The welfare effects of freight travel time savings

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Abstract

In this article we investigate the welfare effect of freight travel time savings. The general setup of this article is to suppose that transport operators face a constraint on minimum travel time and to examine what is occurring when this minimum travel time is changed. We briefly examine the current assessment methods and propose a less restrictive approach, in which we analyse how different economic agents trade off between the duration and cost of the different operations that are used in production and transport activities. We analyse how the change in the minimum travel time affects the different economic agents and investigate how these changes should be valued in cost benefit analysis.

Keywords: freight value of time, cost benefit analysis,

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1. Introduction

In this article we investigate the value that should be placed on travel time savings for freight transportation in cost benefit analysis. While passenger transportation has received accurate attention from the community of transport economists, the value of time savings for freight lies far behind both regarding the availability of a widely recognised theoretical analysis and the number of empirical results available. This situation may be explained by the fact that the value of freight time savings only ranks second among the benefits of transport related projects, after the value of time for passengers. However, the lag in the research for freight value of time clearly exceeds what this second rank may justify.

Such an observation motivates a research on how the welfare effects of freight transportation time savings should be accounted for in cost-benefit analysis.

In the first section, we present the current paradigm that is in use in evaluation practice in industrialized countries, and underline the limits of this paradigm. In the second section, we derive a microeconomic model that describes how different agents have to deal with the duration of transport operations. In particular, we analyse how firms make trade offs between time and cost for different operations, including transportation of outputs. In the third section, we illustrate how savings on travel time affects the cost-duration trade off of firms and investigate how such effects should be taken into consideration in cost-benefit analysis. In the forth section, we investigate the monetary value that should be placed on these effects and implement our findings on the cost-benefit analysis of a set of projects in the UK.

2. The current approaches and their limits

In this section we give a brief overview of the current approaches used for the valuation of freight travel time savings. We also show the limits of these procedures and propose a number of improvements.

Current approaches to value freight travel time savings

The current approach in use in industrialized countries are summarised in Commission Européenne (1994) and Bruzelius (2001). Besides their differences, the commonalities among the different approaches, usually referred to under the name "factor cost approach", are that they rely on a relationship between the duration and the cost of transport operations. In other words, the reduction of travel time affects the cost of transportation because it modifies the quantity of consumed inputs (vehicles.hours and drivers.hours). A more detailed framework, as is exemplified by the COBA Manual in England (DETR 2001), considers that operating costs of the vehicles vary with speed (as is common knowledge about fuel consumption).

A general formulation of the transport production cost, taking into the effect of speed, can be proposed under the form:

$$ct(d_\mu ;k) = w.\ d_\mu + v.\ d_\mu + k.g(k/d_\mu),\ \text{with} \quad (1)$$

$ct(d_\mu;k)$ travel cost
d_μ travel duration
k travel distance
w hourly cost of the driver
v hourly cost of the vehicle
$g(k/d_\mu)$ vehicle operating costs per kilometre as a function of speed.

The last component of the function, $g(k/d_\mu)$ is U shaped, and so will be the function $ct(d_\mu ,k)$, for a given distance k. This reflects the fact that starting from an initial situation where speed is low, transportation time reduction (speed increase) will result in an economy on driver and vehicle as well as a reduction of vehicle operating costs, however when duration decreases further (that is, speed increases), technological factors such as the increase in fuel consumption per kilometre have an adverse effect on cost reduction. Above a certain speed, provided this speed is technically feasible for the vehicle, the adverse effect can override the economy in labour and capital hourly costs and this will result in a cost increase. As far as road transportation is concerned, only part of the U shape curve is relevant, that is the part where cost increase with duration. This is due to the magnitude of the cost component corresponding to the hourly costs of driver and vehicle; that is such that the cost is still increasing with duration (decreasing with speed) for speeds around 100 km/h (base on DETR data 2001), which is larger than the speed at which Heavy Good Vehicles operate in normal conditions. However, in order to be suitable for different modes, the analyst should retain a general formulation where both slopes of the cost-duration relationship are available. This is for instance the case for rail transportation, where costs increase sharply with speed (Thompson, 1990).

Whatever the mode considered, the emerging feature of the cost-benefit procedures currently in use in industrialized countries is that they rely on the relationship between transport costs and transport duration. This procedure has received some criticisms (Mohring and Williamson (1969), Quarmby (1989), Cox (1992), Mackie et Tweddle (1992, 1993), Allen and Baumel (1994), Aberle, Engel and Quinet (1993)) in that it reduces the scope of analysis to transport operations and does not take into account the consequences of transport time savings for the sender or the receiver of the good. Thus there seems to be a gap in transportation science between cost benefit analysis and some approaches in use in logistics that analyses the benefits of transport time reduction for the sender of the good. These benefits consists usually consist of the possibility of consolidating the distribution network in a more reduced number of depots and the possibility to reduce safety stocks. This latest effect is exemplified by the well known model of Baumol and Vinod (1980) that addresses the cost of stockholding in the presence of inventory costs, with a non constant demand. The approach of Baumol and Vinod analyses how transport duration has a cost for the sender of the good because there are inventory costs on the good in transit, and because there are inventory costs on the good in the stocks held by sender in order to avoid stock-out.

A tentative conclusion here is that, although logistic science has produced a number of results on the effects of reduced transport time on logistical costs, such considerations have been kept out of cost benefit analysis practice with a few exceptions[1].

Possible improvements to the current approach

In these paragraphs we propose certain improvements to the understanding of the role of time in freight transportation. We will not comment further the fact that the transport operation is considered separated from the set of activities of the firms that produce the goods, as it has already been introduced above. We will rather concentrate on the introduction of some distinctions that seem fundamental for the understanding of transport time and whose omission, to our understanding is a flaw.

The first distinction is straightforward and deals with the distinction between **transport time and travel time**. It is a well known observation of transport economics that the actual duration of *travel* operations represent only a limited share of *transport* duration, while many operations (cross docking, intermediate stocking, border crossing) where the good is not actually "travelling" occupy large slots of time. This fact, also it is widely recognised, is not taken into account in the current paradigm for the valuation of freight time saving.

The second distinction that needs to be made regards two different relationships with time. Some goods are produced indistinctively for the market. Thus they can be produced in advance, stocked and sold on request. The trade-off made by firms then is very much like the one described by Baumol and Vinod, where increasing the stock has benefits (reducing stock outs) and costs (inventory costs). There is however another type of goods that is made based on the specificities provided by a single customer (think about a car whose colour you can choose together with other customizations, or a pair of glasses that is made based on customer specification, or some pieces of furniture that can be made on order). In this latest case, there is no way a stock can be made where producer would pick an output unit in order to satisfy an order, and the operating framework of the firm is substantially different from the previous situation. Thus, there are two different types of goods, that create two distinctive relationships with time. We will refer to these two categories as **"specific"** versus **"generic**" goods.

Based on these distinctions, we develop in the next section a model for analysing the effect of travel time savings for freight transportation.

3. The effects of travel time savings

We concentrate on the situation of specific goods that has received little attention from transport economists.

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[1] For instance the cost benefit analysis procedures in use in Australia take into account the shippers' value of time. This is done through the allowance of 20 percent extra benefits. BETR (1999) Note as well that the latest release of the cost benefit analysis guidelines for France (Direction des routes 2004) also includes a valuation of the time savings for the owner of the goods. Three figures: 0,45 € t/h , 0,15 € t/h and 0,01 € t/h are used based on the value of the good. The guidelines however recognises that the inclusion of a value for the good is experimental and that the numerical values are subject to improvement.

In this section, we first examine the trade offs made by three types of agents: final customers (that is ordering the specific good), producers (that is the company that possess a good and pays for having it transported) and transport operators. The basic mechanisms underlying these trade offs is that the cost of the various operations that are involved in production and transportation varies with duration, just as what the current paradigm states for travel. Taking into consideration these mechanisms it is possible to show how profit maximising implies the choice of an optimal duration for different operations. It then becomes possible to characterise the situation resulting from profit maximising. This profit maximising situation is contingent to a given constraint on travel duration. When this constraint is relaxed (this is just what travel time savings is about) there will be some changes in the durations and the corresponding costs. These changes will have a value to the agents that should be the basis for the evaluation of the benefits of travel time saving.

The time related trade offs involved by transport duration

Final consumer trade off

A textbook maximisation problem for the customer can be modified to include a preference for an anticipation of the delivery of the good that he orders. Suppose that a consumer satisfaction derives form the purchase of one unit of a specific good, together with x_2 units of a generic good (or a bundle of generic goods). supposing that the price of x_2 is the numeraire.

$\text{Max}(U(d_d,x_2))$ s.t.: $x_2 + p(d_d) \leq B$, with
U, utility of the consumer,
d_d, duration for the delivery of the specific good
$p(d_d)$ price for the specific good (depending of the delivery duration)
x_2 quantity of the numeraire good
B, consumer's budget.

Thus, introducing the Lagrange multiplier λ_c, the program will be:
$\text{Max}\ (U(d_d,x_2) - \lambda_c(x_2+p(d_d)-B))$

$$U'_{x2} = \lambda_c \tag{2}$$

$$U'_{dd} = \lambda_c\, p'(d_d) \tag{3}$$

The latest equation can be rewritten as $U'_{dd}/\lambda_c = p'(d_d)$ which indicates that the marginal willingness to pay of the final customer equates with the marginal price of anticipating the delivery. It is possible to derive a bid function (that is the set of price, duration that have the same utility). When a different customer, with different tastes and different budget constraints will be present on the market, the demand will consist of the envelope of the different bid functions.

Transport operator trade-off

We first examine the trade-off made by the transport operator. The transport operator makes use of a travel operation and a set of non travel operations (to avoid cumbersome difficulties we will suppose that the set of operations is given, so there is no choice between doing or not doing a certain operation) and has to choose the duration dedicated to each operation. In this trade-off, he faces the constraint on minimum travel time, that is the keystone of the situation we study.

Let's label μ (respectively $\bar{\mu}$)[2] the travel (respectively non travel) operation and d_μ (respectively $d_{\bar{\mu}}$) the duration dedicated to travel (respectively non travel) operations, and $c_\mu(d_\mu)$ (respectively $c_{\bar{\mu}}(d_{\bar{\mu}})$) the cost of travel (respectively non travel) operations[3]. Eventually let's label d_μ^{min} the minimum duration of travel operation (due for instance to the conditions of infrastructure). Let's label $rt(d_\mu + d_{\bar{\mu}})$ the revenue of the transport operator. Actually this revenue depends only of the total of travel and non-travel time, irrespective of the actual decomposition. The profit maximising program of the transport operator will be:

$$\underset{(d_{\bar{\mu}},d_\mu)}{Max}\left(rt\left(d_{\bar{\mu}}+d_\mu\right) - \left(c_\mu\left(d_\mu\right) + c_{\bar{\mu}}\left(d_{\bar{\mu}}\right)\right)\right)$$

s.t. $d_\mu > d_\mu^{min}$

Introducing, λ_t , Lagrange multiplier, associated with the constraint on duration, we can write :

$$\underset{(d_{\bar{\mu}},d_\mu)}{Max}\left(rt\left(d_{\bar{\mu}}+d_\mu\right) -\left(c_\mu\left(d_\mu\right) +c_{\bar{\mu}}\left(d_{\bar{\mu}}\right)\right)-\lambda_t\left(d_\mu-d_\mu^{min}\right)\right)$$

Positing that the constraint is active, this will result in the condition:

$$rt'(d_\mu^{min} + d^*_{\bar{\mu}}) = c_{\bar{\mu}}'(d^*_{\bar{\mu}}) \qquad (4)$$

$$d^*_\mu = d_\mu^{min} \qquad (5)$$

The Lagrange multiplier associated to the constraint on the minimum travel duration is

$$\lambda = rt'(d_\mu^{min} + d_{\bar{\mu}}^*)- c_\mu'(d_\mu^{min}) \qquad (6)$$

This multiplier indicates the benefits that a transport operator obtains from a marginal reduction of the minimum *travel* time. Equivalently, it expresses the

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[2] The notations μ, for travel, and $\bar{\mu}$, for non travel, corresponds to the distinction between metakinesic and ametakinesic, from the Greek word metakinesis (travel).

[3] This suppose that the cost of non travel operations does not depend on the duration of travel operation, and conversely. The alternative, more complex situation is discussed in Massiani (2005) p. 313.

willingness to pay of transport operators for a reduction in *travel* time. Thus we can use the notation:

$$wtp_t = rt'(d_\mu^{min} + d_{\bar{\mu}}^*) - c_\mu'(d_\mu^{min}) \qquad (7)$$

d_μ^{min} is the minimum travel time, $c_\mu(d_\mu^{min})$ is the cost of producing a trip with this duration, $rt(d_\mu^{min} + d^*_{\bar{\mu}})$ are the revenues of the transport operators as a function of the transport time that they can offer on a certain corridor. The willingness to pay of a transport operator for a marginal change in *travel* duration is the sum of the marginal change in transport operators' costs and the marginal increase in transport operators' revenues. The second effect, marginal increase in transport operators' revenues, is only the counterpart of the willingness to pay of transport operators' clients, that is the producer of the goods. This makes it necessary to analyse, in turn, the situation of the producer.

Producers' trade offs

In this section, we suppose that a firm producing specific outputs based on specific inputs has to choose an optimal duration for a series of operations. We suppose that the firm faces three successive operations. These operations correspond to the procurement of inputs, the transformation of inputs into output and the outbound transportation. Without loss of generality, we simplify the framework of analysis by restricting to these three operations.

Figure 1 illustrates the succession of the different phases, introducing the notations that will be used further in this paper, where d_s refers to the duration of the supplying phase, d_p is the duration of the processing phase, d_t is the duration for the phase of (outbound) transport.

In this framework, we suppose that a given firm needs to select an optimal duration for each of these phases. We assume that the cost of each phase depends on the duration dedicated to each of them. We posit that this relationship can be represented through U shaped functions. This means for instance that there exists a cost minimising processing (/supplying/ transportation) duration, and that any deviation from this duration will increase the costs. This time depending costs are represented by four functions.

Duration depending costs and revenues

$cs(d_s)$, supplying costs as a function of the supplying duration
$cp(d_p)$, processing costs as a function of processing duration
$ct(d_t)$, transportation costs as a function of the transport duration of the outputs.

These costs correspond to the tariff paid by the producer to the transport operator. We will suppose that each of these functions is strictly positive and U shaped

Eventually, one should consider that the cost of transport time for the producer is not only consisting of the tariff paid to the transport operators but also of other components usually referred to as "immobilising costs". We propose to define more precisely these costs as consisting of three components: the financial inventory costs of having the good in transit, the costs of damage as far as the producer perceive them as proportional to the time spent in transit, the costs linked with the physical change of the good during the transportation (this particularly applies to perishable goods). We will refer to these 3 costs as "generalised immobilisation costs" and denote it with the following function:

$ci(d_t)$ generalised immobilisation costs as a function of the transport duration.

This function is supposed to be monotonic strictly increasing:

$$ci'_{dt} > 0 \tag{8}$$

No specific hypothesis is made on the convexity of the function, and we will consider in the remaining part of this article that the second order derivative of ci(dt) is zero.

Apart from costs, duration also impact revenues because, as analysed in the previous section, clients are willing to pay more in order to receive their goods sooner. This can be expressed by the function $r(d_s+d_p+d_t)$, that makes the revenue depend of the duration between order and delivery, we will suppose that $r(d_s+d_p+d_t)$ is differentiable and monotonously decreasing, that is:

$$r'_{ds} = r'_{dp} = r'_{dt} < 0 \tag{9}$$

Profit maximising

In this framework the maximisation program of the firm becomes:

$$\underset{(d_s,d_p,d_t)}{Max}\left[r(d_s+d_p+d_t) - \left(cs(d_s) + cp(d_p) + ct(d_t) + ci(d_t) \right) \right]$$

Assuming that all functions involved in the trade-off are differentiable, one can write the first order conditions as:

$$r'_{ds} = cs'_{ds} \tag{10}$$

$$r'_{dp} = cp'_{dp} \tag{11}$$

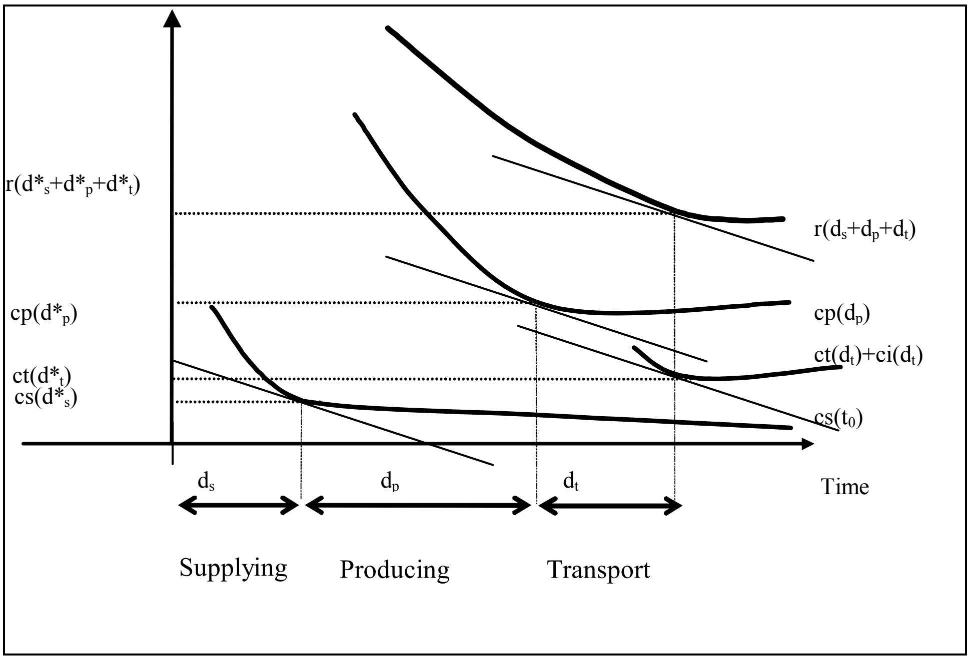
$$r'_{dt} = ct'_{dt} + ci'_{dt} \tag{12}$$

these conditions are illustrated in Figure 1. They can be summarised in:

$$r'_{ds} - ci'_{dt} = r'_{dp} - ci'_{dt} = r'_{dt} - ci'_{dt} = cs'_{ds} - ci'_{dt} = cp'_{dp} - ci'_{dt} = ct'_{dt} \tag{13}$$

Recording that revenues are decreasing with duration: ($r'_{ds} = r'_{dt} = r'_{dp} < 0$) and that generalized immobilisation costs are increasing with transport duration ($ci'_{dt}>0$), we can show: $cs'_{ds} < 0$, $cp'_{dp}<0$, $ct'_{dt} < 0$. These latest inequalities mean that the profit maximising durations chosen by the producer will be located on the downard slope of the three different cost curves. In other words, when the producers maximise profit, it is in a situation where costs would be reduced by an increase in duration. Equation (13) also provides a formal expression to the willingness of the producer to reduce transport time that is: the sum of the extra cost it would encure in reducing the duration dedicated to other operations (purchase and production), plus the reduction in generalised immobilisation costs during transportation.

Figure 1 - duration of the different phases involved in the specific good producer trade-off.



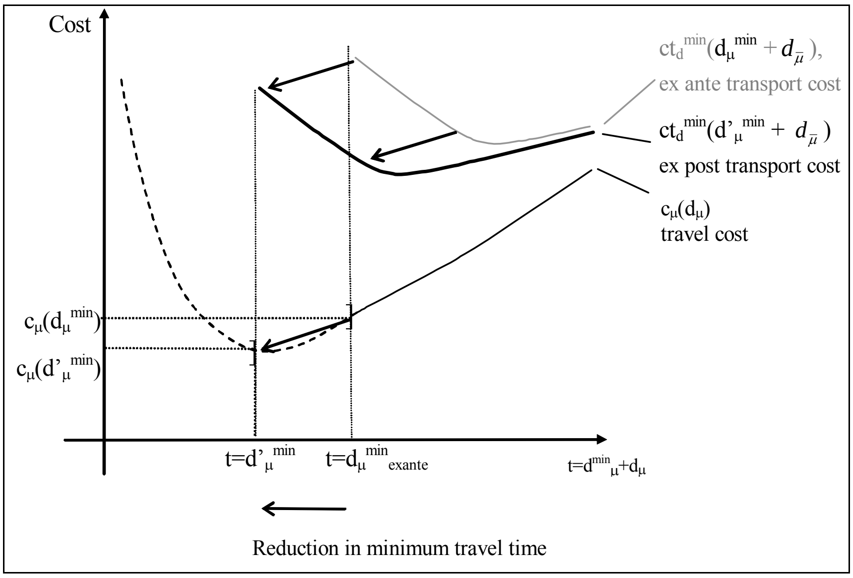
Consequences of travel time saving

Based on the description of the trade offs that we have presented in the latest section, we investigate the consequences of an exogenous change in travel time. This change is typically a consequence of an intervention of public authority. This can be an increase in infrastructure capacity, a change in regulation that modifies traffic conditions, or any action that makes it possible for vehicles to move faster on the network. This change is represented by a shift in d_μ^{min}.

Consequence for the transport operator

The change in the transport operator's situation can be represented as in Figure 2. The horizontal axis represents time. On this axis, two values for d_μ^{min} are represented. d_μ^{min} is the ex ante minimum travel time and $d'_\mu{}^{min}$ is the ex post minimum travel time. The curve c_μ represents the travel cost. The doted portion of this curve corresponds to unattainable duration in the ex ante situation. The grey line in the upper right part of the graph represents the transport cost, that is, the sum of travel and non travel costs. As non travel costs are strictly positive, the curve $ct(d_{\bar{\mu}} + d_\mu^{min})$ is above the travel cost curve. As non travel duration is positive, the curve $ct(d_{\bar{\mu}} + d_\mu^{min})$ is located to the right of the truncation of $c_\mu(d_\mu)$ in d_μ^{min}. Supposing that the constraint on d_μ^{min} is binding in the ex post as well as in the ex ante situation, the shift of the point d_μ^{min} will result in a shift in the transport cost curve $ct(d_{\bar{\mu}} + d_\mu^{min})$.

Figure 2 - Consequences of travel time reduction on the transport operator



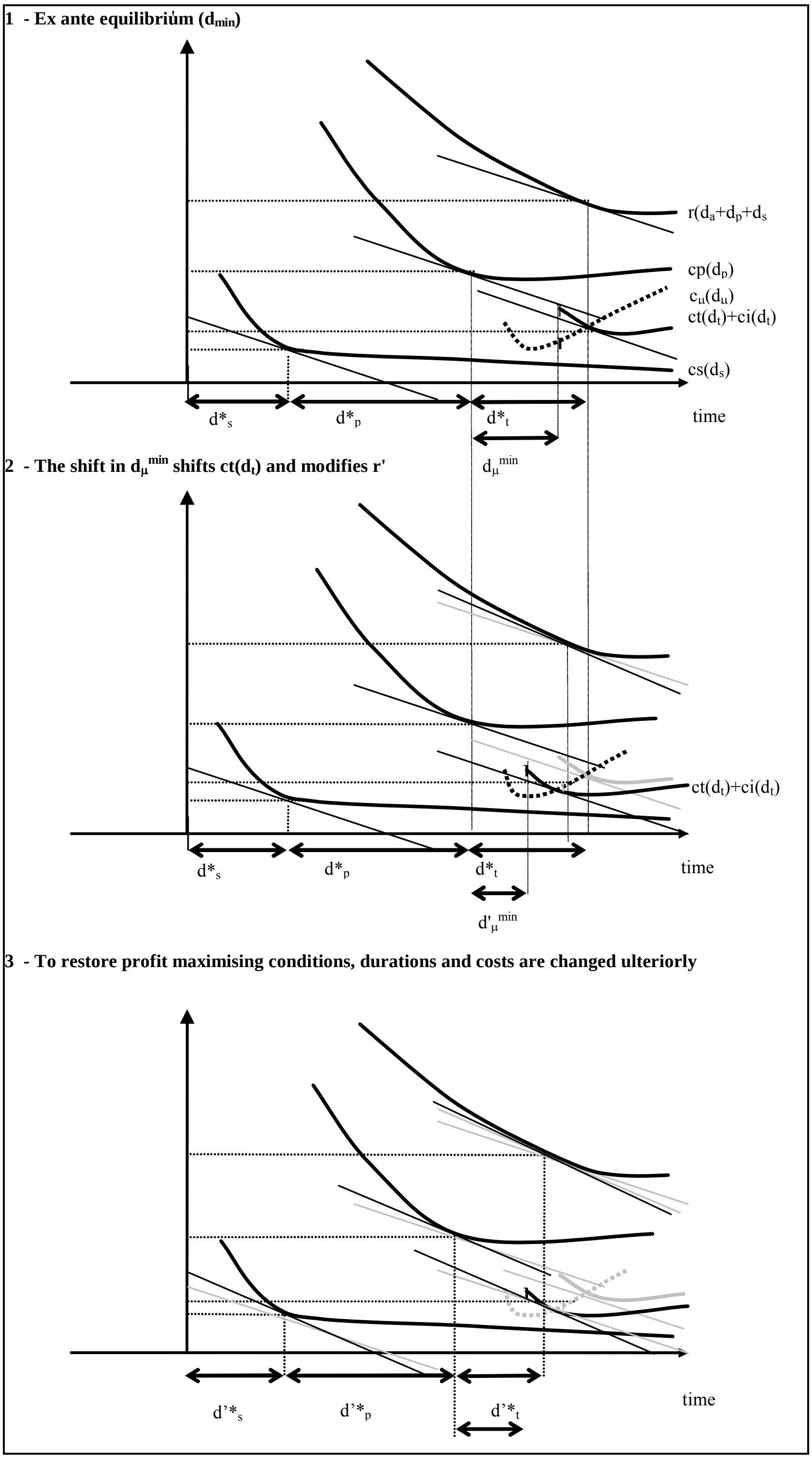
Consequences for the producer

The change in transport operator's supply curve will change the parameters of the profit maximising for the producer. Panel 1 in Figure 3 represents the ex ante (before the change in d_{min}) situation. In this situation the marginal temporal conditions given by equation (13) are respected.

When the minimum travel time is changed, the transport operator will face a transport cost curve that has lower costs for a given duration or, lower duration for a given cost. This is reflected in the second panel of Figure 3.

This may however not be an equilibrium as the marginal temporal conditions are not respected anymore. For instance on panel 2 of Figure 3, r'() is larger (in absolute value) than the other temporal marginal costs. Thus, it is possible for the producer to increase its profit by reducing the durations dedicated to the different operations and anticipating the arrival of the goods at the destination. This will improve also the situation of the customer as long as its marginal willingness to pay is smaller than marginal cost of anticipating the arrival of its goods.

Figure 3 - Consequences of a shift in minimum travel time on the equilibrium



Synthesis

The investigation of the consequences of a change in d_μ^{min} for a transport operator and a producer suggests a more general presentation of the effects of a diminution of travel time. One observes that the producer and the transport operator equate the marginal temporal costs of all their operations, except for the ones whose durations are constrained.

Suppose a process defined as a set of successive operations *i*. The operations in the process can be made by one single or by several firms. The cost $c(d_i)$ of each operation depends on its duration d_i. The relation between cost and duration can take two different forms: it can be (1) U shaped, or (2) monotonic increasing[4]. The operations are suitably defined so that only one single operation occurs at a time[5]. Suppose that this process is producing an output whose price $r(d)$ is variable in function of its whole duration. Suppose also that at least one operation has a constraint on its duration. Thus the profit maximising of the different agents are such that:

- $c'_{dj} = r'_{dj}\ \forall\ j \in J$. where *j* refers to operations whose durations are not constrained by a minimum.
- $d_k = d_k^{min}\ \forall\ k \in K$, where *k* refers to operations whose duration are constrained by a minimum in the optimal situation.
- $r(d)=r(\Sigma d_j + \Sigma d_k)$ refers to duration depending revenues.

The equilibrium resulting from this situation can be understood using a Newtonian metaphor: *r* is acting as a force that tends to attract all operations to their minimum durations. This attraction force encounters two sorts of resistance: the first one is based on the increase in costs when duration is reduced, the second one consists in the existence of 'physical' constraints on the duration of certain operations.

Within this simplified framework, the question on the value of freight time saving is to know the effects of a shift of the constraint of one of the operations whose duration is constrained, on the equilibrium of the whole system.

These effects will be of three sorts:

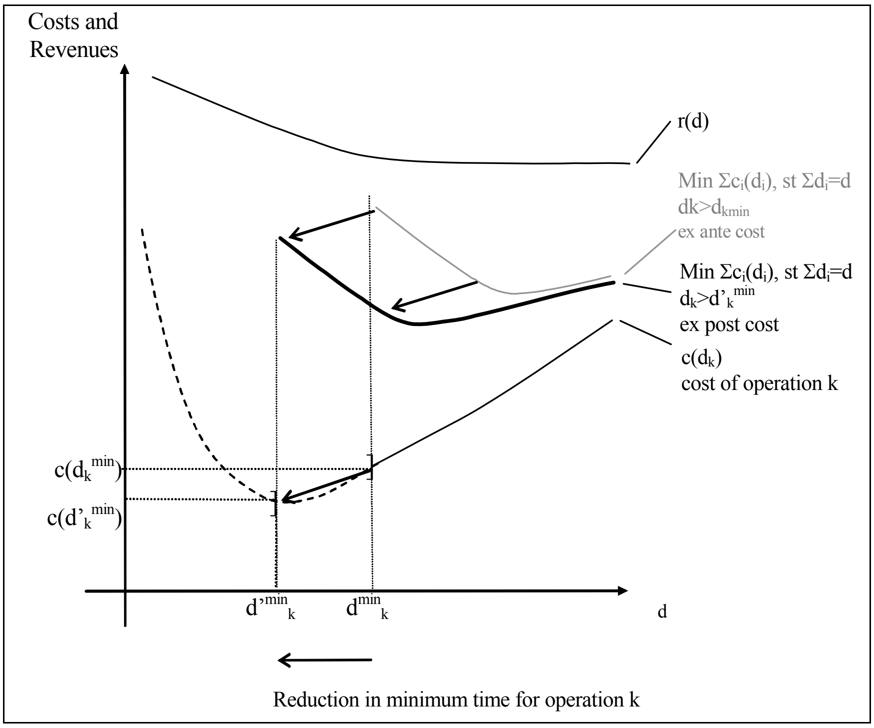
- the shift of the constraint on its own cost curve will reduce the cost of this operation,
- the whole duration of the process will be reduced, in a first instance, according to the change in the constraint,
- the duration of the other operations will be changed so as to recreate the equilibrium conditions, this will alter both the duration and the costs of the whole process. In this latest change the cost may increase, but this increase will be inferior to the increase in benefits from the customers (if not, the agents would not engage into such transactions).

[4] the situation of monotonic increasing costs, that was not presented in the simplified economy discussed in the previous section is included here. This allows the author to make the presentation more general and to take into account operations such a warehousing, whose cost is monotonic.

[5] If different costs incur at the same time, they should be reflected in one single operation. This is the case for instance of generalized immobilization costs, that are included into the costs of the transportation operation.

The effects of steps 1 and 2 are represented in Figure 4.

Figure 4 - Consequences of a reduction of the minimum duration



4. Welfare effects

In the previous section, we have analysed the consequences of a shift in the minimum travel time on the costs, revenues and utility of the different economic agents. In this section we proceed with the investigation of the normative value that should be assigned to travel time savings. We shift from the value of time as an object to the value of time as a norm.

We base our analysis not on the final equilibrium reached by the market after all the adjustments are made, but on the intermediate situation given reflected by panel 2 in Figure 3 or to point 2 of the numbered list at the end of section 0. This provides a lower boundary to the welfare effects as the extra effects that are not taken into account in this measure can only increase welfare (that is, they increase the profit of producers, and they improve the situation of the customer up to the point where the marginal benefits of a decrease in delivery time equals its marginal price). Label W, a measure of the welfare effects of Δd_{μ}^{min} a reduction of minimum travel time. $W^{l}(\Delta d_{\mu}^{min})$ is a lower boundary to W such that:

$$W\left(\Delta d_{\mu}^{\min}\right) \geq W^{1}\left(\Delta d_{\mu}^{\min}\right) \square \underbrace{-\left(ct\left(d'^{\min}_{\mu}, d^{*}_{\bar{\mu}}\right) - ct\left(d_{\mu}^{\min}, d^{*}_{\bar{\mu}}\right)\right)}_{\text{Change in transport cost}} - \underbrace{\left(ci\left(d'^{\min}_{\mu} + d^{*}_{\bar{\mu}}\right) - ci\left(d_{\mu}^{\min} + d^{*}_{\bar{\mu}}\right)\right)}_{\text{Change in immobilization costs}} + \underbrace{\left(wtp_{c} \times \Delta d_{\mu}^{\min}\right)}_{\text{Anticipated delivery}}$$

with

$d_{\mu}^{\min}$	ex ante minimum travel duration
$d'^{\min}_{\mu}$	ex post minimum travel duration
$d^{*}_{\bar{\mu}}$	optimal non travel duration in the ex ante situation
$ct(d_{\mu}^{\min}, d^{*}_{\bar{\mu}})$	transportation cost,
wtp_{c}	willingness to pay of the consumer for a reduction of delivery time,
ci( )	immobilizing costs during the transport.

Thus the welfare effects of a reduction in travel time can be seen as the sum of three components. Ideally the analyst may wish to take into account these three values separately, but this may however not be necessary. Indeed, one can use the equilibrium conditions presented in section 2 to provide an estimate of W^{1} without the need for a decomposition. This can be done using the linkage between the willingness to pay of the different agents (final costumers, producers, transport operators) such as illustrated in Table 1.

Table 1 - Willingness to pay for a time saving for different types of agents

Agent	**Duration**	**Willingness to pay**
Final consumers		
Specific good	"order to delivery"	$wtp_{c} = U'_{ta}/\lambda$, with: wtp_{c} Willingness to pay of the consumer, U'_{ta} Marginal utility of anticipating the reception of the good, λ Marginal utility of money.
Generic good		
Producers		
Specific good	Transport duration	$wtp^{s}_{p} = ci'_{t} - r'_{t}$, with: Willingness to pay of the producer of a specific good for a time saving, Marginal generalized immobilization costs of the producer, Marginal temporal revenues.
Generic good		as expressed for instance in the Baumol Vinod model.
Transport operators	Travel duration	$wtp_{t} = -rt'(d_{\mu}^{\min} + d_{\bar{\mu}}{*}) + c_{\mu}'(d_{\mu}^{\min})$, with willingness to pay of the transport operator, marginal travel costs, marginal revenues of the transport operator.

The relationships between the willingness to pay of the different agents provide results that are relevant to the evaluation of freight transport time saving benefits.

First, one should consider that the marginal revenues of transport operators for a transport time saving are equal to the willingness to pay of the producers for a marginal saving in transport time, and the marginal increase in revenues for the producers equates the willingness to pay of the final consumer for a faster delivery. Thus for a specific good:

$$wtp_t = c'_\mu (d_\mu) + wtp_p = c'_\mu + ci' + U'_{ta}/\lambda$$

it can be found that the **transport operators' willingness to pay** for a travel time saving, incorporates the different components that affect the welfare:

- The consequences of a travel time reduction on the production cost of transport services.
- The generalized immobilization cost of the producer.
- The willingness to pay of the final customer for an anticipation of the delivery of the good.

A second result, is that **equity questions** are relevant for the valuation of freight value of time. This emerges for two reasons. Indeed the willingness to pay of final consumer for a reduction in delivery time depends on the marginal utility of money. This implies in turn, that the willingness to pay of the producer for a faster transportation, and of the transport operator for a faster travel will depend on the revenues of the clients for which the good are transported. There is a second aspect of equity, that could be hid by the first one, but that appears if we suppose a hypothetical situation where the willingness to pay of the customer is null, thus cancelling the first effect. In this case the welfare effects given by W_l represent the decrease of production costs of the whole production system (that is transformation of the good and transportation). This cost reduction can be accepted as a welfare measure only if one assumes that the initial distribution of revenues is optimal.

In the following section we investigate what figure can be placed on W^l lower boundaries of the welfare effects of travel time saving, and we asses the impact of a change in freight value of time on the cost benefit analysis of a set of transport related projects in the UK.

Impact of revised freight values of time on cost benefit analysis

In the preceding section, we have shown that, provided we neglect some second order effects and distributional implications, the information on the transport operators' value of time can be used as a normative value to monetize the consequences on the different economic agents of a change in travel time. Another possibility is to account separately for the different effects. We discuss in turn these two possibilities with special consideration of the availability of empirical quantifications.

Using transport operators' willingness to pay

Table 2 indicates different results estimating the transport operators willingness to pay for a travel time saving.

Table 2 - Value of time for transport operators

Study	**Method**	**Vehicles**	**Euro (98)**	**Country**	**Year**
Fosgerau, Fix link of the Storebaelt, S.P.	S.P. mode choice road+ ferry vs. road + bridge	"trucks" "road train" "articulated vehicle".	47,64 /veh.h. **23,79** /veh.h. **21,44** /veh.h.	Denmark	1989
Rio Antirio Project (TRD, 1995).	R.P.	Trucks	From **29,81** /veh.h à **31,26** veh.h.	Greece	1994
L. Wynter, (1995) S.P.	S.P.: Transfer Price	Road (itinerary choice)	**74,03** /h. veh	France	1994
L. Wynter, (1995) R.P.	R.P., logit	Road (itinerary choice)	**27,71** /h.shipment	France	1994
Blauwens G., Van de Voorde, (1988)	Aggregated R.P.	Intermodal road, inland Navigation	0,0000848 * value of the shipment	Belgium	1981

The figures reported in Table 2 are puzzling, and it seems that they do not make it possible to propose a figure for freight value of time with a certain degree of generality. This is however not surprising considering the difference in context between interviews. It is likely that the different parameters determining the value of time in different locations are different.

For this reason it seems highly speculative to say how much of the value of time is omitted in current cost benefit analysis. Also, one can note that the empirical results available somehow contrast with the theoretical expectations that the willingness to pay of the transport operators for travel time savings should exceed the willingness to pay of the producer. No such pattern is emerging in the comparison of the value of time estimates available from different field studies. The empirical evidence leave space for nothing more than tentative proposals. A possible compromise, also highly speculative, would be to consider a value of 35 euro per veh.hour.

Apart from the lack of consolidated empirical results, another difficulty is that the use of the transport operators' value of time in order to summarise different welfare effects of travel time savings (production costs of transport operations, production costs of the producers, preference for an anticipated delivery of the final customer) is both an advantage and an inconvenience. It can be an inconvenience indeed, because it is not possible to use extra information on one of the components. This can be especially the case when considering that travel cost component of the value of time because the marginal economy in travel costs due to faster transportation depends on the ex ante speed of travel. Thus when using a single aggregated value of time that entails the different component with no further decomposition, the extra information that may be available to the analyst on the travel cost reduction cannot be included (unless cumbersome and uncertain calculations are made) in the computation.

Using separate estimates of the different components of the benefits

The second solution, is to **use a separate estimate of the extra benefits**, that are not included in transport operation costs and add them explicitly to the transport operator costs. This second solution is attractive but it raises a number of issues. The first issue is that the willingness to pay of producers is expressed based on shipments, while the cost benefit analysis of transport projects makes use of vehicle flow. Though some data are available on the number of shipments per vehicle, this conversion factor may be extremely variable from one situation to the other. This probably makes the use of transport operators' willingness to pay as an estimate of the extra benefits problematic.

To conclude on this point, the two possibilities that are available to take into account the full benefits of travel time savings both raise difficulties and this point probably needs not only further investigation from the community of transport scientists but as well a larger number of field data results.

Sensitivity of Cost Benefit analysis to an increase in the value of time

Finally, we investigate how the effect of an increase in the value of time for freight transportation used in Cost benefit analysis would affect the outcome of cost benefit analysis. In the absence of consolidated results we base our simulation on a 20 percent increase in the value of travel time savings. Table 3 provides the main outcome of cost benefit analysis for ten different road projects in the UK. These data are based on the Appraisal Summary Tables elaborated by the Department of Environment Transport and the Regions. The second column in Table 3 indicates an *increase* in the monetary value of freight time saving when the full benefits are taken into account[6]. The following columns indicate how much this increase represents compared with the present value of Travel Time savings, the total benefits and the net value of benefits.

[6] In this table, we refer to freight value of time as the value of HGV + the fraction of Light Good Vehicles that corresponds to work time Considering that only very synthetic information is available in the Appraisal Summary Table, some assumption had to be made to complement missing information. Usually ASP provide information only for the share of HGV. To complement this data assumptions were made regarding: the share of non-car among non-HGV veh (20 percent), the share of light good vehicles among non-car non HGV (80 percent) and the share of work time in LGV time (88 percent).

Given these assumptions, the results of the calculation should be considered as an approximation.

Table 3: sensitivity analysis of Cost Benefit analysis

	Impact on total Present Value of Benefits of Travel Time Saving		Impact on total benefits	Impact on net value of benefits	Benefit Cost Ratio	Benefit Cost ratio
	m£		% increase		Full benefits	Current assessment procedures
M1 J 31-32 (GO-YH)	1,4	5,6%	5,6%	6,1%	11,48	10,87
M1 J6A-10 (GOER)	14,2	5,0%	4,6%	5,6%	5,96	5,70
A63-Selby	4,3	3,9%	3,9%	5,0%	5,19	5,00
Whetherby/Walshford (YH)	10,5	6,6%	5,6%	7,5%	4,56	4,32
A303 Sparkford-Ilchester	1,0	3,6%	3,2%	4,3%	4,14	4,01
M6 J16-19 Widening (GONW)	16,1	6,4%	6,2%	8,5%	3,68	3,47
A556 (M) M6-M56 Link (GONW)	8,8	5,5%	4,6%	6,7%	3,55	3,39
M25 J.16 (M40) to J.19 (A41) (GOER)	8,0	5,0%	5,0%	7,3%	3,36	3,20
A5 Nesscliffe	0,3	4,7%	2,1%	3,7%	2,41	2,36
A3 Hindhead (Gose)	0,9	3,9%	1,6%	6,7%	1,34	1,32

It appears that the impact represents a small percentage increase in total benefits. Such figure appears modest, although one should not forget that they can make the difference between a project whose assessment is positive and a project whose assessment is negative.

The last two colons of Table 3 also indicate the change in the value of the Benefit Cost Ratio when the full benefits of transport time savings are taken into account. The pattern emerging from these two columns suggests that the ordering of projects based on Benefit Costs ratio is not upset when the full benefits of freight travel time savings are taken into account. This evidence should however not be generalized, and the finding could be different if we were to consider some projects that are more specifically related to freight.

5. Conclusions

In this article we have investigated how the welfare effects of freight travel time savings should be accounted for in cost benefit analysis.

Our findings are that the understanding of the welfare effects of freight travel time saving should at least take into consideration two distinctions: specific versus generic goods and travel time versus non travel time (transport time is the sum of travel time and non travel time).

When such distinctions are taken into account, it is possible to characterize how different economic agents trade off between duration and costs of different successive operations. This provides a formal expression of different agents' willingness to pay for a marginal change in the duration of a certain operation. This also provides a description of the ex ante equilibrium, that is the equilibrium that takes place subject to an initial level of the minimum travel time duration. It then becomes possible to analyse the consequences of a shift in the minimum travel time. This provides a positive description of freight value of time. Using this positive description it is possible to propose a normative value of time. Our results regarding this normative value of time are two folds. First, it appears much more tractable to propose a lower boundary for the quantification of the welfare effects of travel time savings than to take into consideration all the benefits that could derive from further adjustments of the different agents. Considering a lower boundary to the welfare effects of freight travel time savings concentrate on first order effects and assume that the consequences of the curvatures of the different costs and revenue functions can be neglected. Another aspect on which our analysis shed light on is that of the distributional implications of freight value of time. Actually, there is no reason, apart from disciplinary distance and analytical difficulties, to consider that the value of time used for the evaluation of freight value of time have no distributional effect.

Regarding the numerical evaluation of a monetary equivalent to freight time saving, we demonstrate that the elicitation of transport operators' willingness to pay offers an attractive way to summarise the welfare effects of time savings. However, empirical results are not converging and the comparison of available evidences is inconclusive. Whatsoever, it appears that the welfare effects are larger than the one accounted for in the factor costs method. Thus one should make allowance for these extra benefits in cost benefit analysis of transport projects. Based on a tentative allowance of 20 percent extra benefits, it is found that the net benefit of a randomly selected set of UK road projects exhibit an increase of 3,7 percent up to 7,5 percent, while the ranking of the project is not upset. The sensitivity of the net benefits to the full benefits value of time is not minor, and would be sufficient to reverse the outcome of cost-benefit analysis of a number of projects.

Eventually, our analysis suggest that it would be relevant for transport economists to have more empirical estimates of the value of time for freight based on surveys, whether SP or RP, made among hauliers, this contrast with the practice that during the latest decades has concentrated on the value of time for shippers.

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