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LARS HULTKRANTZ
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Örebro University School of Business
701 82 Örebro
SWEDEN

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A Note on High-Speed Rail Investments and Travelers' Value of Time

Lars Hultkrantz*

Abstract

High-Speed Rail (HSR) is designed for travelers with high value of time. HSR offer fast and reliable services and good possibilities for work during the journey. Surprisingly, these benefits of HSR investment proposals are often appraised by use of travel-time valuations of people who use conventional (intercity) train services.

The standard approach builds on two major assumptions, linearity of demand, and that the value of time is unchanged between the "before" and "after" alternatives, i.e., that change in the average value of time of passengers can be ignored. While the first of these is well known, the second is not always observed. However, the spread of values of time between individual travelers is large and is an essential motivation for HSR investments. This note therefore considers whether the assumption that the value of time remains unchanged by the speed improvement induces any significant bias in the appraisal. We first use a modal-mix model where travelers have varying value of time to outline some conceptual points and then discuss to what extent these may affect the social profitability of three recently constructed or proposed HSR lines: Oslo- Stockholm (Norway and Sweden), Stockholm-Göteborg (Sweden) and Beijing-Shanghai Hongqiao (China). We conclude that a RoH-based evaluation of an HSR line should be complemented by a sensitivity analysis of how the outcome is affected by possible changes of the composition of travelers with different values of time.

* Örebro University School of Business, lars.hultkrantz@oru.se. I want to thank two referees, Jonas Eliasson, Jan-Eric Nilsson and Matthias Hunold for important comments, as well as seminar participants at Örebro University Business School, the Centre of Transport Studies, Stockholm and the Kuhmo-Nectar conference of the International Transportation Economics Association, Berlin June 21-22, 2012.

1. Introduction

High-Speed Rail (HSR) is designed for travelers with high value of time. HSR offer fast and reliable services and good possibilities for work during the journey. Surprisingly, these benefits of HSR investment proposals are often appraised by use of travel-time valuations of people who travel with conventional (intercity) trains. This note therefore considers whether benefit-cost assessments of HSR investment proposals using standard appraisal methods underestimate the consumer surplus.

The standard procedure for calculating consumer surplus effects starts by computation of the average generalized travel costs, defined as the sum of average monetary expenditure and cost of travel time for a trip. Assuming a linear demand function, the change of consumer surplus[1] from a reduction of the travel time is evaluated by the "Rule of a Half" (RoH) by computing the area of a trapezoid, consisting of a rectangle and a triangle (de Rus 2011, Neuburger 1971, Hotelling 1938). The rectangle area is held by multiplying the number of previous users of the travel mode with the change of the generalized travel cost, while the area of the triangle is the increment of travelers (i.e., the induced increase of demand) times half of the generalized cost reduction.

The main alternative to this method is the logsum method (de Jong et al. 2005a, b). Based on seminal work by McFadden (1978) and (1981), this approach employs the multinomial or nested random utility models (RUM) that sometimes are used to predict travel demand. In this approach demand is estimated for a (possibly weighted) sample of (representative) individuals before and after for instance a change of travel options. The so called logsum value held from the demand model can be interpreted as the sum of the change of all individuals' utilities. This value is converted into a monetary measure of consumer surplus by division with the marginal utility of income (estimated within the RUM). Thus value-of-travel-time savings (VTTS) parameters held from separate studies are not needed. Also, since effects are evaluated for each individual in the data sample and then summarized, various problems of the standard method connected to aggregation and linearity are avoided.

Still, the most commonly used approach is the RoH. This method has some advantages. Often (though not always) the RUM model is estimated on revealed preference (RP) data, while VTTS is estimated on stated preference (SP) data. The choice between RP and SP is partly a choice between observational and experimental data, which means that the SP VTTS studies may better control for various factors influencing VTTS. Also, possibly, the conventional approach is more transparent and easier to explain to decision makers. A more profound problem with the logsum method is that of estimating a reliable measure of the marginal utility of income, which meets a number of challenges such as confounding, non-linearity, etc. Finally and maybe most important, in many cases demand is estimated with other means than a micro data based RUM or from combinations of results from such a model and other models and data sources, which makes the RoH method very convenient.

In recent times, several countries are or have been in the process of evaluating huge high-profile rail infrastructure projects, such as High-Speed Rail (HSR) lines. HSR offers fast travel and provide

[1] Following the practices of national transport planning in Norway and Sweden, evaluations here will be based on willingness to pay, i.e., without differentiated welfare weights. The correct measure of benefits is the compensating variation (Small and Rosen 1981), but here income effects are assumed to be zero and therefore the Marshallian consumer surplus is used. The social valuation of a service quality improvement, like a travel-time reduction, differs from that of a private company, see Spence (1976).

travelers with superior conditions for work during journey. Surprisingly, evaluators have found that both these features result in low benefit values as calculated by RoH. Even though a large portion of the HSR travelers are diverted air passengers[2] that have revealed preference for going by a fast mode, or generated traffic attracted by a combination of a (probably) higher fare and shorter travel time, their benefits are valued with the value of travel-time savings, VTTS, of users of the old rail mode. Moreover, accounting for the value of work during train travel reduces the VTTS of train passengers, and therefore the benefit from faster travel.

This has sometimes been seen as running against intuition[3]. In fact, even the most established analysts of the economics of HSR seem to struggle with the appeal of that intuition:

For instance Nash (2010), in a discussion of how cost benefit analysis of HSR can be enhanced, notices that "HSR offers a comfortable environment in which passengers can work, relax, eat or drink without the interruption of needing to change mode or move from terminal to aircraft" and therefore suggests that "there may be substantial benefits from diverting passengers from air to rail event when there are not significant time savings" (p. 6). However, the effect these aspects may have on the computed consumer-surplus from HSR is in fact to *lower* the "heights" of the RoH rectangle and triangle, by reducing the value of time and therefore the generalized travel-cost reduction from higher train speed.

From another angle, de Rus (2011) reviews benefits and costs of HSR and finds that "the case for HSR investment can rarely be justified by the benefits provided by the deviation of traffic from air transport" (p. 19). The alleged reason is that for previous users of air transport, "time savings experienced from users shifting to HSR come from a reduction of access, waiting and egress time … which hardly offset the substantial increase in vehicle time. Even with a negative balance in terms of time savings, the user benefit can be slightly positive when the different values of time are considered". However, in estimation of the consumer surplus from a predicted increase of rail demand the time difference used with the RoH method, which is the method he uses, is the reduction of *rail travel-time*, not the change of travel time that mode shifters experience (i.e., the difference between their previous travel time by air and the HSR travel time). Moreover, the VTTS used in this calculation is the *rail* VTTS, so the VTTS of air passengers is irrelevant.

It thus seems that the standard appraisal method is at odds with intuition. In this paper, we demonstrate that the reason is that VTTS differences across and within mode are ignored. This is usually not a problem when the average VTTS is largely unaffected by the transport investment that is studied. However for HSR investments that target new categories of users with a higher VTTS than previous train passengers[4], this may invoke a systematic bias.

Besides the specific problems concerning a change of the composition of travelers of a mode with varying VTTS, there are other potential problems when a first order approximation naturally breaks

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[2] Nash (2009) reviews evidence indicating that the air-rail mode share falls rapidly when rail travel-time goes under four hours and virtually to zero when rail travel time is below three hours.

[3] The Swedish value-of-time study made in 1994 (Algers et al. 1995) applied the so called Hensher rule to business VTTS (Hensher 1977) and found surprisingly a negative business VTTS for long-distance train travelers because work during travel was estimated to decrease more when travel time was shortened than the increase of work hours it would give rise to.

[4] De Rus and Inglada (1997) estimate that the consumer surplus from generated traffic on the Madrid-Seville HSR line is more than double that of deviated traffic (mostly conventional train).

down. However, in this study we stick to the linearity assumption, using a model in which travel demand for a specific mode is linearly related to travel time.

In the next section, we use a modal-mix model for travelers with varying VTTS as a conceptual framework for thinking about the implementation of RoH in relation to an HSR investment. We demonstrate that the reduction of train travel time in this model should be evaluated with different VTTS values for previous and new users of the rail mode. For previous users, who are at "the intensive margin", the average VTTS can be applied, but for new users, who are at "the extensive margin", marginal VTTS is relevant. The marginal VTTS appears in two versions however, on both a lower and an upper margin. In the third section we discuss the empirical significance of these conceptual points in three HSR cases, in Sweden, Norway-Sweden, and China.

For this, we derive estimates of the upper margin VTTS as the value of time that makes a traveler indifferent between going by train or air. We find that these values are considerably higher than the average VTTS for train passengers that have been used for benefit-cost assessments of these HSR lines. The significance of this finding for the social profitability varies between these projects.

2. Analysis

2.1 Model

In this section, we expose our arguments in a modal-mix model, focusing on the competition for business travelers between three travel modes: coach, assumed to be cheap and slow; air, assumed to be expensive and fast; and train, assumed to be in the mid range with respect to both travel time and travel expenditure. [5] The effect of a HSR investment is thought to shorten the train travel time. Consistent with the "cost savings" long-run approach to VTTS for business travelers leisure time is not considered to be affected by the travel-time reduction.

We assume that travelers' opportunity cost of time per hour (before consideration of work during travel) is uniformly distributed and given by $v \in [0,1]$. We normalize the (monetary) cost of coach to zero, so p_r is the additional cost of train and $p_r + p_a$ is the additional cost of air travel compared to coach.

[5] The model builds on Hotelling (1929). For the moment we abstract from the car mode. The car can be shared by several passengers and can transport door-to-door, so depending on circumstances car can be more or less costly and more or less rapid than train.

Figure 1 here

We assume that indirect utility is linear in income[6]

$$U = y = (L - \lambda_c t_c - \lambda_a t_a - \lambda_r t_r)v - \lambda_r p_r - \lambda_a p_a + \lambda_r t_r w, \qquad (1)$$

where *y* is income; λ_i takes value one for the chosen travel mode and zero otherwise; $(L - t_i)$ is time spent in office; and t_i is travel time used in coach (*i=c*), rail (*i=r*) or air travel (*i=a*). *w* is the value of work during journey per unit of travel time. This is, for several reasons,[7] expected to be lower than the wage rate. Eq. (1) implies that although the time devoted for leisure is constant, total labor supply can be enhanced either by travel time reductions or by a larger portion of total travel time spent in train.

Finally, assume that each individual makes first a choice on choice of travel mode, and then whether to travel or not. We initially assume that the benefit at the destination, z, is "large enough" to always motivate travel. Then there are two unique switching points (v_1, and v_2) that determine the modal split between coach, train and air travelers, as shown in Figure 1. At v_1 there is a traveler that is indifferent between choosing coach or train, so the following condition is met:

$$t_r(v_1 - w) + p_r = t_c \cdot v_1. \quad (2)$$

Likewise, at v_2 there is a traveler that is indifferent between choosing train or air, so the following condition is met:

$$t_a \cdot v_2 + p_a = t_r\,(v_2 - w). \quad (3)$$

Thus, switching points v_1 and v_2 define the lower and upper VTTS margin for train passengers, respectively.

2.2 Evaluation of a travel-time reduction for the rail mode

Now let train travel time be shortened by Δt_r; $\Delta t_r < t_a - t_r$. Collecting terms in eqs. (2) and (3) and differentiating with respect to t_r, we find that

$$\Delta v_1 = -\frac{(v_1 - w)}{t_c - t_r} \cdot \Delta t_r < 0 \qquad (4)$$

and

$$\Delta v_2 = -\frac{(v_2 - w)}{t_a - t_r} \cdot \Delta t_r > 0. \qquad (5)$$

Thus, demand for the rail mode will increase by inflow from both the slower and the faster mode.

Using Figure 1, we see that the total welfare gain of the train travel time reduction for "old" train passengers, i.e., those that were already using the train mode, is

[6] Thus the marginal utility of income is unity and therefore constant, which facilitates aggregation over individuals.

[7] First, only part of the travel time can be used for work. Second, while people sometimes state that they work better at train than at office, because of fewer disturbances from colleagues and clients, part of their productivity from the employer's point of view may emerge from such "disturbances".

$$\Delta U^{old} = (v_2 - v_1) \cdot \frac{v_2+v_1}{2} \cdot \Delta t_r \text{ . (6)}$$

The total gain made by attracted travelers at the lower and upper margins are, respectively:

$$\Delta U^{low} = \Delta v_1 \cdot \frac{v_1-w}{2} \cdot \Delta t_r \qquad (7)$$

and

$$\Delta U^{up} = \Delta v_2 \cdot \frac{v_2-w}{2} \cdot \Delta t_r. \qquad (8)$$

Thus, the value of the travel time reduction for "old" train travelers and "new" train travelers at the two margins, should be evaluated by the average VTTS, the lower margin marginal VTTS, and the upper margin marginal VTTS ,respectively.

We make the following proposition:

Proposition: The welfare gain from a reduction of the travel time of the rail mode can in this model be evaluated by a Modified Rule of a Half, where the increment of the consumer surplus at the intensive margin among travelers going by train before the travel-time change is evaluated with the average (rail) VTTS, and the consumer surplus gain at the extensive margin among train travelers that have switched from a slower mode is evaluated with the low margin marginal (rail) VTTS and among those that have switched from a faster mode with the upper margin marginal (rail) VTTS.

Obviously, this means that in a case where modal shifters come in equal shares from slower and faster modes, the (equal-weights) average of the two marginal VTTS values could be closely approximated by the average rail VTTS. In such a case, not much is gained by using separate VTTS values. However, HSR lines compete mainly on the high end of the market, i.e., with air and car (when car for some reason is faster than regular train), i.e., with faster modes.

It can be observed that the welfare gain of a train travel-time reduction for both existing train travelers and generated demand should be evaluated with VTTS that account for the value of work during journey. This means that, on the one hand, possibilities for work on train reduce the VTTS used to evaluate the benefit of a travel-time reduction. On the other hand, this makes the initial demand for train travel larger than otherwise.[8]

In addition, as shown in eqs. (4) and (5), the effect will also be that the induced demand increase resulting from a train travel-time reduction will be larger than otherwise. This therefore explains the paradox that we presented in the introduction in connection to Nash's (2010) observation on the social benefit of modal shift from air to rail. The value of work during travel is already (or should be) accounted for as it affects the quantity of the forecasted HSR demand.

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[8] The lower margin will shift downwards (to the left) and the upper margin upwards (to the right).The increment of train demand will be in our model:

$$\Delta(v_2 - v_1) = t_r \left[\frac{1}{t_r - t_a} + \frac{1}{t_c - t_r}\right] \cdot w > 0. \qquad (9)$$

Whether the effects on VTTS and on train demand from the possibility to work during a train journey results in a larger or smaller consumer surplus change when train travel-time is reduced depends on if the elasticity of demand with respect to improved conditions for work in train is greater than or less than one. [9]

3. Empirical significance

3.1 Introduction

We now proceed to a discussion of the empirical significance of the distinction made between average and (upper) marginal VTTS in the case of HSR investments. We first present three investment cases, which all recently have been subjected to benefit cost appraisal. These are a Swedish domestic line, between Stockholm and Göteborg that recently was evaluated by the Swedish Transport Administration (2012); a Norwegian- Swedish line between Oslo and Stockholm, evaluated by the Norwegian Rail Administration (2012); and the newly completed Beijing-Shanghai line, for which we use an appraisal made in a master thesis work (Ding and Zhang, 2012). We then present some evidence on the average and upper margin VTTS of rail travelers in these three cases. Finally, we make some crude assessments on how the overall social profitability of these three investments/investment proposals would be affected by the use of upper margin VTTS for the induced rail demand and by regarding the value of work on journey.

The aim of this section is to see whether the possible bias of the RoH approach discussed in the previous section could be empirically important. We therefore focus on business travelers where the effect is likely to be most pronounced and on the interface between air and rail, thus on the “upper-margin VTTS” competition. Even for the shortest of the lines we study here, Stockholm-Göteborg, 80 percent of diverted business travelers are estimated to come from air travel; all the remaining 20 percent from car (i.e., zero percent from coach), and this includes travelers to and from stations in between (Börjesson 2012). These diverted travelers are likely to be representative of the large share of the HSR travel demand that is generated traffic. Online ticket systems provide train operators with excellent means for price discrimination, and most probably HSR operators will use peak-load schemes that at some times will be attractive for low-budget travelers. However, parallel operation of HSR and conventional intercity rail also makes it possible to segment the market by differentiated products. In Sweden, averages fares of the moderately high speed “X2000” services (which run at a maximum speed of 250 km/h) are reported to be 50 percent higher than the average fares of Intercity trains (WSP 2009).[10] Since HSR services have higher operational costs, fewer stops on the line, and (partly because of that) a higher capacity utilization, the main segment target is likely to be business travelers and other travelers with a higher than average VTTS . Also, the low end of the market is already well supplied as indicated by the zero or even negative “lower-margin” VTTS (coach and car) is close to zero.

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[9] That would even in our simple model depend on the parameters.

[10] Thus the operator was able to capture some part of the increase of the average value of time from the speed improvement compared to IC train. However, the cost-benefit assessment of the Swedish HSR network proposal assumed that average revenues would remain unchanged (Hultkrantz 2009, WSP 2009).

3.2 Three HSR lines

We will have a look on the following three cases that recently have been evaluated in benefit-cost studies:

1) Stockholm-Göteborg.

This line would connect the two largest cities in Sweden on a separate line designated for HSR trains with a maximum speed of 330 km/h. The existing 455 km long railroad is used for mixed freight and passenger train traffic. The current passenger trains are regional (commuter) trains, intercity trains and high speed trains with a maximum speed of 250 km/h. A government appointed investigator suggested in 2009 (SOU 2009) that the HSR line should be built in connection with a fork line departing from the middle of the line (at Jönköping) to Malmö (Sweden's third largest city and adjacent to Copenhagen).The investigator presented a somewhat gold-plated[11] benefit-cost appraisal that later has been revised by the Swedish Transport Administration (2012).

2) Oslo- Stockholm

The distance between the capital cities of Norway and Stockholm is 526 km. The Norwegian Rail Administration has recently presented a study of a range of possible HSR lines connecting the major cities in Norway and Oslo to Göteborg and Stockholm, respectively. Because of low population density and the extremely challenging natural conditions in Norway with its mountains and fjords, the assessed benefits-cost ratios ranged between -0.68 and -0.95.[12] The most favorable of these ratios was estimated for a 330 km/h line connecting Oslo to Arvika in Sweden, from which trains can continue on the existing railroad at the speed of 250 km/h to Stockholm.

3) Beijing-Shanghai (Hongqiao)

This line was constructed between 2008 and 2011. It is designed for a maximum speed of 350 km/h but is now operated at a maximum speed of 300 km/h. A benefit-cost appraisal is done by Ding and Zhang (2012), based on the generic BCA framework of de Rus (2011).

In Table 1, travel times for these three travel relations are compared between HSR, conventional train and air travel. The air travel time refers to total time including access and recess from and to the city centers, using rail links or bus (Göteborg). Compared to conventional train, HSR reduces travel time by around 1 hour (Stockholm-Göteborg), 3.5 hours (Oslo-Stockholm), and 4.5 hours, respectively. Still, air is faster than HSR except for in the Stockholm-Göteborg relation where HSR potentially saves 20 minutes.

Table 1 here

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[11] See criticism in Hultkrantz (2009).

[12] A separate study of the expected "optimism bias" of construction cost estimates suggested that these ratios could be expected to be even worse.

3.3 Empirical estimates of average and (upper) marginal VTTS in Sweden, Norway and China

The VTTS for business travelers in Sweden is since 2008 based on the so called cost-savings approach, which basically asks how much the employer of a business traveler would be willing to pay to reduce his employee's travel time given that in the long run wages will compensate for all work time, including time spent on business trips. Therefore a travel time reduction is valued with the gross wage cost, i.e., including payroll fees and before income tax deduction. This is in contrast to the Hensher approach that was used previously. In the Hensher approach benefits from a travel time reduction are shared between employer and employee according to some proportional coefficient. The employer is assumed to compensate the business traveler when she uses some part of the reduced travel time for working more hours, but not for the part that results in more leisure. As leisure has a lower value, in a first approximation it will equal the hourly net wage, i.e., after income tax deduction, the Hensher method yields a lower VTTS than the cost-savings approach.

Aside this difference, which usually is described as a difference between a long-term (cost savings) and short-term (Hensher) view, proponents of both approaches usually agree that account should be taken to other factors that may affect the VTTS, such as possibilities for work during travel, comfort, time reliability, etc., although this is not always done due to lack of reliable empirical estimates of these aspects (Mackie et al. 2001).

The Swedish application of the cost-savings method is very straightforward, setting business-travel VTTS of all modes equal to the average gross wage-cost per hour in Sweden (SIKA 2008).[13] Differences in average wages across modes are not considered, nor are differences in conditions for doing work during journey. Another possible concern could be that the average wage of employees that spend much time on business trips might differ from the average wage of all employees.

The available Swedish evidence on mode-specific wages among business travelers is scarce. However, in Norway, the national travel survey from 2009 has been used to estimate the average gross wage costs per hour of business travelers by air and train at NOK 445 and 393, corresponding to approximately SEK 512 and 452, respectively. This hence suggests that the wage cost per hour is 13 percent higher for air than for rail passengers. Both values are also considerably higher than the Swedish VTTS. However this seems to mainly be a reflection of the overall differences in wages between oil-rich Norway and Sweden. Multiplying these values by the rate of the average monthly wage in Sweden to that of Norway in 2010[14] results in an average wage cost for rail passengers of SEK 304, i.e., slightly below the Swedish VTTS.

The two upper rows of Table 2 show estimated of the average and upper margin marginal VTTS values for the three cases. The average VTTS for Sweden and Norway are "official values" from the current national guidelines[15]. The Swedish VTTS if from SIKA (2008), inflated with real wage changes from 2006 to 2011. The Norwegian value comes from Ramjerdi et al. (2010) and is in 2010 price level. The Chinese value corresponds to the average wage of the financial sector in China 2011. The two

[13] See the Swedish CBA guidelines issued in 2008 (SIKA 2008). In Norway the national guidelines (NOU 1997) prescribe that the value of work during travel should be subtracted, but the recent update does not comply to that (Secretariat of the Norwegian National Transport Plan 2014-2023, 2010).

[14] The average monthly wage in Norway 2010 was NOK 42 240, in Sweden SEK 28 400 (see official websites of Statistics Norway and Statistics Sweden).

[15] The Norwegian VTTS is expressed in Swedish currency assuming 100 NOK = 115 SEK.

lower rows shows the corresponding values after reduction by 25 percent as (example of) an adjustment in consideration of the value of work during travel (see next section).

Table 2 here

The “upper margin” VTTS estimates are derived as the break-even value of time that makes the generalized cost of train and air equal. Both air and rail companies use revenue management schemes with dynamic pricing so ticket prices vary depending on various circumstances (Chiang and Chen 2007, Armstrong and Meissner 2010). However, a sample of prices read at various occasions show only minor differences. For Sweden and Norway these values are derived for a business traveler that is assumed to be on return to Stockholm from a one-day business trip in Göteborg or Oslo on a late Friday afternoon in January 2012. For China the values refer to a trip on a weekday morning in May 2012 from Beijing to Shanghai Hongqiao. All trips go from city center to city center. Further detail is given in Appendix.

These break-even values can be used as an approximation of the VTTS of the upper-margin traveler. In Stockholm, Oslo and Göteborg, the central rail station is the main ground transportation terminal for air travelers so the marginal traveler is assumed to start and end there irrespective of the ultimate origin and destination of the trip (see Appendix). The values in Table 2 hence show that the marginal values for Stockholm-Göteborg and Beijing-Shanghai are triple the official average values, while this difference for Oslo-Stockholm amounts to just around 20 percent.

For Göteborg-Stockholm travel, similar magnitudes of marginal VTTS are reported in other studies. Börjesson (2012) estimates demand for HSR on national travel survey data. She gets implicit values of time for one-day trip and over-night business travelers at 1180 SEK/hour and 600 SEK/hour (2008 price level), respectively. Further, Carlsson (2003) find, based on a stated preference survey among business passengers travelling by rail or air from Göteborg to Stockholm, very high VTTS values (500 and 1300 SEK/hour for rail and air, respectively).

3.4 Work during travel

Nash (2009) notices that “a relatively high proportion of HSR traffic (30-40% in European conditions) is likely to be traveling on business”. In Great Britain, Lyons et al. (2007) find from an extensive mailback questionnaire survey that 52 percent of business travelers are working some time, and 31 percent working most of the time, during train journeys.[16] More recently, in a report for the UK Department for Transport, Fickling et al (2009, released 2012) report that the proportions of travelers working on the train were 82 and 77 percent on the outbound and return journey, respectively. Further, for those that spent some time working, the percentage of journey time spent working was 60 and 54 percent respectively. These numbers indicate that on average 45 percent of business travel time is used for work. For Norway, Hjorthol and Gripsrud (2008) report that in Norway 40 percent of business train travelers use more travel time for work than for other activities (including doing nothing).[17]

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[16] See ibid. Table 2. The numbers reported here are averages over out and return travel assuming equal shares.

[17] A recent study made in Sweden is Fahlén et al. (2010). Unfortunately, this study sampled a very limited number of business travelers. However, it indicated that more than 50 percent train commuters to and from work used travel time for work and those that were working during travel used on average half of the travel time for work activities.

Of course, some work can be done during air travel as well, but considering that a large part of a domestic air trip is spent in ground travel to and from airport, security check, waiting at the gate, embarking and disembarking, etc., this reduction is probably small. For car users, especially drivers, the scope for work during journey is even more limited, although mobile phones may allow some work to be done. Unsurprising, in a recent meta-analysis of UK value of time studies Abrantes and Wardman (2011) find that business travelers on long-distance trips (200 miles) by car value in-vehicle time by train at 87 percent of the corresponding value by car.

Thus, it is clear that the value of work during train journeys is substantial. Work is also done on commute travel. In fact, it is not uncommon that Swedish companies and government authorities allow long-distance train commuters to include part of their commute travel time as work time. It is therefore fair to conclude that the value of work should be accounted for in an estimate of the VTTS of train passengers

3.5 Adjusted Net Benefit-Cost Ratios

In the preceding sections we have seen that, first, the difference between the upper-margin VTTS and the average VTTS is quite large in two of our three HSR cases; second, that ignorance of work during journey may considerably bias VTTS estimates, especially for business travelers. The first effect means that existing benefit-cost appraisals may have underestimated the net benefit-cost ratios (NBCR), the second works in the opposite direction.

To get an idea of the significance of these biases we show reference and adjusted NBCR in these three cases in Table 3. The reference ratios depend on a large number of assumptions, but the interested reader is referred to the benefit-cost studies from which we have collected these ratios. The adjustments we make are for the purpose of illustrating possible magnitudes of the two biases, not for giving a second opinion on the social profitability of these three HSR investments/investment proposals.

With these reservations in mind, we observe that in the reference cases all three HSR lines show negative NBCR. The Oslo-Stockholm line is very much in the deficit, while the Chinese line is not very far on the negative side.

The second row in the table shows the NBCR when the share of passengers that are not previous rail travelers are inflated by use of upper margin VTTS instead of average VTTS. The “triangle” part of the RoH area is therefore multiplied by 3 for Oslo-Stockholm and Beijing-Shanghai, and with 4/3 for Stockholm-Göteborg. We have assumed that this share in all three cases is 40 percent, which is the share estimated for Stockholm Göteborg in Börjesson (2012). As conventional rail in this case already is operated by high-speed services (but with maximum speed at 250 km/h), it is likely that this share is even larger in the two other cases.

The result of this adjustment has largest effect on the Chinese HSR line. The NBCR is increased by nearly 0.5 and takes a positive sign. The Göteborg-Stockholm ratio is also improved, but not as much, partly because a considerable part of the benefits accrue from external effect reductions that are not affected by the adjustment. Finally, the NBCR for Oslo-Stockholm does not change much, because the initial benefit to cost ratio is low and the VTTS adjustment is smaller.

The third row in Table 3 shows NBCR adjusted also by a 25 percent reduction of the average and marginal VTTS for previous rail passengers to account for the value of work during journey. All ratios are lowered, but the Beijing-Shanghai NBCR remains positive. For Göteborg-Stockholm the effect to a large extent outweighs the effect of the previous adjustment. For Oslo-Stockholm line the deficit is even larger than in the reference case.

Table 3 here

4. Conclusions

In this note, we used a modal-mix model based on the idea that business travelers differ with respect to their individual value of time and chooses between modes with different travel times according to that. We demonstrated that a travel-time reduction of the train mode, considered to represent for instance an upgrade of a rail from conventional inter-city rail to HSR, should be evaluated with different VTTS values for travelers that used the rail mode before the upgrade and those that have been attracted to this mode as a result of the improvement. For the former category, the average rail VTTS is relevant, while for attracted travelers "lower margin" or "upper margin" VTTS should be used.

Our analysis casts some light on a previous discussion in the literature. De Jong et al. (2005a) report:

> "The 'classic' method uses the rule-of-half and calculates the benefits for new travelers (with some (?) mode) as half of the benefit for travelers that stay with that mode. At a workshop on the direct effects it was proposed to use the average of the values of time of the old and new mode here. This is also proposed in Ecorys and 4Cast (2004). Later on, this was criticized for not being consistent with the underlying welfare economics (and the rule of half in particular). We agree with this criticism: the short-term 'improvement' is not actually an improvement, and the 'classic' method should be used instead." (p. 54-55)

The result we have derived implies that using another VTTS for new travelers can indeed be consistent with welfare theory. However, what is relevant is not the average of VTTS of the old and new modes but the marginal, break-even, VTTS(s).

However, there may be various "high" and "low" margins, depending on the availability and features of alternative modes, so the simple method of using an average VTTS can probably be defended in many rail infrastructure investment cases. For instance, an improved regional transit may divert commuters equally from a slow (bus) and fast mode (car).

Further, we noticed that although the possibility to work during a train journey reduces rail VTTS, which seems to reduce the calculated consumer surplus, this increases the demand for rail, and the size of the induced demand increase of an HSR upgrade, so while "price" (height) is lowered, "quantity" (base) is widened.

Turning to our three example cases in Sweden, Norway and China, we found that estimates of the social profitability of HSR projects made with conventional approaches can be substantially biased. We get polar results for the Beijing-Shanghai line, where the net benefit-cost ratio is significantly enhanced when adjusting for both effects, and the Norwegian Oslo-Stockholm line for which the adjustments result in an outcome that is even worse than the initial.

The overall conclusion for planners and policy makers of this note is that for HSR projects and other large investment projects that are expected to substantially change the modal mix and where the main modal competition comes from a faster mode, it may be worthwhile to analyze more thoroughly the size of a possible bias invoked by a too coarse implementation of the standard RoH procedure. If the logsum approach is not to be used, the RoH method should be computed for subgroups to account for their differences in VTTS and perhaps other variation in preferences across travelers. At the least, a sensitivity analysis of the possible effect of a change of the composition of travelers with various values of travel time should be conducted.

A second upshot is that the value of work on rail journeys needs to be properly handled in benefit-cost appraisals of rail investments.

For future research, we have highlighted three areas where there is much need for more empirical studies: on VTTS distributions, mode-specific estimates of average wage of travelers, and the value of work performed on journeys.

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Appendix

Calculation of upper margin break-even VTTS

1. Sweden and Norway

In Table A1, we show break-even VTTS, all expressed in Swedish currency, for a choice between air and train for a traveler on return to Stockholm from a one-day business trip in Göteborg, Oslo, or , for comparison, Malmö on a late Friday afternoon in January 2012. This business traveler goes, with hand luggage only, by economy class with a ticket that allows a last-minute change to go at another departure time. The regional-travel networks of all these cities, in particular Stockholm, are heavily monocentric with the main nodes located at the central rail station. The airports (except for the Bromma airport in Stockholm) are situated a long distance from the city centers and express trains and coaches have few stops before the central station (express train to Oslo has one stop, to Stockholm all trains operate nonstop). Moreover, in Oslo and Stockholm the express trains bring air travelers to the central station in 20 minutes while a taxi requires at least 40 – sometimes much more depending on traffic. We therefore use the central stations in these cities as endpoints of the respective trips. She arrives at the Stockholm central station 5.50 pm if she comes from Göteborg, going by either train or air. If she comes from Malmö, air takes her there 7.25 pm, train 7.50 pm. In Göteborg and Malmö she goes by bus from the central stations there. In Stockholm she goes by the bus if arriving at Bromma airport (BMA) and by the express train if arriving at Arlanda airport (ARN). From Oslo Central, she catches either the intercity train or the airport express at 3.50/4.00 pm, and arrives at Stockholm Central 10.15/6.30 pm. Train services from all three cities are operated by the former Swedish incumbent operator, SJ AB.

Table A1 here

The results show that the break-even values are higher on trips from Göteborg than from Malmö and Oslo. These values (not considering the value of work during travel) are double or triple the average VTTS for this line, while they exceed the average VTTS by only a quarter or a third in the other two cases. This indicates that the train operator utilizes the comparative advantage it has to air travel in terms of travel time between Göteborg and Stockholm.

We also show the corresponding break-even values after reduction by 25 percent to consider the value of work during travel. In this case, the Göteborg values are still considerably higher than the official VTTS values, while for Malmö and Oslo they are close to these values (however, note that for travel from Oslo to Stockholm, many passengers will come from Sweden, with on average lower wages than Norwegians).

As a robustness check, we read off air and train ticket prices for similar trips from Göteborg and Malmö on the last Friday in April, accessing the web sites every day during the preceding week. The breakeven VTTS values seven days before the day of the trip were found to be about 30 percent higher than those reported above for a Friday in January. During the week, both air and rail tickets from Göteborg were sold out and before that prices had been raised by 9 and 4 percent, respectively. Ticket prices from Malmö increased by 31 and 34 percent for air and train, respectively.

To complete the picture, Table A2 shows lower-margin break-even values for the same travel relations by coach and car, respectively, on a weekday in April and June. These values include VAT as most travelers are non-business travelers. We have not adjusted for value of work during travel. There is clearly a fierce competition on this lower segment of the market between train and bus services. The results show that the lower-margin VTTS by coach are very low, in particular for going from Göteborg and Malmö. As a comparison, the minimum wage of a 19-years old retail store clerk is presently 110 SEK/h, with a marginal tax of around 16%. The break-even values for car from Göteborg and Malmö are negative and large, i.e., both cost and travel time are (much) higher than for train. For Oslo, the break-even value is positive and very high, which is because car is much more expensive but slightly faster (323 minutes compared to 376 minutes); adding an hour for a fuel and food stop would reverse this.

Table A2 here

2. China

The upper-margin break-even values of time for Beijing-Shanghai (shown in Table 2) were computed from the official websites of Air China (air) and TravelChinaGuide.com (rail), accessed at different dates in May 2012. Very small price variations were noticed between different dates. As we don't have information on rail ticket prices before the opening of the HSR line, we used the first class ticket price (RMB 650) for the relatively slow train service that starts from Beijing weekdays at 8.22 and arrives in Shanghai at 17.16. (The second class ticket price for this train is RMB 410). An Economy class air ticket was RMB 1497. (Using the second class ticket prices raises the upper margin VTTS from 124 to 162 RMB/h.)

Figure 1. The modal split between the rail mode and a slower mode (coach) and a faster mode (air) on a uniform distribution of the opportunity cost of time

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             Coach                     Rail                      Air

[----------------------------------o-------------------------------------o----------------------------------]

0                                  v1                                    v2                                 1
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Table 1. Travel time in minutes with high-speed rail, conventional rail and air. Air includes access and regress times.

	Stockholm-Göteborg	**Oslo-Stockholm**	**Beijing-Shanghai**
HSR	120	167	323
IC rail	188	376	593
Air	140	150	220

Table 2. Average and upper margin marginal VTTS

	Stockholm-Göteborg	**Oslo-Stockholm**	**Beijing-Shanghai**
	SEK/hour	SEK/hour	RMB/hour
Average VTTS	318	452	41
Upper marginal VTTS	939	539	124
Average VTTS, adj. work	239	339	31
Up marg VTTS, adj. work	704	404	93

Table 3. Net benefit-cost ratios. Reference case; Adjusted VTTS (using the upper margin VTTS for generated traffic); and Adjusted VTTS and work (also adjusting for the value of work during travel for previous travelers)

	Stockholm-Göteborg	**Oslo-Stockholm**	**Beijing-Shanghai**
Reference	-0.30	-0.68	-0.09
Adjusted VTTS	-0.10	-0.65	0.37
Adjusted VTTS + work	-0.25	-0.74	0.03

Source: *Reference*, Sweden and Norway, base case results (Trafikverket 2012, Atkins 2012). Reference China, own calculations based on Zhang and Ding (2012) for rate of discount 6%, market rate of growth 7% and share of generated traffic 40%. *Adjusted*, own calculations based on 40% share of generated traffic and 25% of travel time used for work. For Stockholm-Göteborg benefits from reduced external effects etc. not depending on VTTS values are assumed to amount to 37.5% of the investment cost.

Table A1. Travel times, upper-margin break even value of time, and average train value of time, SEK/hour.*

	Göteborg			Malmö			Oslo	
	Train	Air, BMA	Air, ARN	Train	Air, BMA	Air, ARN	Train	Air, ARN
Travel time, minutes	188	135	140	279	140	145	376	150
Break-even value of time, SEK/hour		739	939		429	556		539
Break-even value of time with journey work, SEK/hour**		554	704		321	417		404
VTTS	318***			318***				437***

* Excl. of VAT.
** Value per hour of work during travel is assumed to correspond to 25% of total value of time (see section 3.4)
** *The VTTS recommended in the national CBA guidelines (SIKA 2008) for train business travelers; 275 SEK/h (2006), inflated with real wage changes to the 2011 price level.

Table A2. Lower-margin break-even values of time, SEK/hour.*

	Göteborg	Malmö	Oslo
Coach	15	20	54
Car**	-462	-1758	1790

* Incl. VAT 6%.

** Cost of car. Based on the web calculator provided by the Swedish Consumer Agency (www.konsumentverket.se) for a four-year old Volvo V50. The road distances are 470, 612, and 523 km, respectively, and the car travel-time distances 4h 35m, 6h 42m, and 6h 23 m, respectively. No parking costs or stops on the way are included.