Measuring Passenger Transport Quality by Disutilities

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Abstract. This paper aims to show the importance of measuring Passenger Transport quality by its disutilities. Even when the offer fulfills the demand, Passenger Transport (PT) imposes disadvantages on the passengers and to the society as it costs money, wastes time, is insecure, is uncomfortable and harms the environment. These disadvantages, also known as disutilities, influence customer choices and PT assumes the character of a negative consumption service. In order to demonstrate this new approach, a methodology for measuring PT quality by its disutilities is developed. A case study was conducted to present the methodology for the route Narita Airport, Japan, to Tokyo Central Station. The results show the cheapest option as Bus (Ordinary).

Keywords: Passenger transport quality, Quality management, Public transport, Narita Airport Japan, Tokyo.

1 Introduction

Passenger Transport (PT) history is intertwined with the history of humanity [1]. Human displacements are always due to the fact that human activities are not carried out in the same places and at the same time [2]. Therefore, PT has accompanied the challenges of overcoming spatial and temporal limits, generally by the progressive increase in the speed of transport modes [3]. Although PT exists to meet travel demand, it is not limited to provide mere displacements, but is part of the economic infrastructure and it has assumed a mobility dimension, as a social relationship linked to the change of place, i.e., how the members of a society deal with the possibility of themselves or others to occupy several places successively [2].

In this way, PT, in its collective or individual form, organized or not in systems and networks, provides people displacements. However, its performance is conditioned by different factors. These factors influence irregular and uneven quality, especially in the collective modes, because of its function of an economic activity [4]. PT also produces externalities, requiring market regulation, and justifying the intervention of the State [5].

PT expresses a kind of trade-off: it is efficacious because it fulfills its purposes, but it is not very efficient, because it has variable quality, produces externalities and disadvantages to the passengers and to the society. Even when the offer fulfills the demand with the highest level of quality possible, PT itself imposes disadvantages on those people who use it and to the society. Why does this kind of thing happen? Generally, because PT costs money and wastes time. Moreover, it is unsafe and uncomfortable, and it harms the environment, requiring urban space and consuming non-renewable energy. These disadvantages, called disutilities, influence customer choices and PT assumes the character of the negative consumption service, or, in other words, something that everyone needs, but nobody wants [6].

The concept of disutility has been utilized by Transport Economics initially to support studies of valuation of displacement associated with the choice of transportation modes or routes in individual transport. [7]. Savings in transport time, by definition, reduce the disutility associated to the total time of displacement. It is clear, then, that one of the fundamental issues of PT is disutility, which can be finally and simply defined as the difficulty in making a trip [8, 9].

The duality between level of service and disutilities might also explain why the entire structure of planning, investment, financing and regulatory framework of PT, in its public form, has been established in terms of an “answer” to the desires, needs and expectations of passengers, usually related to the characteristics of service [10]: (i) speed, (ii) comfort, (iii) regularity, (iv) reliability, (v) and (vi) reasonable fares. On the other hand, the individual modes of PT (pedestrian/walking, bicycle/cycling, motorcycle and car, including taxis, car sharing and carpool, paid or unpaid), even showing similar limits and producing the same externalities, hide themselves from this assessment, because they are not clearly classified and properly inserted as modes of transport in the network and transport systems. As a

corollary, there isn't a systematic way of a comprehensive assessment of the individual modes of transport in terms of service quality. There also isn't a global evaluation of performance of individual transport modes, except partial and relating to classical externalities (economic impacts of time wasting, accidents and environmental impacts related to emission of pollutant gases and gases of the Greenhouse effect) [11, 12].
Under these conditions, the objective of this article is to show the importance of measuring PT quality by its disutilities, instead of trying to fulfill the desires, needs and expectations of passengers.

2 Background

2.1 Concepts of Utility and Disutility

In Economics, utility is the property of goods satisfying needs and desires. Goods in superior amounts to the needs, even though useful, are considered free and they don't belong to the economical world. Economical goods are like this: useful and scarce [6, 13, 14]. In this way, utility can be interpreted as the level of satisfaction of needs and desires, while the opposite (negative utility, or disutility) refers to the sacrifices and losses arising from the use of a good or of a service.
The utility concept has been present in the classic history of economic thinking thanks to Adam Smith, David Ricardo, John Stuart Mill, Hermann Heinrich Gossen, Carl Menger, Léon Walras and William Stanley Jevons, among others [13, 14]. However, thanks to the thoughts of Alfred Marshall [13, 14], there were more detailed indications of the significance of disutility such as the sacrifices, losses or dissatisfaction caused by the use of a good or of a service, consolidating the idea of disutility as opposed to the idea of utility.
As a consequence, the concept of disutility has been utilized by Transport Economics initially to support studies of valuation of displacement associated with the choice of transportation modes or routes in individual transport [7]. According to Button [15], savings in transport time, by definition, reduce the disutility associated to the total time of displacement. Transport Economics, as an applied area of economics that is concerned with the efficient use of society's scarce resources for the movement of people and goods from an origin to a destination, brought to the debate about disutilities applied to PT, a fundamental contribution: it considered that demand for transport is said to be a derived demand, or in other words, people do not travel for the joy of travelling; rather they travel as they need/want to engage in some activity. PT demand can be focused upon the following [15]: the need for people to travel to other locations to partake in an activity.
It is clear then that one of the main issues involved in PT is disutility, which can be finally and simply defined as the difficulty in making a trip [16].

2.2 Application of the Concept of Disutilities to PT

The acceptance of PT disutilities is the first step to plan, implement, operate and maintain more efficient transport systems. Thus, it will be possible to measure its quality and performance more effectively, because the disutility is also closely linked to the level of service. The occurrence of high levels of service implies low levels of disutilities and vice-versa. The main disutilities of PT are [17]:

- From the point of view of the passengers: (i) total time of displacement (TTD), (ii) cost, (iii) discomfort (iv) insecurity; and
- From the point of view of the negative impacts on society: (i) urban space required by road and parking systems, and (ii) negative environmental impacts, concerning noise production and emissions of pollutant gases.

So, what can be said is that the problems of PT are not evident for the occurrence of their disutilities, but rather by its occurrence in undesirable levels [17]. Therefore, the aim is not a system, a network, or a passenger line with zero disutility, because this condition does not exist. The challenge is, however, to minimize the total disutility of PT.

2 Methodology

A simplified structure was developed of quality assessment for disutilities (Table 1) to show the importance of measuring PT quality by its disutilities.

Table 1. Structure of Assessment of Passenger Transport Quality

Disutilities	Components	Performance Indicators
Total Time of Displacement – TTD	Time to Access, Wait, Travel (vehicles) and Transfer	Time (informed or calculated)
Cost	Cost of time, Operational Cost (vehicles) and cost of the infrastructure	Average cost of time and average cost per passenger (calculated)
Insecurity	Traffic Accidents	Insecurity level
Discomfort	Stops, Terminals and Waiting Areas	Discomfort level
	Vehicles	Discomfort level
Environmental Impacts	Urban Space Required	Urban space required level
	Pollution	Greenhouse gas emissions per passenger (calculated)

Source: Adapted [6, 17]

The methodology to build the performance indicators was applied as follows:

- **Time**: the ideal way to establish TTD is to have, separately, the components of time related to accessing, waiting, travelling (in vehicles) and transferring from one mode to another [17]. In case of a lack of these components, it is possible to consider only the average TTD, or assuming, for example, a form of TTD ±10% or ±20%, depending on the period of the day considered;
- **Cost**: is calculated utilizing an average income per person per minute. The Operational Cost is only calculated to “Own Car” in its classical way [18], considering the most common vehicle in the fleet. In this case, it is considered that the cost of infrastructure is embedded in the Operational Cost. An additional cost must be considered for “Own Car” related to parking expenses. For Public Transport, it is assumed that all the costs are embedded in the fares, independently of the level of subsidies and costs of infrastructure;
- **Insecurity**: according to the road fatalities (accidents), it’s possible to infer the level of insecurity, in terms of very high, high, medium, low or very low [17];
- **Discomfort**: for stops, terminals and waiting areas, considering the situation of cleaning, lighting, noise, ventilation, places to sit down, availability of health services, ratio between passengers and capacity in escalators, elevators and ticket offices, it is possible to establish the level of discomfort in very high, high, medium, low or very low [17]. For vehicles, considering privacy, cleaning, lighting and thermal and acoustic comfort [17], it’s also possible to apply the same classification; and
- **Environmental Impacts**: (i) related to Urban Space Required: for the road system, which is shared by cars and buses, it is assumed that the surface devoted to roads and parking in relation to the total urban area allows the establishment of the level of urban space required in very high, high, medium, low or very low [19]. It should be noted that for rail systems, with underground infrastructure, this kind of consideration cannot be applied; and (ii) related to Pollution: the emission of CO_2 represents the main contributor to the Greenhouse effect [19]. Then, from the average rate of emission of CO_2 per vehicle per kilometer multiplied by distance, and divided by passengers, the quantity of CO_2 emission per passenger can be obtained. It should be noted that this calculation is valid for cycle Diesel and cycle Otto engine emissions, even in a hybrid vehicle. In the case of pure electric engines, the emission considered should take into consideration the emission of the respective source of electric energy.

Once the methodology was established, it was necessary to test it using a case study, performed in the Metropolitan Region of Tokyo (MRT). MRT was chosen because its mobility quality ranking index is 49.2 (between Hong Kong - 58.2 and Baghdad - 28.6) [20]. This choice was reinforced due to the size, geographical location and importance, and also because MRT is the most populous urban area in the world [21].
The case study consisted in travelling from Terminal 1 of Narita Airport, the busiest international airport in Japan [22], to Tokyo Central Station, the typical displacement for those who arrive by plane in the Japanese capital [22].
The options for Individual Transport are Own Car and Taxi. For Public Transport we have Bus (Ordinary), shown by Google®, Bus (Limousine Service - charter service from the airport to the main hotels) and Trains, also shown by Google®. The web search engine Hyperdia® was additionally used because it offers an optimized utilization of Public Transport available, providing the below suggestion for Public Transport (Trains), as listed in Table 2.

Table 2. Elements of the Route Terminal 1 of Narita Airport to Tokyo Central Station, by Option

Options	Distance (km)	TTD (min.)	General Conditions	Fares/Expenses (¥)
Own Car	78.3	68	Non- traffic congestion	Parking: 520/day Toll: 2,500
Taxi	78.3	65	Non- traffic congestion	Taxi: 20,500
Bus (Ordinary) (Google®)	78.3	90	Non- traffic congestion	Bus: 900
Bus (Limousine Service)	78.3	60	Non- traffic congestion	Limousine: 3,200
Public Transport (Trains) (Google®)	79.2	93	Out of peak	Train: 1,380
Public Transport (Trains) (Hyperdia®)	79.2	60	Out of peak	Train: 3,020

As shown in Table 2, the elements of each option are:

- **Own Car, Taxi, Bus (Ordinary) and Bus (Limousine Service)** – Distance, TTD and general conditions were obtained from Google®, adopting a condition of non-traffic congestion, while the toll fare was obtained from [23]. The average Taxi fare was obtained from [24], considering that the toll fare is included in the Taxi fare. For Bus (Ordinary) and Bus (Limousine Service) the toll fare is included in the fares, which were also taken from [24]. For Bus (Ordinary) there are direct lines to Tokyo Central Station, the fleet is composed of urban buses with two or three doors, and there is the possibility of not being able to get a seat. For Bus (Limousine Service), coach buses with air conditioning are offered (standing is forbidden), having direct lines to the main downtown hotels in Tokyo, with a headway of 15 min. [24];
- **Public Transport - Trains (Google®)** – Except distance, all the information was obtained from Google®. The average headway is 15 min., sometimes there is no place to sit and there is a compulsory transfer from the Narita Skyaccess line to Oedo Line at the Keisei-Ueno Station and Tocho-Mae Station, whose times are embedded in the TTD [24]; and
- **Public Transport - Trains (Hyperdia®)** – All the information was obtained from Hyperdia®. The Narita Express is a direct line with a headway of 15 min. (non-peak period), and only seated passengers are allowed (previously booked or not) [24].

In addition, some hypotheses were adopted for the six options listed in Table 2 (monetary values were maintained in local currency):

- **Cost**: to calculate the Cost of Time, a basic value of ¥ 30 per person per minute was adopted for all options, corresponding to the "Japan Monthly Average Wages" of ¥ 299,854 in October 2015 [25]. The Operational Cost for Own Car is ¥ 110/km, considering: use of 7.5 years per vehicle, 50% financed, 7,500 km/year distance traveled and fuel consumption of 10 km/l [26]. The daily parking fare of ¥ 520 was obtained from [24], and a seven days usage was adopted. It should be noted that these costs don't represent the "generalized cost", that is, in Transport Economics, the sum of the monetary and non-monetary costs of a journey [8];

- **Insecurity**: for Own Car, Taxi, Bus (Ordinary) and Bus (Limousine Service) a rate of 8.3 road fatalities per billions of vehicle x kilometers was considered [27]. For Public Transport (Trains), the rate of fatalities of 0.009 accidents per millions of train x kilometers was considered [28];
- **Discomfort** (Stops, Terminals and Waiting Areas): a subjective evaluation was adopted by the authors as previously mentioned, based on [17]. For Discomfort (Vehicles), a subjective evaluation was made as above and the disutility component of discomfort related to stress on the drivers (Own Car or Taxi) wasn't considered; and
- **Environmental Impacts** (Urban Space Required): in an urban area like MRT, on average 30% of the surface is devoted to roads, while another 20% is required for off-street parking [29]. Subways and rail have their own infrastructures and, consequently, their own rights of way [29]. (Pollution): the rates of CO_2 emissions in grams per passenger per kilometer, for cars, buses and trains, considering the average occupation per vehicle, in the conditions of the MRT (2012), were obtained from [30], and correspond to 168 g, 60 g and 22 g, respectively [31, 32].

3 Results and Discussion

The results of the case study can be seen in Table 3:

Table 3. Quantitative and Qualitative Measurement of Disutilities

Options	TTD$^{(2)}$	Cost (¥)	Insecurity	Discomfort		Environmental Impacts	
				Stop Term. Wait. Areas	Vehicles	Urban Space Req.	$CO_2$$^{(3)}$
Own Car **(16,793)**$^{(1)}$	68	Time: 2,040 Operation: 8,613 Toll: 2,500 Parking: 3,640	Medium	Low	Low	High	13.2
Taxi **(21,950)**	65	Time: 1,950 Fare: 20,000	Medium	Low	Low	High	13.2
Bus (Ordinary) (Google®) **(3,600)**	90	Time: 2,700 Fare: 900	Medium	Low	Medium to High	High	4.7
Bus (Limousine Service) **(5,000)**	60	Time: 1,800 Fare: 3,200	Medium	Low	Low	High	4.7
Public Transport (Trains) (Google®) **(4,170)**	90	Time: 2,790 Fare: 1,380	Very Low	Low	Medium to High	Low	1.7
Public Transport (Trains) (Hyperdia®) **(4,820)**	93	Time: 1,800 Fare: 3,020	Very Low	Low	Low to Medium	Low	1.7

(1) Total cost (¥) (2) minutes (3) Emissions in kg

The cheapest option is represented by Bus (Ordinary) (¥ 3,600). In the sequence we have Public Transport (Trains) (Google®) (¥ 4,170), Public Transport (Trains) (Hyperdia®) (¥ 4,820), Bus (Limousine Service) (¥ 5000), and Individual Transport, represented by Own Car (¥ 16,793) and Taxi (¥

21,950). In all cases, the Cost of Time represents, respectively 75.0%, 66.9%, 37.3%, 36.0%, 12.1% and 8.9% of the Total Cost, for each option.
The cheaper options (Public Transport) are those which have the best level of security, the lowest consumption of urban space required and the lowest CO_2 emissions per passenger. Public Transport is only lower in the disutility discomfort, due to the lack of privacy, which is relatively preserved in the Individual Transport (Own Car and Taxi). Individual Transport is more expensive, more unsafe, requires more urban space and pollutes the environment more (CO_2 emissions). The consideration of the toll and parking expenses should be taken with care, due to their relatively high values.
Taxi, as the most expensive option, even with a TTD practically equal to that of Public Transport (Trains) (Hyperdia®), costs 6.1 times more than the cheapest option, represented by Bus (Ordinary), but it presents a low level of discomfort. It can be observed that taxis may have limitations related to privacy, because of their characteristic of public service. Equally, taxis have their well-known vulnerabilities, due to the dependency on the drivers' behavior (the way they drive, the way they treat the passengers etc.) and to the kind of vehicle, its maintenance condition and other elements that can affect discomfort and insecurity. Own Car suffers from the same vulnerabilities as taxis, lowering its competitiveness, because, beyond the high costs, the owners are obliged to pay for tolls and parking.
In MRT, due to abundance and quality of Public Transport, the disutilities differences in relation to Individual Transport are intensified in a pro-Public Transport advantage. This is mainly related to competitive TTDs, a very low level of insecurity and a tolerable level of discomfort, in addition to low negative impacts on society, because they require minimal urban spaces and produce very low pollution.
The results still suggest that for Public Transport, if the average wage increases more than the fares, the Cost of Time reduces its participation in the Total Cost, and in Individual Transport the wage growth can be offset by the increase of the other costs and expenses. Thus, it is not the Total Cost that needs to be prioritized in this kind of analysis, but the overall consideration of the group of all disutilities. Moreover, the variability of insecurity and discomfort could dramatically change not only the perception of the passengers, but also the way that they make their choices. Finally, the level of uncertainty of each disutility and the relationship between them should be managed in order to make it possible to build a powerful instrument to support the decision-making process of the passengers, authorities and operators.

4 Conclusion

In summary, we can conclude that the results express a general idea of the comparison between Public Transport and Individual Transport, where the first, even sometimes offering less comfort and more TTD, is cheaper, safer and causes less pollution per passenger than Individual Transport.
On the other hand, the consideration of the Cost of Time could represent an important aspect of the disutilities, and could be questioned in terms of its dimension in the personal economy of the passengers.
Thus, the results should be carefully examined, because they are merely for illustrative purposes and the case study doesn't aim to establish the final supremacy between each option, on the contrary, it aims to demonstrate the possibility and importance of measuring the quality of PT by its disutilities.
Finally, it is expected, however, that new studies may be designed to deepen the research and the calculation of disutilities.

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