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Travel Time Savings Perception and Well-Being through Public Transport Projects: The Case of Metro de Santiago

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Abstract: Relying mostly on travel time savings, cost-benefit analysis has been widely used in transport project appraisals in the Chilean context, with utility maximisation theory as its background. Nevertheless, subjective well-being advocates have challenged the notion of the rational man underlying this theory by proposing that other trip attributes, individual perceptions and personal features mediate satisfaction with travel, alongside global well-being. Using the recently-opened Line 6 of Metro de Santiago (Chile) as a case study, this research has two main aims: (1) to verify to what extent travel time savings, which support the cost-benefit analysis process, are present after the launching of the new line; and (2) analyse the perception of passengers' travel time savings, and to what extent this element contributes to the travel satisfaction and to the global well-being at the individual level. Using passive data from smart cards, the results show that travel times decreased by 14% in comparable trips after the launching of Line 6. Furthermore, a confirmatory factor analysis (CFA) construct is proposed, including travel and life satisfaction as latent variables of the model. This revealed that travel times in the Metro system are highly valued by people. However, this element does not mediate travel satisfaction, as users take low travel times for granted. Waiting times, stations' design, safety and intermodality are perceived attributes that effectively mediate travel satisfaction. Moreover, the latter variable has a relevant influence on global life satisfaction, revealing that transport conditions mediate in day-to-day well-being. These results challenged travel time savings as the most important driver in transport projects' appraisal processes, and some recommendations are made in order to incorporate these findings in future appraisals.

Keywords: subjective well-being; travel time savings; public transport well-being

1. Introduction

Transport project appraisal using cost-benefit analysis (CBA) is based on the theory of utility maximisation, which assumes that individuals are completely rational. Therefore, they choose alternatives that, in the particular case of transport, will try to minimise or avoid the disutility caused mainly by the costs of the trips (namely travel times and fares) measured in monetary terms [1,2]. Hence, the main goal of investments in mobility projects is to provide new means of transport that increase levels of people's utility (or diminish disutility). For instance, this could be achieved through travel time savings (TTS), which in theory would free up time for other activities that could generate greater utility for the people [3–5]. On the other hand, during recent years, it has been argued that passenger transport has a strong link with the well-being of communities, and in turn, well-being has a strong link with the quality-of-life at the individual level [6]. This is why research in how travel behaviour affects subjective well-being (SWB) has gained momentum recently, challenging the notion of the *rational man* underlying the theory of utility maximisation and questioning the assumptions of unconstrained choices and perfect information that support this theory [7].

Nevertheless, CBA-based appraisals are still widely used in decision-making stages regarding transport projects, and TTS are a key component of social benefits forecasts. For instance, in the U.K., this component has accounted for around 80% of monetised benefits in major road schemes [8]. In Chile, transport project appraisals are also based on CBA [9], where even if environmental benefits (such as emissions reduction) and economic benefits (such as operation cost savings) are considered, TTS still represent a large proportion of future monetised benefits. Furthermore, several weaknesses and limitations have given rise to some criticism regarding CBA as a guiding tool in the decision-making process. For instance, the difficulties in monetising the socio-economic or political impacts of transport projects may lead to some biases in measuring social or distributional impacts. In the end, CBA focuses on economic values over other moral or ethical perspectives [10]. Moreover, even if CBA is frequently referred to as a scientific and objective procedure, there appear to be some arbitrary assumptions that could reflect political positions. Such assumptions could be the discount rate, as impacts occurring in the future get minor weighting in the present day [11]; the accuracy of costs and benefits forecasts in the long-run [12]; or the treatment of residual value at the end of the project's lifecycle [13]. The issue of using CBA as the only decision-making tool is highly questionable, as major transport projects must be designed under a quality-of-life improvement vision, which goes beyond TTS. Otherwise, the society could get transport infrastructure that could be highly useful for moving people, but would have no advantages in other fields, such as social, urban or economic areas, and consequently, would have limited scope in the well-being and quality-of-life.

Line 6 (L6) of Metro de Santiago was launched in November 2017, with 15 km of tracks and serving 10 new stations. As several public transport projects, the estimated social benefits for this infrastructure rely on TTS to a great extent. Nonetheless, empirical TTS findings in transport projects are not broadly reported in the literature [8]. And even if travel time is largely recognised as a key variable that influences travel satisfaction and global well-being [14], to what extent this particular element is contributing to both remains an open question. Using the Metro de Santiago case study, the goals of this article are twofold: (1) to verify to what extent TTS, which supported the CBA process, are present after the launching of the new line; and (2) to analyse the passengers' perception of TTS, and to what extent this element contributes to the travel satisfaction and to the global well-being at the individual level. Regarding the first goal of this study, smart card passive data will be used in order to estimate travel time savings in comparable trips after L6's launching. On the other hand, a user satisfaction survey conducted over L6 users and a confirmatory factor analysis construct, with travel and life satisfaction as latent variables of the model, will reveal if TTS effectively mediate these dimensions. Furthermore, as the travel time component will be analysed among several other socio-demographic variables and trip attributes, this will reveal if the given importance of TTS in the appraisal processes of public transport projects is justified or not. This is assuming that the ultimate goal of transport infrastructure development is the increase of the global well-being and quality-of-life of the population.

The outline of this article as follows: in Section 2, a review of the literature regarding global well-being and travel satisfaction is presented. Section 3 presents the methodology and materials that will be used for achieving both goals of this research are described, including the use of Santiago's passive data in order to quantify TTS after the launch of L6. Furthermore, a passenger survey to measure how travel times affect travel satisfaction and global well-being is introduced. In Section 4, quantitative results for TTS using passive data are presented, and later on, in Section 5, passenger survey results and the contribution of travel time in travel satisfaction and global well-being are analysed. Finally, Section 6 presents the conclusions and final remarks about travel time savings perception and well-being regarding the case study of Line 6 and future transport projects.

2. Literature Review

2.1. Subjective Well-Being

The concept of subjective well-being (SWB) has been interchangeably used with other related concepts, such as quality-of-life or happiness. All these concepts could be measured at the individual level, reflecting a subjectively personal lifestyle perception depending on behaviours and objective circumstances [15]. SWB is related to experiences of happiness or pleasure, based on the satisfaction of individual preferences and choices [16]. As a subjective individual issue, an approach using subjective measures instead of objective indexes and indicators has been the trend, particularly over the last decade [17]. Moreover, measures of SWB could be domain-specific over one particular dimension of life (e.g., work, family, studies) or global (life as a whole) and have a cognitive and an affective or emotional component, as well [18].

As described by Diener [19], SWB has three components: the presence of positive feelings, the absence of negative ones and the overall satisfaction with life. The first two components are related to short-term feelings and emotions, whereas the latter is related to a cognitive evaluation in the long term. Regarding the long-term dimension of SWB, the overall satisfaction with life is commonly measured by the Satisfaction With Life Scale (SWLS) [20,21], where five statements such as *I am satisfied with my life* or *In most ways my life is close to my ideal* are rated by respondents in a seven-point Likert scale, ranging from *strongly disagree* to *strongly agree*. Alternatively, the less used Personal Well-being Index [22] measures seven quality-of-life domains, such as health, achievement in life or future security, and one global question of overall life satisfaction, rated by respondents in a ten-point scale ranging from *completely dissatisfied* to *completely satisfied*.

On the other hand, in order to measure short-term SWB feelings, two main scales have been developed to this end. The first one is the Positive and Negative Affect Scale (PANAS) [23]. In a questionnaire containing 10 descriptors, both for positive affects (e.g., excited) and negative affects (e.g., afraid), respondents are asked how they felt during a certain past time lapse (e.g., the last day or the last week), rating each descriptor on a five-point scale. The second scale is the Swedish Core Affect Scale (SCAS) [24]. The core affect approach argues that feelings can be decomposed into two orthogonal dimensions called valence (related to the extent of pleasure, ranging from *positive* to *negative*) and activation (related to the extent of arousal by environmental cues, ranging from *activated* to *deactivated*). End-points of each scale are defined by three descriptors: for the valence scale, the descriptors are *sad*, *depressed*, *displeased* and *glad, happy*, *pleased* respectively; whereas for the activation scale, the descriptors are *dull*, *passive*, *sleepy* and *peppy*, *active*, *awake*, respectively. However, SCAS descriptors have been criticised before, as in some instances, one of the end-points is highly desirable when the other end-point is not (e.g., happy/depressed), leading to some biases in responses [17]. Nevertheless, SCAS has been successfully adapted in the domain-specific context of urban transport, as will be reviewed in depth in Section 2.2.

2.2. Travel Behaviour and Subjective Well-Being

As an activity performed on a daily basis in urban societies, scholars have argued that urban travel behaviour affects SWB in different ways, both in affective and cognitive dimensions. According to a complete review by De Vos et al. [17] on this subject, there are five ways in which SWB is influenced by travel behaviour. First, travel could induce positive or negative feelings in a person, depending on the context in which this trip is performed. For instance, traffic congestion could induce a stressful feeling in a car driver, while a peaceful trip by cycle could induce a relaxing feeling [7]. Second, as daily activities are distributed across space, travel enables activity participation in society, which in turn has a direct effect on personal goal achievements and well-being [25]. Third, when a complementary activity is performed during the trip inside a vehicle (e.g., reading a book or working), this could influence the mood and the experience of a person in the activity performed at the destination [26]. Fourth, when trips are regarded as the activity itself, with no particular destination (e.g., recreational walking or cycling), this *undirected travel* is performed only for the increasing of satisfaction or joy [27]. Finally, the capacity to become mobile and having access to transport resources, also know as *mobility* [28], could enhance feelings of freedom, competence and belonging, giving to people the idea that they are capable of reaching life goals.

One of the main goals of this article is to study the perceived users' importance of TTS, regarding the development of new public transport infrastructure. The section will explore how travel attributes, personal perceptions and context induce individual positive or negative feelings, and to what extent these components influence the cognitive dimension of individual global well-being. To this end, some scholars have adapted the concepts and measures of SWB to the particular context of travel behaviour. The most used measurement tool so far has been the Satisfaction with Travel Scale (STS) [14,29], designed to consider both affective and cognitive components related to urban travel. The affective component is evaluated using the SCAS methodology with six scales: three that consider positive deactivation and negative activation (e.g., *relaxed/time pressed*) and three that consider positive activation and negative deactivation (e.g., *alert/tired*). Meanwhile, the cognitive component is evaluated with three scales related to the quality and efficiency of the trip (e.g., *travel was of a low/high standard*). In one of the seminal versions of STS [14], respondents were asked to rate each of the nine pairs of descriptors on a nine-point scale.

In the last decade, STS has been widely used to estimate empirically the satisfaction with travel in the urban travel context. Ettema et al. [14] proposed a test based on STS under several scenarios, where Swedish respondents were asked to rate how they would feel when facing different hypothetical daily agendas with different travel attributes (e.g., more or less use of bus or car, travel time or activities performed during the day). Although the results supported the intuitive notion of satisfaction with travel in the urban travel context (for instance, satisfaction decreases with travel time and access time to bus stops), this test was not validated under real travel conditions. Still in Sweden, Bergstad et al. [29] performed a study based on STS, researching if urban travel had a positive impact on SWB. They concluded that both the affective and cognitive dimension of SWB are directly influenced by travel satisfaction. Moreover, SWB is also mediated by the performance of activities that urban travel enables. Although in their version of STS, both affective and cognitive dimensions were captured, it was designed as a general evaluation of SWB regarding urban travel, and it was not decomposed into specific elements, such as stress or tiredness.

On the other hand, Cao [30] analysed the impacts in the global well-being of a new tram service in Minneapolis, beyond the satisfaction with daily travel. He demonstrated that this kind of rail transport had a direct and positive influence on the satisfaction with travel and an indirect and positive influence on global well-being, by enhancing access to activities and improving public transport service and accessibility, although the size of the impacts was marginal. Nevertheless, one of the main contributions of this work was the introduction of confirmatory factor analysis (CFA) approach as a special case of structural equation modelling (SEM) in order to capture direct and total (indirect) impacts of each element, both in satisfaction with travel and global well-being. The advantage of using the CFA approach is that this tool allows testing if the data fit a hypothesised measurement model or construct (i.e., travel behaviour and perceptions). This construct includes observed indicators (such as travel and personal attributes), latent or unobserved variables underlying these indicators (such as global SWB) and the causal relationships between both. CFA allows concluding if the hypothesised construct fits the data, and to what extent observed and latent variables influence each other. Additionally, other studies had used a combined STS and factor analysis approach, such as De Vos et al. [31] and De Vos et al. [32]. Both studies were performed in Ghent (Belgium), but considered leisure trips only. A detailed mathematical introduction of CFA can be found in Mueller [33] and Byrne [34].

In summary, STS has proven useful to measure well-being in the urban travel context. Combined with a CFA approach, the hypothesised construct could reveal how, and to what extent, different explanatory variables such as travel and personal attributes, alongside individual perceptions, influence satisfaction with travel. However, even if travel attributes (such as in-vehicle travel time, waiting time or fares) are largely considered as explanatory variables of satisfaction with travel, two main gaps are recognised: first, research on satisfaction with travel and SWB has focused particularly on Western European countries, and in the USA to a lesser extent, whereas research of these topics in other parts of the world is relatively scarce; and second, only Cao [30] has focused on how new transport projects impact travel-related and global well-being. Those are the gaps that this article will try to cover.

3. Methodology and Materials

Regarding TTS and well-being perception in new public transport projects, this article will tackle two main issues using the case study of Line 6 of Metro de Santiago: (1) verify to what extent TTS exist in an empirical and quantitative way; and (2) analyse the perception of TTS by users, as well as their contribution to satisfaction with travel and global SWB. In order to achieve these goals, both passive data generated by the use of an smart card in the public transport system of Santiago (namely *Tarjeta Bip!*) and a travel satisfaction and well-being survey applied over Line 6 users, specifically designed for the purposes of this study, were used as the main data sources.

3.1. Case Study and Passive Data Description

Santiago is a city with a population of 6.1 million, and its urban extension covers more than 250 sq miles. In terms of mobility, more than 18 millions trips are generated during a working day, where private car and public transport shares are 28% and 25%, respectively [35]. Furthermore, almost half of the latter are trips that have a stage in the Metro, giving the urban rail a crucial role in the mobility in the city. Therefore, the expansion of the Metro network has been a priority since the 1990s, independently of the political coalition in the government. That was the case of Line 6 (L6) of Metro de Santiago, announced in 2009 and launched in November 2017, with 15 km of tracks and serving 10 new stations in seven communes in the city (see Figures 1 and 2 for more details). Two new communes were added to the Metro network for the first time, Cerrillos and Pedro Aguirre Cerda (P.A.C.). As shown in Figure 3, where households' socioeconomic status based on income, education and occupation indexes in Greater Santiago are displayed; low socioeconomic households prevailed in these two communes, particularly in P.A.C. Furthermore, L6 has three transfer stations with other already existent lines and one transfer station in Lo Valledor with Metrotren Nos, a recently-opened suburban train service.

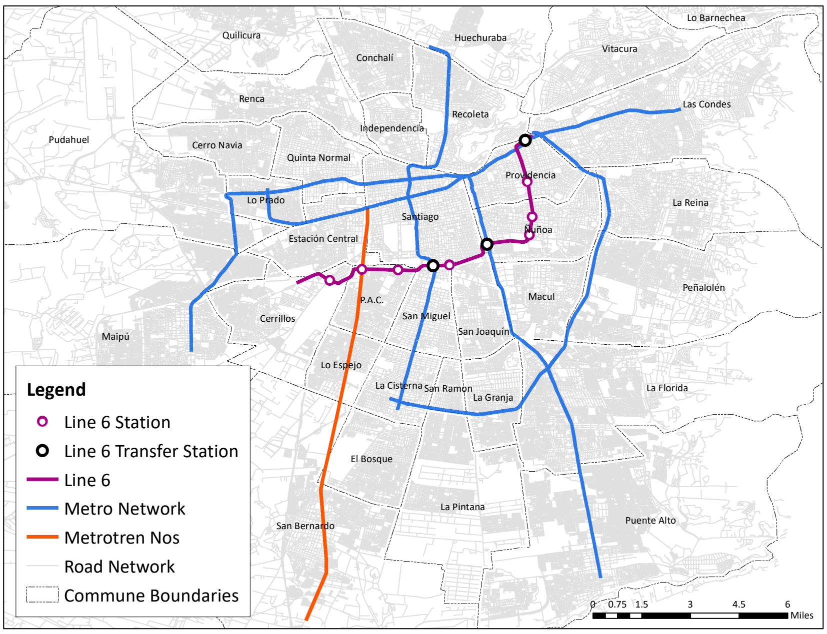

Figure 1. Metro and suburban train network in Greater Santiago (source: own elaboration).

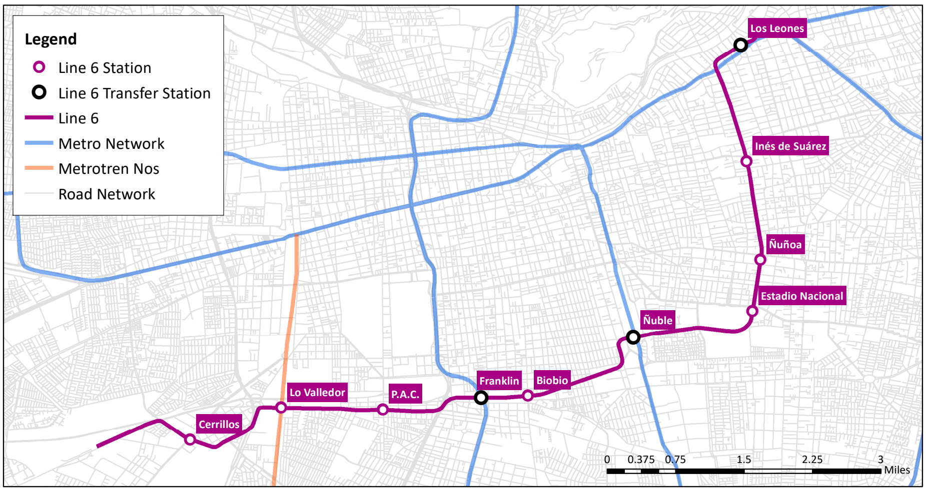

Figure 2. Line 6 of Metro de Santiago (source: own elaboration).

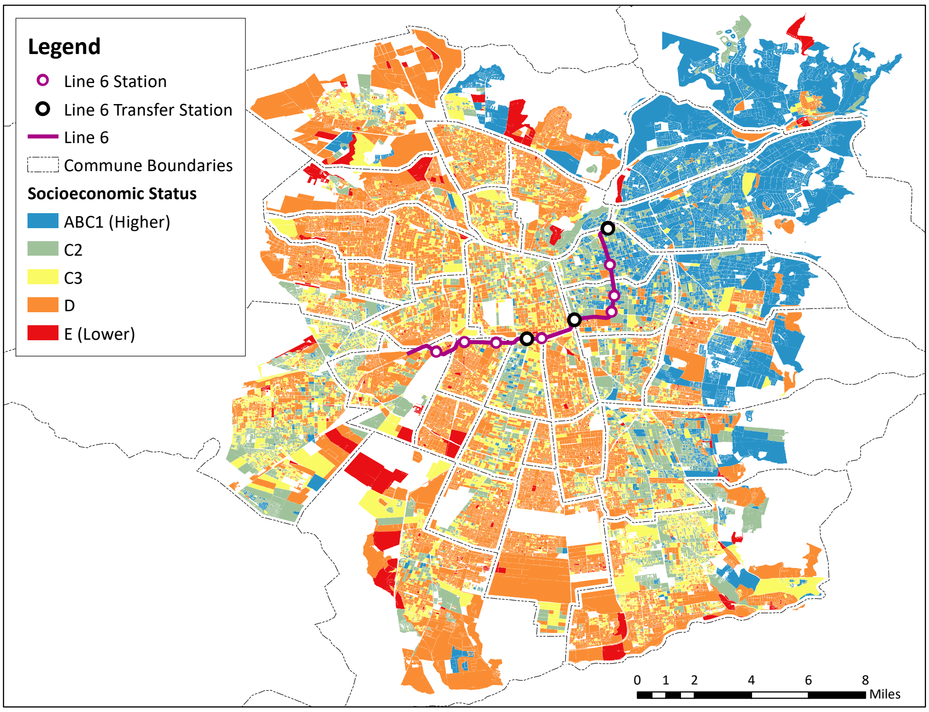

Figure 3. Socioeconomic households status distribution in Greater Santiago (source: own elaboration, based on [36,37]).

Since its launching in 2007, the payment scheme in Santiago's public transport system, namely Transantiago, is almost exclusively done through the use of an electronic smart card called *Tarjeta Bip!*. This smart card allows passengers to benefit from the fare integration scheme in the three main public transport modes of the system: buses, Metro and Metrotren Nos (a suburban train service). Currently, electronic payment (smartcard) is the only accepted method in all these modes.

Transantiago has a flat fare scheme in the system, regardless of the distance travelled. With a single fare, up to three stages in buses, Metro or Metrotren Nos could be used in 120 min. Only a tap-in validation in each stage is required. Therefore, bus services, boarding bus stops (using GPS systems installed onboard) or Metro/Metrotren Nos station and timestamps are recorded automatically by a farebox technology system for each validation. As tap-out validations are not required, Munizaga and Palma [38] used this passive data to develop an alighting estimation method, successfully identifying an alighting bus stop or Metro station for more than 80% of trip stages. This model was subsequently validated for the case of Santiago's public transport system [39] and even replicates observed origin-destination matrices and routes within Metro de Santiago's network [40].

In order to estimate travel time savings after the introduction of Line 6, regarding the first aim of this study, two datasets of passive data were used: one before the launch of Line 6 (in the week of 23–27 October 2017) and one after the launching (in the week of 9–13 April 2018). Datasets were provided by The Complex Engineering Systems Institute (ISCI). The goal here was identifying all the smart cards transactions made at any station of Line 6 in the second dataset, in the morning peak period (07:00–09:00). Then, the smart card IDs of these transactions were sought in the first database, before the launch of L6, matching all those trips whose origin and destination bus stops/Metro stations were in the same zone. These databases were based on the standard zonification of 777 zones within the city, widely used by transport authorities in Santiago. The latter condition, as depicted in Figure 4, determined if the trip is the same in origin, destination and period in both databases. Hence, travel times in both trips, before and after L6, were estimated. Finally, the difference between these two values was the empirical travel time savings after the introduction of L6, which could prove to what extent this new transport infrastructure contributed to reducing travel times.

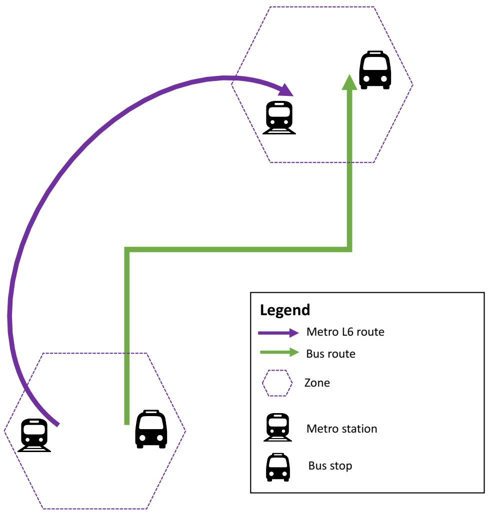

Figure 4. Same-trip matching rule, before and after L6 launching (source: own elaboration).

3.2. TTS Perception and Global Well-Being Survey

Regarding the second aim of this study, in order to capture how and to what extent TTS perception among other trip and personal attributes of L6 users influenced travel satisfaction and global well-being, the study used a CFA approach alongside a specifically-designed satisfaction and global well-being survey for this purpose. Therefore, a construct of the elements underlying satisfaction of travel and global well-being was hypothesised as follows (see Figure 5). First, it is assumed that observed variables such as individual socio-demographics, trip attributes and trip perceptions have a direct effect over latent variables, namely travel satisfaction and life satisfaction (or global well-being). Second, it is assumed that travel satisfaction also mediates the perception of life satisfaction.

Observed and latent variables were characterised and quantified by a web-based travel satisfaction survey, targeting frequent L6 users. Respondents were asked to consider the most frequent trip performed on L6 and not the last trip performed. As previously discussed by De Vos et al. [31], this could introduce some biases in survey responses, as retrospective averaged measures could distort memories and evaluation of the trip. However, the goal of this article is more related to satisfaction and global well-being in the long-term regarding public transport infrastructure, and less with travel satisfaction in the short-term, similar to Cao [30] in the case of the introduction of a new tram line and SWB in Minneapolis.

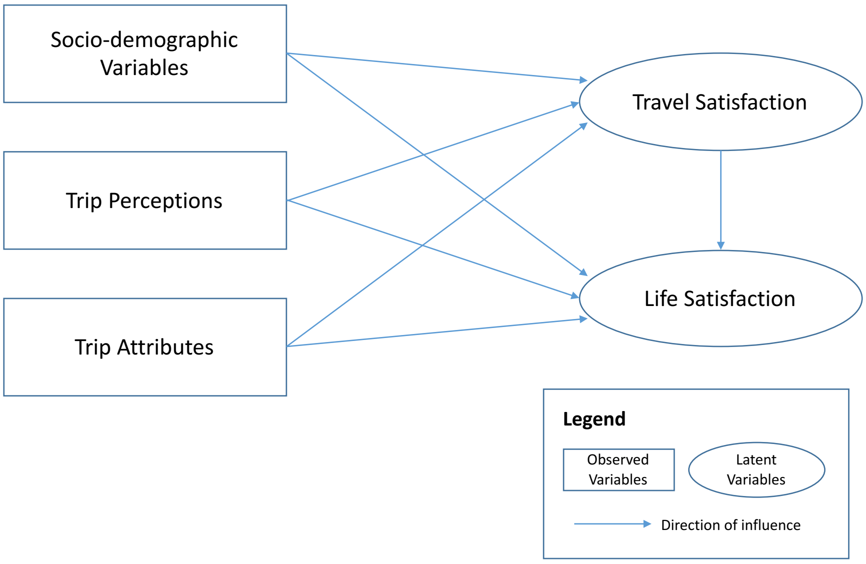

Figure 5. Travel satisfaction and life satisfaction hypothesised construct (source: own elaboration, modified from [30]).

Respondents were asked about socio-demographic variables (e.g., age, gender, household income and size), trip attributes (e.g., trip period, usage of other transport modes, fare), and trip perceptions (e.g., in-vehicle travel time, waiting time, crowdedness, safety and security). The latter group was measured by a five-point scale with a neutral midpoint, where (1) is *completely disagree* and (5) is *completely agree*. For a full list of observed (measured) variables asked in the survey, see Table 1.

Table 1. List of observed (measured) variables asked in the satisfaction with travel and global well-being survey

Socio-Demographics	Trip Attributes	Trip Perceptions (Satisfaction)
Gender	Frequency of use	In-vehicle time
Age	Period	Waiting time
Household size	Boarding station	Stations design
Household monthly income	Alighting station	Crowdedness
Educational level	Fare	Complementary uses of travel time
Commune of residence	Stages	Security
Car ownership		Safety
Driver licence possession		Intermodality and transfers
Mobility disability		

On the other hand, satisfaction with travel was measured using STS in three dimensions: positive activation-negative deactivation (PA-ND), positive deactivation-negative activation (PD-NA) and the cognitive dimension [31]. Respondents were asked to rate all STS pairs of concepts and statements on a five-point Likert scale (see Table 2). Finally, global well-being was measured through five statements of Satisfaction with Life Scale (SWLS), previously used in the public transport context by Cao [30]. Respondents were asked to rate each statement on a five-point scale, where 1 is *completely disagree* and 5 is *completely agree* (see Table 3).

Table 2. Satisfaction with Travel Scale (STS). PA-ND, positive activation-negative deactivation; PD-NA, positive activation-negative deactivation.

Dimension	Negative End-Point	Positive End-Point
Affective PA-ND	Bored Fed up Tired	Enthusiastic Engaged Alert
Affective PD-NA	Stressed Worried Hurried	Calm Confident Relaxed
Cognitive	*Travel was worst I can think of* *Travel was low standard* *Travel did not work out well*	*Travel was best I can think of* *Travel was high standard* *Travel worked out well*

Table 3. Satisfaction With Life Scale (SWLS).

Code	Statement
SL1	*In most ways my life is close to my ideal*
SL2	*I am satisfied with my life*
SL3	*So far I have achieved the important things I want in life*
SL4	*The conditions of my life are excellent*
SL5	*If I could live my life over again, I would change almost nothing*

4. Quantitative Travel Time Savings Estimation

Using passive data from smart cards before and after L6 launching, as previously described in Section 3.1, TTS were estimated for same-trips (namely, same origin and destination zone) in the morning peak period (07:00–09:00). Of the 10 stations of L6, the three transfer stations (Franklin, Ñuble and Los Leones) were discarded for this analysis, as the databases structure only considered origin, destination and intermediate bus stops or stations where passengers are required to tap-in. Therefore, route reconstruction in trips within the Metro network was not possible from the available data, as tap-ins on transfers between Metro lines are not required. Hence, people that effectively used L6, but entered through a L6 transfer station or through other Metro stations besides L6 and transferred to this line in a later stage were not properly identified in these databases. This is not the case of Lo Valledor station, as a tap-in is required to transfer between Metrotren Nos and L6.

With the methodology applied on both databases, 2986 trips were successfully identified as people that changed public transport routes and started to use L6 in any stage of their trips after its launching. These trips were equivalent to more than 2% of reported total ridership of this line in the morning peak period, in the same week of analysis. Given that both databases contained not just a sample, but all the trips of the public transport system, this could appear as a relatively low proportion of effectively-identified trips in relation to total ridership, but this issue can be explained by different causes. First, more than 35 million smart cards have been issued since the launching of Transantiago in 2007 [41]. However, only five million smart cards are actively used in the system annually, showing that smart card replacements per user due to lost or malfunctioning cards are rather high. Second, the same-trip matching rule in both databases was based on a model zonification, which in turn, could give rise to some issues regarding the spatial location of origins or destinations. These locations could be relatively closer in a certain place in the city, and a change of public transport route is straightforward to users under real conditions, but these are recognised as two completely different zones in both databases. Therefore, the methodology did not recognise these special cases as the same trip, and certainly, this issue could be improved in futures analysis. For instance, a proximity rule between origins and destinations stops could be used instead of a rather arbitrary zonification. Nevertheless, the volume of effectively-identified trips was still significant for the purposes of this research.

Travel time savings results are shown in Table 4, where users of L6 were experiencing 7.2 min less travel time every morning on average, equivalent to a relevant 14% less travel time per trip compared to the previous scenario. However, it is important to point out that the proposed methodology, regarding passive data from smart card usage, only considered travel times between the first tap-in and the last alighting in the trip. The first walking stage of the trip, between the actual origin site (e.g., house, school, shop or work place) and the first bus stop or Metro station, was not considered in all these analyses. The same applies for the last walking stage of the trip, between the last bus stop or Metro station and the actual destination site. Unfortunately, this issue could introduce some biases in overall travel time estimations. Nevertheless, the estimations presented here were the the sum of in-vehicle and intermediate transfer travel times (with their waiting time intervals associated). This proportion of time represents on average more than 70% of door-to-door travel time, reported by users in the Metro [42]. Therefore, even with this drawback, travel time savings estimations reported in this article are still a good proxy of total savings, as the methodology covered much of the trip length in general.

Table 4. Average public transport route changes after Line 6's (L6) launching.

	Before L6	After L6	Difference
Travel Time (min)	52.5	45.2	7.2 (−14%)
Bus Stages	1.06	0.81	−24%
Metro Stages	0.86	1.00	+16%
Metrotren Nos Stages	0.19	0.20	+6%
Total Stages	2.11	2.01	−5%

Furthermore, bus stages decreased by 24% among those users who changed routes and preferred L6 after its launching. Metro and Metrotren Nos stages increased by 16% and 6%, respectively. Considering the perceived poor performance of bus services compared to Metro and other rail services in Santiago [43], this fact would represent an improvement in travel conditions for L6 users, at least in the perceived quality dimension. Furthermore, average total stages decreased from 2.11 to 2.01 stages per trip (−5%). As will be shown in Section 5.1, intermodality and transfers obtained a comparatively low score among L6 users, and a decrease in total stages per trip represents an overall improvement in public transport conditions, as users were choosing more direct routes (i.e., with less transfers) in their trips.

Travel time savings by L6 entry station are shown in Figure 6. Furthermore, average travel time savings by commune and trip origins by commune are shown in Figures 7 and 8, respectively. Several issues could be described regarding these results. First, P.A.C. station has the most substantial travel time savings, equivalent to 10.2 min less on average. P.A.C. is a relatively small commune in terms of area, but it is the first commune of origin, with almost 19% of identified trips. Therefore, P.A.C. is the most benefited commune with the launch of L6, given that the short extension of the commune helps to improve accessibility to the Metro network by a reasonable walk or a short bus ride. This is a remarkable fact in terms of transport equity, given that this commune has a highly deprived proportion of households, as shown in Figure 3. Similar arguments of accessibility improvements are valid for Estadio Nacional and Ñuñoa stations, but TTS were lower in these cases, given that the commune of Ñuñoa already had good Metro accessibility by the other two lines in the boundaries of its territory. On the other hand, Inés de Suárez had shorter TTS, equivalent to 3.2 min on average. Considering that the northeastern area of Santiago is an important trip attractor zone in the morning peak period, as work, education and services are highly concentrated in this area, it is likely that people using Inés de Suarez as their entry station are travelling by shorter trips, given the proximity of this station with the northeastern area. Therefore, travel time savings were lower in this case.

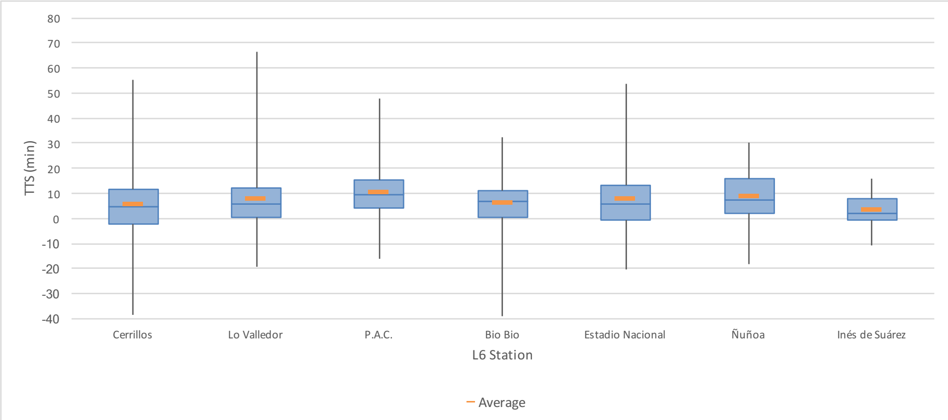

Figure 6. Average travel time savings (TTS) by L6 entry station after its launching. P.A.C., Cerrillos and Pedro Aguirre Cerda (source: own elaboration).

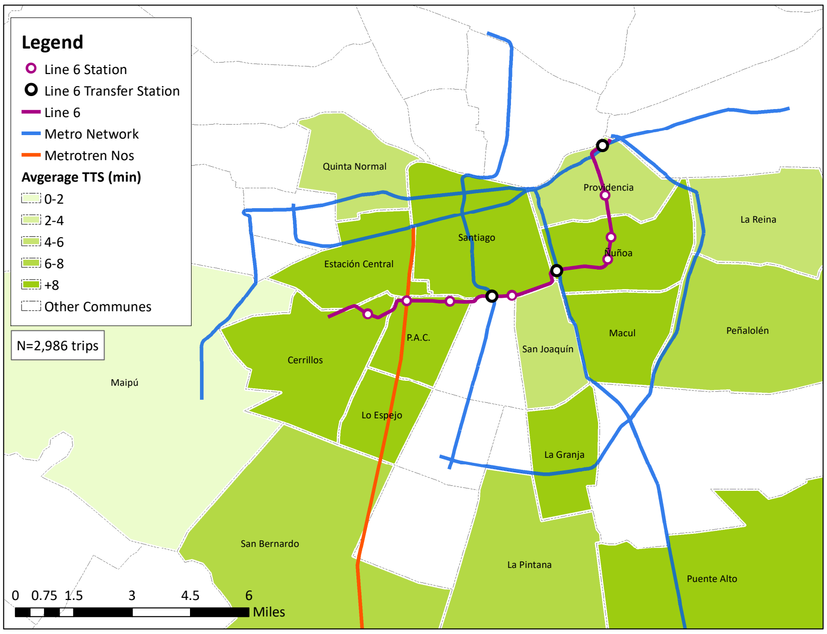

Figure 7. Average TTS by commune after L6's launching (source: own elaboration).

In general, relevant travel time savings were found in communes where L6 stations were placed, such as Cerrillos, P.A.C., Santiago and Ñuñoa, as shown in Figure 6. However, the extent of the benefits of L6 measured by TTS went beyond the immediate surroundings of its stations. San Bernardo and Lo Espejo are some of the deprived suburban communes in the south of Greater Santiago, as shown in Figure 3. With Metrotren Nos serving five stations in the former commune and two in the latter, the connection of this service with L6 in Lo Valledor station provides a seamless ride to those who want to travel between these communes and the northeastern area of Santiago, resulting in 6.6 min (−12%) and 8.6 min (−15%) travel time savings, respectively. Moreover, users who are using Lo Valledor as the entry station to L6 had TTS equivalent to 7.7 min on average. In a similar way, Maipú is a middle-class commune in the west of Santiago that is also benefited by L6 (see Figure 3). A dedicated bus corridor connects an important area of the commune with Cerrillos station. However, even if an important 17% of identified trips started in Maipú, the road network is rather congested, and the resulting travel time savings amounted only to 3.1 min (−4%).

Furthermore, trips with negative travel time savings were found in all stations, although these trips were a minority. This fact could reveal that travel time is not the only driver in route choices of users. However, fare is off the table due to Santiago's flat fare scheme in the public transport system. These findings challenge the notion of the *rational man* underlying utility maximisation theory, as mentioned before. In Section 5, the L6 user survey will shed some light on which perceptions and dimensions influence satisfaction with travel and could be considered as the main drivers regarding public transport route choices.

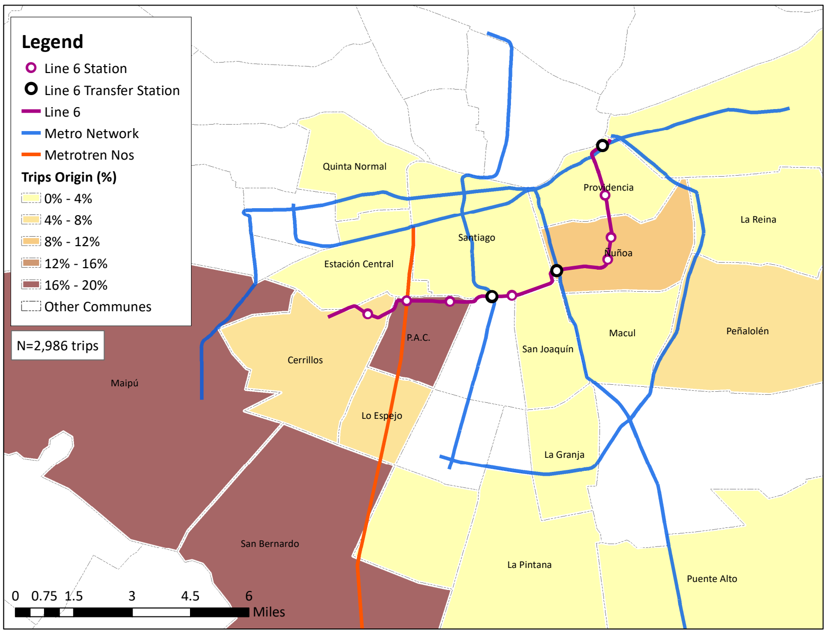

Figure 8. Origin of the identified L6 trips with route changes after its launching (source: own elaboration).

In summary, L6 is not only increasing accessibility in the two new communes that were added to the Metro network, the results of travel time savings showed that this new Metro line project has extended spatial benefits, which go beyond the immediate surroundings of the stations. In particular, L6 increased accessibility of deprived southern communes of the city and the middle-class area in the west, improving equity levels in terms of urban transport, even if this line is not located precisely in these areas.

5. Travel Time Perception and Subjective Global Well-Being

5.1. Survey Analysis

As previously mentioned in Section 3.2, a web-based survey was conducted in order to characterise and quantify observed and latent variables of travel and life satisfaction of L6 users of Metro de Santiago. The survey was conducted through an on-line questionnaire in June 2018, and 271 complete responses were received. A comparison of some socio-demographic attributes of respondents of this research survey and previous origin-destination survey conducted by Metro de Santiago in its network in 2017 is shown in Table 5.

The results showed that the L6 survey was highly biased towards male respondents (68%), compared to the Metro survey in 2017 (45%). This result was expected due to the nature of the survey applied, as male respondents are more willing to answer an on-line questionnaire than women, although the Metro survey was also biased as female respondents were more willing to answer an on-site questionnaire at stations than men. Furthermore, the same effect of on-line versus on-site survey application could be seen regarding differences in the young population (18–30 years) against adults (31–60 years) and high-income households (more than EUR 1768 monthly) against middle-class households (EUR 408–1088). However, in the latter dimension, 28% of Metro survey respondents preferred not to answer this question, and the income distribution of Metro users remains an open issue today. It should be noted that these effects are some specific issues observed before in the Metro, regarding previous surveys and its responses rates, and does not represent a generalisation of survey applications.

Table 5. Socio-demographic L6 survey attributes versus the Metro [42] ODsurvey.

Attribute	L6 Survey		Metro Survey	
Gender				
	Male	62%	Male	45%
	Female	38%	Female	55%
Age				
	(−)18	1%	(−)19	12%
	18–30	63%	19–30	40%
	31–60	35%	31–60	42%
	(+)60	1%	(+)60	6%
Household income (EUR)+				
	(−)408	3%	(−)340	5%
	408–1088	17%	340–1183	47%
	1088–1768	25%	1183–2694	15%
	(+)1768	45%	(+)2694	5%
			DK/NO	28%

+Exchange rate (December 2017): EUR 1 = CLP 735.

Although the survey applied has important differences with respect to the Metro survey in terms of sample socio-demographic characteristics, it is still useful to make an inference about which attributes were mediating satisfaction with travel and global well-being.

Regarding the results of satisfaction with travel in the L6 user survey, in Figure 9, trip perception aggregate scores for each attribute are shown. Furthermore, the standard deviations of each variable are displayed in Table 6. The survey was specifically designed to reflect good perceptions regarding each attribute through higher scores (e.g., a high score in the *crowdedness* attribute means that the respondent was perceiving a low density inside the train). Consequently, crowdedness, complementary uses of travel time (such as reading a book or using a mobile phone when travelling) and security were the most valued perceived satisfaction attributes for L6 users. In-vehicle travel time was only the fourth most valued attribute, with an average score of 3.95 on a scale of 1–5. Nevertheless, the set of attributes proposed had a high score in general, as all attributes were ranked in the upper half of the scale on average. Only waiting time had a relatively low average score, equivalent to 3.18. This could be explained as due to the low frequency of L6 trains compared with the rest of the Metro network. For instance, L6 operated in its first year with an interval of 4.0 min in peak hours, but other lines reached intervals between 1.5 and 2.5 min in the same period. Furthermore, it is likely that stations' design and intermodality/transfer dimensions obtained a comparatively low score due to the depth of L6 tunnels and platforms, constructed below the existing network of the Metro, which require that passengers must use an important amount of time on stairs, escalators or elevators in order to enter or exit stations.

On the other hand, in Figure 10, STS scores obtained in the L6 user survey by each dimension are displayed, namely six affective and three cognitive scales. Regarding affective dimensions, *enthusiastic* and *engaged* obtained relatively high scores, possibly due to the novelty that is implied by a new line of the Metro, the first with an unattended train operation in Santiago. *Relaxed* appears with a slightly relatively low score, possibly due to the inexperience in the first months of the use of the new line, and also, respondents declared using this line more during peak hours (56%), where people are inclined to have fixed appointments regarding work or study activities, increasing anxiety. Furthermore, cognitive dimensions obtained relatively high scores, revealing that users had some valuable opinions of the Metro infrastructure related to non-affective and long-term issues.

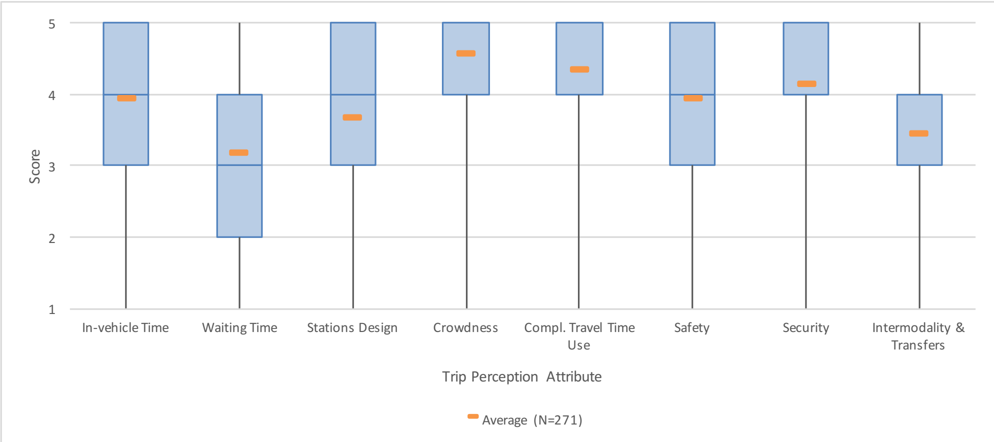

Figure 9. L6 user survey results: trip perception (satisfaction) by attribute (source: own elaboration).

Table 6. Standard deviations of trip perception scores in the L6 user survey.

Variable	Standard Dev.
In-vehicle time	1.08
Waiting time	1.21
Station design	1.29
Crowdedness	0.90
Compl.travel time use	0.99
Safety	1.10
Security	0.95
Intermodality and transfer	1.21

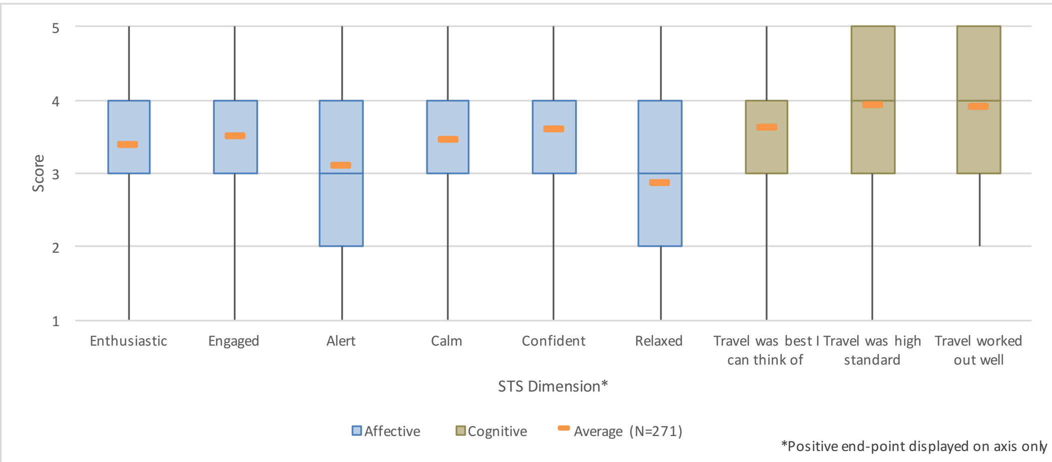

Figure 10. L6 user survey results: Satisfaction with Travel Scale by dimension (source: own elaboration).

In relation to global well-being and SWLS results, Figure 11 shows that L6 users were satisfied with their lives in general. Scores were quite flat across all five statements, with an average of 3.63. Only statement SL4, regarding overall conditions of life, obtained an score of 3.83, slightly above the average. However, if respondents are disaggregated by age groups an interesting effect occurs, as shown in Figure 12, where respondents below 18 years and above 60 years were discarded due to low response rates in the sample. All five satisfaction-with-life statements were consistently less rated in adults (31–60 years) than in young people (18–30 years). Furthermore, this effect is clearly visible in statement SL5, related to life changes if they would have the opportunity to live their life over again. These findings are consistent with previous studies that had found evidence of a U-shaped relationship between well-being and age [44,45], where the minimum satisfaction of life occurs around middle age (35–50 years).

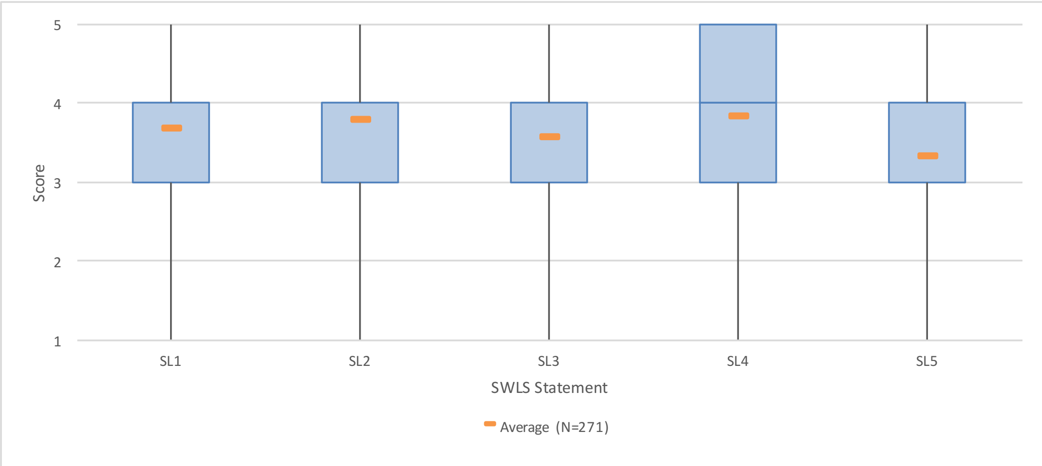

Figure 11. L6 user survey results: Satisfaction with Life Scale by statement (source: own elaboration).

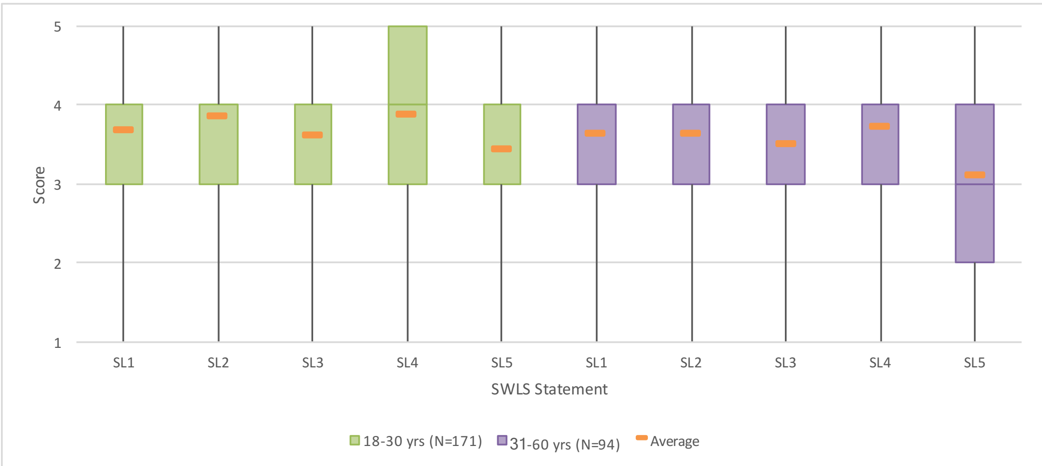

Figure 12. L6 user survey results: Satisfaction with Life Scale by age group (source: own elaboration).

5.2. Model Results

Using a confirmatory factor analysis (CFA) approach, applied to the L6 user survey, a construct was designed and modelled in order to reveal which observable variables were mediating in satisfaction with travel and life, respectively, as detailed in Section 3.2. A particular emphasis in the in-vehicle travel time was made, trying to find to what extent this variable was relevant to both latent satisfaction dimensions.

First, relevant goodness of fit indices for CFA models are described in Table 7. In this case, the construct proposed had a goodness-of-fit index (GFI) of 0.675 and a root mean squared error of approximation (RMSEA) of 0.096. Therefore, this specification is in the threshold of an acceptable fit, accordingly to the RMSEA index in particular.

On the other hand, standardised effects of observed variables on travel and life satisfaction are shown in Table 8, where for the sake of simplicity, only significant effects are displayed. Regarding satisfaction with travel, waiting time, stations design, safety and intermodality were mediating this variable, and in general, observing the standardised coefficients, the effects of each of them were all rather similar. However, in-vehicle travel time was not correlated with travel satisfaction.

Recalling perception scores in the survey, shown previously in Figure 9, this variable obtained a high average score anyway. Both facts could be interpreted as that even if in-vehicle time is highly valued by L6 users, users are taking travel time savings for granted in the case of the Metro. In the context of a more complex public transport network considering other modes, in-vehicle travel time does not mediate satisfaction with travel. Furthermore, crowdedness, complementary travel time use and security were not correlated with satisfaction with travel either, although these variables were highly scored by users as well. However, in this case, the variances of these variables across the sample were rather low, as reflected in the standard deviation results in Table 6 for all four variables. Therefore, the model was not able to capture any effect caused by these variables.

Table 7. Relevant goodness of fit indices of SEMs.

The goodness-of-fit index (GFI) is the relative proportion of variance and covariance in the sample covariance matrix explained by the model-implied covariance matrix, with values closer to one being better
The root mean squared error of approximation (RMSEA) measures the estimated discrepancy between the model-implied and true population covariance matrix, corrected for degrees of freedom; values less than 0.05 indicate a good fit, and values as high as 0.10 still represent an acceptable fit

Source: own elaboration, adapted from Cao [30].

Table 8. Standardised effects of observed variables on travel and life satisfaction.

Type	Variable	Travel Satisfaction	Life Satisfaction
Socio-demographics	Gender		0.112
	Age	0.113 *	
	Household size	−0.015	
	Income		0.236
	Education		
	Commune		
	Car ownership		
	Driver's license		
	Mobility disability		
Attributes	Frequency		
	Period	0.149	−0.126
	Fare	−0.104	
	Stages		
Perceptions	In-vehicle time		0.124
	Waiting time	0.136	−0.143
	Stations design	0.152	
	Crowdedness		
	Compl. time use		
	Security		
	Safety	0.163	
	Intermodality	0.172	0.121
Travel satisfaction			0.121

Goodness of fit: GFI = 0.675; RMSEA = 0.096; only significant effects at the 0.05 level are shown, unless indicated; * significant at the 0.10 level.

In relation to socio-demographic variables, household size has a negative influence on travel satisfaction, although this influence is marginal. Presumably, the probability of users with greater household sizes travelling with other members of the same family together, such as parents travelling with little children, is high in these cases. This fact makes the mobility inside the Metro network more difficult. Besides, age had a positive influence on satisfaction with travel, revealing that older people were more satisfied with the Metro service than young people. However, as this variable is only significant at the 0.10 level and the sample of elderly people (above 60 years) was limited in this survey, this presumption must be made carefully, and further research and data to address this particular issue are needed.

In terms of trip attributes, the period of use and fare were the only variables that had a significant influence on satisfaction with travel. In the case of period, travelling outside of peak times increased travel satisfaction as expected, as the crowdedness was less in this period. Also expected, fares had a negative effect in travel satisfaction, as groups such as students and elderly people had concessionary fares in the Metro network, and therefore, these groups were more satisfied in relation to travel.

Regarding life satisfaction, this latent variable was highly mediated by household income in the first place. In a highly unequal society such as Chile [46,47], the lack of accessibility to effective social rights such as good health or education caused disposable income to determine strongly the quality-of-life of the population. Rather surprisingly, gender had a relevant influence on life satisfaction as well, revealing that women were more satisfied than men overall. Further research is needed in order to clarify which are the personal and social characteristics that are influencing this result in the Chilean context.

Furthermore, aggregate travel satisfaction was also influencing life satisfaction, revealing that day-to-day urban transport issues were mediating overall quality-of-life, and consequently, mobility was an important dimension in the context of Santiago. However, other dimensions of mobility had a direct and noteworthy influence on life satisfaction as well. For instance, in-vehicle time and intermodality, which reflect to some extent the quantity of daily time assigned by each person to mobility purposes. Physical conditions between different transport modes in relation to Metro stations was highly influential on its own. Both had an effect almost equal to aggregate travel satisfaction, revealing particularly that travel conditions mediated global well-being. Unexpectedly, waiting time had a significant and negative correlation with life satisfaction. A logical explanation of this effect, and a negative influence of this variable in particular, is not possible at this stage, given the limitation of data of the survey applied.

Besides, the period of use of L6 had a significant effect on life satisfaction. Likely, people travelling outside of peak hours had more flexibility in their daily routines, as they did not have fixed appointments at peak hours when the Metro network (and the transport system in general) was highly congested, increasing overall quality-of-life.

Finally, in Table 9, the standardised effects of travel and life satisfaction on observed indicators of STS and SWLS are presented, showing that the observed variables of both scales were highly useful to represent latent variables for travel and life.

All previously-mentioned issues are relevant at the planning and design stages of future public transport projects, and in the appraisal processes in new Metro infrastructure development in particular. In-vehicle travel time (as a proxy of travel time savings) was highly valued, but taken for granted by users in the case of the Metro, as analysed before. Nevertheless, other remarkable issues arose from the survey analysis. First, overall travel satisfaction had an effective correlation with life satisfaction, revealing that public transport by Metro was an influential dimension in Santiago's urban life. However, to what extent transport was relevant in the context with other life dimensions, such as family conditions, health, work or education, is out of the scope of this research. However, even if urban mobility is a daily-based activity and public transport is continuously mentioned as one of the priorities in which the government should invest time and resources, Chileans still declare that solving street crime, retirement pensions, public health and education are more urgent than other issues [48]. This could constitute a barrier to attract relevance to public transport projects in a political dimension in the local context. Second, specific variables concerning urban transport were influential in both travel satisfaction and life satisfaction, and should be included in future project appraisal processes, aiming to increase the quality-of-life of the population. For instance, waiting time relevance could lead to defining a standard in the supply, namely service frequency, of public transport routes, which today are mostly adjusted to the demand in Santiago. This causes that in certain routes with low demand, low frequency services are supplied, and waiting time increases proportionately, decreasing travel satisfaction. Besides, a particular focus on stations' design and intermodality should be considered in future Metro projects. Considering that new lines must be constructed increasingly deeper in the city, usefulness for users should be put in the centre of the physical design stages, thinking about how elements such as ticket machines, turnstiles, escalators, stairs, elevators, platforms and trains are contributing to seamless travel inside the Metro network, and how the urban train provides integration with other modes, an issue that today is not generally considered during the appraisal and design stages. Finally, a disaggregation of potential users should be considered in future Metro projects. Gender, age, household income or household size influenced travel and life satisfaction, revealing that people with different characteristics had a different viewpoint about the transport system. Nevertheless, the appraisal processes today in Chile assume that an *average person* exists, which given the evidence of this article's results, is not supported.

Table 9. Standardised effects of travel and life satisfaction on observed indicators.

Indicator	Travel Satisfaction	Life Satisfaction
Travel satisfaction		
Enthusiastic	0.617	
Engaged	0.574	
Alert	0.578	
Calm	0.646	
Confident	0.693	
Relaxed	0.615	
Travel was best I can think of	0.566	
Travel was high standard	0.610	
Travel worked out well	0.575	
Life satisfaction		
In most ways my life is close to my ideal		0.782
I am satisfied with my life		0.897
So far I have achieved the important things I want in life		0.756
The conditions of my life are excellent		0.769
If I could live my life over again, I would change almost nothing		0.583

Source: own elaboration. All effects shown are significant at the 0.05 level.

6. Conclusions

Research in subjective well-being has challenged in a noteworthy way the assumption of the *rational man* underlying the utility maximisation theory, regarding the urban transport field. Travel times and fares are advocated by utility maximisation theory as the main drivers of users' behaviour and choices, suffering from an economic bias and leaving aside other social dimensions that we can find in the complex urban context today. In the same line, new transport projects are still analysed under CBA principles, where travel time savings are a key component of social benefits.

The latter was the case of Line 6 of Metro de Santiago in its appraisal process. Using this recently-launched public transport project as a case study, and subjective well-being theory as the background that questioned this travel time savings assumption that was established in its appraisal process, two main goals were proposed regarding this article. The first goal was to verify to what extent travel time savings are empirically present after the launching of the new line. Based on smart card passive data recorded from the public transport system of Santiago, travel time savings were found over a sample of users that had the same origin and destination in the morning peak period, but changed their transport routes after Line 6's launching, preferring the latter. An effective decrease of 14% in travel time, equivalent to 7.2 min on average, was found in the analysis. This constitutes by itself relevant evidence of travel time savings regarding transport projects, as empirical values reported in the literature are extremely scarce, particularly in the Global South context. On the other hand, total stages per trip were reduced by 5%, as users were now choosing more direct routes, avoiding intermediate transfers in their trips. Furthermore, travel time savings were found in other communes of Santiago, far away from immediate stations' locations, revealing that the opening of the new line had positive effects at a rather Metropolitan scale, particularly in deprived communities of southwest Santiago. Consequently, from a travel time savings perspective, results showed that Line 6 was responding to previous expectations of travel times decreases and effectively providing better transport options to users, particularly in trips between the southwest to the northeast of the city, increasing transport equity for people living in the former area. Furthermore, as bus services are perceived by users as lower quality and having poor performance compared to the Metro in Santiago, the decrease of 24% in bus stages found in the same analysis could be considered as a successful policy by transport planning authorities.

Nevertheless, the second goal of this article shed some light on to what extent travel time savings in the case study of Line 6 were contributing to travel satisfaction and global well-being perspective. First, in-vehicle time, used as a proxy variable to travel time, was rated with an average score of 3.95 on a scale from 1–5, perceived as a good attribute by Line 6 users. Second, in-vehicle time had the fourth best average score, after the attributes of crowdedness (low densities), complementary uses of travel time (such as reading a book or listening to music) and security. These facts revealed that travel times were highly valued by users, but this attribute was not the only one relevant to them at the moment of choosing Line 6 as a stage of their trips. Nevertheless, all attributes measured obtained good ratings from users, except waiting time, due to a relatively low frequency in Line 6 after the launching of the line.

On the other hand, regarding the construct of satisfaction with travel and global well-being proposed, in-vehicle travel time had a significant influence just in the latter. However, waiting time, station design, safety and intermodality were the perceived attributes that had an effective influence on satisfaction with travel, alongside the period of use and fares. As in-vehicle time was highly rated by Line 6 users, but had no significance on satisfaction with travel, this could reveal a certain issue of the normalisation of good service and faster trips in the Metro network regarding travel times, in comparison to other modes of public and private transport. That is, users were taking lower travel times for granted in the case of the Metro, rating this attribute at high levels, but not considered at all in satisfaction with travel. Furthermore, these facts support the idea that travel satisfaction is correlated with other trip attributes and perceptions beyond travel times and fares, completely challenging the notion of the *rational man*. In addition, aggregate travel satisfaction had a significant influence on life satisfaction, and this effect was almost half of the influence that income had on global well-being, which was also relevant as expected. This issue emphasises the importance of travel satisfaction as a highly-relevant dimension in day-to-day satisfaction, although to what extent travel satisfaction is significant alongside other life dimensions such as family, health or work status is out of the scope of this research. Besides, in-vehicle time and intermodality were also significant by themselves in life satisfaction, revealing that certain individual perceived attributes cannot be disregarded in urban transport planning. Meanwhile, gender and income were the socio-demographic attributes that have some effect on life satisfaction. Certainly, these findings open the way to explore travel satisfaction in a broader context regarding global well-being in the Chilean context.

In summary, travel time savings were highly valued by users regarding new Metro projects, but people were taking these savings for granted in this particular case and did not have a relevant significance on travel satisfaction. This issue absolutely challenges current appraisal methodologies, based purely on utility maximisation theory and having travel time savings and fares as key drivers of modal and route choice by users. Other aspects such as inclusive station design, which provides good physical accessibility for all kinds of people under different requirements, or an adequate intermodality with other modes that provides conditions for seamless trips must be considered in modified appraisal processes. This is particularly important in the case of Santiago, considering that transport authorities have just announced the expansion of the Metro network by more than 50% over the next 10 years.

Moreover, tools other than CBA could enrich the decision-making process, complementing its economic dimension and values. For instance, cost-effectiveness analysis (CEA) is useful for ranking options using a tangible criterion and comparing policy options based on available evidence, ensuring that predefined goals will be met at the least possible costs [10]. Furthermore, participation and public debate are important to legitimise rational decisions. The multi-criteria decision analysis (MCA) tool supports the inclusion of stakeholder groups, allowing impacts to be assessed against multiple criteria, incorporating intangible factors and different views about the issue to be discussed [12,49,50].

The integration of other attributes and views beyond travel time savings in planning and appraisal processes could produce better transport projects, improving not only travel and life satisfaction, but also transport equity levels in a highly-segregated city.

Author Contributions: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing (Original Draft Preparation) and Visualization by C.P. Writing (Review & Editing), Validation and Supervision by B.M.L.

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