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Evaluation of User Costs in Terms of Public Transportation Fare: A Literature Review

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ABSTRACT

The welfare level differs in every geography depending on the economy. This also differentiates the variables that are taken into account when determining transportation fares. While underdeveloped or developing countries determine prices by focusing only operating and investment costs, developed countries take user and environmental costs into consideration. However, the failure to describe the parameters used in determining these costs leads to the emergence of ineffective pricing policies. Especially the concept of user cost has become the focus of human-oriented policies in recent years. To this end, the paper provides a literature-based analysis of user costs using in calculation of public transportation fare. The fact that the studies in the literature did not address user costs in a clear framework has created an important gap in this regard. The aim of this study is to fill this gap in the literature by systematically examining the user cost factor affecting transportation fare and to provide a source for other research.

1. Introduction

Increasing the mobility of inhabitants in a region and the quality of life is possible through the designing of sustainable transportation systems. Both public transport pricing and ridership are important to ensure profitability and sustainability in public transport (PT). Reduced PT costs can increase ridership and reduce service quality while providing lower pricing. Conversely, increasing in ticket prices due to PT costs can reduce ridership and improve service quality. Providing the balance between public transportation pricing and the demand affects positively both the operator and the user. Therefore, it is necessary to understand the factors that affect transportation costs and to determine their relationship each other.

Previous studies show that there are different interpretations while classifying PT costs. Pozdena and Merewitz [1] examined rail costs by dividing them into fixed and variable costs. Wirasinghe and Seneviratne [2] examined urban transport costs under four headings; user time cost, operating cost, rail cost (resulting from land acquisition, construction, station and maintenance costs), fleet cost

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depending on ridership. Stone *et al.* [3] and Savage [4] examined costs only as operating and investment costs. Parajuli and Wirasinghe [5] classified transportation costs as user costs, operating costs, and environmental costs such as noise and pollution. Jha and Oluokun [6] divided the costs into three categories: investment cost (land acquisition and construction of facilities such as stations, parking), train operating cost, travel frequency-dependent operating cost, and user cost (access to the station, travel time). Similarly, O'sullivan [7] divides urban transport costs into three headings showing the rail cost under investment costs, but without showing the fleet cost as the main parameter. Jha *et al.* [8] examined costs by dividing into two. As opposed to other studies, the authors evaluated rail and station construction costs, expropriation costs and excavation costs within the scope of operating costs. On the other hand, they showed the parameters of access to the station, travel time and waiting time as user costs. Martinez [9] examined user time cost, user money costs and vehicle operating costs under user transport costs. Unlike other researchers, external costs that have a burden and cost to society, but do not require direct payment, were also described as major costs. Health, accident, social costs and carbon emissions were evaluated under external costs. Like in similar researches, Verma *et al,* [10] added user costs in addition to capital and operating costs to their model and presented an objective function. Li and Yin [11] examined costs under internal and external costs. Accordingly, planning and design costs, construction costs and operating costs were categorized as internal; costs due to traffic, noise, air pollution and other environmental factors were categorized as external. Z. Li *et al.* [12] divided rail transport costs into train operating cost, railway line cost, and railway station cost. Unlike other researchers, Tsai *et al.* [13] adopted the approach that only operating costs affect public transport pricing. In our study, we examined rail public transit costs under three main headings as capital cost, operating cost and user costs. Xueyu and Jiaqi [14] cited operating costs, travel demand and willingness to pay, competition between modes of transport, financial targets and government regulations as affecting factors of public transport pricing.

Based on past studies and missing aspects, it would be more accurate to collect public transportation pricing costs under four main headings. These; capital costs, operating costs, user costs and environmental costs. Except for user costs, all other costs may vary depending on the region and public transportation mode. However, user costs are related with human. Hence travel behavior is a key factor for user cost and its components are constant under all conditions. Although there are many studies in the literature that adopt the user costs factor and optimize transportation fare, there is no study that treats this cost type in a systematic and holistic way. The main purpose of this paper is to fill the gap in literature by explaining the user cost factor and its applications. In addition, this study will not only be limited to definitions, but will also be the source of future research on formulations used to obtain user cost components.

The remaining contents of the study are as follows. The second section discusses the transportation literature related to user costs. In addition, the concept of user cost and the components of this cost type in the literature is intended to be transferred within a broad framework. According to this framework, Section 2 also examines the user cost types and its applications in the literature. Section 3 discusses the concept of time value, the most basic parameter used in the calculation of user costs and its place on literature. Section 3 examines the methods used to obtain the value of time. The important points and summary of the whole study are given in Section 4 with suggestions and discussion.

2. User Costs

Passengers are interested in parameters such as waiting time, service level, and in-vehicle travel time in order to travel the best way. They also consider this when selecting the mode of PT. Therefore, it is important to be able to define the components of user costs well and to understand their relations with other components in order to make the right decisions about transportation policies. User cost is defined as the cost to which passengers are exposed. Studies on user costs have been the subject of various researches as an element of transportation policies. The components used in the calculation of transportation fare were handled by different authors with different optimization techniques. Table 1 contains information summarizing the literature in these respects.

Table 1
Studies on Public Transportation Pricing

Author	Year	Mode	Area	Model	Parameters
Xueyu and Jiaqi [14]	2013	Railway	China	Bi-level Programming Model (Particle Swarm Optimization Algorithm)	Operating Cost
Deng, Liu, et al. [15]	2014	Railway (Metroline)	China	Nonlinear Optimization Model (Simulated Annealing)	Operating Cost
Borndörfer et al. [16]	2012	Bus, Tram, Railway, Ferry	Germany	Nonlinear Optimization Model (Discrete Choice)	Operating Cost
Huang et al. [17]	2016	Bus	China	Bi-level Programming Model (Genetic Algorithm)	Operating Cost
Parry and Small [18]	2009	Bus, Railway	USA & United Kingdom	Analytical Model	User Cost, Operating Cost, Capital Cost
Liu et al. [19]	2017	Railway (Metro Line), Bus	China	Bi-level Programming Model (Genetic Algorithm)	Operating Cost, User Cost (named Travel Cost)
Tang et al. [20]	2017	Bus	China	Mixed Integer Nonlinear Programming Model (Penalty Algorithm)	Operating Cost, User Cost
Jansson et al. [21]	2015	Bus	Sweden	Algebraic Model	Operating Cost (named Producer Cost), User Cost
Kaddoura et al. [22]	2015	Bus	Germany	Agent Based Modelling	User Cost, Operating Cost, Capital Cost
Wang and Deng [23]	2019	Railway (Metroline)	China	Nonlinear Optimization Model (Simulated Annealing)	Operating Cost, User Cost
Yook and Heaslip [24]	2014	Bus, Railway	USA	Bi-level Programming Model (Genetic Algorithm)	Operating Cost, User Cost
Tirachini et al. [25]	2014	Bus	Australia	Multimodal Social Welfare Maximisation Model	Operating Cost, Capital Cost
Chin et al. [26]	2016	Railway (Metroline)	Canada	Stochastic User Equilibrium Model	Unspecified
Lam and Zhou [27]	2000	Bus, Railway	China	Bi-level Programming Model (Heuristic Solution Algorithm based on a Sensitivity Analysis)	Unspecified
Chien and Tsai [28]	2007	Railway (Metroline)	USA	Sensitivity Analysis	Operating Cost, User Cost (but not specified)
Tsai et al. [29]	2008	Railway	Taiwan	Nonlinear Optimization Model (Sensitivity Analysis)	Operating Cost
Li et al. [30]	2008	Bus, Railway (Metroline)	China	Network Equilibrium Model	Operating Cost, User Cost (but not specified)

Author	Year	Mode	Area	Model	Parameters
Li & Yin [11]	2012	Railway	China	Analytical Model (Heuristic Solution Algorithm)	Operating Cost, Capital Cost, User Cost (but not specified)
Zhou et al. [31]	2005	Bus, Railway	China	Bi-level Programming Model (Heuristic Solution Algorithm)	Operating Cost
Neumann [32]	2007	Bus, Railway	Germany	Discrete Choice Model	Operating Cost (but not specified)
Borndörfer et al. [33]	2006	Bus, Railway	Netherlands	Nonlinear Optimization Model (based on a discrete choice logit model	Operating Cost (but not specified)
De Borger et al. [34]	1996	All	Belgium	A Static Partial Equilibrium Model	Social Cost

Deng, Zhang, *et al.* [35] took advantage of the simulated annealing algorithm in their study, which contains fare optimization for a public transportation system operated under an elastic demand. In the study, user cost were detailed as waiting time, in-vehicle time, congestion cost and fare spending. However, congestion cost is a geographically variable parameter. In other words, it may have a significant effect where population of city is very high, but it does not have a significant effect in other regions. Parry and Small [18] ignored congestion cost for rail system and took into account access time, in-vehicle time and waiting time. Verma *et al.* [10] aimed to identify an optimal railway corridor from the users' and operators' point of view. Because the model was a complex, multi-purpose and intense problem, a GIS-based approach was used for optimization. Waiting time, in-vehicle travel time and access-egress time were considered as user costs. Objective function for user cost was presented in the study of Verma *et al.* [10] as follow;

$$U_C = \sum_i \begin{matrix} \{(q_{(wi)} \cdot t_{wi}^{a} \cdot \gamma_{(walk)}) + (q_{(oi)} \cdot t_{oi}^{a} \cdot \gamma_{(other)})\} + \\ \sum_i \{(p_{(wi)} \cdot t_{wi}^{e} \cdot \gamma_{(walk)}) + (p_{(oi)} \cdot t_{oi}^{e} \cdot \gamma_{(other)})\} + \sum_i (T_{(sj)} \cdot R_{(j)} \cdot \gamma_{(riding)}) \end{matrix} \tag{1}$$

where,

$\gamma_{(walk)}$the average walk time cost,
$\gamma_{(riding)}$ the average riding time cost,
$\gamma_{(walk)}$ the average access/egress cost.

Zhu *et al.* [36] tried to solve the timeline design problem for the urban railway line. In the study, a bi-level optimization model was solved by using two-stage genetic algorithm. While the user cost was determined, the value of time and the penalty costs were taken into account in addition to the waiting time and in-vehicle travel time. On the other hand, Chen and Nie [37] examined the penalty costs separately from other parameters. Accordingly, user cost metrics included three main components: waiting time, in-vehicle travel time, and penalty cost for each transfer between two fixed lines. Tirachini *et al.* [38] created a model based on user cost and operating cost in order to minimize the total cost, and added a crowd-related penalty factor to the in-vehicle time cost. Some researchers have evaluated user costs based on access and egress time, waiting time, in-vehicle travel time, and the value of time [12], [39-42]. Samanta and Jha [40] developed a problem of combinatorial optimization on the layout of a railway line. In this problem, which was solved by using genetic algorithm based on a Geographical Information System (GIS) database, user cost was expressed as follows:

$$\begin{aligned} UC = (&access\ time(at) x\ unit\ access\ cost(uac) + \\ &unit\ travel\ cost(utc) x\ invehicle\ travel\ time(tt) + \\ &unit\ waiting\ time\ cost(uwc)\ x\ waiting\ time(wt))\ x\ demand \end{aligned} \tag{2}$$

In-vehicle travel cost can also be called as the riding cost ([5], [8], [10]). Genetic algorithm and geographic information system approach were adapted to railway line optimization and the need for data was met with GIS in the study of Jha *et al.* [8]. Parajuli and Wirasinghe [5] proposed a decision analytical model for the selection of public transport technology and created a decision tree in their study. In the study, user costs were shown as waiting costs, access and egress cost and riding cost and are expressed as follows:

$$c_u = \sum_{k=0}^{n+1} (c_{ae}.(s_k^*) + c_r.(s_k^*)) + c_w.(h^*) \tag{3}$$

where,

c_{ae} - the access/egress cost,

c_r - the riding time cost,

c_w - the waiting time cost.

User costs and operating costs are always in a conflict. Reducing the cost of waiting time requires increasing the frequency of headways. However, this increases operating costs. Verma and Dhingra [43], who tried to minimize both operating costs and waiting times of passengers, took into account only the cost of waiting time as user expense. Lai and Schonfeld [44] associated unit user cost with daily demand and travel time. Chowdhury and I-Jy Chien [45] who create a model for optimizing the coordination of the intermodal transit network, cited user costs as total waiting cost, in-vehicle travel time cost and transfer cost. In J. Li *et al.* [46]'s study based on fleet size, it is assumed that access and exit times were not affected by the fleet size and that the user-perceived cost consisted of two parts: these are PT pricing and travel time.

2.1 Access and Egress Cost

Although the first and last parts of the journeys represent a significant part of the total travel time, access and egress times have been studied very scarcely in the literature. However, this issue has attracted some researchers recently. The length of access and egress time is a crucial factor for the mode choice of public transport passengers [47]. Ignoring such factors in pricing policies can cause ineffective transportation projects.

Access time is the time from a door (e.g. school, work, home, etc.) to the first transportation infrastructure used in the city [48]. Access to the public transport system is divided into two, access to the transport line and access within the line. Access to the transport line is time spent on foot, subway, bus or car (taxi, private car, etc.) to reach the train station. Access time within the line is the duration, which takes to get on the train by walking along the platform after entering the station. On the other hand, the egress time is defined as the duration from the used transportation infrastructure to the final destination [41].

Passenger access and egress time depends on the walking distance between the passenger's position and the station to which the passenger wishes to reach and the walking speed of the passenger. Shorter distances between stations can reduce passengers' access time to stations. However, this may increase average passenger in-vehicle travel time and operating costs due to acceleration and deceleration delays derived from frequent stop and go. On the contrary, a longer station distance can increase trains operating speed and reduce the average in-vehicle travel time, but it can also increase the average passenger access time to stations [12]. In reference to Tirachini *et al.* [49], the cost of access time is not affected by the headway that are tried to be accessed. Nevertheless, it depends on the transportation mode.

Access and egress time can be calculated with public transit surveys or data obtained from urban and regional transit agencies and operators. Goel and Tiwari [47] applied a survey to Delhi metro passengers. The survey divided into two segments; outside and inside the public transportation system. Access and egress parameters such as mode and time constituted the main part of the survey. Moyano *et al.* [50] aimed to evaluate the importance of access and egress times from/to high-speed rail stations. Data collection was completed in two steps. Firstly, data were obtained from General Transit Feed Specification files. This public transport data was complemented by a pedestrian network that would allow real pedestrian access to stations to be modelled.

Access time cost was mathematically expressed by Tirachini *et al.* [49] as follow:

$$c_a = P_a \frac{d}{2v} y \tag{4}$$

where,

P_a - value of access time savings
v - walking speed
d - the distance between two consecutive stations
y - demand.

Zhao *et al.* [42] introduced a formulation of access cost as follows:

$$c_a = u_a \sum_{o \in O} q_o \cdot t_{a_0} \tag{5}$$

where,
u_a - the value of passenger access time,
q_o - demand,
t_{a_0} - the average access time

The average access time is calculated by dividing the average access distance by the average passenger access speed.

$$t_{a_0} = \frac{D_{K_O} + D_{L_O}}{V_p}, \forall_O \in \ 0 \tag{6}$$

O'sullivan [7] multiplied the access time by the marginal disutility of the access time to calculate access time cost. The marginal disutility of the access time is the amount of money the passenger is willing to pay to avoid one minute of access time. Another definition used for the marginal disutility of access time is the opportunity cost of access time. Tirachini *et al.* [49] defined this as the value of access time savings. Zhao *et al.* [42] called the same parameter the value of the passenger access time.

Goel and Tiwari [47] investigated the association between access-egress mode and trip length, vehicle ownership, access-egress location, and population density through a multinomial logistic regression model. According to the study, while travel length has not an impact; vehicle ownership, spatial variations and population density have a significant impact on access and egress. Moreover, using the duration of access and egress, interconnectivity ratio was estimated. This concept helped to understand trip length differences between public transit modes. Moyano *et al.* [50] calculated travel times, which included access and egress time through network analysis GIS tools. The results showed that access and egress times varied depending on changes in traffic, congestion and frequency of public transport services.

2.2 Waiting cost

The waiting time of the passengers at the stations is one of the most crucial criteria in evaluating the quality of public transportation vehicles. The duration from the arrival of the passenger to the train station until the boarding of the train is called the waiting time. Waiting time and quality of service are interacted each other. Accurate determination of waiting times enables optimal scheduling frequency of travel. The headway between trains increases the waiting times for passengers, which reduces service quality and operating costs. On the contrary, if the headway is high, the waiting time of the passenger decreases and the service quality and operating costs increase. However, even with high service frequency during peak hours, passengers cannot be satisfied because of in vehicle comfort or waiting time. Because of the high ridership, some passengers may not want to entrain and they may want to wait for the next train. This situation causes increasing both the crowd in the stations and the waiting time [51].

When the waiting time is low, passengers usually arrive at the stations at random, but when the waiting time is high, there is usually a timetable and most passengers arrive at the station according to this schedule to reduce waiting times [49]. Waiting time cost is a product of some parameters such as average waiting time, demand and the value of waiting time [45]. Another factor affecting waiting time is train speed. Higher train speed also reduces waiting times. However, this means an increase in braking and launch times.

There are various ways of collecting data for waiting time. Parry and Small [18] calculated waiting times over service frequency, which is one of the data obtained from transport authorities. In doing so, an elasticity coefficient that varies according to travel frequency was used:

$$\eta_w^{ij} = \left|dw^{ij}/df^{ij}\right| \times \left(f^{ij}/w^{ij}\right) \tag{7}$$

where,

η_w^{ij} - wait cost elasticity,

w^{ij} - waiting time divided by passenger mile,

The general formulation of waiting time is shown below,

$$W = \sum_{ij \neq iCAR} w^{ij} M^{ij} \tag{8}$$

where,

W - is the time spent waiting at stop,

M^{ij} - is passenger miles traveled during period i by mode j.

Parajuli and Wirasinghe [5] expressed waiting cost as follows:

$$c_w(h) = \frac{P_{\gamma wt}}{2}\left[\psi\, \overline{h_p} + (1-\psi)\overline{h_{op}}\right] \tag{9}$$

where,

$\overline{h_{op}}$ - off-peak headway,

$\overline{h_p}$ - peak headway,

ψ - the fraction of total demand,

γ_{wt} - the unit wait time cost per passenger,

P - demand.

This formulation, which also shows the change in demand during peak hours, also reflects the relationship between headway and waiting time.

Similarly, Chowdhury and I-Jy Chien [45] used demand and headway to calculate waiting time. However, since this study aimed to optimize the coordination of the intermodal transit network, the cost of transfer was also added to the formulation;

$$c_w = \frac{1}{2}\left(\sum_{i=1}^{n}\sum_{j=1}^{mi} H_{ij} I_{ij1} + \sum_{i=1}^{n}\sum_{d=1}^{2} H_r \alpha_{id}\right) u_w \tag{10}$$

where,

H_{ij} Headway of bus route j at station i,

I_{ij1} the demand of bus route j in direction 1 at station i,

H_r Rail headway,

α_{id} Rail demand walk to station i in direction d,

u_w the value of users' wait time.

According to Chien and Schonfeld [39], the waiting cost for rail systems is the multiplication of the user's waiting time value and the total demand, with the average train waiting time, which is half of the rail headway as shown below:

$$c_{WT} = \frac{WH_T u_W}{2} \sum_{i=1}^{k} (q_i + d_i) Z_i \quad (11)$$

where,

W - zone width,

u_w - the value of user wait time,

H_T - the rail headway,

q_i - the demand density originating in zone I,

d_i - the demand density destined for zone i,

Z_i - zone length.

Zhao *et al.* [42] developed a mathematical model for the optimization of bus stops. Genetic algorithm was applied in the study. Waiting cost was calculated based on demand, total waiting time and value of waiting time. Mean headway and headway variance at stop were taken into consideration while calculating the waiting time in this formula.

$$c_w = u_w \sum_{i \in I} b_i \cdot t_w \quad (12)$$

where,

b_i - the number of boarding passengers at stop i,

t_w - the average wait time at stop i,

u_w - the value of passenger waiting time,

$$t_{w_i} = \frac{H}{2} + \frac{V_i}{2H}, \forall i \in I$$

where,

H - mean headway

v_i - headway variance at stop i

Deng, Liu, *et al.* [15] explained the waiting time formula by simply linking it to the headway as follows:

$$t_w = \frac{1}{2} H / 60 \quad (13)$$

Chien and Tsai [28] developed an optimization algorithm to maximize profit in public transport pricing under service capacity constraints and opted for a solution similar to the Gauss Southwell and Powell methods. In this study, the waiting time was calculated as follows.

$$t_w^t = \alpha H^t \quad (14)$$

where,

α - the ratio of average wait time,

H^t - headway.

2.3 In Vehicle Travel Time (Riding Time) Cost

In-vehicle travel time cost refers to the cost caused by the duration between entrain and detrain for varying travel depending on the train station platform length and the running speed of the train. In other words, in-vehicle time cost is the cost of the total time spent by passengers during the time a train travels between stops and dwells at stations [45]. That is, in-vehicle cost can be classified into train run time cost and dwell time cost. In-vehicle travel time depends on route length and travel conditions. The delay of the trains' movement due to entraining and detrain of passengers, causes a decrease in service quality and an increase in operating costs in addition to user costs. In a crowded vehicle, detrain time also increases due to passengers who are standing. Hendrickson [52] stated that other factors such as the amount of baggage of passengers, the physical structure of the vehicle or station and number of entrance door increased the duration of detrain. In addition, other studies show that passengers are willing to pay more if there is less crowd in-vehicle [53,54].

Travel times between stations, the demand corresponding to each station and the value of time are the constituent parameters the cost caused by train run time between stations. The in-vehicle cost resulting from the waiting time of the train at the stations can be obtained by demand, the dwell time and the value of time. Chowdhury and I-Jy Chien [45]'s in-vehicle cost formula includes in-bus cost and in-train cost together. The in-train part of this formulation is as follows;

$$C_{in-vehicle(train)} = \sum_{i=2}^{n-1}\sum_{d=1}^{2}[A_{id} - \{I_{id}(2-d) + Q_{id}(d-1)\}]\,(I_{id} + Q_{id})\frac{H_r}{q_r}u_v + \sum_{i=1}^{n-1}\sum_{d=1}^{2}\frac{A_{id}I_i u_v}{V_r} \tag{15}$$

where,

A_{id} - difference of rail demand and rail outflows,
I_{id} - rail demand in direction 1 at station i,
d - index of rail service directions,
Q_{id} - rail outflows at station i in direction d,
H_r - rail headway,
q_r - the passenger boarding and alighting rate,
u_v - value of user in-vehicle time,
I_i - interstation spacing between station i and i+1,
V_r - average train running speed.

Similarly, Parry and Small [18] calculated the in-vehicle time over train run time and stop time, as shown below:

$$t_I(i,j) = \frac{w(i,j)}{v} + |j-i-1|t_0 \tag{16}$$

where,

t_0 - train operation time and stop time of each intermediate station,
v - train speed,
$w(i,j)$ - mileage between two station.

$$t^{iR} = t^R + \theta^R o^{iR}$$

where,

t^{R} - travel time while moving.

θ^{R} - the average dwell time per passenger from boarding and alighting divided by trip length

o^{iR} - vehicle occupancy.

Li *et al.* [12], as in others, split the in-vehicle time into non-stop line-haul travel time and train dwell time. When calculating the non-stop line-haul travel time, the distance travelled is divided by the average train speed:

$$T_{s1} = \frac{D_s}{V_t}, \forall s \; = \; 1,2, \ldots . N \tag{17}$$

where,

D_s - Distance of station s from the CBD,

V_t - Average train cruise speed.

Dwell time was considered as constant for all stops as in the other researches [39],[55-58] and the following formulation was used.

$$T_{s2} = \beta_0(N + 1 - s), \forall s = 1, 2, \ldots . N \tag{18}$$

where,

β_0 - Average train dwell time at a rail station.

Contrary to all these studies, Liu *et al.* [19] ignored dwell time and they calculated in-vehicle time only by dividing the distance between stops by vehicle speed.

$$T_{L_m} = \sum{}_{L_m} d_{I_m}/V_m, m \in \{b, s\}, \; I_m \in \; L_m \tag{19}$$

where,

d_{I_m} - the length of each unit segment of transit service *m,*

V_m - the average vehicle operating speed of mode *m,*

L_m - the set of travel segments in transit line.

3. Value of time

The value of time is the most basic parameter used to calculate all user cost components. It is defined as a cost assigned to the user's delay [59]. Assuming that the time has a monetary equivalent; time losses due to waiting time, travel time and access time, can be expressed in monetary terms. Various parameters such as travel time, transport mode, time interval at which travel takes place, purpose of travel, environmental factors, characteristics of passengers, income per hour and comfort affect the value of time [60,61]. Li *et al.* [51] proposed an optimization strategy about service frequency in order to achieve a balance between service quality and operating cost. In order to determine the value of time, they applied a survey and the results in Table 2 were obtained. According to the study, it was understood that the time values of passengers could vary according to the time period and public transportation mode.

Table 2
Passengers' value of time in each period [51]

Periods (n)	Urban rail transit	Bus
n=1,2 (6:00-7:00)	11.5	8
n=3,4 (7:00-8:00)	14.5	10
n=5,6 (8:00-9:00)	19.2	13.2

Value of time also varies regionally according to rural or urban settlements. In a study conducted in Florida, the value of time in urban areas was detected to be about $ 12 per hour, while the value of time in rural areas was detected to be about $ 10 per hour [62].

The value of time was calculated by some researchers by the mode choice approach and the income approach [63,64]. The mode choice approach was used to estimate the value of time during weekdays and weekends, depending on vehicle types. With the income approach, value of time can be calculated with a correlation of per capita gross national product and individual's working hours. Differences in passenger income levels may change priority expectations for public transport. The higher the income level, the higher the time value. In addition, passengers who have higher income tend to choose a faster and more expensive mode of transport. Athira *et al.* [65] calculated the value of time by evaluating monthly income per person and length of travel. According to the study, as the monthly income increases, the value of time increases, and the length of the trip has a positive effect on the value of time. Ambarwati *et al.* [64] argued that the time value of personal car users is about 1.5 times higher than the value of public transport users and that the time value of trips during the week is twice that of the weekend. Wardman [66] showed the value of time by modelling travel behavior and demand forecasts. In this study, in addition to the effect of monthly income and distance, it was concluded that the purpose of travel and the mode of transportation are also important components affecting the value of time. It is widespread to use the monetary value of time when calculating costs. Li *et al.* [22] determined the monetary cost by multiplying the value of time by travel time. Surbakti and Pinem [67] calculated the value of time with utility maximization (mode chose approach), random regret minimization, and income approach.

4. Conclusion

The uncertainty of the parameters related to user costs and the inadequacy of researches in the literature necessitated a systematic evaluation of the issue in terms of both transportation engineering and economics. Although different user costs approaches are taken into consideration in the researches, no qualified classification and definition has been made. This study has tried to fill the gap in this area and aimed to be a pioneer in order to make future studies more appropriate. In the study, the variables used in transportation pricing calculations were re-determined based on the literature. Since these costs, except for user costs, may vary due to the public transport type and regional changes, only focus was placed on user costs, which can be drawn to a general framework that is always valid everywhere.

User costs are basically divided into waiting cost, access and egress cost and in-vehicle cost. The most basic parameter used in determining these costs and common to all user costs is the value of time of the passenger. This value can be calculated simply by GDP or by mode selection approach. Travel behavior surveys can be applied to obtain this parameter. In this study, other parameters and calculation methods of the user costs are also mentioned. For the future studies, we propose a systematic explanation of other transportation cost concepts according to regional and mode-based conditions. In particular, the lack of adequate studies in the literature on environmental costs remains a gap that needs to be addressed in the transport economy.

Author Contributions

Conceptualization, I.G. and A.K.; methodology, I.G.; investigation, I.G. and A.K.; resources, A.K.; writing—original draft preparation, I.G. and A.K.; writing—review and editing, I.G. and A.K..; visualization, A.K.; supervision, I.G.; All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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