Predicting satisfaction of railways users: the role of perceived evolution of the service and on-board activities

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Abstract

This study investigates the determinants of user satisfaction in railways by using both machine learning techniques and econometric models. In particular it assesses the impact of service quality attributes and the ability to conduct on-board activities on overall satisfaction. The analysis is based on data from a large-scale satisfaction survey with 4,286 respondents, administered by the French Court of Auditors and designed by academics. The results indicate that (1) users prioritize service performance over price, (2) perceived changes in service quality significantly affect satisfaction. Also, the ability to conduct activities (3), as well as the reasons for being unable to do so (4), influence satisfaction levels. This study is the first of its kind in France and contributes to a deeper understanding of railway user satisfaction.

1. INTRODUCTION

Transportation significantly impacts the environment and contributes to negative externalities such as congestion, accidents, and pollution in urban areas. Public transportation often faces stiff competition from cars, leading to a rapid decline in rail use during the 20th century[1]. However, in recent years, there has been a growing interest in promoting public transport as a viable alternative due to its potential to reduce the environmental footprint. Fulton et al.[2] found that carbon emissions could be reduced by 40% by 2050 with a significant increase in public transportation, walking, and bicycling. In France, according to the National Institute of Statistics and Economic Studies, only 16% of daily trips are made by public transport, while 74% are made by car. This share drops below 5% in suburban and rural areas. Rail-based transport is a viable solution, particularly in urban and interurban areas, as it presents a credible alternative to car travel. Increasing the use of public transportation, specifically rail-based systems, depends on understanding the determinants of user satisfaction [3], [4], [5], [6], [7], [8].

This paper aims to investigate one primary question: (1) What drives user satisfaction in railway transportation services? (1.2) how the ability to conduct activities during rail travel also impacts satisfaction? The question (1) is a common focus in satisfaction-related studies. The objective is to ascertain which quality attributes are most highly valued by users of railway services, for example, punctuality, price, cleanliness and so forth. This investigation of users' preferences has prompted some authors to examine heterogeneity among them[9], [10], [11], [12], [13], [14]. Such heterogeneity is frequently attributed to personal characteristics (gender, age, revenues etc.). While not directly addressed in this study, the personal characteristics-based heterogeneity can be completed by an unobserved heterogeneity [14]. The unobserved heterogeneity leads to sub-question 1.2: To what extent does the ability to engage in on-board activities such as reading or working influence overall satisfaction? Specifically, the capacity to perform activities while traveling may significantly contribute to variations in satisfaction levels. Although this ability is not a service quality attribute, it is complementary to understanding satisfaction. Ettema et al.[15] demonstrated that the ability to engage in activities positively impacts satisfaction. Shaw et al. [16] found that multitasking increases the likelihood of receiving benefits but also raises the probability of cognitive disadvantages. Additionally, Malokin et al. [17] showed that the likelihood of conducting on-board activities influences modal choice, suggesting that public transit modes can increase ridership by accommodating the productivity preferences and behaviours of commuters. Similar findings were reported by Choi et al.[10]. It has been observed that multitasking in railways has increased with the advent of digital alternatives, resulting in a larger proportion of passengers perceiving their travel time as worthwhile[18]. For Frei et al.[19], value of time is affected by multitasking and conducting activities should be recognized as productive. However, contextual factors have a strong impact on the ability to conduct activities [20].

The data used for this paper come from a satisfaction survey administrated by the French Court of Auditors. The Court conducted a public policy evaluation of the strategy and quality of service of the Auvergne-Rhône-Alpes region's railways. In order to measure the user satisfaction, the Court sent an email to 27,000 users which resulted in 4,286 fully exploitable answers.

The method is based on a two-step analysis using two different models. First, we used a Random Forest model to identify the variables that most significantly contribute to satisfaction. Random forests, which are non-parametric tree-based algorithms, are particularly useful for survey analysis. Many authors have used such algorithms, in particular Classification and Regression Trees (CART) [9], [21], [22]. Following the random forest analysis, an ordered logit regression was performed to assess the effect of activities, crowdedness and available space on overall satisfaction. The interest of the multivariate ordered logit regression is to perform a *ceteris paribus* analysis in order to measure the impact of one variable when the others are held constant.

Consistent with previous findings, our study reveals that users value service performance (regularity, punctuality, frequency) more than price [1], [3], [9], [12], [14], [21], [23], [24]. Users primarily seek a reliable service, which is significant in the context of free transportation debates. Interestingly, one of the most important variables affecting satisfaction in Random Forests is the perceived evolution of the service. This suggests that negative experiences with the service can impact long-term satisfaction, a finding supported by previous research in railways [25] and the prospect theory [26]. Additionally, the ability to conduct activities during the trip, and the reasons for not doing so, impact satisfaction.

This paper is organized as follows. In section 2, we review the literature to assess what users value most in rail-based systems. Section 3 presents our original database on railways users' satisfaction in the Auvergne-Rhône-Alpes Region. Section 4 describes the methodology of our two-stage analysis. We discuss our results in section 5 and provide policy recommendations in Section 6.

2. LITERATURE REVIEW

In order to identify what service attributes users value the most, we selected relevant papers aligned with our research question [1], [3], [5], [7], [8], [9], [12], [14], [21], [22], [23], [24], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37]. We systematically analysed the attributes across the selected papers, by counting the number of times each attribute was mentioned. **Table 1** summarizes the relative importance of service attributes in the literature. The first column ("First 10 items") indicates the frequency of an attribute's mention across the reviewed papers. Attributes like frequency, personal safety, punctuality, information, and price-quality emerge as the most frequently mentioned. The second column ("Top 10 items in terms of importance") captures the number of times an attribute ranked within the top 5 most important factors based on user responses. Finally, the third column ("Ratio importance / mentioned") presents a ratio between the number of times an attribute appears in the top 5 and its total mentions. This ratio helps mitigate potential bias arising from attributes that are infrequently mentioned but highly impactful when addressed in surveys.

Table 1: Attribute importance

First 10 items in terms of mention in papers	**First 10 items in terms of importance**	**Ratio importance / mentioned**
Frequency	Punctuality	Regularity
Personal safety	Regularity	Punctuality
Punctuality	Frequency	Seat cleanliness
Information (station)	Information (station)	Crowding
On-board information	Crowding	Frequency
Personnal safety (station)	Seat comfort	Seat comfort
Quality-price ratio	Quality-price ratio	On-board space
Sympathy and competency	On-board information	Toilet cleanliness
Travel safe	On-board comfort	Substitute service
On-board comfort	Train cleanliness	Speed travel

Source: authors

This analysis demonstrates that service performance attributes, encompassing punctuality, regularity, and frequency, are both frequently mentioned and highly valued by railway passengers. Crowding is another important aspect of the service according to passengers. Price is a service quality attribute

often asked but not considered as important as service performance or crowding. Meaning that users are more attached to a reliable service than a cheap one.

THE EFFECTS OF MULTITASKING ON SATISFACTION

There is a growing body of literature exploring the role of multitasking on satisfaction [10]. Study found that in-vehicle activities impact commuters' satisfaction, as does the nature of the commute itself [15]. For Lyons et al. [18], activities involving digital technologies are associated with a better travel experience. However, the positive relationship between satisfaction and activities using digital tools is moderated by crowdedness. It has been found that service valuation is closely related to multitasking, emphasizing that the value of time while traveling should be recognized, given its productive use [19]. Also, the type of activities, whether useful or pleasant, affects satisfaction, with pleasant activities having a stronger impact [38]. Choi et al. [10] argue that using travel time productively positively influences commuters' satisfaction. Although being able to engage on-board activities affects utility, is also has an effect on mode choice of transport [17]. Shaw et al. [16], found that on-board activities enhance the benefits of travel but are also linked to cognitive disadvantages, such as unsafe distractions or fragmented attention. Additionally, socio-demographic characteristics contribute to heterogeneity in time-use preferences [39]. For Axtell et al., [20] mobile work on trains is hindered by a lack of reliable communication networks, limited access to co-workers, and insufficient privacy.

These studies collectively indicate that on-board multitasking impacts the utility of travel, with the extent of this impact varying according to user profiles. However, a deeper analysis is needed to understand why certain activities are not possible. There may be differences in users' appreciation of the inability to engage in productive activities, whether based on individual preferences (e.g., a reluctance to work on a train) or service-related factors (e.g., overcrowded trains).

LIMITATIONS OF PREVIOUS RESEARCHES

Previous researches are flourish and give good insights about what users value in railways transportation. Although, this field is rich, we did not find any French case on regional railways satisfaction. To our knowledge, this paper represents the first French analysis. Secondly, for this paper we can rely on a unique source of data, since it comes from a large-scale satisfaction survey of 4,286 answers. In addition, this survey wasn't administrated by the public transport authority or the operator and was designed by academics. Previous researches on multitasking are also flourishing. If the role of conducting activities on satisfaction is assessed, the reasons of not being able to conduct activities on satisfaction need more studies.

3. SURVEY

DESIGN OF THE SURVEY

The Court of Auditors conducted a public policy evaluation in the Region Auvergne Rhone Alpes, regional public transport authority (PTA). The Court aimed to directly interview users and administrated its own survey. The purpose of this survey was to measure the satisfaction of railways users related to service performance and rolling stocks (space, comfort etc.). On behalf of the Court, the survey was designed by the authors with the support of two academics specialized in the field of satisfaction in railways[1].

[1] Laura Eboli and Gabriella Mazzulla, University of Calabria, Italy.

The user survey comprised five sections (details in Appendix 1). The first section captured user profiles through questions on travel habits and subscription types.

The second section focused on service quality attributes, where users rated both their importance and their satisfaction with them [3], [9]. Participants were also asked about the perceived evolution of service quality with the question, "Have you noticed evolutions in the service since you started using the TER?".

The third section explored users' ability to perform desired activities during their journey (i.e. working with a laptop, working with a cell phone, personal activities on a laptop, personal activities with a cell phone, reading a book, magazine, or engaging in playful activities such as crosswords, applying makeup, sleeping, resting or watching the scenery, and listening to music), along with easiness to conduct these activities.

The fourth section employed images to facilitate user evaluation of train crowding density [40]. Finally, the fifth section collected respondents' socio-economic characteristics like income, gender, and age, which we do not consider in this study.

SURVEY ADMINISTRATION

The data source was a database provided by the railway operator, containing email addresses of 150,000 subscribers and discount card holders. Subscribers accounted for approximately 70% of total trips. In September 2023, the Court, not the Public Transport Authority (PTA) or the operator (SNCF), emailed 27,000 randomly selected users to participate in the survey. A total of 6,200 responses were received, with 4,286 deemed usable for analysis.

DATA

For inclusion in the final database, respondents had to answer the overall satisfaction question, provide information on gender, age, and socio-professional category, and successfully complete at least 85% of the questionnaire. To ensure accurate descriptive statistics, post-stratification (marginal calibration) was applied, adjusting for gender, socio-professional category, and age. **Table 2** shows the descriptive statistics of our sample.

Table 2: Descriptive statistics of the sample characteristics

Characteristics	Total	Characteristics	Total	Characteristics	Total	Characteristics	Total
Gender		**Profesionnal condition**		**Frequency of use**		**Duration of use**	
Male	42%	Full-time worker	51%	At least 4 time a week	48%	More than 3 years	40%
Female	56%	Part-time worker	7%	2-3 time a week	26%	1 to 3 years	40%
Other	2%	Student	32%	1 time a week	10%	6 m to 1 year	13%
Age		Unemployed	4%	Less than 1 time a week	17%	Less than 6 m	6%
Less than 18	9%	Retired	6%			**Departure station**	
18-26	33%	**Qualification**		**Day of trip**		Lyon	12%
27-35	16%	Master degree	34%	Weekdays	90%	Other	88%
36-45	16%	Bachelor degree	25%	Week-end	29%	**Arrival station**	
46-59	17%	Other higher education	19%	**Time of the trip (go)**		Lyon	45%
60-	9%	Upper secondary school	11%	On-peak hour	51%	Other	55%
Mean	*39*	Lower secondary school	5%	Off-peak hour	49%	**Trip purpose**	
		No degree	2%	**Time of the trip (return)**		Work	54%
		Don't want to answer	4%	On-peak hour	52%	Studies	27%
				Off-peak hour	48%	Leasure	12%
						Other	7%

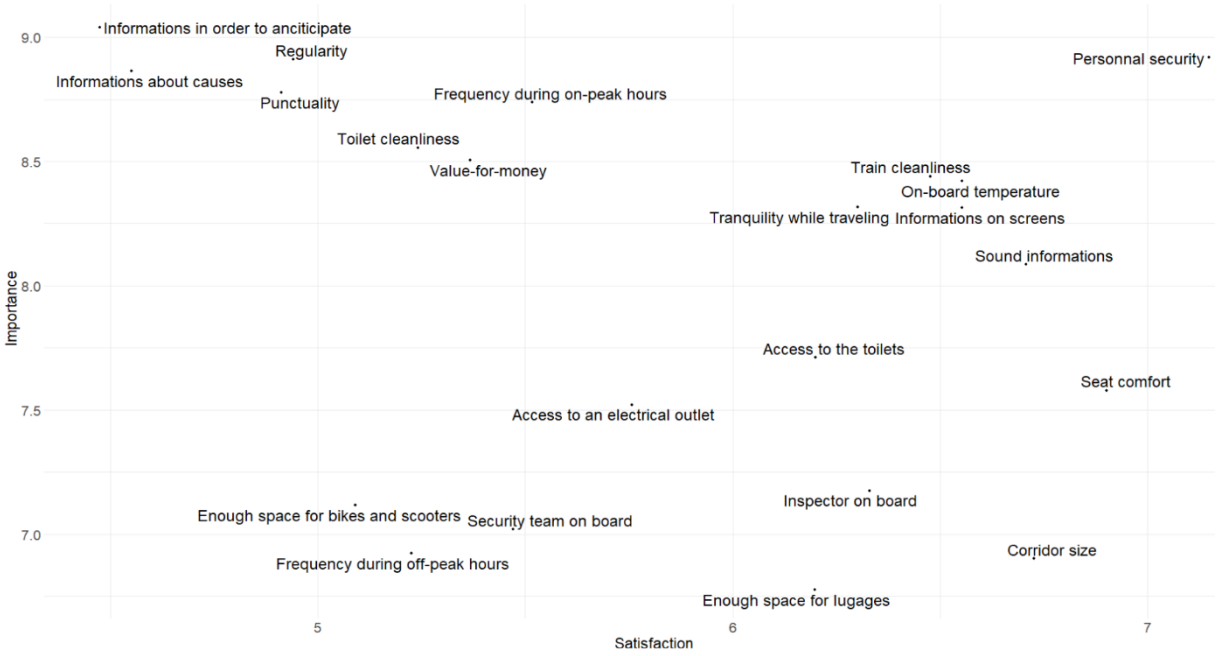
Source: authors

Our sample primarily consists of commuters traveling for work or study purposes, with the majority traveling to Lyon for their outbound journey. Notably, 48% of the sample travels at least four times per week, while 42% report working from home. This indicates that many railway service customers belong to professions that require less frequent travel due to remote work capabilities. According to SNCF data[2], the total number of trip - kilometers traveled increased by 14% between 2019 and 2022. However, the frequency of trips by subscribers decreased by 2%, whereas occasional users increased their usage by 33%. These trends suggest a shift in the customer base.

In our survey, users were asked to rate their satisfaction with and the importance of various aspects of the service on a 1 to 10 Likert scale. **Figure 1** presents the average importance and average satisfaction as reported by users. Attributes in the top-left quadrant are considered important but unsatisfactory; those in the top-right quadrant are both important and satisfactory; attributes in the bottom-right quadrant are not important but satisfactory; and those in the bottom-left quadrant are neither important nor satisfactory.

[2] https://www.laregionvoustransporte.fr/sites/aura_transport/files/2023-05/COTECH%20VDRN%20TRAME%20FINALISEE.pdf

Figure 1: Average satisfaction and importance by service quality attributes according passengers



Source: authors

Attributes related to performance and information are regarded as the most important yet least satisfying by users. In contrast, attributes concerning security and comfort (such as temperature, cleanliness, and tranquillity) are considered both important and satisfying. This declared hierarchy closely aligns with previous findings [9], [32], where attributes related to security, performance, and cleanliness were identified as the most important.

4. METHOD

We conducted a two-step analysis using a Random Forest algorithm and an ordered logit regression to identify the effects of service attributes, space, crowdedness and reason for not being able to conduct activities on overall satisfaction. The objectives were to determine what users value most and to assess the impact of multitasking on satisfaction. Both models aim to predict satisfaction, categorized as "poor," "fair," or "good" in order to limit non-linearity bias that could occur with Likert-type scale [24]. Our categorisation follows the Net Promoter Score [41]: scores from 1 to 6 were recoded as “poor”; 7 and 8 as “fair”; 9 and 10 as good. This recode scheme was applied to overall satisfaction and service attributes rated from 1 to 10.

RANDOM FORESTS

Random Forest models are extensions of Classification and Regression Trees (CART) models, which have been extensively utilized in the analysis of transport surveys [9], [21], [22], [30], [31]. The rationale behind their widespread use includes several factors: CART models yield easily interpretable outputs and provide insights into the importance of independent variables in predicting outcomes. Moreover, CART models are nonparametric, making them particularly effective in handling multicollinearity, which is advantageous in satisfaction surveys where scores for attributes like punctuality and frequency may be correlated.

Random Forests, introduced by Breiman [42], enhance predictive performance by aggregating multiple decision trees, each constructed from a random sample of the dataset. This method mitigates the risk of overfitting, a common limitation of individual decision trees. Formally, Random Forests are algorithms based on decision trees to predict a variable. Considering a variable to predict *Y*, and a vector of variables $X = (X_1, \ldots, X_i)$, the object of the regression is to estimate the function $f(x) = \mathbb{E}[Y[X = x]]$ with *Y* the overall satisfaction and *X* the service quality attributes. Data are recursively split based on a feature that maximizes the purity of each child node. This purity is measured by the Gini Index:

$$G = \sum_{i=1}^{K} p(i) \times \left(1 - p(i)\right), \qquad (1)$$

where *K* is the total number of classes, and *p(i)* is the probability of an instance being classified into class *i*. The Gini Index measures variance, and higher variance indicates more misclassification. To reduce variance and improve model accuracy, a bootstrap aggregating (bagging) method is used. From the original data D_1, a new dataset D_2 of the same size *n* is created by randomly sampling with replacement from D_1. Bootstrap samples are then aggregated by majority voting in classification problems.

One of the key outputs of a Random Forests model is feature importance, which indicates the significance of each variable in predicting the model's outcome [43], [44]. Mean Decrease Gini measures how each variable contributes to the homogeneity within the decision trees. To assess the importance of a feature X_m for predicting Y, impurity decreases ΔG are summed up and averaged over all trees N_T in the forest [42], [45]

$$Imp\ (X_m) = \frac{1}{N_T} \sum_{T} \sum_{t \in T: v(S_t) = X_m} p(t) \Delta G(t), \qquad (2)$$

where *p(t)* is the proportion of samples reaching node *t* and $v(S_t)$ is the variable used in split S_t.

Higher Mean Decrease Gini scores signify that a feature is the most common one when it comes to split the data. In simpler terms, the most important features reduce the impurity of all trees, so increase the prediction.

ORDERED LOGIT REGRESSION

The nature of the data determined the regression model used to analyse the links between overall satisfaction and the various indicators of service quality i.e. ability to conduct activities, crowdedness, and standing up frequency. Ordered logit regression measures the effect of individual variables relative to others, making it suitable for mutually exclusive responses such as reasons for not performing activities and perceptions of crowdedness.

Given that our dependent variable (overall satisfaction) is categorical with three modalities (poor, fair, good) and is naturally ordered, we opted for an ordered logistic regression:

$$satisfaction_i = \begin{cases} 0 & \text{if } s_i^* < \mu_1 \ (\textit{poor satisfaction}) \\ 1 & \text{if } \mu_1 \leq s_i^* < \mu_2 \ (\textit{fair satisfaction}) \\ 2 & \text{if } s_i^* \geq \mu_2 \ (\textit{good satisfaction}) \end{cases}, \qquad (3)$$

with $s_i^* = X_i\beta + u_i$,

where $satisfaction_i$ is the overall satisfaction level of the individual i, s_i^* is the latent variable associated with the satisfaction variable, X_i is the matrix of covariates that contains the indicators of service quality, β the associated parameters to be estimated, and μ the threshold parameters for which $\mu_1 < \mu_2$. u_i is a random term *iid* distributed by the standard logistic distribution.

The coefficients associated with the covariates were estimated by maximizing the standard following likelihood:

$$L(\beta|X_i)=\prod_{i=1}^{N}\prod_{j=0}^{2}\left[\frac{\exp\left(\mu_{j+1}-X_i\beta\right)}{1+\exp\left(\mu_{j+1}-X_i\beta\right)}-\frac{\exp\left(\mu_j-X_i\beta\right)}{1+\exp\left(\mu_j-X_i\beta\right)}\right]^{y_{ij}}, \quad (4)$$

where μ_0 is defined as $-\infty$ and μ_3 as $+\infty$, and y_{ij} is a binary variable, equals to 1 if $satisfaction_i=j$ and 0 otherwise.

To quantify the own effect of each covariate, we referred to the average marginal effects. **Table 3** shows those calculated for the probability of having a good level of overall satisfaction (Pr(*satisfaction*=2)).

5. RESULTS

In the context of Random Forests, our objective is to assess the importance of various service quality attributes, perceived crowdedness, perceived evolution of the service, and the ability to conduct activities on overall satisfaction. While crowdedness, perceived evolution, and the ability to conduct activities are not inherent attributes of the service, their impact on satisfaction make their inclusion in the model highly pertinent.

The ordered logit regression is used to assess the particular effect of perceived crowdedness and reasons of not being able to conduct activities on satisfaction. The three most important service quality attributes derived by the random forests were included in the model in order to avoid omission bias.

This two-step has been done using R software.[3]

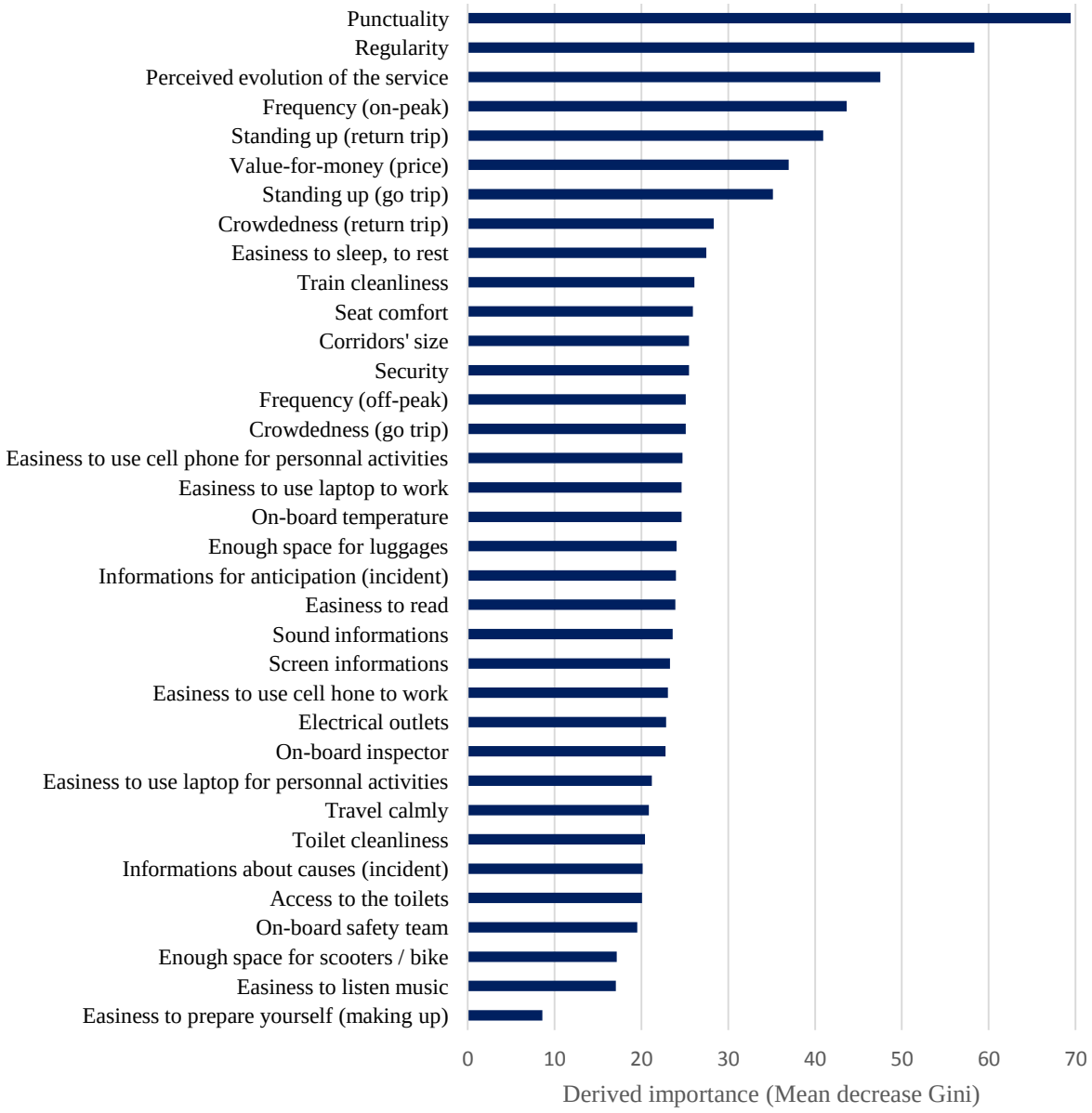
RESULTS FROM THE RANDOM FORESTS

Figure 2 presents the output of the Random Forests model, illustrating the importance of each variable. Variables that significantly reduce impurity are deemed more critical in predicting overall satisfaction. The Random Forests model identified punctuality, regularity, frequency during peak hours, and perceived evolution of the service as the most influential features. These findings align closely with user-declared importance ratings from the survey, with the notable exception of security, which ranked 13th in importance within the model. This discrepancy mirrors previous findings[9], [3], with security considered important by users but not by the model.

[3] These results were obtained using R software and the following libraries: "randomForest" for the Random Forests model (Liaw and Wiener, 2002), "MASS" for the ordered logit regression (Venables and Ripley, 2002), and "erer" for the calculation of marginal effects (Sun, 2022).

Our "Out of Bag" estimate of error rate is set at 27% (i.e., in 73% of case, our algorithm predicted the output, bad, fair, good, correctly). The overall error rate on the test data (20% of the sample) is set to 30%.

Figure 2: Most impactful features on overall satisfaction derived by the Random Forests



1.1.1 Perceived evolution of the service has an impact on users' satisfaction

As observed in **figure 2**, our model identified perceived evolution of the service as one of the most important variables. This finding suggests a potentially strong influence of perceived service evolution on overall satisfaction. However, the causal direction remains unclear: does current satisfaction influence the perception of service evolution, or vice versa?

Limited research in railway transportation directly mirrors this finding. However, Gijsenberg et al.[25] analyzed time series data and observed that service quality declines have a greater impact on user perception, both in the short and long term, compared to service quality improvements. This aligns with the notion that perceived quality suffers more significantly from deterioration. This finding resonates with the work of Monsuur et al. [46], in which they found that passenger satisfaction is influenced by "true" performance (delays, cancellations). Users who experienced strong delays (> 30 minutes) or cancellations increase heavily the probability of unsatisfaction. These studies and our finding could be interpreted as (1) a greater elasticity concerning performance losses than improvements in user satisfaction and (2) a strong persistence of performance losses on the satisfaction. In other words, users continue to be sensible to performance losses even after a long time. This finding aligns with Prospect Theory [26], which predicts that a loss in performance has a greater impact on satisfaction than a gain of the same scale. Smith and Bolton [47] found the existence of a service recovery paradox, when a high recovery can maintain or increase satisfaction. However, the recovery is challenging since every customer must be satisfied with every service failure.

1.1.2 Users value service performance over price

Another finding is the importance of service quality attributes related to performance (punctuality, frequency and regularity) derived by users. It shows an attachment to an efficient service to rely on, as we saw in our literature review where punctuality, regularity and frequency were the most important items for users (**table 1**). These attributes, related to performance, are considered as "basic" in opposition with "non-basic" attributes [48].

Satisfaction with price comes after performance of the service features, showing less attention for price than performance. In France all companies have to refund half of public transport subscription paid by their employees since 2008. Any subscriber who is also employed in a company pays in reality half of the subscription price. Since it's km-based fees, it is not possible to define precisely the gain for subscribers. For a trip of 26km (Villefranche-sur-Saône – Lyon) the total cost per month is 84.90€ and 42.45€ for the user. The data used for the analysis come from subscribers' answers, who, by definition, pay less than other users. This could be an explanation of these results: commuters need an efficient service on which they can rely on to go to work. A lower price paid, since the employer pays the half, contributes also to limit the value for money importance.

1.1.3 Perceived frequency of standing up and on-board crowdedness impact satisfaction.

Participants were prompted to indicate the frequency of standing during both their outbound and return journeys, selecting from the following options: every trip, one trip out of two, one trip out of three, rarely, or never. The level of crowdedness was estimated using an image-based approach, following the methodology of Haywood et al. [40] Both standing and crowdedness are critical factors that impact travel comfort, with higher levels of crowding resulting in more passengers standing rather than sitting. This can be particularly discomforting for passengers, given that over 57% of respondents reported travel times exceeding 30 minutes. According to the model, users seem to less value available space than performance. Several studies showed the effect of crowding on satisfaction[6], [40].

1.1.4 Possibility to easily conduct activities is another driver of satisfaction.

In the survey, participants were prompted to rate the feasibility of engaging in various activities while traveling. In terms of importance, the ease of sleeping or resting was ranked ninth, followed by the ease of using a cell phone for personal activities (16th position) and the ease of using a laptop for work (17th position). The feasibility of engaging in activities is considered another proxy for travel comfort, as overcrowded trains can make it difficult for passengers to conduct activities, potentially affecting their perceived waiting time and value of time. Ettema et al. [15] found that in-vehicle activities affect users' satisfaction with public transport, while it has been shown that conducting activities reduces

commuters' value of time by 30% [49]. The following section is meant to dive deeper on the role of activities on users' satisfaction.

RESULTS FROM THE ORDERED LOGIT

In addition to Random Forests, an ordered logit model was employed to examine the ease of conducting desired activities. The model also incorporated features related to space and comfort, such as the frequency of standing and feelings of crowdedness. To avoid omitted variable bias, the top three service quality attributes identified in the Random Forests model were included. The results of the model are presented in **table 3.**

Table 3: Ordered logit output

	Dependent variable: overall satisfaction				
Level of reference	**Feature**	**Coef.**	**Std. Err.**	**P>z**	**Average marginal effect (good)**
Poor	Punctuality (good)	1.43318	.1679642	0.000	.0886791
	Punctuality (fair)	.9934016	.0992142	0.000	.0460086
	Regularity (good)	1.066386	.1699067	0.000	.0606782
	Regularity (fair)	1.062672	.1014366	0.000	.0505901
	Frequency (good)	1.08215	.1362794	0.000	.0609933
	Frequency (fair)	.8337992	.086165	0.000	.0383984
Never	Standing-up (go trip - one trip out of three)	-.2396837	.1692513	0.157	ns
	Standing-up (go trip - one trip out of two)	-.428113	.2034393	0.035	-.0166937
	Standing-up (go trip - rarely)	-.2268203	.1098588	0.039	-.0098626
	Standing-up (go trip - always)	-.603615	.2614773	0.021	-.0220629
	Standing-up (return trip - one trip out of three)	-.3061594	.166563	0.066	-.0125083
	Standing-up (return trip - one trip out of two)	-.6030743	.1977382	0.002	-.0224196
	Standing-up (return trip - rarely)	-.2714385	.1174447	0.021	-.0119366
	Standing-up (return trip - always)	-.8756517	.2875171	0.002	-.0292168
Empty	Crowdedness (return trip - crowded)	-.1821776	.1126506	0.106	ns
	Crowdedness (return trip - overcrowded)	-.4605567	.1794206	0.010	-.0171207
	Crowdedness (go trip - crowded)	-.2579627	.0994909	0.010	-.0114408
	Crowdedness (go trip - overcrowded)	-.3324654	.1989569	0.095	-.0164721
I can easily do what I want	Can't conduct activity - not enough place (seat)	-.098212	.1190119	0.409	-.0041821
	Can't conduct activity - not enough space	-.3904295	.1438676	0.007	-.0167412
	Can't conduct activity - too much noise	-.2653809	.0999249	0.008	-.0110392
	Can't conduct activity - travel time too short	.2425446	.1053906	0.021	.01125
	Can't conduct activity - train shakes	-.4460806	.1431393	0.002	-.0173283
	Can't conduct activity - other passengers can see what you are doing	.0883252	.1124902	0.432	ns
	Can't conduct activity - connection issues	-.2959441	.0822996	0.000	-.0128173
	Interaction effects				
	Crowdedness (go trip - overcrowded) * Can't conduct activity - not enough space	-.51591	.2427445	0.034	-.0309356
	Crowdedness (return trip - overcrowded) * Can't conduct activity - not enough space	.3022505	.2101447	0.150	ns
	Crowdedness (go trip - overcrowded) * Can't conduct activity - not enough space (seat)	-.028828	.2480832	0.907	ns
	Crowdedness (return trip - overcrowded) * Can't conduct activity - not enough space (seat)	-.1624	.2168329	0.454	ns

According to the regression outputs, high satisfaction with punctuality is associated with an increase in overall satisfaction by 9 points. Similarly, high satisfaction with regularity and frequency is associated with increases of 6 and 5 points, respectively. Conversely, consistently standing during both go and

return trips results in decreases in satisfaction by 2 and 3 points, respectively, aligning with previous results [46], [6], [40]. Crowdedness negatively impacts satisfaction for both trips, with a 2-point decrease when users perceive the train to be overcrowded.

Additionally, the inability to conduct activities due to specific reasons further decreases satisfaction: shaky trains lead to a 2-point decrease, insufficient space results in a 2-point decrease. Connection issues and noise cause a 1-point decrease, aligning with literature [20].

Only the interaction effect between over crowdedness during go trips and insufficient space to conduct activities was significant. This finding suggests a complex interplay between the purpose of the trip and passenger resignation; when space is limited, attempting to conduct activities becomes more futile. Lyons et al. [18], found that multitasking affects positively travel time usage, but crowding limits the worthwhileness of time use in trains. Similar results have been found, although the effects varied depending on whether commuters were traveling to or from work [15].

6. CONCLUSION: THE ROLE OF PERCEIVED EVOLUTION AND ON-BOARD ACTIVITIES ON USERS' SATISFACTION

This study employed a combined approach utilizing both Random Forests and ordered logit regression models to investigate passenger satisfaction in the railway industry. The findings reveal a consistent emphasis on a specific set of variables – perceived service quality evolution, service performance and ability to conduct activities – as significantly impacting overall satisfaction. These variables act as "splitters" in the Random Forests model, indicating their ability to divide the data based on class homogeneity and exert a strong influence on overall satisfaction. This implies that passengers prioritize these service attributes, and their satisfaction with them heavily influences their overall evaluation of the service. With an ordered logit model, we found that reason of not being able to conduct an activity has also an impact. When a user can't conduct an activity, issues with space and shaky trains have the strongest importance on satisfaction.

These findings have several implications for operators and policymakers:

- **Perceived evolution of service interacts with current satisfaction:** Our results align with literature [25], [26], [46], indicating that perceived evolution of service quality is more negatively impacted by declines than improvements in both the short and long term. Therefore, operators should avoid train cancellations or significant delays to prevent dissatisfaction. Policymakers could consider implementing regulations based on satisfaction measures to identify affected passengers for specific compensation, such as discounts or gift cards.
- **Emphasis on industrial performance:** Our findings show that users highly value service performance. Moreover, users prioritize performance over value-for-money, indicating that they expect reliable and efficient train systems. Therefore, operators and policymakers should prioritize service attributes such as punctuality, frequency, and connectivity.
- **Ability to conduct activities while traveling has an impact on satisfaction:** The ability to conduct activities while traveling impacts user satisfaction. When users cannot conduct their desired activities, it leads to dissatisfaction. This finding could also explain the significance of the impact of seating availability and train crowdedness. Operators should ensure adequate train capacity to meet user demand.
- **Reasons of not conducting activities do not have an equal impact on satisfaction:** Shaky trains, insufficient space, connection issues and noise are significant drivers of dissatisfaction. This indicates that the reasons for not engaging in activities do not impact satisfaction to the same extent.

While not directly addressed in this study, data from the Auvergne-Rhône-Alpes region indicates a 91% punctuality rate since 2018, exceeding the national average of 90%. However, train cancellations remain an issue, with 763 cancellations recorded compared to the average of 674 cancellations per month since 2018. Future research could explore the specific impact of cancellations on user perception and satisfaction.

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8. AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Nicolas Fabre, Florent Laroche, Louafi Bouzouina; data collection: Nicolas Fabre; analysis and interpretation of results: Nicolas Fabre; draft manuscript preparation: Nicolas Fabre. All authors reviewed the results and approved the final version of the manuscript.

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APPENDIX

Appendix 1: Survey

Section 1: user profile
Subscriber or discount card holder
Type of subscription or discount card
Using more than one transport mode
Ease of doing without the train service
Driving licence holder
Number of cars
Disability
Day of travel
Hour of travel (go and return)
Departure station
Arrival station
Reason of the travel
Frequency of travel
Travel time
Duration of use
Possibility of working from home
Number of day of home-working
Estimation of the number of standing trips (go and return)
Travel with bike, scooter or luggages

Section 2: service attribute	Importance	Satisfaction
Many trains during on-peak hours	X	X
Many trains during off-peak hours	X	X
Value-for-money	X	X
Punctuality	X	X
Regularity (i.e cancellations)	X	X
Enough space to travel with luggages	X	X
Enough space to travel with bike or scooter	X	X
Seat comfort	X	X
Corridor size	X	X
Availibility of working electrical outlet	X	X
Ease of access to the toilets	X	X
Cleanliness of the toilets	X	X
Cleanliness of trains interior	X	X
Temperature on-board	X	X
Calm during travel	X	X
Security on-board	X	X
Sound information	X	X
Displayed screen information	X	X
Information on the cause of an incident	X	X
Information to help you to anticipate	X	X
Ticket inspector	X	X
Security team	X	X
Video surveillance	X	
Overall satisfaction		
Recommendation to a friend		

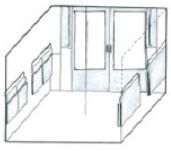
Activities

Section 3: activities

In general, do travel conditions allow you to do these activities during your journey?	I easily can	I do, but it's difficult	I would like, but I can't	I don't want to do this activity
Work with your laptop	X	X	X	X
Work with your cellphone	X	X	X	X
Personnal activities with your laptop	X	X	X	X
Personnal activities with your cellphone	X	X	X	X
Read a book or other recreationnal activities	X	X	X	X
Get ready (makeup, comb your hair)	X	X	X	X
Sleep, rest watch landscape	X	X	X	X
Listening music	X	X	X	X

Why don't you do some of the things you'd like to do?
Travel time is insufficient
There is not enough space
There is not enough seat
Other passengers can see what you do
Too noisy
Train shakes
Connection issues (wifi, cellphone)
You can conduct all the activities you want
Other reason

Crowdedness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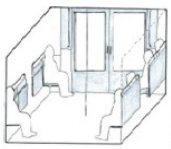
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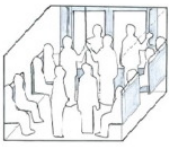
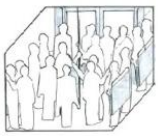

Crowded


Overcrowded

Socio-economics characteristics

Gender
Age
Number of person in the household
Professionnal situation
Social category
Qualification (degree)
Income per month