extent of inferential interpretation, it does not affect the operational usefulness of the identified service quality dimensions for monitoring passenger experience over time.

Seventh, it is important to recognize that the present study does not empirically demonstrate the complete pathway linking passenger satisfaction to modal shift or greenhouse gas emission reductions. Variables such as travel behaviour, mode substitution, car ownership, or environmental attitudes were beyond the scope of the survey. Accordingly, the relationship between passenger satisfaction and sustainability outcomes is discussed conceptually, based on the existing literature and current transport policy frameworks.

Future research should integrate operational satisfaction monitoring with behavioural and environmental indicators to directly evaluate how improvements in passenger experience influence modal choice and contribute to climate mitigation objectives.

Eighth, other service quality approaches were not used. For instance, IPA (Importance Performance Analyses) is a valuable decision-support tool for prioritizing service improvements by simultaneously evaluating the importance and perceived performance of individual service attributes. However, IPA is generally designed as a cross-sectional diagnostic framework and does not explicitly capture temporal changes in passenger perceptions or the effects of operational disruptions across successive monitoring periods. In contrast, the repeated monitoring framework proposed in this study was specifically designed to support the continuous evaluation of service quality through standardized measurement waves, allowing railway operators to identify emerging trends, assess the effects of operational events, and monitor the evolution of passenger satisfaction and NPS over time. Another example is SERVQUAL, which provides a robust conceptual framework for assessing service quality through the gap between customer expectations and perceived performance. Nevertheless, its application requires the measurement of both expectations and perceptions, increasing questionnaire complexity and respondent burden. The operational passenger satisfaction programme developed by EFE Valparaíso was designed to provide concise, repeatable, and easily interpretable indicators that could be collected periodically under real operating conditions while minimizing interview duration.

Therefore, mitigations and directions for methodological improvement are suggested:

- Sampling designs: move toward probabilistic stratified sampling by station and time period, or apply weighting/post-stratification based on observed flows (e.g., validations, automated passenger counts) to approximate representativeness.
- Power and coverage: increase sample size and ensure coverage of weekend windows; document and report rejection rates and nonresponse profiles.
- Longitudinal approach: implement repeated cross-sectional waves on a fixed calendar or a rotating subpanel to estimate event-driven and seasonal effects.
- Data integration: triangulate with operational records (punctuality, headways, load by train/door) and transactional data (validations) to model drivers and adjust for confounders.
- Analytical strategies: report effect sizes, robust confidence intervals, and sensitivity to alternative specifications; limit causal inferences and explicitly state assumptions.
- Instrument refinement: assess measurement invariance across waves, reduce construct redundancy, and complement with targeted qualitative modules (short interviews at critical stations) to contextualize abrupt changes.
- Fieldwork environment: reduce social desirability effects through greater privacy and reinforce interviewer neutrality protocols.

Overall, the evidence collected is consistent and useful for tactical service management, particularly in identifying gaps in safety, predictability, crowding, and environmental conditions. However, external validity and inferential capacity are conditioned by quota sampling, sample size, and the operational context of the measurement period. Advancing improvements in design, measurement, and data integration will strengthen the robustness of conclusions and the reliability of trend tracking in future waves.

It is important to note that multivariate approaches such as regression models, structural equation models (SEM), or ordered logit models would provide a stronger analytical framework for identifying the relative influence of specific service attributes on satisfaction and NPS. However, the primary objective of this pilot study was exploratory and descriptive, aiming to identify critical experience attributes and monitor their evolution across

measurement waves. The available sample size and the survey design were not originally intended to support causal or predictive modeling.

#### 4.3. Recommendations to Improve Passenger Satisfaction

Based on the findings of the study—high overall satisfaction but a temporally declining NPS, setbacks in perceived safety and predictability, pressure from peak-hour crowding, and deterioration in environmental conditions—this section proposes infrastructure improvement guidelines focused on capacity, safety, comfort, and information, organized by implementation horizon (short, medium and long term). Those interventions that emerge directly from passenger-reported concerns (e.g., safety, crowding, environmental conditions, and information provision) are distinguished from longer-term infrastructure strategies proposed to address recurring operational challenges identified in the study. In particular, long-term recommendations such as signalling modernization, platform extensions, electrical resilience improvements, and platform screen doors should be interpreted as strategic planning options rather than direct outcomes of passenger responses.

As an example, Table 5 presents a prioritization matrix linking each recommendation to specific issues according to frequency of mentions, proposed intervention, feasibility, impact and time horizon.

**Table 5.** The prioritization matrix linking each recommendation to specific issues.

| Identified Issue        | Frequency of Mentions | Proposed Intervention                        | Feasibility | Expected Impact on Satisfaction/NPS | Time Horizon |
|-------------------------|-----------------------|----------------------------------------------|-------------|-------------------------------------|--------------|
| Crowding                | 71%                   | Passenger distribution measures              | High        | High                                | Short-term   |
| Platform safety         | 77%                   | Additional CCTV and guards                   | High        | High                                | Short-term   |
| Temperature and odors   | 47%, 43%              | Ventilation improvements                     | Medium      | Medium-High                         | Medium-term  |
| Operational disruptions | NPS decline           | Real-time passenger information              | High        | High                                | Short-term   |
| Capacity constraints    | Recurrent crowding    | Platform extensions/signalling modernization | Low-Medium  | Potentially High                    | Long-term    |

Short term (0–12 months):

- Platform and boarding flow management: marking waiting zones and distributing passengers along the train; installing guide barriers and retractable beacons in high-demand stations; increasing signage for active doors and “even loading” to reduce bottlenecks. Rationale: reported crowding and decline in the pleasantness of travel during peak hours.
- Access and validation reinforcement: adding validators and widening access corridors in stations with bottlenecks; implementing preventive corrective maintenance to avoid turnstile failures. Rationale: link between access times and perceived order/comfort during peak periods.
- Situational safety: improved LED lighting on platforms and circulation areas; denser CCTV coverage with basic analytics (crowding detection); visible emergency buttons; security booths in blind spots. Rationale: perceived safety as a main source of dissatisfaction.
- Environmental conditions and cleanliness: intensive cleaning protocols for high-turnover trains; replacing textile materials with easy-to-sanitize surfaces where possible; checking seals and natural ventilation; installing gel dispensers and enhanc-

ing waste removal. Rationale: increase in reports of bad odors and decline in cleanliness evaluations.

- Operational information during disruptions: standardized messages on PIS (platform and onboard screens) and PA systems with estimated times and cause of disruption; integration of color codes for line status. Rationale: NPS decline associated with high-salience events and need for reliability.
- Critical complementary services: provision of public restrooms in strategic stations with high passenger turnover, under outsourced operation and cleaning models. Rationale: explicit demand in dissatisfaction mentions.

Medium term (12–36 months):

- Platform widening and redistribution: expanding waiting areas in stations with recurrent saturation; adding flow-ordering furniture (railings, pre-boarding markings) and anti-slip surfaces. Rationale: peak-hour demand spikes and platform safety risks.
- Rolling stock and onboard comfort: interior configuration with more vertical poles and transverse handrails; optimizing seat layout to increase standing room in central cars; improved forced ventilation and air-filtration systems. Rationale: tensions in comfort and environmental conditions under high occupancy.
- Accessibility and pedestrian infrastructure: correcting slopes, widening ramps, and adding redundant elevators in high-demand stations; segregating pedestrian and bicycle flows. Rationale: operational robustness and environmental safety.
- Modal integration: secure bike parking, kiss-and-ride zones, and reorganized feeder bus stops to reduce interference at station entrances. Rationale: improved travel continuity and higher satisfaction with key attributes.

Long term (36+ months):

- Structural capacity increases: assessment of platform extension for frequent coupled-train operations; modernization of signaling to reduce safe headways; creation or strengthening of passing sidings where the network topology allows. Rationale: peak-hour supply–demand gap.
- Electrical and catenary resilience: strengthening substations, additional sectioning, and protections against weather events; programmed replacement of critical components. Rationale: reported energy-related contingencies and climatic impacts.
- Platform-edge protection: feasibility analysis for platform screen doors in higher-risk stations, prioritizing nodes with high density and incidents. Rationale: safety and flow control.

Cross-cutting technology and analytics:

- Automatic passenger counting (APC) and video analytics: installation on trains and in stations to manage load distribution in real time and trigger redistribution messages. Rationale: dynamic alignment between demand and perceived supply.
- Perceived-quality monitoring: station-level dashboards with NPS, satisfaction, and key attributes; early alerts for sudden deterioration. Rationale: NPS volatility during contingencies.

Monitoring indicators:

- Capacity and flow: density (passengers/m<sup>2</sup>) on platforms and onboard during peak periods; access/egress times; validator utilization.
- Safety: incidents per million trips; perceived safety on platforms and onboard.
- Comfort and environment: onboard temperature/CO<sub>2</sub>; odor complaints; cleanliness evaluations.
- Information: time to issue announcements during disruptions; message comprehension (flash surveys).

Prioritization:

- Criteria: expected impact on safety and comfort, technical feasibility, cost-effectiveness, and operational criticality by station. Rationale: concentration of gaps in high-turnover nodes and during peak periods.

Taken together, these guidelines address the gaps identified in the study—safety, crowding, environmental conditions, and informational certainty—and aim to strengthen the robustness of the service, stabilize perceived quality, and recover the NPS without compromising operational efficiency.

## 5. Conclusions

The findings indicate that passengers continue to value the service primarily for its speed and efficiency. Overall satisfaction remained relatively stable throughout the study period; however, NPS exhibited greater variability, suggesting that users' willingness to recommend the service is more sensitive to operational disruptions and highly visible incidents than overall satisfaction. This result highlights the importance of considering satisfaction and NPS as complementary indicators that capture different dimensions of passenger experience and loyalty.

The analysis also identified several areas requiring attention. Perceived platform safety, peak-hour crowding, onboard environmental conditions, and information provision during service disruptions emerged as the principal factors negatively affecting user experience. These findings emphasize that maintaining high levels of satisfaction requires not only reliable operations but also effective management of comfort, safety, and communication throughout the passenger journey.

From a practical perspective, the results support the implementation of targeted interventions aimed at improving safety conditions, managing passenger flows during peak periods, enhancing onboard environmental quality, and strengthening communication during operational contingencies. Addressing these issues may contribute to improving passenger perceptions and stabilizing willingness to recommend the service.

From a sustainability perspective, the study highlights the importance of continuously monitoring passenger experience as part of broader strategies aimed at improving the attractiveness and resilience of urban railway systems. By identifying operational attributes that influence users' perceptions of service quality, the proposed monitoring framework supports evidence-based decision-making consistent with the objectives of sustainable urban mobility and SDG 11.2. Although the present research does not directly evaluate environmental impacts or modal shift behaviour, improving passenger satisfaction may contribute indirectly to strengthening public transport competitiveness and promoting more sustainable travel patterns.

This study is subject to several limitations. First, the use of quota sampling and a repeated cross-sectional design limits the generalizability of the findings and does not allow causal relationships to be established. Second, the survey instrument did not include a specific measure of perceived fare value, preventing an assessment of the relationship between fare perceptions, satisfaction, and recommendation behavior. Third, the analysis relied primarily on descriptive and comparative approaches and therefore could not quantify the relative influence of individual service attributes on satisfaction and NPS.

Future research should build upon the operational monitoring framework proposed in this study by incorporating advanced behavioural modelling techniques capable of estimating the causal relationships among service quality attributes, passenger satisfaction, loyalty, and recommendation behaviour. In particular, Structural Equation Modelling (SEM), ordinal logistic regression, and Importance–Performance Analysis could be employed to quantify the relative influence of individual service attributes and validate the

latent dimensions identified through exploratory factor analysis. Longitudinal panel data and probabilistic sampling strategies would further improve external validity and enable a more comprehensive understanding of how operational interventions influence passenger perceptions over time. Additionally, future studies should investigate sustainability-related behavioural outcomes, including modal shift intentions, continued public transport use, and environmental perceptions, thereby strengthening the connection between passenger satisfaction and sustainable urban mobility objectives. Moreover, future studies should extend the exploratory analyses presented here by applying confirmatory multivariate techniques using complete statistical reporting, including regression coefficients, goodness-of-fit indices, reliability measures, and construct validity assessments. Such approaches would enable a more rigorous evaluation of the causal mechanisms linking service quality attributes with passenger satisfaction, loyalty, and willingness to recommend commuter railway services. With respect to sustainability, new studies are needed to integrate passenger satisfaction monitoring with sustainability-oriented indicators, including modal shift intentions, travel behaviour, greenhouse gas emission reductions, and environmental perceptions of public transport. Combining operational monitoring with behavioural modelling would provide a more comprehensive understanding of how improvements in service quality contribute to the broader objectives of sustainable urban mobility and climate mitigation policies.

Overall, the study demonstrates that while the Limache–Puerto railway service maintains a strong value proposition for metropolitan mobility, improvements in safety, comfort, crowding management, and disruption communication are essential to strengthen passenger experience and long-term service attractiveness. More broadly, the findings contribute to the growing body of research on sustainable railway transport by highlighting the importance of combining operational performance with user-centered indicators when evaluating service quality and system resilience.

**Author Contributions:** Conceptualization, G.A., V.A., M.F., A.P., H.P. and S.S.; methodology, G.A., M.F. and S.S.; software, G.A. and M.F.; validation, S.S. and V.A.; formal analysis, G.A.; investigation, V.A., M.F., A.P., H.P. and S.S.; resources, A.P.; data curation, I.B., E.B. and S.S.; writing—original draft preparation, G.A. and S.S.; writing—review and editing, V.A., M.F., A.P., H.P., I.B. and E.B.; visualization, G.A. and S.S.; supervision, V.A. and S.S.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received funding from FONDEF ID22I10018 ANID and Concurso DI Investigación Asociativa Interdisciplinaria 2025, proyecto código: 039.776/2025, Pontificia Universidad Católica de Valparaíso, Chile.

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Pontificia Universidad Católica de Valparaíso, Chile (protocol code BIOEPUCV-H 548-2022 and date of approval 3 October 2022).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The anonymized dataset and JASP scripts are available from the corresponding author upon reasonable request.

**Acknowledgments:** The authors would like to thank the researchers of the Mobility and Transport Laboratory at Pontificia Universidad Católica de Valparaíso, Chile, for their valuable support and contributions to this study. The authors are also grateful to EFE Valparaíso for providing the data used in this research.

**Conflicts of Interest:** EFE Valparaíso collaborated by facilitating access to survey locations, operational information and the definition of operational monitoring attributes. However, the study design,

statistical interpretation, manuscript preparation and publication decisions were conducted independently by the research team. The operator had no influence on the interpretation of the findings.

## Appendix A

Table A1 presents the rotated factor loadings obtained from the exploratory factor analysis conducted on the passenger experience attributes included in the survey; the results are described as exploratory and indicative, rather than as a definitive or fully validated construct. In addition, the adjusted  $R^2$  and other standard regression diagnostics were unavailable because the original statistical outputs provided by the operator could not be accessed retrospectively. Consequently, the regression results are presented for illustrative purposes only and should not be interpreted as confirmatory evidence.

**Table A1.** Factor analysis based on five dimensions.

| Services                                                                                     | Safety, Service Quality and Travel Experience | Travel Time and Travel Conditions | Passenger Information and Accessibility | Complementary Services and Fare Collection | Intermodal Connectivity |
|----------------------------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------|-----------------------------------------|--------------------------------------------|-------------------------|
| Safety against potential crimes and accidents                                                | 0.724                                         | 0.231                             | 0.213                                   | 0.204                                      | −0.098                  |
| Courtesy and ability of staff to address questions and concerns                              | 0.410                                         | 0.214                             | 0.264                                   | 0.157                                      | 0.290                   |
| Concern for providing customers with information about the current status of the service     | 0.545                                         | 0.059                             | 0.546                                   | 0.212                                      | 0.081                   |
| Safety against potential accidents                                                           | 0.783                                         | 0.058                             | 0.285                                   | 0.192                                      | 0.133                   |
| Safety against theft and robbery                                                             | 0.800                                         | 0.176                             | 0.174                                   | 0.207                                      | 0.009                   |
| Safety while waiting for the train on the platform                                           | 0.753                                         | 0.148                             | 0.017                                   | −0.032                                     | 0.295                   |
| Safety during boarding and alighting from the train                                          | 0.613                                         | 0.034                             | 0.039                                   | 0.176                                      | 0.332                   |
| Travel comfort on the train (personal space, temperature, and odors)                         | 0.410                                         | 0.307                             | −0.102                                  | 0.225                                      | 0.215                   |
| Feeling of safety during the train journey                                                   | 0.736                                         | 0.248                             | 0.128                                   | 0.051                                      | 0.319                   |
| Travel times considering the entire trip from platform access to exit at destination station | 0.154                                         | 0.557                             | 0.352                                   | 0.010                                      | 0.281                   |
| Travel conditions in stations and trains                                                     | 0.236                                         | 0.708                             | 0.157                                   | 0.120                                      | 0.216                   |
| Cleanliness of stations and trains                                                           | 0.138                                         | 0.753                             | 0.010                                   | 0.154                                      | −0.006                  |
| Ease of predicting travel times                                                              | 0.127                                         | 0.485                             | 0.602                                   | −0.001                                     | 0.093                   |
| Ease of finding information for your journey                                                 | 0.200                                         | 0.098                             | 0.755                                   | 0.176                                      | 0.226                   |

Table A1. *Cont.*

| Services                                                                               | Safety, Service Quality and Travel Experience | Travel Time and Travel Conditions | Passenger Information and Accessibility | Complementary Services and Fare Collection | Intermodal Connectivity |
|----------------------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------|-----------------------------------------|--------------------------------------------|-------------------------|
| Availability of complementary services that improve my trip                            | 0.174                                         | 0.258                             | 0.163                                   | 0.642                                      | 0.241                   |
| Available channels to recharge a travel card or purchase a ticket                      | 0.088                                         | −0.060                            | 0.379                                   | 0.710                                      | 0.092                   |
| Transparency of fare collection when passing through the fare gate                     | 0.290                                         | 0.179                             | −0.114                                  | 0.723                                      | 0.122                   |
| Information provided about surrounding area and connections with other transport modes | 0.269                                         | 0.226                             | 0.195                                   | 0.142                                      | 0.715                   |
| Ease of transferring to other transport modes to reach the final destination           | 0.175                                         | 0.101                             | 0.147                                   | 0.216                                      | 0.779                   |

The first factor, Safety, Service Quality and Travel Experience, is strongly associated with attributes related to personal security, accident prevention, platform safety, onboard safety, and overall travel comfort. The highest loadings correspond to safety against theft and robbery (0.800), safety against accidents (0.783), platform safety (0.753), and perceived safety during the journey (0.736), indicating that safety is a dominant component of passengers' evaluations.

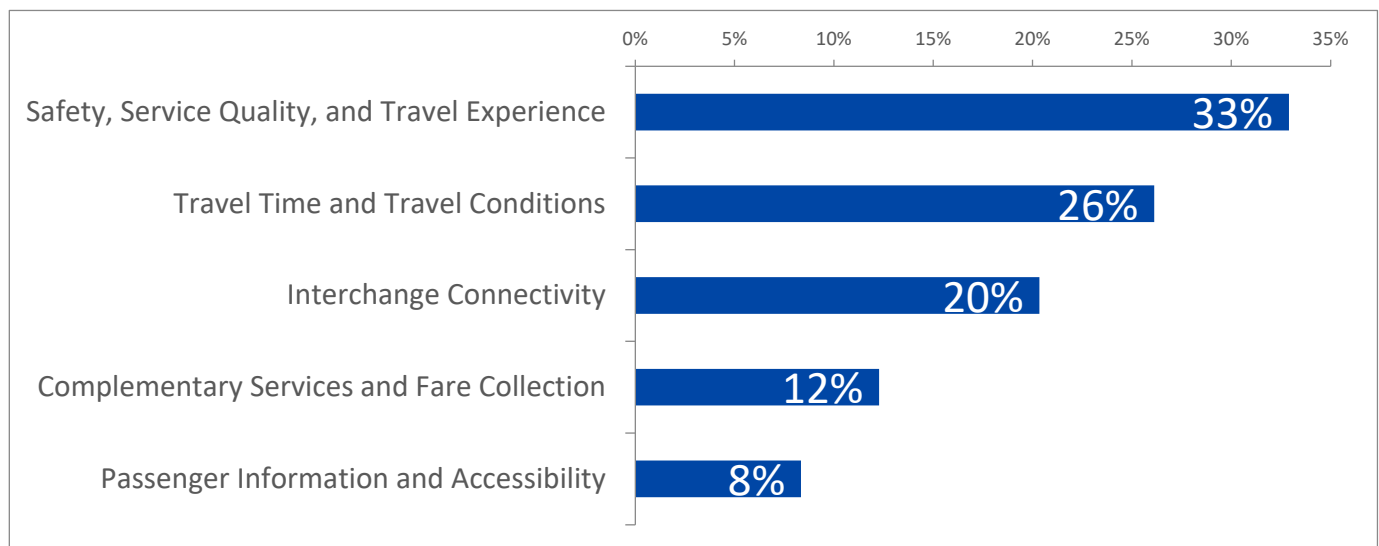
The second factor, Travel Time and Travel Conditions, groups variables associated with journey duration, cleanliness, infrastructure conditions, and overall travel environment. Cleanliness of stations and trains (0.753) and travel conditions in stations and trains (0.708) exhibit the strongest relationships with this dimension, highlighting the importance of the physical environment in shaping passenger experiences.

The third factor, Passenger Information and Accessibility, reflects the availability and accessibility of travel information. Ease of finding information for the journey (0.755) and predictability of travel times (0.602) load most strongly on this factor, suggesting that reliable information contributes significantly to perceived service quality.

The fourth factor, Complementary Services and Fare Collection, is primarily associated with ticket purchasing channels, transparency of fare collection, and the availability of complementary services. The strongest loadings are observed for fare transparency (0.723), ticket purchase and card recharge channels (0.710), and complementary services (0.642).

Finally, the fifth factor, Intermodal Connectivity, captures the ease of combining rail travel with other transport modes. This dimension is represented by high loadings for ease of intermodal transfers (0.779) and information regarding connections with other transport services (0.715).

In addition, a regression was performed based on the main factors described above. Figure A1 shows the relative weight values from which an R-square of 49.9 is obtained. Therefore, the regression model explained approximately 49.9% of the observed variance in overall passenger satisfaction, indicating that the identified service quality dimensions account for a substantial proportion of users' evaluations. However, because the analysis was designed to support operational monitoring rather than behavioural modelling, the results should be interpreted as indicating relative associations between service quality dimensions and satisfaction rather than statistically validated causal relationships.



**Figure A1.** Relative weight values for the regression with an R-square of 49.9 according to each factor.

The statistical outputs available from the operator included the explained variance ( $R^2$ ) and relative importance measures for the identified dimensions. Additional diagnostics commonly reported in exploratory factor analysis and regression modelling (e.g., KMO, Bartlett's test, regression coefficients, and significance levels) were not available and therefore could not be reported. Therefore, these analyses should be interpreted as indicative rather than fully validated, owing to the lack of access to the complete statistical outputs from the operator's database.

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