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Let Me Save You Some Time... On Valuing Travelers' Time in Urban Transportation

Maria Nordström, Sven Ove Hansson, & Muriel Beser Hugosson
KTH Royal Institute of Technology

Abstract

Systems of urban transportation are largely shaped through planning practices. In transport economics, the benefits of infrastructure investments consist mainly of travel time savings calculated using monetary values of time. The economic interpretation of the value of travel time has significantly shaped our urban environment and transportation schemes. However, there is often an underlying assumption of transferability between time and money, which arguably does not sufficiently take into account the specific features of time. In this paper, we analyze the various properties of time as an economic resource using findings in behavioral economics and psychology. Due to limitations in the standard model, it is proposed that an alternative model value should be investigated in which time rather than money is the primary carrier of and the basic features of such a model are outlined. An improved understanding the nature of time as a source of utility puts us in a better position to determine what aspects of time matter. Additionally, the analysis can be applied to further develop modeling where value of time plays a significant role; such as new models for the planning of urban transport.

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Correspondence: marnords@kth.se

Introduction

Spending time is unavoidable. Whether we like it or not, time is being spent and we usually do our best to spend it in ways that make our lives better. In a way, time can seem like money, which is even reflected in the way we talk about time (Brown 1970). We *spend* time, *can't afford* to spend time and *waste* time when it isn't *worth* it. Nevertheless, time differs from money and from most commodities with a monetary value in several ways. In particular, it cannot be bought, sold or otherwise transferred between persons. Although a person can sell and give her own (work) time to another person, she cannot give time for that other person to spend or use herself.

It is clear that we value our freedom to decide how to spend our own time. In our private lives we can allocate our time so that it influences our wellbeing directly, such as doing something we truly enjoy, or indirectly, such as working in a tedious but well-paying job. We are also willing to spend money to reduce the time we need to devote to certain activities. Some activities that are time demanding without directly adding to our wellbeing, such as the commute to and from work, are necessary. In this sense, the demand for travelling is a demand derived from our needs and wants to be at certain locations, sometimes at certain times, though not all demands for travel are purely derived (Mokhtarian and Salomon 2001). In transport economics, travelling is seen as a means to something else. In modern societies, we usually need to physically move from one place to another in order to work and engage in other activities. We often plan our days according to where we need to be and when, and we rely on modes of transportation to carry out such plans.

In economic analysis of public policy, it is common to assign monetary value to time to compare alternatives options in public decisions where time is a factor. When quantifying 'typical' costs of travel, the dominating elements are travel time and the unreliability of travel time (Small 2012). Therefore, the value of time savings has a critical role when calculating potential benefits of a transport improvement. In a recent paper, the use of the term 'savings' has been questioned on the grounds of being misleading and unhelpful since time cannot actually be stored or borrowed (Daly and Hess 2019). This has also been noted in earlier works (Truong and Hensher 1985). Still, as of now, the expressions *travel time savings* and *value of travel time savings* are commonly established terminology in transportation economics. Increased travel time savings is one of the most prominent goals of transport investments (Mackie et al 2001; Small 2012). In transport science, the benefits of a certain intervention are usually calculated by carrying out a cost-benefit analysis (CBA) and counting time savings (including factors such as improved reliability) as part of the economic gains obtained from the intervention. A monetary value of

time (depending on the mode, comfort, type of trip, etc.) is used to calculate the worth of the total time saved for all travelers in monetary terms.

There is no question that it is a practical necessity when performing these calculations to have values of time that can be used in evaluating transport infrastructure projects or forecasting travel behavior. However, the traditional way of measuring the value of time depends on the assumption that time can easily be evaluated in terms of money and that the outcome of this evaluation reflects the underlying preferences of individuals regarding time. The usual argument in favor of monetizing all the aspects of the decision is that in the end, the different dimensions of a complex decision problem will always have to be weighed against each other, and presumably it is better to do this as transparently as possible, with all the conversion factors publicly known. Critics have pointed out that the monetary values may be misleading, that the calculative procedure furthers technocracy rather than democracy, and that decisions often have important aspects that will not be included in the calculations because they are too difficult to quantify (Metz 2008; Naess 2016; Vickerman 2017). Although the monetization of time is not as controversial as that of human fatalities (which has often been dismissed as morally repulsive), this criticism applies to time valuations as well. Even if we are able to compare different ways of using time with each other, it does not follow that we are able to compare these temporal alternatives with other entities such as sums of money. As we will show more in detail in Sections 5, 6 and 7, our valuations of time have properties that make them quite distinct from our valuations of money and of goods that we are used to value in monetary terms. This means that the economic models standardly used in the planning of urban transport are philosophically unsatisfactory and do not adequately represent the ways in which we value our time.

Based on these problems with the standard model, we will also consider an alternative approach that takes the disposition of time as the only ultimate source of utility (Zeckhauser 1973). Some of its major aspects can be divided into two categories: aspects due to the nature of time (as a commodity) and aspects due to the interconnections between activities and their temporal location. In the first category, we place the characteristics of time: non-accumulativity, irreversibility and non-transferability. These are innate characteristics that set time apart from other commodities and goods. In the second category, we consider the following four aspects: (i) process vs goal gains, (ii) the temporal division of activities, (iii) the order of activities and (iv) the notion of 'joint production'. Based on an analysis of the characteristics of time as well as research on behavioral economics and temporal well-being, we will argue that it is warranted to require transportation models to consider and account for the specific nature of time rather than take its comparability to money for granted. Such an argument should particularly be seen through the lens of

value of travel time savings, since this is the main benefit of many transportation investments and thus significantly impacts transportation schemes and urban development as a whole.

Projects that free up more time for individuals to spend in whichever way they like, such as doing more work, being with family and friends, traveling elsewhere or carrying out other activities, can reasonably be assumed to increase human welfare. However, they have to be compared to other values that public funds can be spent on, such as safety, sustainability, and individual health. Such comparisons are made in cost-benefit analysis by comparing the monetary values assigned to these other factors of the project. Yet, these comparisons are only reliable to the extent that the monetizations of the different factors are all adequate and fully comparable. We argue that this is far from indubitable. In the next section, we will briefly present the theory of valuing time that is standardly used in urban transport planning and the methodology of value of time studies. This will be followed by a section on the underlying assumptions of welfare economics. Section 4 presents the generally acknowledged basics of modeling value of travel time in transport economics, and in Section 5 we discuss the inherent characteristics of time as an object of economic analysis. In Section 6, we consider findings from behavioral economics and psychology that further nuance the relationship between time and money. Thereafter, in Section 7, we consider aspects of a model of time as the primary source of utility and in Section 8 we connect these aspects with the notion of value of travel time. Lastly, conclusions are drawn in Section 9.

The theory of valuing time

Methodology of value of travel time and value of time studies

Every day, we make numerous decisions on how to spend time. Some of these decisions reflect the way we value time, for example if we prefer to buy a more expensive ticket for the express train rather than traveling on the cheaper, slower train. Other decisions are more long-term, such as where to live and where to work. If the place of residence is far from the workplace, spending time travelling is unavoidable (assuming working from home is not an option). This is reflected in the housing market; more central locations that can be assumed to have shorter travel time to numerous workplaces are usually more expensive (Black 1981). Other factors are obviously also considered when we choose (if we have the option to choose) where to live and work. Furthermore, most of the work that has been performed on the value (and evaluation) of time has apparently

taken place in transport economics[1], which is therefore the area to which we can turn for previous attempts to assign value to time.

The underlying assumption in 'traditional' economic valuations of travel time is that time is an economic resource which individuals allocate so that it maximizes their personal utility (De Palma et al 2011; Hensher and Button 2007). All individuals are assumed to have the same quantity of this resource, and it cannot be stored, only reallocated between activities. The value of allocating time to a particular activity can be measured in monetary terms, which allows policymakers to examine whether the monetary costs (such as the costs of building a new road) are lower than the monetary benefits (the 'saved' value resulting from quicker journeys). Generally, there are multiple factors to be considered that may have an impact on the value of time (Abrantes and Wardman 2011; Small 2012). It is common to distinguish between types of trips based on their purpose, for example between travel done for business purposes and other travel (including commuting). It is also of interest to take the different modes into account, i.e. to distinguish between travel by car, bus, train and so on. This reasoning results in several values of time, depending on the characteristics of the trip. Other factors can also be incorporated, such as travelers' incomes and the types of jobs they have. The characteristics of the journey are also considered, such as if there is crowding, how reliable the travel mode (car, bus, train, etc.) is and the levels of comfort during the trip (Shires and De Jong 2009).

Commonly, the values of travel time used for appraisal and forecasting purposes is based on the results of two types of empirical studies. The first type is stated choice studies using discrete choice models (stated preference) while the second type of studies are based on observations of how travelers actually travel (revealed preference). In stated preference studies, respondents are asked to make a choice among a set of hypothetical alternatives, such as to accept or decline a monetary bid in return for longer travel time (or accept a monetary loss for faster travel time, depending on the design of the study). Often, the options are tied to an actual trip they are taking to make the choice as realistic as possible. The observed trade-off between time and money makes it possible to derive a marginal rate of substitution between travel time and cost, and this rate is seen as the willingness to pay (WTP) to reduce travel time. When we pay to spend a little less time in transit, we pay to exchange the saved travel time for time to be spent on a more desirable activity. The overarching assumption is that there is a sufficiently stable, average value of time to be used for modelling purposes. Since stated preference surveys are based on hypothetical choices and may not always reflect actual preferences, the second type of

[1] Value of time from a different perspective is discussed in the context of time poverty (Williams, Masuda, and Tallis 2016) and in work related to temporal autonomy (Goodin, Rice, Parpo, and Eriksson 2008) among others.

studies, revealed preference studies, can be used to corroborate the stated preference evidence. Revealed preferences, such as ticket sales data as well as statistics of road traffic can be used to test the validity of stated preference since they represent actual choices made by the travelers (Wardman 1988).

While revealed preferences can confirm that travelers indeed act according to their stated preferences, some scholars argue that this still does not support the assumption that travel choices reveal how travelers believe the government should spend funds in transportation investments (Mouter and Chorus 2016). One argument for this standpoint is that individuals in their role as citizens assign a higher value to safety than travel time, as compared to the value they assign to safety versus travel time as consumers (Mouter et al 2017). It can be claimed that the value of time from a 'citizen' perspective differs from the value of time from a 'consumer' perspective. This is another reason why the normative debate with regards to value of time deserves more attention (Mouter and Chorus 2016).

The practice of assigning monetary values to time gains is part of a larger practice, namely cost-benefit analysis, which is based on the assignment of such values to all the major aspects that one wishes to take into account when making a major decision such as the building of new transportation infrastructure. The underlying assumption is that all these aspects -- environmental impacts, deaths and injuries in accidents, costs, time gains and others -- are pairwise comparable, so that you can say how much of one of them corresponds to exactly how much of another. The use of money as the common currency for all these evaluations is just a practical choice; the crucial problematic assumption is the comparability taken to hold between them. Most of us would find it difficult if not impossible to decide how many cases of asthma would have the same weight as the loss of three insect species, how large a reduction in travel time would be needed to compensate for the need to move a stone age grave, etc. Comparisons of any of these items with monetary values are about equally difficult.

Welfare economics and preferences

The practice of using willingness to pay (WTP) for a perceived gain (or willingness to accept a perceived loss) as a measure of welfare is not without complications. Willingness to pay is used since it is assumed to measure preferences. (This is the standard terminology, but 'strength of desires' would probably be a more clarifying term than 'preference' in this context.) Unfortunately, the match between preferences and willingness to pay is far from perfect. There are things you may want very much but would not like to obtain with money, such as friendship, respect, and love. You may also refuse to

pay for something to happen although you very much want it to happen, because you think someone else is obliged to pay for it (Hansson 2007). Therefore, an individual's willingness to pay is at most a very rough, approximate, measure of her preferences (desires). In economic analysis, another problematic identification, that of welfare with preference satisfaction, is often added, and willingness to pay is then used as a measure of welfare (Hausman and McPherson 2009). This adds further uncertainties. Furthermore, in the formal analysis, the preferences of all concerned individuals have to be combined or aggregated in some way. This is difficult if the preference information is based on willingness to pay, since a person's willingness to pay depends on other factors than the strength of her preferences, not least on her economic situation.

"WTP and WTA are measures of human preference. That human preferences should count and be "sovereign" is the fundamental value judgement in CBA"
(Pearce 1998, p. 87)

This does not actually address what our preferences are, how to measure them or which scale to use. Neither does it addess nor the challenges of comparing or aggregating the preferences of different individuals. One common approach to the properties of preferences is to assume that they comply with ordinal utility theory (Fishburn 1970). It can also be noted that utility when defined this way merely indicates preference rankings. It is not assumed that people actually maximize utility, only that they behave as if they did so. So, the question of how to compare the utility of various individuals still stands.

When a specific value of time is plugged into a cost-benefit analysis, it is probable that this value will be used to provide guidance on which public action (such as an infrastructure project) would be of most benefit to the population. It is assumed that the value used is sufficiently stable for the purpose of the analysis. Furthermore, since the same value of time is used in different analyses, it is assumed that it can validly be transferred from one context to another. When the value of time is based on WTP, it is understood that the project which will satisfy the preferences of the population the most will yield the most benefits according to the analysis and will most likely be built. Some critics claim that this does not necessarily mean that this project is more likely to increase the actual welfare or wellbeing of the population (Hausman 2011). So, why should we strive to satisfy people's preferences if a connection between the satisfaction of preferences and welfare or wellbeing is not established? Additionally, one can claim that "preferences are not always self-interested and that false beliefs may lead people to prefer what is worse for them even when people are self-interested" (Hausman and McPherson 2006). Therefore, "it is a mistake to regard welfare as deriving [empirically] from preference satisfaction" (Hausman and McPherson 2006).

The circumstances of time allocation and trade-offs between money and time are particularly complex, and it is far from evident what implications the commodification of time has for welfare and well-being[2]. For instance, when nudged to put a price on time, people reported higher levels of psychological stress and displayed higher levels of physiological stress (Pfeffer and Carney 2018). Another study found that people who focused more on time in a choice between time and money reported feeling happier and more satisfied with life than those who focused more on money (Hershfield et al 2016).

Moreover, in the context of time-related decisions and choices, the notion of false beliefs may be relevant. Many "time optimists" would perhaps claim that they do not wish to be late, nor is it in their interest to be late. Yet, they are, due to somewhat conscious decisions they make. Should we judge the behavior of such people to be welfare-guiding?

Modelling the value of travel time

Many factors influence our decision to travel at a particular time and to use a particular travel mode. Assuming that the journey is undertaken with a destination in mind, the expected arrival at the desired destination can constitute a boundary condition; one might not want to arrive too early or too late. Also, the choice of travel mode can be dependent on factors other than those related to the specific destination and activity in mind. For example, one can choose to travel to work by public transport rather than by car due to plans to take part in an activity after work, which entails an intake of alcohol. Similarly, one can chose to travel to work by car to be able to carry out errands after work. Travel decisions often depend on complicated scheduling with multiple sequential activities, sometimes spanning over multiple days. Aspects such as "time of day choice, aversion to unreliability, labor supply, taxation, activity scheduling, intra-household allocation time and out-of-office productivity" (Small 2012) have been shown to impact willingness to pay for time savings. It can also be noted that while planning and scheduling of activities can depend solely on the needs of the primary traveler, they can also be affected by the needs and expectations of the family and the social circle of the traveler.

The standard practice in transport economics is to consider the work by Becker on the time allocation framework as a starting point for value of time models (Becker 1965). Assuming that time can be freely transferred between work and non-work, individuals optimize how much labor to supply given a constraint of having to divide the total time available between labor, leisure and travel. In economic models based on these assump-

[2] See (Mogilner, Whillans, and Norton 2018) for a review of the research on the connections between time, money and subjective well-being.

tions, there is a trade-off between travel time and money, which implies that travel time is worth the net wage rate.

In more detailed models, three concepts of time value have been stipulated: the value of time as a resource, the value of assigning time to an activity and the value of saving time in a constrained activity (DeSerpa 1971). DeSerpa considered travel time as lacking intrinsic value but necessary in order to be able to carry out activities that have intrinsic value. Assuming budgetary constraints for various activities such as work, travel and leisure, an optimization problem can be formulated. The value of time is then defined as the point where a marginal tradeoff between travel time and loss of income would leave the individual indifferent. This approach also allows for the value of travel time to depend on the difference between the value of time spent travelling and time spent working, meaning that if work is disliked more than travel, then the value of travel time is higher than the wage rate. Reduction in travel time leaves more time to be reallocated to more desirable activities and the value of time (as a resource) is the value of having more available time rather than spending time on travel.

This theory was further developed by considering the quality of life to be determined by what we do with our time, distinguishing between the value of time and the value of leisure time. The willingness to pay to reduce travel time depends on how much it is worth to do something else and on the value of travel time (Jara-Díaz et al 2008). By making the assumption that there is a monetary value of an increase in the available time for other activities and defining the ratio between the marginal utility of an activity and the marginal utility of money, the willingness to pay to reduce the time assigned to an activity, such as travel, can be derived.

Leisure activities can thus be defined as activities in which one spends more time than required, and the willingness to pay to reduce time in such an activity is zero. This is the equivalent to having the same value at the margin as the value of time as a resource. It is assumed that this value is the true worth of time and that it corresponds to the willingness to pay to reduce the time spent on unwanted activities, such as travel. The theory can be adjusted to incorporate constraints, such as individuals not having the option to choose the hours they work freely (meaning how much they work), with some working more and others less than they desire. The theory can also incorporate the various variations one expects, such as the value of time varying with trip purpose, socio-economic status, family status and other factors. As expected, if one has many time-consuming family and work commitments, the time constraints are tighter and the value of time is higher (De Palma 2011).

While most models, such as the ones described above, are discrete choice methods there is also a growing interest and literature on activity-based models, which can be seen as a more behaviorally oriented approach (De Palma 2011). The activity-based approach takes into consideration the complexity of activity planning and travel behavior and can be seen as more holistic.

Is time a commodity?

For the sake of analyzing of time as a resource, we believe it is beneficial to take a step back and consider the actual nature of time compared to other types of resources. In a recent paper, Wolfgang Fellner discusses the history of the commodification of time, starting with the commodification of labor which in turn led to a commodification of life's time (Fellner 2017). Further, he considers the value of time in household production (unpaid work) and the value of leisure. Unfortunately, Fellner does not discuss the value of travel time; a field where we believe the commodification of time surpasses many other fields of economics.

Below, with the conception of value of travel time in mind, we will discuss three characteristics of time as an object of economic analysis. Namely, that time cannot be stored and saved, that time cannot be reversed and that it cannot (directly) be transferred between individuals. We believe the analysis highlights aspects that need to be considered when reflecting upon the status of time as a commodity.

Non-accumulativity

Many types of resources, such as money, can be aggregated and saved for later use. This allows us to value each unit "in accordance with its anticipated best use" (Festjens and Janiszewski 2015.) However, this is not the case for time. It can only be reallocated to another activity (even if that activity is 'do-nothing', you cannot get that time back). Festjens and Janiszewski suggest that poor people might experience money similarly to time since they are not able to save and aggregate money (Festjens and Janiszewski 2015). Another example of non-accumulative money might be under conditions of extreme inflation, when the banknotes you hold have monetary value today but are just paper tomorrow. Intuitively, both of these examples assume that the way you would value your non-accumulative monetary assets differ from 'regular' valuations, due to the property of non-accumulativity.

On one hand, one can argue that value of money also fluctuates with time, for example one can hope to gain more money over time with smart investments, and the value of

certain goods declines over time, such as the value of fresh produce. On the other hand, we claim that the feature of not being accumulative is distinctly special for time since time can *never* be accumulated, not even a little. Recent technological developments such as devices making it possible to work remotely as well as more flexible working arrangements than the traditional norm have contributed to the perception that time is something that can be saved (Tuckman 2005). Nevertheless, in reality, there is simply no way to actually save time; time can only be instantaneously reallocated to other activities.

Irreversibility

It is commonly accepted that we cannot freely move along the temporal axis; time goes on and it cannot go back. Without going too deep into the philosophical discourse on the essence of time and temporality, there is at least a general notion of the perception of passage of time, of temporal asymmetry and irreversibility (Le Poidevin 2015). We cannot revisit previous events and make different decisions in relation to points in time that have already passed. For example, one cannot allocate more time to study for an exam after learning of the results on the exam. One also cannot choose to leave home earlier after missing the bus. In a way, it is the linear progression of time that prohibits the accumulation of time units. We can only plan what to do with our time to come, how to allocate our future time. Not only is time irreversible, it is also constantly passing and it is not possible to pause it or take a leap over parts of it. There is no feature of money (except perhaps in situations of extreme inflation) that reflects this.

Non-transferrability

Time cannot be un-conditionally given away, meaning that one individual cannot pass a unit of time to another. To some extent, we can help one another and there are markets where an exchange can be made, such as one individual paying another to carry out certain tasks and thus being able to freely allocate that time to other activities. However, time is not directly transferable in the way that money is. When in financial need, many can turn to financial institutions or friends and family and ask for a loan. While certain conditions and costs will be necessary, the loan is still considerably more flexible than any 'temporal' help one may get. Moreover, there are certain types of basic activities that cannot be carried out by someone else for you, such as sleeping. In a sense, the personal nature of time as a resource drives the need for the individual to optimize time allocation. All of us have our 24 hours per day to spend, no more, no less.

Irrationality in valuing time

Traditionally, the theory of transport economics depends on the assumption of rational behavior and stable preferences. However, many deviations from rational behavior in real life have been reported, such as loss aversion and the presence of an "endowment effect" (Kahneman et al 1990). Such irrationality has been studied extensively, but mostly in other application areas than time-related decisions. Below, we discuss some findings that relate to behavioral differences between time-related decisions compared to monetary ones. We believe the findings further strengthen the difference in nature between time and money.

First of all, research indicates that people experience time through occurrences of specific events (Blount and Janicik 2001). Throughout the day these events provide reference points based on which time is considered as saved or lost. It seems reasonable to assume that behavior regarding time depends on whether there is a schedule to adhere to compared to when no schedule is set and time is considered completely flexible. The difference between schedule-dependent and schedule-independent decisions can depend on whether time decisions are seen as independent of reference points or as parts of a planned schedule. If an individual has a schedule to adhere to, part of the flexibility of the value of time is taken away. It has been suggested that "when [their] schedules are taken into account, consumer[s] may have mental accounts for time that parallel those for money" (Zushi et al 2009).

The scheduling dependence also explains why time gains are less valuable than money gains, unless the time saved can be spent in a meaningful way. Leclerc et al. suggest that "aversion of uncertainty due to the nonfungibility of time seems to have a large impact on risk attitudes" (Leclerc et al 1995). At the same time, it can also be claimed that certainty with regars to time might not always be the preferred option. There are cases when individuals might choose a gamble with time if their schedule allows it. Nevertheless, it would seem that choice under risk depends on circumstances not controlled for affecting the willingness to adjust plans already made.

A more recent study (Festjens et al 2015) showed that decisions regarding time under risk were similar to decisions regarding money under risk, except for the valuation of losses. Their view is that the differences in the loss domain between time and money can be explained by the effect of 'slack'. Slack in this context is defined as the perceived surplus of a given resource available to complete a focal task. Contrary to what applies to money, more time 'slack' is perceived by individuals in the long term compared to the short term (Zauberman and Lynch Jr 2005). Simply put, individuals believe they

will have more time in the future, while not believing they will have more money. This would indicate that individuals are better at estimating the costs of a large-scale project than the time the project will take.

All in all, it has been found that time value is more 'ambiguous' than the value of money (Okada and Hoch 2004). This means that people's perceived valuation of time is not as precise as a fixed monetary value. Okada and Hoch suggested that this in part due to different budget constraints for the different domains, with the temporal budget constraints being "pretty soft or at least elastic" (Okada and Hoch 2004), leading to a more flexible value of time. The so-called ambiguity comes from individuals being able to more easily rationalize a higher (or lower) outcome ex post than expected with regards to time. This also affects the ex ante decisions because of anticipation to be able to more easily explain differences in time outcomes than in money outcomes.

Lastly, another aspect where time and money are seemingly different is the notion of signaling status. Whereas mainstream economics assumes that more money is desirable as well as presumably reflective of a higher social status, being busy (i.e. having less time) can partly be a status symbol with regards to time allocation. A recent overview (Keinan et al 2019) examines this notion of having less time as a sign of productivity and being in demand, and suggests that future research should focus (among other things) on how "control over one's time can influence perception of status" (Keinan et al 2019).

In summary, money and time have been shown to be evaluated in different ways, and these differences add to the difficulties of a model in which time and money are fully comparable.

How do the specifics of time matter to valuing time?

Based on the discussion in Sections 5 and 6, we propose that rationality when taking decisions about time (how to spend time) is significantly different from rationality with regards to other goods, such as material objects and services.

More money, without any conditions, is better than less money. It would seem probable that more time, without any conditions, would be better than less time, as well. However, time often seems to have conditions, a context, something we are doing with the time we have. Thus, the monotonicity so clearly observed in the monetary domain is not as obvious in the time domain.

Additionally, the directionality and the inevitable passage of time brings up the question of whether we should differentiate between bundles of activities (time allocation alternatives) that include the same activities for the same duration but in different temporal order (i.e. does the order matter?). Assuming there are temporal relations between goods and services, certain goods can only be used at certain temporal positions. Once those temporal positions are passed, those goods cannot be used. Hence, all activities are temporally positioned with respect to other activities.

Knowing that we are generally more optimistic about our future time availability, the willingness to pay for future time savings should be put in the perspective of this optimism. If it is reasonable to assume that we value time savings more if we are able to spend them in a meaningful way, our optimism about how much we would be able to do with the saved time should be taken into account. A future saving of time can be perceived to be worth more compared to how much we would actually be willing to spend on this time saving once it is an option. In general, the established conversion of time into money for practical purposes disregards some of the specifics of time as a resource. The assumption that the conversion of time into money is of essentially the same nature as to the conversion of other commodities into money would seem to require more justification than it is currently given.

Taking time as the basic variable

Given these concerns, we will now discuss what we believe to be the essential elements of a model that would adequately handle the value of time as the main basic variable. Our intent is not to propose a fleshed-out model but rather to show some of the aspects that would have to be considered when formulating such a model. Evans suggested that the primary source of satisfaction should be the type of activity that is being performed, measured by the amount of time assigned to that activity within a specific period (Evans 1972). Activities are costly because they require goods in order to be carried out. Thus, the cost of an activity is dependent on the cost of the goods required for it. Here, time is viewed as one type of good required for carrying out activities. The amount of time assigned to each activity is the basic variable, the source of direct utility and the source of both income and expenses. As Jara-Diaz has pointed out, "it seems that the fundamental role assigned by Evans to activity time allocation generates a more general and meaningful framework" (Jara-Díaz 1998).

However, this framework still considers time on par with other goods. We see it as a more promising approach to take time to be the primary good whose allocation is to be optimized. Such an approach was proposed by Zeckhauser (1973). In this account,

the only ultimate source of utility is the disposition of time. Instead of taking time as a constraint, Zeckhauser considered constraints on how an individual can allocate his or her time. In his barebone model he defined lifetime utility as

$$U_L = f(a_1, \ldots a_t, \ldots a_n)$$

with a_t being an allocation for the discrete time period t. The objective for each individual is to maximize U_L. In this model, goods play an indirect role by enabling individuals to carry out certain activities. Further developments of this model have included budget constraints, with the objective being to optimize time allocation given a budget (W. Fellner and Seidl 2012; Steedman 2003). This condition can be seen as secondary since individuals would still have to decide on the allocation of their time, even if there is unlimited wealth.

As Zeckhauser pointed out, "[t]ime-related decisions involve complexities not encountered in a well-behaved, goods-oriented, neoclassical consumption model" (Zeckhauser 1973). Some of these complexities are due to the specifics of time as a commodity discussed above, and some are due to aspects of the interconnections between activities and their temporal location.

Process gains vs goal gains

One important starting point in analyzing models with time-based utility is to distinguish between process benefits and goal benefits (Fellner and Seidl 2015). Simply put, some activities are enjoyable to perform while others are enjoyable to have done. The process benefit is the intrinsic benefit of the activity, i.e. the value of carrying out the activity, while the goal benefit is its instrumental benefit, i.e. the value of the outcome. This distinction is relevant when formulating the value of time for a certain activity per unit of time and for example assuming that the value of a segment of time is proportional to its duration. Clearly, while the process of carrying out an activity can be a source of utility, it is not necessarily proportional to the pay-off for finishing the task (Zeckhauser exemplifies this by stating that surely the pay-off for a half-completed painting, manuscript or education isn't proportional to the pay-off for a finished one (Zeckhauser 1973)). Moreover, certain activities such as learning to play an instrument develops one's skill and can reasonably be assumed to eventually lead to a greater pay-off for the same time playing the instrument once one's skills have evolved. This can also be considered from the perspective of monetary costs of activities, since "[f]or most activities, the assumption of constant activity cost per unit of activity time does not apply" (Fellner and Seidl 2015).

It should be noted, though, that this model assumes that all the values we want to take into account can be located in one or several specific time period(s). Arguably, we should not exclude the possibility that there may be evaluatively relevant aspects of human life that lack such temporal specificity.

The temporal division of activities

The property of non-accumulativity has an obvious impact on valuing a longer instance of 'free' time higher since the duration of the available time determines the activities one is able to carry out. This can be illustrated with a simple example of monetary allocation. Imagine having five vouchers of $10 each, which gives you a range of options of buying five goods that cost up to $10 each. This is not the same as having $50 to freely allocate. The option of allocating $50 on goods is intuitively preferable to that of allocating $10 five times. In monetary terms this example seems highly artificial. Why would one have five times $10 and not $50? We are so used to aggregating units of monetary value that keeping them separate seems strange. Yet, for time, this is a realistic scenario. Imagine you have 10 minutes of 'free' time on five occasions in-between necessary activities. Your option set is then more limited than if you have 50 minutes of uninterrupted free time. This reasoning shows that time in one aspect violates the conditions that lead to diminishing marginal utility. Longer instances of time should be valued higher per unit of time since they allow for greater flexibility (Festjens and Janiszewski 2015).

We have already given reasons to question the common assumption of constant unit values of time. Another such reason is the argument from longevity, namely the claim that longevity matters to us. Broome has argued against separability of times in aggregation of well-being, using this argument from longevity, and claiming that intuitively longevity is something we value (Broome 2004). This argument can apply to the value of duration of specific activities as well. Assume you are to carry out two activities during a predefined time period, all else equal. Without any restrictions on how to divide the time, an intuitive division seems to be to start with one activity, carry it out for as long as needed and then take on activity two. Another option would be to go back and forth between the activities and for example switch after doing the same activity for a certain unit of time, say 10 minutes. Assuming that there are no transfer losses (meaning going back and forth does not require more time in total to carry out the activities), the total time for the former and latter allocation is the same. If the value of time per time unit is constant, the total value of both allocations is equal. Yet, there seems to be a significant difference between the allocations that is not captured in the simple model of a constant unit value of time. Performing an activity for a longer time period, uninterrupted, can yield a higher (or lower) value in total.

It should be noted that in many cases, we also strive to allocate time to certain activities simultaneously with other people. This reflects that the value of time carrying out a certain activity can differ depending on whether the activity is undertaken by the individual alone or together with others. This can be incorporated as a constraint on the time allocation, meaning that certain activities have to be performed at a specific temporal instance, or it can be considered as externality, meaning that one individual's allocation of time to a specific activity can impact the value of others performing the same activity at the same time and the same spatial location (Zeckhauser 1973).

The order of activities

As discussed above, the duration of an activity is an important factor for its value to the individual. As a very rough approximation, one could assume that the value of a performance of an activity is proportionate to how much time you spend on it. But most activities have a more complex relationship than that between duration and value. Spending only a few minutes on something pleasurable may be more frustrating than fulfilling. But on the other hand, doing something pleasurable for a very long time may be fatiguing and therefore quite unendurable[3]. Probably, most desirable activities have both these features. Even if you long for two or three hours when you can read the novel you just bought, you might not care to pick it up to read half a page during a break of two minutes, and the prospect of reading it for ten hours in a row might not either enthuse you.

The order in which we do things, and their temporal distance, can also be highly relevant for how we value them. For instance, many Finns highly value a visit to the sauna immediately followed by a swim in an ice-hole. Many of them are not equally enthusiastic about a swim in an ice-hole immediately followed by a visit to the sauna, or, for that matter, a visit to the sauna followed an hour later by a swim in an ice-hole. More examples of this nature can easily be found. In addition, most of us seem to have a strong preference for improvement rather than worsening. Working twenty years in the opera choir and afterwards twenty years as an acclaimed solo singer in the same house is usually conceived as better than having the two jobs in the opposite order. To account for such effects, two options are available:

[3] Additionally, while carrying out the same activity over time will, sooner or later, lead to a decrease in returns to scale, "repetition of the same activity after a (long enough) period of abstinence can restore the enjoyment productive capacity of that activity" (Nisticò 2014). This reasoning indicates a link between the satisfaction obtained from an activity and the frequency of carrying out the activity, formulated by Gossen as one of the 'laws of pleasure' (Gossen 1854).

We can relativize the value of a time unit to what occurs at various distances in time to it. Hence, the value of swimming in the ice-hole may be higher if we just came from the sauna than if we came from some cold place.

We can assign values not only to the minimal units of time but also to patterns that cover longer periods of time, such as "swimming in the icehole immediately after visiting the sauna ". One way to do this is to assign (a) an 'intrinsic' value to each combination of a unit of time and a way spending it, and (b) 'relational values' to more complex patterns that have been identified as contributing to the total value.

'Joint production'

The notion of 'joint production' refers to the possibility of carrying out multiple activities simultaneously (Nisticò 2014). The basic model presented above assumed one activity being carried out at a time, but this is hardly true for everyday life. Reading while being on the train and eating while watching TV are two of the many possibilities of combining activities. In transportation research, the possibility of combining activities and thus turning 'useless' travel time into 'productive' time has been reflected in lower values of travel times on trains and busses, i.e. travel modes that enable multitasking (Lyons and Urry 2005). However, it is challenging to separate the value of each of the activities being carried out simultaneously or rather clarify how the value of such combined activities relate to their components.

Also, while certain activities can be combined, such as reading while traveling by train or listening to music while running, possible combinations of activities are limited. Running while travelling by train is complicated (though not fully impossible). Hence, the relationship between the activities in themselves needs to be taken into account.

8. Value of travel time revisited

All in all, whenever considering the value of time, it is intuitively plausible not only to consider the total amount of time spent on each activity but also the order of these activities and how much time is devoted to each activity at each instance. Taking into account that the grouping of activities matter, the value of saved time by shortening travel time can depend on which activities you are able to perform instead. If you can prolong one of the activities adjacent to the travel, it would typically seem to be worth more compared to having to take on a new activity. This is particularly true for very short time savings since many activities require longer periods of time in order to be considered meaningful.

If the saved time is allocated toward an activity that could as easily be performed while travelling ('joint production'), then the value of the saved travel time is seemingly low. Say a shorter trip makes it possible for you to arrive at your destination a couple of minutes earlier and you spend this time utilizing your smartphone. This is an activity you could do while travelling and having saved some travel time does not seem worth much, in this case. Of course, if these savings are long-term, you are expected to adjust your departure time and be able to leave later, the assumption here being that you have a wider range of activities you could perform at the location you left (such as your home).

These are just some of the implications on the perception of value of travel time if we adopt a time-based view of utility that takes into account the complexities discussed above. We recognize that a transport economist might argue that all these complexities are irrelevant. We can make people think about time as about money (Chang et al 2013; DeVoe and Pfeffer 2007) and carry on as usual. But why should we? We believe this is a normative question, especially in light of psychological research showing that treating time as money seems to make people less happy and more stressed (DeVoe and House 2012; Pfeffer and Carney 2018). Why should we prompt people to behave as if time is money, if the discrepancies are for good reason and time is not like money at all?

Another counter argument is that the premise of utility maximization and the conditions of rationality allow us to disregard reasons why people choose the way they do, i.e. their reasons do not matter to us. If the complexities discussed in this paper are 'reasons', they can be disregarded. We believe this counterargument is to a certain extent misguided. We are not questioning that people make trade-offs between time and money in everyday life, nor that when asked they can tell how much a shorter commute would be worth to them in monetary terms. What we are questioning is whether this is sufficient justification for the simplistic transferability and comparability between time and money commonly assumed in evaluations of infrastructure investments. In light of how influential this practice is in the development of our cities and urban environments, we believe the considerations raised in this paper are warranted.

Conclusions

We believe that the problems associated with monetary valuations of time give us reasons to consider alternative approaches. The mismatch between temporal and monetary value should be considered in the construction of models for transport economics and transport policy. As we see it, the assumption of full transferability between time

and money is not justified, at least not in the way it is used in transportation appraisal. Time duration is easy to measure, and arguably it provides a sense of objectivity, which feels less arbitrary than evaluations of qualitative measures. Moreover, people do want a shorter commute; they do want to travel less. This conception of time has shaped our urban environment with many transportation investments aiming to shorten commute times. But this focus on time savings may very well lead to neglect of other aspects that shape our cities. In particular, we believe that the issues concerning the quality of travel time will become more prominent with the approach we have outlined in Section 7.

One reasonable way forward would be to incorporate and further develop the model of time as the main source of utility, taking into account the complexities discussed in this paper. This would give rise to an alternative model to be used in the development and evaluation of systems of urban transportation. Another approach would be to incorporate these aspects of time as an economic resource into extended versions of the traditional models. In either case, dismissing the characteristic features that make time fundamentally different from other goods does not seem to be a way forward.

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