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TECHNICAL
REPORT

Benefits of Punctuality Improvements for the Paris Suburban Railway Network

Eric Kroes, Hugues Duchateau, Laurence Phillipart, Marco Kouwenhoven

Prepared for the Syndicat des Transports d'Ile de France

RAND EUROPE

STRATEC

The research described in this report was prepared for the Syndicat des Transports d'Ilse de France.

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Preface

The punctuality of trains is an important service characteristic of the public transport system. Trains that suffer from frequent and severe delays cause substantial nuisance to their users and reduce the perceived utility of the system. In other words: irregularity costs money. Therefore, rail authorities and train operators look at ways in which they can improve punctuality. In order to appraise the benefits of such measures in relation to the costs associated with them, perceived "values of punctuality" are needed: how much is it worth to a rail traveller to improve punctuality by a certain amount?

The objective of the project "*Enquêtes qualitatives et quantitatives visant à évaluer les projets de fiabilisation des radiale ferrées en Île-de-France*" is to determine a robust method to appraise *a priori* the monetary benefits of different possible measures to improve train service regularity. More specifically, the use of this methodology will guide decisions concerning specific projects aimed at making rail lines operate more in line with their published timetables.

The project was structured in three main phases. In phase 1, information about punctuality and how it is valued by passengers was obtained through a review of the international literature, an analysis of the available statistical data concerning Paris-oriented suburban rail was performed and a passenger survey was organised and analysed in order to learn about actual passenger arrival patterns (and hence their waiting times) at rail stations and platforms. In phase 2, qualitative research through focus groups was conducted to examine the impact of punctuality on passengers. In phase 3, a stated-preference survey was conducted with existing rail travellers to obtain quantitative valuations of punctuality.

The results of these phases have been reported in several documents (see the Reference List at the end of this document). The first chapter of this report introduces the project. The next two chapters of this report briefly summarize the main findings from the first phases of this study, Chapter 2 reports findings from phases 1 and 2 and Chapter 3 summarises the findings from phase 3. The remaining chapters focus on how the results of all the previous phases can be applied, specifically describing a methodology to appraise *a priori* the monetary benefits of different possible measures to improve regularity, and show an example of how this methodology can be applied.

This document is intended for people who are interested in the details on how this methodology should be applied in practice. Although knowledge on stated preference research and discrete choice modelling is not strictly necessary, it will help in understanding the application tool that was built.

The project client is the Syndicat des Transports d'Île de France (STIF), based in Paris, and co-financed by RATP, SNCF and RFF. The project was carried out by a consortium consisting of STRATEC S.A. (Brussels, main contractor) and RAND Europe (Leiden). The fieldwork and qualitative research was carried out by Catherine Delannoy & Associés (Paris).

STRATEC was formed in 1984 by a group of specialist consultants from renowned consultancy companies and university research. The group is the sole owner of the company's capital, thus ensuring total independence. Since its inception, STRATEC has served a highly diversified clientele, comprising large and small businesses, local, regional, national and international authorities in Belgium and abroad.

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Summary

Trains that are delayed or cancelled have a direct impact for the passenger: he has to wait longer, and may become uncertain about his arrival time. If he then misses a connecting train or bus with a low frequency service his journey time will increase further. All of this leads to extra "costs".

The costs associated with unpunctuality are incurred by the suburban train users themselves and by society. The summation of these costs makes up the (social) cost of unpunctuality. The value of this cost is currently not well known, as there has been little interest in valuation of punctuality effects up until a few years ago. This is why it was seen as necessary by STIF to undertake an in-depth research project aimed at providing all the elements necessary to estimate such values, and to calculate the impacts of punctuality improvements that can be envisaged. That is the subject of the present study.

The main objective of this study is therefore to provide a robust operational methodology which enables STIF to assess possible alternative investments aimed at improving the quality of the suburban rail services to and from Paris. The methodology is needed to assist the decision-making process regarding possible alternative projects (combinations of measures) to improve the punctuality of suburban rail services. Punctuality is defined here as the provision of rail services with actual train departure times from and arrival times at stations as published in the timetable.

Given that there was little information readily available about the many elements associated with the unpunctuality of trains, and the value that passengers attach to improving the punctuality of suburban rail services, a comprehensive research programme was carried out. This was structured in three main phases:

1. Background research. This included a review of international literature, a statistical analysis of train delays in Paris, and a survey of passenger arrival patterns.
2. Qualitative research of the impact of unpunctuality. This included three focus group discussions.
3. Quantitative analysis of the impacts of unpunctuality. This included a survey among 1200 travellers in which they were asked to make a number of choices between (hypothetical) services that had different travel times, frequencies of delay, in-train comfort and the provision of information about delays.

After the completion of these three phases a seven-step methodology has been developed (see Figure S.1) to assess possible investments and to calculate the perceived value of all punctuality benefits to all passengers (both existing and new). To aid users with the necessary calculations, a Microsoft Excel tool has been built. Travel times, delay probabilities, comfort and information levels before and after the project are the inputs. The direction of the line, its general regularity level and its passenger mix in terms of purposes also need to be specified. Based on the results of the stated preference study, the daily impact of the project on passengers, expressed in equivalent minutes of travel time, is calculated. This impact can be different for passengers of different segments (based on their journey purpose). Next, this impact is converted into monetary units (benefits per passenger, in euros), using an appropriate value of time. The benefits over all passengers are simply calculated by multiplication by the total number of passengers.

The number of passengers using a service may also be expected to change, because of changes in the rail level-of-service. This change in demand is estimated using appropriate travel time elasticities. When this is added to the benefits already calculated, the total monetary benefits of the project are determined.

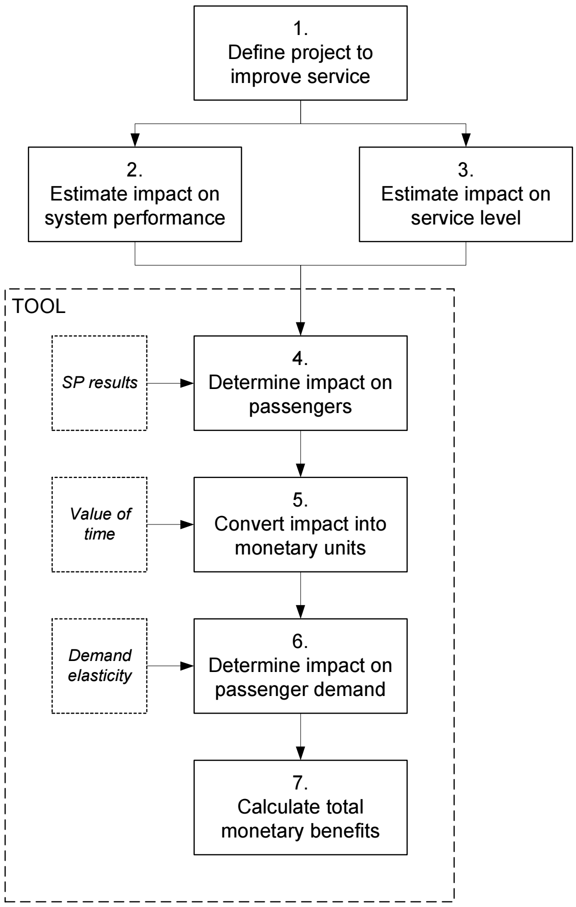

Figure S.1 Outline of the methodology

CHAPTER 1 Introduction

1.1 Background

The railway network linking Paris to its suburbs comprises 1400 kilometres of railway and serves 445 stations in total. It is operated by the SNCF (Société Nationale de Chemins de Fer Français), RER (Réseau Express Régional) and suburban trains and the RATP (Régie Autonome des Transport Parisiens; RER lines A and B). SNCF provided 79 billion seat-kilometres in 2001, while RATP provided 20.3 billion seat-kilometres in 2004.

Since July 2000, the SNCF and RATP operations have been regulated by specific contracts concluded between these operators and the Syndicat des Transports d'Île de France (STIF). These contracts address the provision of transport services, the fares that apply, the quality of service standards to be complied with, the operators' remuneration and a financial incentive system based on actual performance. This system includes a bonus-malus system based on the quality of service actually achieved.

The quality of service indicators specified in the contract are essentially the punctuality of train services and passenger facilities in the stations. The agreed punctuality indicators differ between the STIF/RATP contract (RER-A and RER-B services) and the STIF/SNCF contract. For the RATP, the punctuality indicator consists of the number of passengers (per day, month and whole year) whose arrival at the destination station has been delayed by more than 5 minutes, and the number of those for whom this delay exceeds 15 minutes. For the SNCF, the indicator consists of the number of trains arriving at their terminal stations with a delay of more than 5 minutes during the morning and evening peak periods, for the most crowded direction only.

Poor punctuality, whether through trains being delayed or cancelled, has a direct impact for the passenger: their journey will take more time than expected, leading to extra "cost". If they then miss a connecting train or bus with a low frequency service, their journey time will worsen further. Indirectly, poor punctuality during peak periods can have a negative effect on other aspects of the quality of suburban train services as well: passengers accumulate on the station platforms, and density may exceed comfort and even security standards. The delayed train is likely to be more crowded than usual so that passenger comfort on the journey will be poorer than usual, and stop times at stations will increase. In extreme cases, trains may be so overloaded that travellers cannot board at all, and will have to wait for the next train. Such degrading of service quality will increase the perceived cost of poor punctuality further.

The costs associated with unpunctuality are incurred by the suburban train users themselves and by society. The summation of these costs makes up the (social) cost of unpunctuality. The value of this cost is currently not well known, as there has been little interest in punctuality effects until a few years ago. Recently, in the United Kingdom and the Netherlands, stated preference surveys have provided the indications of cost (or disutility) functions containing an explicit indicator of travel time variation. In the Île de France region, one research project has already addressed the subject for bus services.[1] However, these studies do not provide results enabling utility functions to be constructed which can be applied for the suburban railway services in Île de France (on-board travel time and related variation thereof, service frequencies, train and platform loading factors, etc).

It is for this reason that STIF viewed it necessary to undertake an in-depth research project aimed at providing all the elements needed to develop and calibrate models explicitly containing punctuality, and to calculate the impacts of punctuality improvements that can be envisaged. That is the subject of the present study.

1.2 Study objectives

The main objective of this study is to provide a robust operational methodology which enables STIF to assess investments aimed at improving the service quality, specifically with regard to improvements in punctuality, of the suburban rail services to and from Paris. The methodology is needed to assist the decision-making process regarding possible projects (combinations of measures) to improve the punctuality of suburban rail services. This is to be achieved by enabling a quantitative assessment of the perceived value of all punctuality benefits to passengers, and the expected impact on patronage and revenues. Within the framework of this study, the key aspect of the quality of railway services is punctuality. Punctuality is defined here as the provision of rail services with actual train departure and arrival times at stations as published in the timetable.

The starting point of the assessment process needs to be an accurate and reliable translation of each project (investment/series of measures) aimed at improving punctuality into operational performance statistics, which is then turned into passenger valuations and finally into equivalent amounts of perceived travel time or monetary cost. This should enable STIF to assess the expected impact of improved regularity, comfort and information on patronage and revenues. It must be noted that the research needs to take into account the existing statistics objectively describing railway performance as supplied by the operators (SNCF and RATP).

1.3 Structure of the research

Given that there was little information readily available about the many elements associated with unpunctuality of trains and the value that passengers attach to improving

[1] RATP study of the regularity of bus services controlled on a frequency base.

the punctuality of suburban rail services, a comprehensive research programme was carried out. This was structured in three main phases.

Phase 1 Improving our knowledge of punctuality: the main objective of this phase was to learn about the key operational elements of punctuality associated with suburban rail. In order to achieve this, the international literature was reviewed, the available statistical data concerning Paris-oriented suburban rail were analysed and a passenger survey was organised and analysed to learn about actual passenger arrival patterns (and hence their waiting times) at rail stations and platforms.

Phase 2 Qualitative research on the impact of unpunctuality on passengers: the main objective of this phase was to find out how delayed trains affect rail passengers, and what the consequences are. In order to achieve this, three group discussions were organised. The groups consisted of a carefully selected mix of suburban rail passengers of different ages, professional activities and household responsibilities, with different journey purposes, and using rail lines with different punctuality levels.

Phase 3 Quantitative analysis of the impacts of unpunctuality: the main objective of this phase was to quantify the disutility associated with unpunctuality as perceived by the passengers. In order to do this a stated preference (or trade-off) survey was carried out among a large number of rail passengers, in which different frequencies of delays were traded off against mean travel time, in-train comfort and the provision of information about delays. The results were analysed to obtain utility estimates, which were expressed in equivalent minutes of mean travel time (e.g. reducing the frequency of delays from 10% to 5% of all trains is worth the same as a 5-minute reduction of travel time).

Finally, a methodology was developed to enable STIF to assess investments aimed at improving the service quality.

1.4 Structure of the report

The structure of the report is as follows:

Chapter Two provides a summary of the main findings obtained in Phase 1 and Phase 2 of the research This includes the results of a literature review, a statistical analysis of punctuality data and a survey among departing suburban rail passengers.

Chapter Three describes briefly some results from Phase 3 of the research. This includes the qualitative research in the form of three focus groups and the large-scale stated preference survey among suburban rail passengers.

Chapter Four describes how the results of the study can be used to obtain the required estimate of costs (and benefits) of reduced or improved punctuality levels. In particular, it shows how the expected benefits from specific projects aiming to improve punctuality can be estimated using a simple spreadsheet tool. An application of the method to a project concerning RER-B is presented for illustrative purposes.

CHAPTER 2 Main Findings – Phase 1 & 2

In this chapter we summarise the main findings of phases 1 and 2 of the research which were introduced in Chapter One.

2.1 Literature review

The literature search identified over 100 articles and reports dealing with punctuality, which were reviewed for potential relevance. Out of these, 21 articles were selected as relevant and were summarised. The main findings are summarised below. For a complete list of findings (with references to the original papers) we refer to our Phase 1 report.

- The key consequence of unpunctuality for passengers is that they (can) arrive late at their destination. Key elements are the frequency and length of the delay.
- The predominant passenger responses to unpunctuality are: (a) to accept the late arrival; (b) to build in a "safety margin" of time to minimise the risk of late arrival. There are few indications that passengers change their mode of transport or even their route to avoid irregularity.
- The distribution of train arrival times at their destination is non-symmetrical, skewed to the right, and with on average a small expected delay.
- Suitable statistical distributions to describe the train arrival pattern are the lognormal distribution, the gamma distribution and the Weibull distribution.
- The mean–variance method has been used most often to derive utility functions for public transport, with separate coefficients for the mean journey time and the spread (variance) in journey time.
- Passengers seem to understand the logic of an "unpunctuality" or "irregularity" variable when this is presented to them in the form of a "sample" of travel times of journeys on different days (e.g. the travel times on 5, 10 or 20 days).
- In the literature, stated-preference experiments involving punctuality typically include two, three or four variables, with (apart from the delay) variables including travel time, ticket price and/or comfort.
- In several stated-preference experiments, punctuality was described by means of percentage of trains delayed more than 5 minutes.

2.2 Statistical analysis of train delays

2.2.1 Where are trains delayed

In the early 1990s the mean percentage of delayed SNCF trains (as defined in Chapter One) was around 4–5%. Since then punctuality has worsened significantly, and around 2001 the overall mean was approaching 9–10%. In the punctuality statistics that we obtained from SNCF for 2002 the mean percentage was 8.3%. The corresponding 2002 statistic for RATP was rather similar.

When results are compared between lines, it is clear that there is substantial variation around the mean: "good punctuality" lines show percentages of around 4% of delayed trains, while "poor punctuality" lines have percentages up to 18% of delayed trains. The frequency of delays does not seem to be related to frequency of service: in Table 2.1 it can be seen that all frequencies of delays (high/low) occur about equally often with all frequencies of service (high/low).

2.2.2 When are trains delayed?

There is substantial variation in the frequency of delays over time. In terms of seasonality,

	High average frequencies (> 4.0 per hour)			Low average frequencies (<= 4.0 per hour)		
		Frq	Dly		Frq	Dly
High probability of delays (> 9%)	Persan (Val) (Paris Nord)	7	18%	Bretigny (RER-C)	3	18%
	Longueville (Paris Est)	5	17%	Coulommiers (Paris Est)	2	17%
	Nord (RER-D)	11	13%	Pontoise (Paris Nord)	4	13%
	SE (Combs) (RER-D)	6	12%	Dourdan (RER-C)	3	13%
	Groupe V (Paris St Laz.)	5	12%	La Ferté-Milon (Paris Est)	1	13%
	Château-Th (Paris Est)	6	11%	Vers. Chant (RER-C)	4	12%
	VMI (RER-C)	6	10%	Etampes (RER-C)	4	12%
	SE (Corbeil) (RER-D)	12	9.9%	Massy (RER-C)	4	11%
	Persan (Mont) (Paris Nord)	7	9.7%	Plaisir-Mantes (PRG/Montp.)	4	11%
	Groupe VI (Paris St Laz.)	8	9.1%	Crépy (Paris Nord)	2	11%
				Dreux (PRG/Montp.)	2	10%
				Montereau (Paris Sud Est)	2	9.7%
Low probability of delays (<= 9%)	RER B	19	8.5%	Coulommiers-la Ferté (Paris Est)	1	8.2%
	Groupe III (Paris St Laz.)	11	8.0%	Montargis (Paris Sud-Est)	2	8.1%
	Bondy-Aulnay (Paris Est)	4	7.6%	St Quentin (RER-C)	3	8.1%
	Versailles (RER-C)	5	7.4%	SQDF (Paris St Laz.)	3	6.8%
	Groupe IV (Paris St Laz.)	7	6.0%	Rambouillet (PRG/Montp.)	4	6.3%
	RER-A	11	5.8%	Villiers (RER-E)	4	5.4%
	Groupe II (Paris St Laz.)	12	5.0%	Sèvres (PRG/Montp.)	3	4.0%
	Chelles (RER-E)	6	4.2%	Navettes (RER-E)	1	3.7%
				Esbly-crécy (Paris Est)	2	3.5%

Table 2.1 Segmentation of the lines on the basis of their frequency per hour (Frq) and of their probability of delay (Dly)

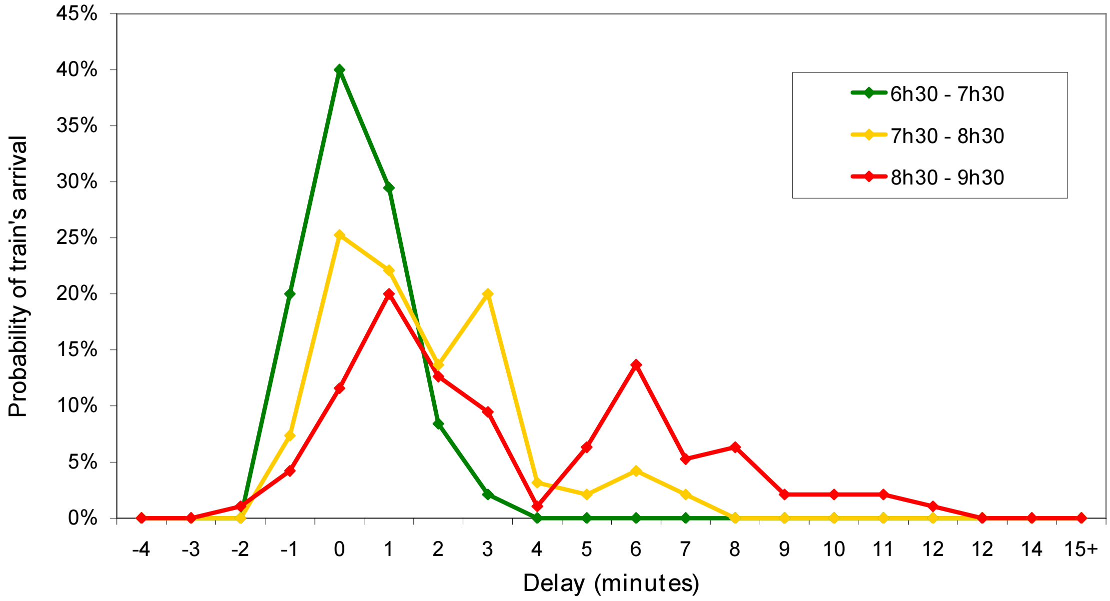

Figure 2.1 Evolution of the distribution of train delay amplitudes during the morning peak period (RATP RER-A, February–March 2003)

the SNCF train statistics show that during August (2002) less than 4% of trains were delayed, while November and December (2002) had more than 11% of all trains delayed. For the RATP trains a similar pattern is observed, but less extreme (August: 4%, December: 9%).

Analysis of delays for different days of the week also show clear differences between working days (Monday–Friday) and weekend days (Saturday, Sunday). For the RATP lines during the weekend about 4% of all trains were delayed, while over 8% of the trains were delayed on working days (2002).

When we compared SNCF frequencies of delay during morning and evening peaks it was clear that during evening peaks the delays are systematically more frequent than during morning peaks.

This is confirmed by detailed train-by-train data obtained from RATP for the period from 17 February to 22 March 2003 which is considered a representative period. In Figure 2.1 we show the results obtained for RER-A, but the results for RER-B are similar. On the *x* axis the difference between actual arrival time at destination and scheduled train arrival time is shown. The *y* axis gives the frequency of trains, or the probability of a late (or early) arrival.

It can be observed that during the first morning peak hour, 06.30–07.30, most trains arrive on time or with only a small deviation (2 minutes maximum). The probability of a delay of more than 5 minutes is very small. During the next peak hour, 07.30–08.30, most trains are still (almost) on time, but a second peak in the frequency distribution builds up around 3–4 minutes late, and a third small peak around 6–7 minutes late. For the third peak hour, 08.30–09.30, most trains arrive 1–2 minutes late, and the second peak of the

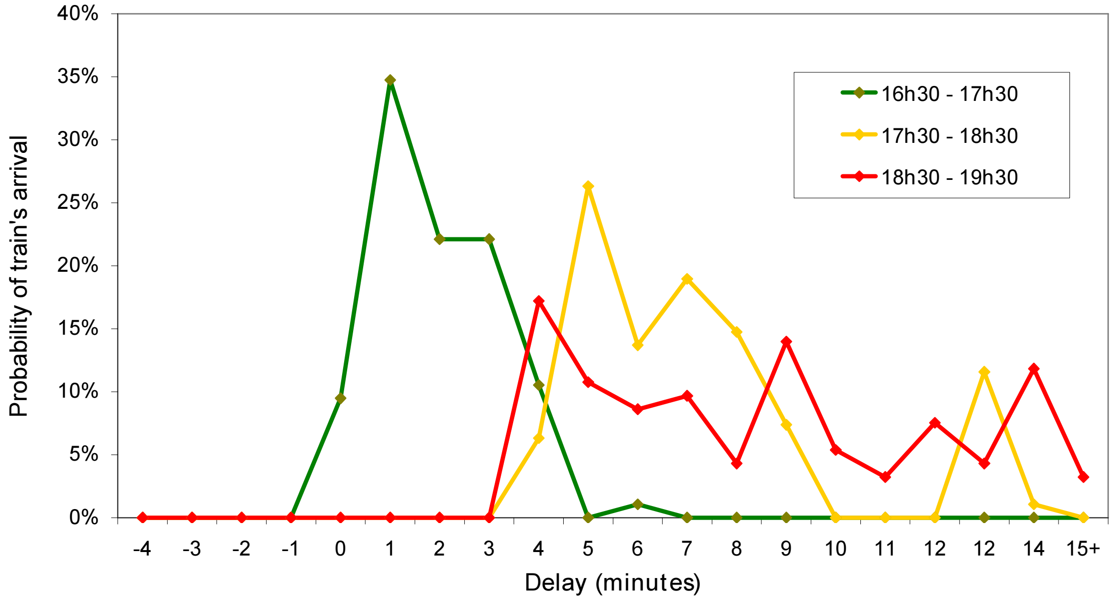

Figure 2.2 Evolution of the distribution of train delay amplitudes during the evening peak period (RATP RER-A, February–March 2003)

preceding hour seems to have moved to the right and increased in size. It is also clear that the probability of a delay of more than 5 minutes is now very substantial.

An important conclusion is that the probability of a train being on time decreases over the day: 60% of the trains arrive on time between 06.30 and 07.30, while only 17% of the trains arrive on time between 08.30 and 09.30.

A similar pattern can be observed for evening peak data (Figure 2.2), although the trains already begin the peak hour with small delays. But the probabilities of delay here also increase over time, with most of the trains being delayed between 18.30 and 19.30. This pattern may be as a consequence of the narrow time slots assigned to the trains and the related knock-on effects of delays on later trains. In other words, as soon as a train is delayed, even slightly, all subsequent trains are likely to be delayed as well.

2.3 Survey of passenger arrival patterns

2.3.1 How much time do passengers spend waiting?

In order to quantify how much time passengers spend waiting for trains with different service frequencies and different levels of punctuality, interviews and passenger counts were carried out on 18 different stations. The stations were carefully selected to represent a mix of conditions: high and low frequency services, and high and low punctuality. The fieldwork was carried out by Catherine Delannoy & Associés on Tuesday 13 January and Thursday 15 January 2004, between 07.00 and 09.30, and 16.30 and 19.00.

Passenger counts were performed at each access point to the platform, with counts recorded every minute. Train departures were recorded using hand-held computers at the

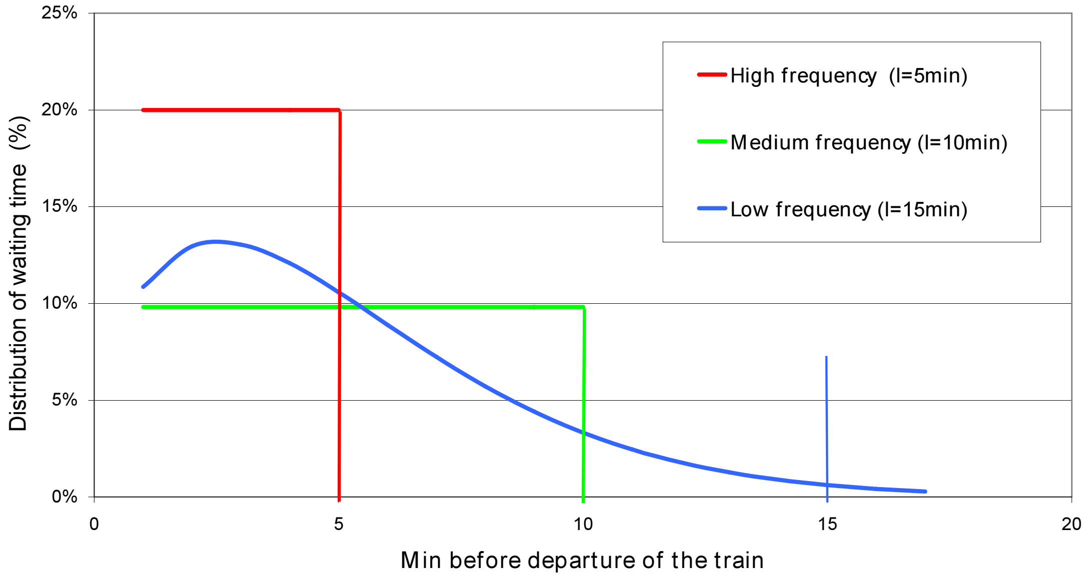

Figure 2.3 Distribution of the time spent by passengers on the platform, considering different train frequency levels. Passengers arriving just before the train departure are on the left side of the diagram. Passengers waiting a long time at the station are on the right side.

moment train doors were closed. In total 292 trains were counted, with a total number of 40,928 passengers boarding.

Passengers were approached for a short interview at the bottom of the access points to the platforms so that interviews and counts could be linked together. The interviews included questions about arrival time at the station, whether or not the passenger aimed at a specific train/departure time, access mode to the station, journey purpose, and destination station. The questionnaire is reproduced in the Appendix I. In total 1521 passengers were interviewed.

The main findings from analysis of the interviews and counts are described below.

- The percentage of passengers aiming for a specific train is strongly related to the scheduled frequency of service: for train services with headways of 15 minutes or longer around 80% of all passengers aim for a specific train whereas for services with headways of 5 minutes or less only around 20% aim for a specific train.
- The amount of time that passengers spend *in the station* (both on the platform and in the service areas) is about half the headway according to the timetable, plus about 4 minutes for services with good punctuality For poor punctuality services about half the headway, plus about 5 minutes are spent in the station.
- Figure 2.3 shows the computed distribution of the time spent by passengers *on the platforms*. These have been computed from the counts and the observed train departure times, and represent the net waiting time for the train. The results clearly indicate that for headways of 5 or 10 minutes, passengers arrive uniformly at the platform. For longer headways (15 minutes) about 60% of the passengers

arrive within 5 minutes before departure. The average waiting time is little more than 5 minutes, i.e. less than half the headway.

2.4 Qualitative research of the impact of unpunctuality

In order to assess whether perceptions of train delay differed by the type of passenger or the purpose of the journey, three focus group discussions with 10 participants each were held by Catherine Delannoy & Associés. The group participants were carefully selected so that they contained a mix of rail passengers who travelled for different journey purposes, and on different lines with good as well as poor regularity (i.e. punctuality). All ages, professional activities and family situations were represented among the participants.

The main conclusions of the group discussions were as follows.

- The actual cost of delays is not always borne by the passenger; part of it is sometimes transferred to a third party. For example, when an employee's trip to work is affected by a delayed train, this may be presented as *force majeure*, and the costs may be borne by the employer. Therefore the perceived cost of a delay affecting a trip made for personal purposes (travelling home, visiting a doctor, etc.) may be valued higher by the traveller.
- Most Île-de-France rail users own a car and therefore the potential to switch from train to car for travel is high.
- Passengers who rarely suffer from train delays tend to view a delay as less acceptable than passengers who frequently face irregular services.
- Passengers with more flexible working time schedules view irregularity as less of a problem than passengers with rigid office hours.
- Men and women with children give a higher importance to delays occurring in the evening; the younger the children, the more onerous is the perceived delay.
- Passenger journey times are less affected in the case of high-frequency services than in low-frequency ones. In other words, delays are less for high-frequency services.
- Only the delay at the final destination matters to passengers.
- A small delay can be very annoying if it results in the user missing a connecting rail or bus service.
- The value of delay increases with decreasing comfort in trains and on platforms.

Passengers indicate that information about delays greatly reduces the cost associated with them, insofar as the information allows them to decide to change their mode of transport.

CHAPTER 3 Main Findings – Phase 3

In order to appraise *a priori* the monetary benefits of different possible measures to improve the regularity of the Paris suburban train network, it is imperative to quantify how passengers value the quality of the service offered. This can be done by a "stated preference" discrete choice experiment. In such research a large sample of passengers is offered multiple choices between two (or more) hypothetical alternative service levels. These service levels differ in characteristics, such as travel time, reliability, comfort level, etc. Passengers are asked to state their preference for one of the alternatives.

3.1.1 Qualitative research

In order to test and validate the different possible ways in which to present the selected key variables in the stated preference survey, qualitative research was carried out by Catherine Delannoy & Associés. This involved a group discussion with rail passengers, during which three different types of stated preference questionnaire were presented:

- version 1, with frequencies of train delays per month presented as percentages: 5% of all trains have a delay of 5–15 minutes;
- version 2, with frequencies of train delays per month presented as *n* times out of 20: 1 train out of 20 has a delay of 5–15 minutes; and
- version 3, with frequencies of train delays per month presented graphically (with dashes and crosses indicating trains with and without delays on certain days).

It turned out that version 2 was understood best and was the most clear to the majority of all passengers. Consequently, this presentation was retained in the stated preference survey.

3.1.2 Fieldwork

More than 1200 travellers participated in the stated preference survey. They were recruited on platforms of several train stations in Paris or in the trains. These travellers were spread over the different passenger segments that were under investigation. These segments differed by:

- motive for the trip (commute/education or other);
- frequency of the line (high or low);
- regularity of the line (good or bad); and
- direction of the trip (to or from Paris).

Purpose \ Frequency + Regularity combination	Low frequency + Good regularity	Low frequency + Bad regularity	High frequency + Good regularity	High frequency + Bad regularity	Total
Commute / eduation	195 *(200)*	266 *(200)*	195 *(200)*	249 *(200)*	**905** ***(800)***
Other	92 *(100)*	83 *(100)*	106 *(100)*	87 *(100)*	**368** ***(400)***
Total	**287** ***(300)***	**349** ***(300)***	**301** ***(300)***	**336** ***(300)***	**1273** ***(1200)***
Of which are travelling from Paris					624 *(600)*
Of which are travelling towards Paris					649 *(600)*

Table 3.1 Observed distribution of the SP survey respondents over the segments. The figure in brackets is the number of respondents aimed at in each segment.

Table 3.1shows the number of respondents in each of the segments.

The recruited travellers received a personalised questionnaire by ordinary mail. A few days later they were called by the fieldwork bureau to conduct the interview. These interviews were conducted in the last week of June and the first week of July 2004.

Each interviewed person was asked to make 19 choices between two alternatives. Each alternative was described by:

- travel time;
- frequency of short delays (delays between 5 and 15 minutes);
- frequency of long delays (delays of more than 15 minutes);
- comfort level; and
- level of information on delays.

These attributes varied between a low, base and high level. The base levels of travel time and frequency of the short and long delays were equal to the current levels as perceived by the traveller. The low and high level of the travel time differed 5%, 10%, 20% or 30% (determined by random draw) from the current level. The low level of the frequency of delays was about half the current level, the high level was about double the current level.

The level of comfort could be either of three options: seated; standing; or standing in a crowded environment. The information about delays was presented as announcement of disturbances; announcements of disturbances and their causes; announcement of disturbances, their causes and the expected amounts of delay.

Figure 3.1 shows an example of a choice card.

3.1.3 Statistical analysis

The stated choices were used to determine the relative weight of each of the factors of service quality using discrete choice modelling. All estimated coefficients in the final models have intuitive signs and sizes.

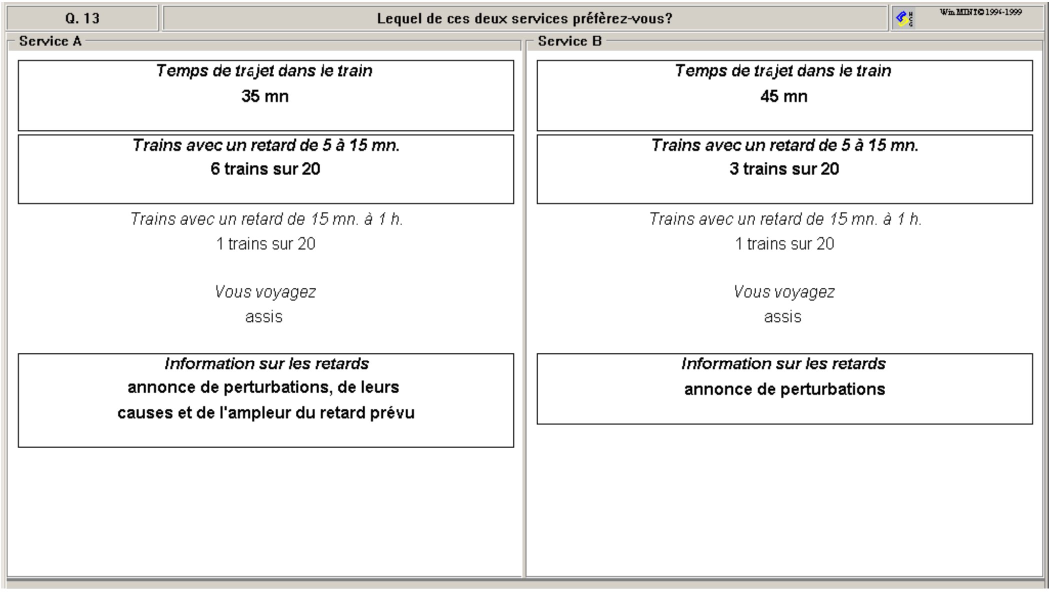

Figure 3.1 Example of an SP choice (card as seen by the interviewer)

Separate significant coefficients were estimated for people travelling with different motives (commuting, education or other). The final results are shown in Table 3.2. For a complete overview of the model results (including the significance of each of the coefficients) we refer to our Technical Report on the stated preference data analysis.

Table 3.2 indicates the value of each parameter relative to one minute of travel time. For example, a person travelling from Paris on a commute trip on a line with good punctuality, values a 5% probability of having a delay (1 out of 20 trains) equal to 4.6 minutes of travel time. If this person is travelling for another purpose, he values this delay probability equal to 6.2 minutes of travel time. Note that the values for the information level are negative: indicating that extra information about the cause of the disturbance and/or about the size of the expected delay is valued equally to a reduction of the travel time by a few minutes.

The models indicate that the extra disutility corresponding to each step in the level of delays decreases as the number of delays increases, for example the disutility of the first delayed train out of 20 is high (equivalent with 4.6 or 6.2 minutes of travel time, depending on the trip purpose), but the extra disutility of the eighth delayed train is much less (equivalent with 2.6 or 1.9 minutes of travel time, respectively). On lines with high regularity, having a seat is mainly valued for longer trip lengths; on lines with a bad regularity, having a seat is always valued highly, regardless of length of travel. Finally, we found that information about the cause of delays is always valued highly for journeys towards Paris, but for journeys from Paris this information is more valued if the perceived number of short delays is higher.

The model that has been developed here will be used in the application described in the next chapter.

		Commute / education trips								Other trips							
		Travelling from Paris				Travelling towards Paris				Travelling from Paris				Travelling towards Paris			
		Good regularity	t-ratio	Bad regularity	t-ratio	Good regularity	t-ratio	Bad regularity	t-ratio	Good regularity	t-ratio	Bad regularity	t-ratio	Good regularity	t-ratio	Bad regularity	t-ratio
Traveltime	for each minute of traveltime	1.0	(*)	1.0	(*)	1.0	(*)	1.0	(*)	1.0	(*)	1.0	(*)	1.0	(*)	1.0	(*)
Short delays (between 5 and 15 minutes)	1 out of 20 trains	4.6	(10)	4.6	(10)	4.6	(10)	4.6	(10)	6.2	(8)	6.2	(8)	6.2	(8)	6.2	(8)
	2 out of 20 trains	9.2	(10)	9.2	(10)	9.2	(10)	9.2	(10)	12.3	(8)	12.3	(8)	12.3	(8)	12.3	(8)
	3 out of 20 trains	13.8	(10)	13.8	(10)	13.8	(10)	13.8	(10)	18.5	(8)	18.5	(8)	18.5	(8)	18.5	(8)
	4 out of 20 trains	18.0	(13)	18.0	(13)	18.0	(13)	18.0	(13)	24.1	(10)	24.1	(10)	24.1	(10)	24.1	(10)
	5 out of 20 trains	22.2	(14)	22.2	(14)	22.2	(14)	22.2	(14)	29.7	(11)	29.7	(11)	29.7	(11)	29.7	(11)
	6 out of 20 trains	26.4	(15)	26.4	(15)	26.4	(15)	26.4	(15)	35.3	(11)	35.3	(11)	35.3	(11)	35.3	(11)
	7 out of 20 trains	29.0	(17)	29.0	(17)	29.0	(17)	29.0	(17)	37.2	(12)	37.2	(12)	37.2	(12)	37.2	(12)
	+ for each extra delayed train out of 20	2.6	(14)	2.6	(14)	2.6	(14)	2.6	(14)	1.9	(5)	1.9	(5)	1.9	(5)	1.9	(5)
Long delays (more than 15 minutes)	1 out of 20 trains	6.7	(17)	6.7	(17)	6.7	(17)	6.7	(17)	8.9	(10)	8.9	(10)	8.9	(10)	8.9	(10)
	2 out of 20 trains	13.3	(17)	13.3	(17)	13.3	(17)	13.3	(17)	17.8	(10)	17.8	(10)	17.8	(10)	17.8	(10)
	3 out of 20 trains	20.0	(17)	20.0	(17)	20.0	(17)	20.0	(17)	26.7	(10)	26.7	(10)	26.7	(10)	26.7	(10)
	4 out of 20 trains	25.3	(21)	25.3	(21)	25.3	(21)	25.3	(21)	33.9	(12)	33.9	(12)	33.9	(12)	33.9	(12)
	+ for each extra delayed train out of 20	5.4	(16)	5.4	(16)	5.4	(16)	5.4	(16)	7.2	(9)	7.2	(9)	7.2	(9)	7.2	(9)
Comfort level	Standing	4.9	(2)	14.0	(6)	4.9	(2)	14.0	(6)	6.5	(2)	18.7	(5)	6.5	(2)	18.7	(5)
	+ for each minute of traveltime	0.3	(4)	0.1	(2)	0.3	(4)	0.1	(2)	0.4	(4)	0.1	(2)	0.4	(4)	0.1	(2)
	Standing in a crowded environment	27.2	(14)	27.2	(14)	27.2	(14)	27.2	(14)	36.3	(9)	36.3	(9)	36.3	(9)	36.3	(9)
	+ for each minute of traveltime	0.2	(5)	0.2	(5)	0.2	(5)	0.2	(5)	0.3	(4)	0.3	(4)	0.3	(4)	0.3	(4)
Information level	Announcement of perturbation and cause	0.0	(*)	0.0	(*)	-4.4	(6)	-4.4	(6)	0.0	(*)	0.0	(*)	-5.9	(5)	-5.9	(5)
	+ for each shortly delayed train out of 20	-0.9	(3)	-0.9	(3)	0.0	(*)	0.0	(*)	-1.3	(3)	-1.3	(3)	0.0	(*)	0.0	(*)
	Announcement of perturbation, cause and size	-9.9	(10)	-9.9	(10)	-9.9	(10)	-9.9	(10)	-13.2	(7)	-13.2	(7)	-13.2	(7)	-13.2	(7)

Table 3.2 Results of the stated preference research, indicating for each segment how passengers value a certain quality level with respect to one minute of travel time and the corresponding t-ratios

CHAPTER 4 A Methodology to Value Punctuality Improvements

Before an investment decision can be made, alternative projects aimed at improving the quality of suburban rail services to and from Paris need to be assessed. In order to facilitate objective decision-making, a robust operational methodology to assess possible investments has been developed for STIF. This methodology enables a quantitative assessment of the perceived value of all punctuality benefits to all passengers (both existing and new).

4.1 Methodology

This assessment methodology consists of seven steps, which are displayed in Figure 4.1. First, the project(s) to improve the quality of the service needs to be defined (step 1). Next, the impact of the project needs to be estimated, both in terms of the performance of the railway system (travel time, waiting time, level of punctuality; step 2) and in terms of the quality of the service (probability of having to stand, level of information provided to passengers; step 3).

This information about the system before and after the project is the input to an Microsoft Excel tool that performs the remaining steps. Based on the results of the stated preference study, the daily impact of the project on passengers, expressed in equivalent minutes of travel time are calculated (step 4). This impact can be different for passengers in different segments (based on their motives for travel). Next, this impact is converted into monetary units, using an appropriate value of time (input by the user, see step 5). Because the level of service has changed, it is to be expected that this will influence the number of passengers using this service. This change in demand is estimated using appropriate travel time elasticities (input by the user, see step 6). Finally, the total monetary benefits of the project are determined (step 7).

4.2 Punctuality assessment tool

A Microsoft Excel spreadsheet was developed to perform all calculations in steps 4 to 7. The spreadsheet is made up of three sheets: one for the input; one for the coefficients that are used to calculate the impact on passengers in terms of equivalent minutes of travel time (the so-called “utility” coefficients); and one for the output.

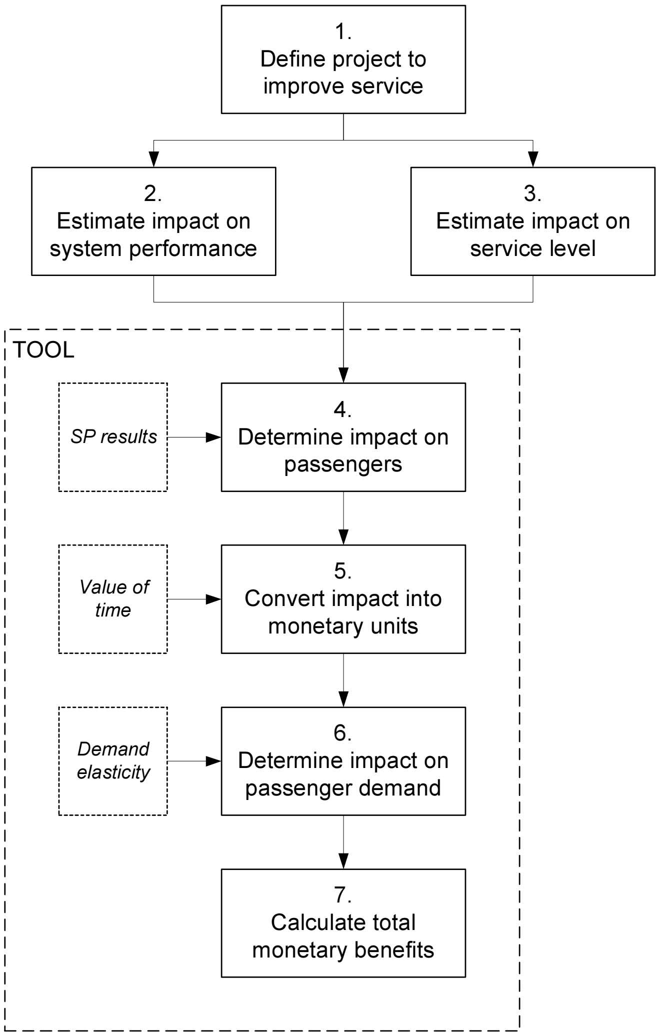

Figure 4.1 Outline of the methodology

The punctuality assessment tool only handles one train line at the time. If the project influences more than one line, the tool has to be run for each line separately and the outcomes have to be added by the user (unless passengers can interchange between these lines, then a combined run has to be made). If the characteristics or the quality of the line change over the course of the day, then the tool has to be run for each time period separately as well.

4.2.1 Input

The stated preference research has shown that quality of service is perceived differently depending on some characteristics of the trip, such as the direction of the line (travelling towards or from Paris), the regularity of service (good or bad) and the passenger's motive for travel (commuting/education or other). Information is therefore required on each of these for input into the tool. An example input screen is displayed in Figure 4.2.

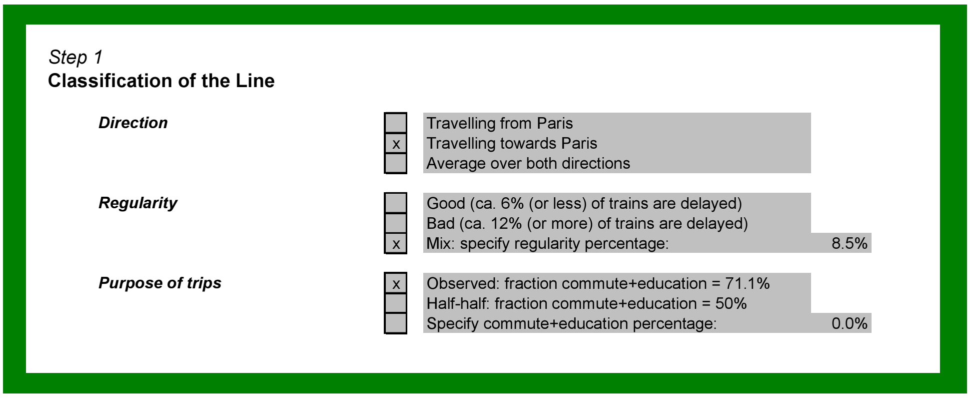

Figure 4.2 Input screen for the classification of the line

For the direction of the line the user must choose one of three options: travelling from Paris, travelling towards Paris or an average over both directions. Depending on their choice the corresponding utility coefficients that are used to calculate the impact of the project on the passengers are selected. When the third option is chosen, the utility coefficients for travelling from and towards Paris are averaged.

The stated preference research distinguished passengers on the basis of the regularity of the line on which they travelled. This regularity was classified "good" (i.e. the probability of experiencing a delay of more than 5 minutes was less than 9%), or "bad" (probability in excess of 9%). The average probability of delay on the good and bad lines was approximately 6% and 12%, respectively. The user must select the appropriate regularity level of the line for which they are conducting the assessment on the input screen. So, if the probability of delay is less or equal to 6%, "good regularity" needs to be selected. If the probability of delay is more or equal to 12% "bad regularity" needs to be selected. To prevent sharp transitions for lines with a probability of delay between 6% and 12%, there is a mixed option. The user can specify the regularity percentage (= probability of delay). For values between 6% and 12% the utility coefficients transform linearly from their values for a line with a good regularity to their values for a line with a bad regularity.

The impact on a passenger of a change in service quality depends on their motive for the trip, whether commute/education or other (note that business trips are included in "other"). In order to calculate the total impact over all passengers, the fraction of travellers with the motive "commute/education" has to be specified on the input screen. The user can select a fixed fraction (either 71.1%, which is the observed percentage from the stated preference survey, or 50%) or they can specify the appropriate percentage.

The second step ("Quality of Service") can be completed in two ways: either in terms of the average per person (see Figure 4.3), or in terms of the output of the RFF (Réseau Ferré de France) model (see Figure 4.4).

If the first part of the table is used, the average travel and waiting time per person needs to be entered, both in the present situation and in the future situation after the project has been finished. Also, the probability of experiencing a short delay (between 5 and 15 minutes) and long delay (more than 15 minutes) has to be specified, as does the

Step 2

Quality of Service

Use table A (average per person) or table B (output of RFF model)

A: average per person	*Present*	*Future*	
Travel time			minutes
Short delays (5-15 min.)			(in %)
Long delays (15+ min.)			(in %)
Standing			(in %)
Standing, crowded			(in %)
Information level (1-3)			

1: announcement of perturbations
2: announcement of perturbations and their cause
3: announcement of perturbations, their cause and their size

Figure 4.3 Input screen for quality of service in terms of averages per person

probability of having to stand (normal, i.e. in a non-crowded environment), as well as having to stand in a crowded environment. Finally, the level of information on delays needs to be specified for both the present and future situations. There are three levels: announcement of service disruptions (level 1), announcement of disruptions and their cause (level 2); and announcement of disruptions, their cause and size (level 3).

If the second part of the table is used, the number of passengers (total, experiencing both short and long delays) has to be specified. The user should define over which time period this total is calculated: usually this should be one hour. The number of passengers needs to be specified for four cases. Aside from the split between present and future, the numbers for a smooth situation (all trains running on schedule) and a random scenario (with disruptions occurring with a specific probability) need to be filled in.

Further, the user should specify the total amount of travel time that all passengers spend travelling in trains, as with the time spent travelling while standing, and the time spent travelling while standing with more than three persons per square metre. Finally, the scheduled frequency of the trains and the information level should be entered.

B: output of RFF model	*Present*		*Future*	
	no perturb.	random scen.	no perturb.	random scen.
Number of passengers	19,905	19,929	19,848	19,874
of which have short delay	875	1,418	0	13
of which have long delay	0	0	0	0
Number of travel minutes	305,552	319,696	340,842	354,986
of which are standing		77,562		75,489
idem crowded env. > 3P/m²		376		444
Information level (1-3)	1		1	

1: announcement of perturbations
2: announcement of perturbations and their cause
3: announcement of perturbations, their cause and their size

Figure 4.4 Input screen for quality of service in terms of RFF model output

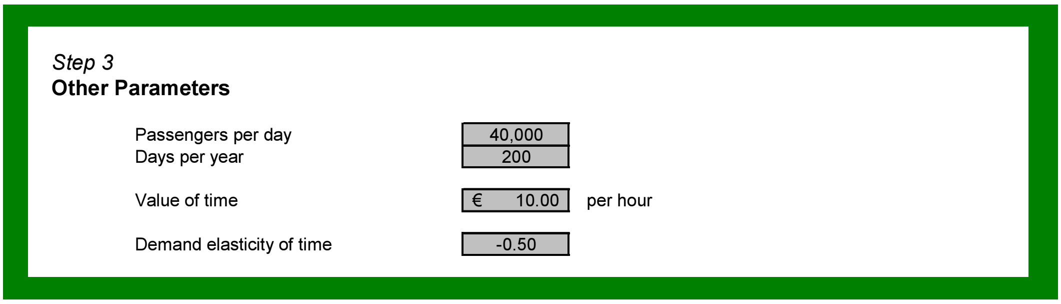

Figure 4.5 Input screen for the other parameters

In the example on the RER-B project it will be explained how these numbers can be obtained from the RFF model, also how these totals are converted to averages per person.

The third step of the input covers the other remaining parameters; see Figure 4.5 for details.

In this input screen the number of passengers per day can be specified, as can the number of days per year. Note that these numbers should be specified for situations pertaining to the characteristics of the line and level of service. If these characteristics are specified for a morning peak hour, the number of passengers per day should be limited to morning peak hours only, and the number of days per year should be limited to those days that have such a morning peak (i.e. no weekends or holiday periods).

This input screen also asks for the value of time that will be used for the monetarisation of the benefits. Finally, the demand elasticity of time needs to be specified in order for the tool to be able to calculate the impact on demand.

4.2.2 Utility coefficients

The second sheet in the Excel file contains the Stated preference findings (labelled the "UtilCoeff" sheet). This sheets begins with a summary of the stated preference results expressed in terms of the utility coefficient for time. This means that the travel time coefficient is 1 by definition and all other coefficient express the weight of the coefficient relative to the time coefficient (see Table 3.2). This sheet also shows the utility coefficients for travellers for each purpose (commute/education and other) for the selected line type (see Figure 4.6).

4.2.3 Output

The final sheet contains the output. The first table (Figure 4.7) contains the calculation of improvement of service as perceived by travellers, expressed in equivalent travel minutes. The structure of this table is similar to the structure of the stated preference results (Table 3.2). For each travel purpose and for both present and future situations, the total disutility of the service as perceived by the traveller is calculated. By taking the difference between future and present situations the improvement per person in equivalent travel time is determined.

		Commute / education	other
Traveltime	for each minute of traveltime	1.0	1.0
Short delays (between 5 and 15 minutes)	1 out of 20 trains	4.6	6.2
	2 out of 20 trains	9.2	12.3
	3 out of 20 trains	13.8	18.5
	4 out of 20 trains	18.0	24.1
	5 out of 20 trains	22.2	29.7
	6 out of 20 trains	26.4	35.3
	7 out of 20 trains	29.0	37.2
	+ for each extra delayed train out of 20	2.6	1.9
Long delays (more than 15 minutes)	1 out of 20 trains	6.7	8.9
	2 out of 20 trains	13.3	17.8
	3 out of 20 trains	20.0	26.7
	4 out of 20 trains	25.3	33.9
	+ for each extra delayed train out of 20	5.4	7.2
Comfort level	Standing	8.7	11.6
	+ for each minute of traveltime	0.2	0.3
	Standing in a crowded environment	27.2	36.3
	+ for each minute of traveltime	0.2	0.3
Infor-mation level	Announcement of perturbation and cause	-4.4	-5.9
	+ for each shortly delayed train out of 20	0.0	0.0
	Announcement of perturbation, cause and size	-9.9	-13.2

Figure 4.6 Results of the stated preference research for commute/education and other travel (utility coefficients divided by the travel time coefficient)

Utility Calculation

================= Utility (in equivalent travel minutes) =================

			Purpose = commute/education		Purpose = other		Average over both purposes	
	Present	*Future*	*Present*	*Future*	*Present*	*Future*	*Present*	*Future*
Travel time	0:15:21	0:17:10	15.35	17.17	15.35	17.17	15.35	17.17
Short delay (5-15 min.)	2.7%	0.1%						
Contribution delayed trains 0-3 out of 20			2.50	0.06	3.35	0.08	2.75	0.07
Contribution delayed trains 4-6 out of 20			0.00	0.00	0.00	0.00	0.00	0.00
Contribution delayed trains 7+ out of 20			0.00	0.00	0.00	0.00	0.00	0.00
Total			2.50	0.06	3.35	0.08	2.75	0.07
Long delay (15+ min.)	0.0%	0.0%						
Contribution delayed trains 0-3 out of 20			0.00	0.00	0.00	0.00	0.00	0.00
Contribution delayed trains 4+ out of 20			0.00	0.00	0.00	0.00	0.00	0.00
Total			0.00	0.00	0.00	0.00	0.00	0.00
Standing	24.3%	21.3%						
Fixed contribution			2.11	1.85	2.82	2.47	2.31	2.03
Variable contribution with travel time			0.85	0.83	1.14	1.12	0.93	0.92
Total			2.96	2.68	3.96	3.59	3.25	2.94
Standing, crowded	0.1%	0.1%						
Fixed contribution			0.03	0.03	0.04	0.05	0.04	0.04
Variable contribution with travel time			0.00	0.00	0.00	0.01	0.00	0.00
Total			0.04	0.04	0.05	0.05	0.04	0.04
Information level	1	1						
Fixed contribution			0.00	0.00	0.00	0.00	0.00	0.00
Variable contribution with short delayed trains			0.00	0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00	0.00	0.00
Total			20.85	19.95	22.70	20.89	21.38	20.22
Difference (in minutes)			-0.89		-1.81		-1.16	
Difference (in h:mm:ss)			- 0:00:54		- 0:01:49		- 0:01:10	

Figure 4.7 Output sheet with the utility calculation for both present and future travellers for "commute/education", "other" or "mixed" travel purposes

Average Person Calculation

	Present	Future		Delta (minutes)	Delta (h:mm:ss)
For an average person					
Travel time increases	0:15:21	0:17:10	=	1.82	+0:01:49
24.3% of his time he is standing and he has to stand longer			~	0.11	+0:00:07
0.1% of his time he is standing in a crowded environment and he has to stand longer			~	0.00	+0:00:00
Probability of having a short delay (5-15 min.) decreases	2.7%	0.1%	~	-2.68	-0:02:41
Probability of having a long delay (15+ min.) remains the same	0.0%	0.0%			
Probability of having to stand decreases	24.3%	21.3%	~	-0.41	-0:00:25
Probability of having to stand in a crowded environment increases	0.1%	0.1%	~	0.00	+0:00:00
Information level remains the same	1	1			
Total				-1.16	-0:01:10

Figure 4.8 Output sheet with results of the project in terms of equivalent travel time for an average traveller

This way of displaying the result is not very informative for a person who has no knowledge about utility functions. An alternative way to present the result is to look at an average person and list the modifications for them as a result of the project. For instance, if 25% of the travellers have to stand, it is assumed that the average traveller is standing for 25% of the travel time. Each modification is converted into an appraisal in terms of equivalent travel time. So, if the travel time increases by 2 minutes, it is assumed that the average traveller has to stand 30 seconds longer (in this example) and that his disutility increases because of this. The complete calculation for an average person is shown in Figure 4.8. [2]

The final part of the output sheet contains a summary of the results. First, the improvement per average passenger is reported. Second, this number is converted into monetary units by multiplying the improvement by the value of time as specified in the input sheet. Third, this number is aggregated to a day and a year total. Finally, the change in demand is calculated by multiplying current demand by the fractional improvement of equivalent travel time per passenger and demand elasticity of time. An example for the output sheet is shown in Figure 4.9.

Year totals

	Purpose = commute / education	Purpose = other	Average	
Gain per passenger	0.89	1.81	1.16	in equivalent travel time minutes
Benefits per passenger	€ 0.15	€ 0.30	€ 0.19	in euro's
per day (40,000 passengers)			€ 7,725.23	
per year (200 days)			€ 1,545,046.34	
Passenger increase per day	1,084 (2.7%)			
Passenger increase per year	216,773			
Extra benefits due to new passengers			€ 20,932.79	
Total benefits			€ 1,565,979.14	

Figure 4.9 Output sheet with aggregated totals

[2] Note that the total of improvement in both Figure 4.7 and 4.8 is the same: 1 minute and 10 seconds (1.16 minutes).

CHAPTER 5 Example: RER-B Nord+ project

To show how the methodology works in practice an example case is presented. Each step in the methodology will be discussed separately.

5.1 Step 1: define the project

The line under consideration is the northern part of the RER-B line in the direction of Paris (from Aéroport Charles de Gaulle 2 TGV to Gare du Nord, and from Mitry Claye to Gare du Nord, see Figure 5.1). For reasons that will be explained in step 2, the part between Gare du Nord and Châtelet les Halles is excluded.

Currently, trains run in the morning peak hour with a frequency of eight trains per hour from each branch to Paris. All trains from Mitry Claye are fast services between Aulnay sous Bois and Paris, as are 50% of the trains that depart from Charles de Gaulle 2 TGV. Extra services run between Aulnay sous Bois and Châtelet les Halles; these also stop at most intermediate stations. In total 20 trains run between Aulnay sous Bois and Châtelet les Halles: these do not stop at all stations.

As a result, the waiting time for most connections is on average 7.5 minutes (alternatively 6 or 9 minutes), but for some origin–destination combinations, connections are only possible at an interval of 15 minutes.

The project under consideration is to increase the train frequency on each leg of the line to 10 services per hour. These trains will stop at all stations. The frequency of trains between Aulnay sous Bois and Châtelet les Halles remains at 20 per hour, but now these stop at all stations. Optimising the performance of rolling stock and schedule design can facilitate better travel times for omnibus trains with respect to the present situation. As a result, the average waiting time at the departure station will decrease. While the travel time between some origin–destination pairs decreases (as no transfer is necessary), the average travel time between other origin–destination pairs increases, as services now stop at all intermediate stations (no fast services). Another consequence is that passengers will experience less delay on average. Since the interval times between trains are smaller, the average probability of catching the previous (delayed) train increases. Finally, the passengers are distributed more evenly over the trains, so the probability of having to stand also decreases.

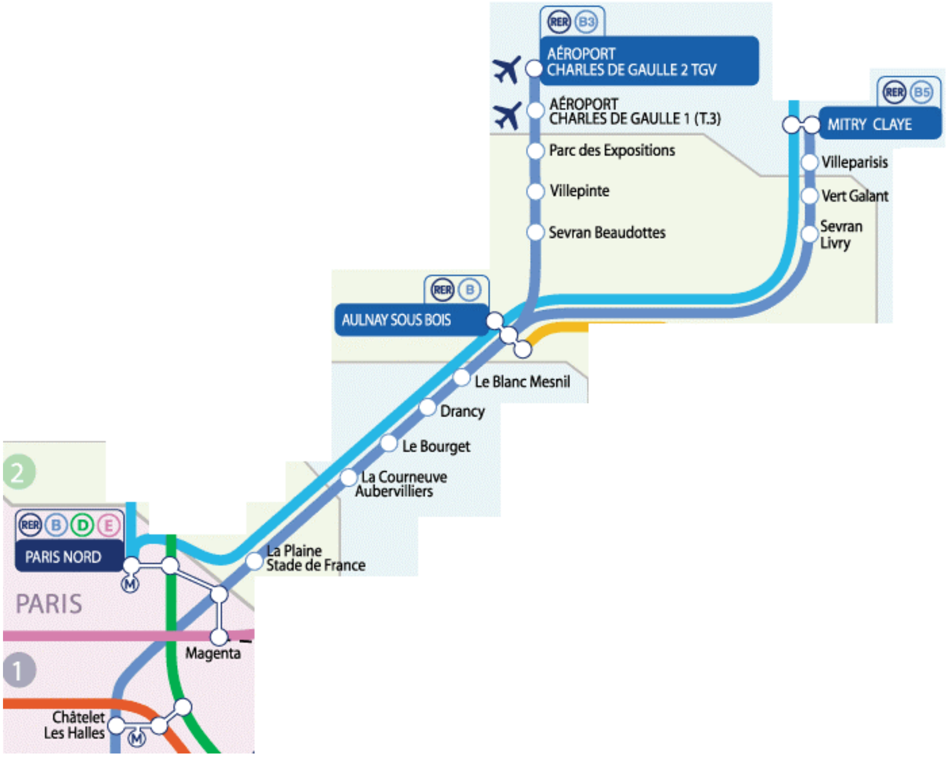

Figure 5.1 Part of the RER-B line (dark blue line) that is under consideration in this example

5.2 Steps 2 and 3: estimate impact on system performance and service level

System performance (travel time, waiting time and punctuality level) and service level (probability of having to stand) can be estimated using a model developed by RFF (see box). The future level of information is not yet defined within the project; for this example it has been assumed to remain unchanged. It is emphasized that these model results are for illustrative purposes only, since the model has not yet been validated.

Figure 5.2 shows that 588 travellers depart per hour from Mitry Claye (third column). The fourth column shows the proportion of the sample that leave the train at each destination station. The fifth column indicates the absolute number of travellers that leave the train. The last columns indicate the number of travellers who experience a specific deviation between their expected travel time and their actual travel time (see box for explanation). If these numbers of travellers are summed over all the possible origin–destination combinations (including the people travelling beyond Gare du Nord), the total number of travellers on this section is determined. This number needs to be filled in on the first line of step 2, part B of the tool's input sheet.

It is noteworthy that this column only adds up to 96%. We have assumed that the remaining 4% of travellers have destinations beyond Châtelet les Halles. These travellers are assumed to have the same distribution over the deviations from their expected travel times as the travellers with the destination Gare du Nord. Since there is no information in the tables on the deviations from the expected travel time for the travellers between Gare du Nord and Châtelet les Halles, this section of the line is excluded from further analysis.

Box: RFF model

The RFF has developed a model which simulates passengers travelling with a Paris suburban train line. This is a preliminary model which is not yet validated. The model assumes that passengers arrive uniformly at their origin (or departure) station (note that this research has shown that this is valid assumption, as long as the frequency of trains is six or more per hour). According to this model, trains run at their scheduled times with some random service disruptions, and passengers take the first available train to their destination (including a possible transfer). In this way, the travel time can be calculated for each passenger and delay can be determined with respect to the expected journey time. Since this expectation is taken to be the average travel time, including the average waiting time at the departure station in a situation free from service disruptions, it is possible that the traveller will arrive early (this is the case when they arrive at the platform just before a train arrives, so that their waiting time is less than average). Furthermore, even in the non-interrupted situation, delays up to half of the train interval times occur.

In order to calculate all the necessary numbers for the project assessment, at least four of these simulations have to be run: a simulation of the present situation in the case of no disruptions and in the case of random disruptions at some specific level, as well as similar simulations for the future situation. The output of these simulations consists of two tables: first, with the number of passengers experiencing a certain deviation from their expected travel time for each combination of departure and arrival station (Figure 5.2); second, a table with the train arrival times at each station, including the number of passengers travelling on this train to the next station (Figure 5.3).

Origine	Destination	Montants	Part	Persor	TdP mr [min]	TdP mi [min]	Attente [min]	Nombre de personnes touchées -4	-3	-2	-1	0	1	2	3	4	5	6	7
Mitry-Claye	Villeparisis	588	18%	105	6	3	3	0	12	18	18	16	18	16	7	2	0	0	0
Mitry-Claye	Vert Galant	588	8%	46	9	6	3	0	8	8	8	8	8	5	2	0	0	0	0
Mitry-Claye	Sevran-Livry	588	9%	54	12	9	3	4	9	9	8	9	9	4	2	0	0	0	0
Mitry-Claye	Aulnay-sous-Bois	588	11%	62	15	12	3	5	10	10	9	10	10	4	2	0	0	0	0
Mitry-Claye	Blanc Mesnil	588	5%	32	17	14	3	2	5	5	5	5	5	3	2	0	0	0	0
Mitry-Claye	Drancy	588	5%	27	20	17	3	3	5	5	5	5	5	1	0	0	0	0	0
Mitry-Claye	Le Bourget	588	4%	22	22	19	3	2	4	4	4	4	4	1	0	0	0	0	0
Mitry-Claye	La Courneuve-Aubervilliers	588	3%	19	25	22	3	0	2	3	3	3	3	3	1	0	0	0	0
Mitry-Claye	La Plaine Stade de France	588	4%	23	27	24	3	0	3	4	4	4	4	4	1	0	0	0	0
Mitry-Claye	Gare du Nord	588	18%	105	33	30	3	12	17	17	16	16	16	5	0	0	2	2	2
Mitry-Claye	Châtelet-les-Halles	588	11%	63	37	34	3	7	10	10	10	10	10	3	-	-	1	1	1

Figure 5.2 Part of the first output table of the RFF model: number of passengers experiencing a certain deviation from expected travel time

If only the travellers experiencing a deviation from their expected travel time of more than 5 minutes are summarised, the number of people experiencing a short delay is determined. This number needs to be added on the second line of the tool's input table.

Note that even in the case of no service disruptions it is possible for a traveller to have a short delay (e.g. trains stop at Le Blanc Mesnil only four times per hour; the average waiting time for this connection is 7.5 minutes, but the actual waiting time can be up to 15 minutes). To achieve the correct improvement for this project the percentage of people experiencing a short delay in the uninterrupted situation should be subtracted from the percentage of people experiencing a short delay in the situation with service disruptions. This correction is made within the tool and the user does not have to be concerned with this.

In the simulation no travellers experienced deviations from their expected travel time of more than 15 minutes, so the number of people experiencing a long delay are zero.

Mitry-Claye	7:01	49	|		7:09	78	|		7:13	39	|		7:20	69
Villeparisis	7:05	226	|		7:14	344	|		7:17	128	|		7:23	246
Vert-Galant	7:08	504	|		7:16	715	|		7:20	313	|		7:26	524
Sevran-Livry	7:11	679	|		7:19	948	|		7:23	430	|		7:29	698
Aulnay-sous-Bois	7:14	789	7:17	551	7:22	1132	7:24	419	7:28	577	7:30	469	7:33	809
Blanc-Mesnil	7:16	816	7:19	578	7:24	1177	7:28	455	7:31	604	7:34	496	7:36	827
Drancy	7:18	878	7:21	639	7:26	1279	7:30	537	7:33	665	7:36	558	7:38	868
Le Bourget	7:21	952	7:24	713	7:28	1378	7:32	636	7:35	740	7:38	632	7:41	942
Aubervilliers-la-Courneuve	7:24	992	7:27	753	7:31	1431	7:35	689	7:38	779	7:41	671	7:44	982
La Plaine Stade de France	7:27	995	7:30	756	7:33	1434	7:37	693	7:40	782	7:43	675	7:46	985
Paris-Nord RER	7:31	1326	7:34	1087	7:37	1765	7:41	1134	7:45	1224	7:48	1005	7:51	1316
Châtelet-les-Halles	7:35	1326	7:38	1087	7:41	1765	7:45	1134	7:49	1224	7:52	1005	7:54	1316

> 624 P.: Toutes les places assise occupées
> 1422 P.: Plus de 3P / m²
> 1688 P.: Plus de 4 P/m²

Figure 5.3 Part of the second output table of the RFF model: train arrival times at each station and number of passengers travelling to the next station

The total number of travel minutes can be determined from Figure 5.3. This table indicates the number of people travelling in a certain train to the next station. If this number is multiplied by the number of minutes it takes to reach the next station, the total number of travel minutes can be determined.[3] If this is limited to only those trains in which people have to stand (number of people > 624), the total number of travel minutes while standing can be determined. Similarly, the number of travel minutes while standing in a crowded environment (more than three persons per square metre, so more than 1422 passengers per train) can be determined. These numbers need to be filled in on the next lines of the input sheet. The numbers regarding the travellers that are standing only have to be determined for the simulations where service disruptions are included.

The tool uses these numbers to determine the average travel time (dividing the total number of travel minutes by the number of people for which a deviation is known) and the probability of having to stand (dividing the number of travel minutes while standing by the total number of travel minutes).

5.3 Step 4: determination of impact on passengers

The model determines the impact of the possible investments on passengers in terms of their valuation of their journey. The numbers found in the previous steps need to be filled into the input table of the tool (Figure 4.4). For the line classification (Figure 4.2) the direction towards Paris is selected. A percentage of 8.5% of trains delayed is specified in the box for mixed regularity (as observed, see Table 2.1). For the trip purpose mix the observed fraction is selected.

The results are presented in Figure 4.8. While the average travel time increases by 1 minute and 49 seconds when the project is completed (due to the fact that there are no fast trains), as a result of the longer journey time, the average passenger has to stand for a longer period as well. He values this equivalently with 7 seconds of travel time. However, the probability of having to stand decreases, which gains him the equivalent of 25 seconds of travel time. The biggest gain is due to the fact that the probability of experiencing a short delay decreases to almost zero. The average traveller values this equivalent to a gain in travel time of 2 minutes and 41 seconds.

In total this project leads to an average gain per passenger which is equivalent to 1 minute and 10 seconds. The decrease of the waiting time (a decrease of 45 minutes, because of the increased train frequency from eight to ten trains per hour) is not included in this impact calculation. This cannot be included because the value of the waiting time has not been investigated in the stated preference research. This improvement (and other improvements that have not been included at this stage) need to be reviewed in the overall assessment of the project.

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[3] This is the number of travel minutes actually made in a train. Any connection time (waiting time at a connecting station) is excluded. As a result, the average travel time that is determined using these numbers is an underestimate of the actual average travel time. In principle, the table in Figure 5.2 can be used also to determine the average travel time. However, so far we have not been able to obtain consistent numbers from both tables in Figure 5.2 and Figure 5.3. Therefore, we advise using the table in Figure 5.3 to determine the total number of travel minutes, to get a consistent fraction of people that have to stand (which is derived from the same table).

5.4 Step 5: conversion to monetary units

The travel time and punctuality changes are converted into monetary units by multiplying the travel time gain of 1 minute and 10 seconds by the value of time. In this example this value of time is taken to be €10 per hour, which leads to an average gain per passenger of 19 cents (15 cents for a passenger travelling for the commuting/education purpose and 30 cents for a passenger travelling for other purposes).

5.5 Step 6: determination of the impact on demand

The relative gain per passenger expressed in travel time equivalents is 5.4% (1.16 divided by the total utility at present, i.e. 21.38, see Figure 4.7). This relative gain is multiplied by the demand elasticity. In this example this elasticity is taken to be –0.5. So, the demand increases by a factor of 2.7%. If we assume that the morning peak (the period over which the project increased the train frequency) lasts two hours, the demand is about 40,000 passengers in the present situation. We therefore expect an increase in demand of 1080 passengers (see Figure 4.9).

5.6 Step 7: determination of the total monetary benefits

The total benefits are equal to the benefits of the present passengers plus the benefits of the new passengers. The benefits of the average present passenger were calculated in step 5. Multiplying this number by the number of passengers per year, this results in a benefit which is equivalent to about €1.55 million.

The benefits of each new passenger are less than that of an existing passenger. The "rule-of-half" states that the benefits of each new passenger are equal to half the benefits of an existing passenger (the first new passenger has the full benefits, the last new passenger has no benefits; on average each new passenger has half the benefits). This results in a total benefit for new passengers over a whole year of approximately €21,000. The total benefits of this project are equivalent to €1.57 million.

CHAPTER 6 Conclusion

A seven-step methodology has been developed to assess possible rail investments and to calculate the perceived value of all punctuality benefits to all passengers (both existing and new). To aid users with the necessary calculations, a Microsoft Excel tool has been developed. Travel times, delay probabilities, comfort and information levels before and after the proposed project are the inputs. The direction of the line, its general regularity level and its passenger mix in terms of purposes also need to be specified. Based on the results of a stated preference study, the daily impact of the project on passengers, expressed in equivalent minutes of travel time, is calculated. This impact can be different for passengers of different segments (based on their journey purpose). Next, this impact is converted into monetary units (benefits per passenger, in euros), using an appropriate value of time. The benefits over all passengers are simply calculated by multiplication by the total number of passengers.

The number of passengers using a service may also be expected to change, because of changes in the rail level-of-service. This change in demand is estimated using appropriate travel time elasticities. When this is added to the benefits already calculated, the total monetary benefits of the project associated with punctuality are determined.

The method has been used in a first application to the “RER B Nord” project. There, the benefits of the improved punctuality are estimated at 14.9 million Euro per year, while the benefits due to travel time reduction are estimated at 31 million Euro per year. This clearly shows the relevance of projects aiming at reducing unpunctuality.

Other projects aimed at reducing unpunctuality of suburban railways in the Ile-de-France region are currently being developed, and the methodology described above will be applied to appraise the benefits of these projects. Applications elsewhere, in other regions or countries could be envisaged, although local circumstances could lead to different valuations and hence different benefits. Finally the methodology could be extended to other forms of public transport, including buses, trams and metros where currently no accepted method is available. But also there we would recommend validation of the values of punctuality prior to large-scale application.

Reference List

Reports written for this study

RAND Europe (2004) Value of reliability of travellers on the paris suburban railway network. Technical report on the data analysis.

STRATEC and RAND Europe (2003) Syndicat des Transports d'Île de France: *Enquetes qualitatives et quantitatives visant a évaluer les projets de fiabilisation des radials ferrées en Île-de-France, Phase 1, Recherche bibliographique*.

STRATEC and RAND Europe (2004) Syndicat des Transports d'Île de France: *Enquetes qualitatives et quantitatives visant a évaluer les projets de fiabilisation des radials ferrées en Île-de-France, Phase 2*.

STRATEC and RAND Europe (2004) Syndicat des Transports d'Île de France: *Enquetes qualitatives et quantitatives visant a évaluer les projets de fiabilisation des radials ferrées en Île-de-France, Phase 1, Qualification de l'irrégularité*.