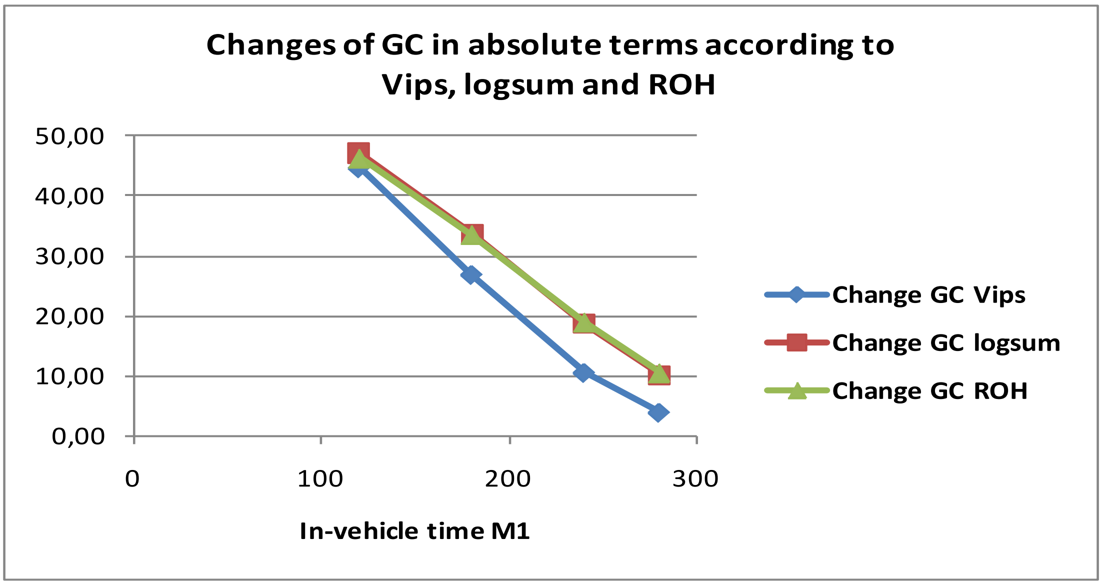
Descriptive and theory report for “Towards a model for long distance passenger travel in the context of infrastructure and public transport planning”



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Contents

1 Introduction

This report includes contributions by the members of the research group for the project “Possibilities to combine passenger transport models”. It goes into some more detail on certain aspects than the main report “Towards a model for long distance passenger travel in the context of infrastructure and public transport planning”.

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The basic prerequisite in this project is that travellers for long-distance journeys use timetables. The travellers “already at home” compare various combinations of lines and modes, by use of for example “travel planners” on the Internet. They consider price and travel time components, and also how well actual departure or arrival times suit their ideal departure or arrival times.

Sections 2-7 include descriptions of the models Sampers, Vips and Visum.
Section 2 describes Sampers from users´ points of view. In section 3 we provide an overview of characteristics of the models. Section 4 includes a theoretical discussion, with basic fundaments of the models, how consumer surplus is calculated etc. Section 5 includes a description of the Sampers and section 6 of the Vips and Visum models which employ the RDT principle. Section 7 briefly describes the calibration methods in Sampers and Vips

Sections 8-10 include theoretical analyses and examples.
Section 8 discusses logit models and the logsum. Section 9 includes a theoretical discussion on consumer surplus assessment, and gives some examples of how the models assess consumer surplus when headways are changed for one of the modes. Section 10 discusses frequency-based assignment versus timetable-based assignment.

Sections 11-12 provide results and analysis of real runs with Sampers and Vips for the Swedish national network.
Section 11 describes how Sampers and Vips handle sequential changes of ride time and frequency for two modes. In section 12 we present examples where we can see the effects where most travellers need combinations of modes to get to the destination.

Section 12 includes conclusions and final discussion.

Appendix 1 Includes notes on the RDT Model
Appendix 2 describes how networks are represented in the two models
Appendix 3 discusses effects of headway changes for the models
Appendices 4-6 describes the results of the two models of assumed faster rail services
Appendices 7 and 8 describe the calibration methods in Sampers and Vips.
Appendix 9 summarizes viewpoints on our work.

Authors of various parts
Kjell Jansson: Sections 2-6, 7.2-7.4, 8.5, 9.2, 9.3, 10-13, appendices 2-6, 8
Staffan Algers: Section 7.1, appendix 7
Harald Lang: Section 9.1.
Odd Larsen and Reza Mortazavi: Sections 8.1-8.4
John Bates: Appendix 1
Andrew Daly: Appendix 9

2 Sampers according to users

Here we present two reviews of experiences of Sampers. The first one of these may be most relevant since it is recent, from 2009. The other one is by Staffan Widlert, former director of the Swedish Institute for Transport and Communications Analysis (SIKA), from 2003, but may be interesting in relation to the recent one.

2.1 Sampers – experiences and development possibilities

This section contains Kjell Janssons attempt to translate some of the viewpoints from users of the Sampers/Samkalk model "Sampers – erfarenheter och utvecklingsmöjligheter på kort och lång sikt (Sampers – experiences and development possibilities in short and long run), October 30 2009".

From introductory text

The system is complex and requires that the user has substantial knowledge of the method. The run times are so long that some users abstain from doing all the analyses they would like to do. Some critics mean that the complexity of the system implies that it is not used as much as one would wish. Others claim that the system, in spite of its richness in details and complexity, cannot anyway realistically enough describe effects or relevant transport measures.

One may ask if Sampers is a modern model system at highest scientific level.

New issues may require that Sampers is further developed or is replaced by a new system for transport analyses.

Summary of viewpoints from a survey November 2008 till January 2009.

Continuing model development for public transport is needed (handling of fares, assignment on lines, adaptation to Emme/3 and in the long run a real time model)

Run times are too long.

More details from the survey in tables below.

Table 2.1.1 Needs of decision makers and problems with use of Sampers.

Need	Problem	Suggestion
Investment analyses, e.g.		E.g. study introduction of X2000 Stockholm-Göteborg
High-speed trains	Unreasonable small shifts between modes, air-train, car-train	
- New Rail lines e.g. Bottnia- track)	Unreasonable low flows on links, not clear how this affects CBA. Large time gains according to Samkalk	
Combination of changes (e.g. new rail line and less bus supply)	Gives small demand changes, large negative consumer effects for bus	
Public transport	Wrong assignment on line/path level Travel time components are valued differently in Sampers and Samkalk	

Table 2.1.2 General needs and problems for users of Sampers

Need	Problem	Suggestion
Faster and simpler tool	Wish to make more analyses in short time	A study to give concrete suggestions of improvements

Table 2.1.3 Strategy in short run (2009) for Sampers, Samkalk

Input data Network and line coding: improve, update for all modes Values of time: update and scrutinize, different values in Sampers and Samkalk Fares: public transport, update
Model development International model; can the present model be made to work?

Table 2.1.4 Strategy for longer run (2010-) for Sampers, Samkalk

Examples on issues that need investigation: Shift between modes - new algorithms

Furthermore in text:

A problem that has been noticed is the lack of consistency between values of time in the forecast models and the evaluation.

Concerning the national standard model a development work is commencing, aiming to give the possibility to calculate effects of investments in high-speed rail.

2.2 Earlier viewpoints by Sika

Staffan Widlert was director of the Swedish Institute for Transport and Communications Analysis (SIKA). SIKA procured Sampers in 1999 and Widlert wrote a note “Ger Sampers rimliga resultat” (Does Sampers provide reasonable results?) in 2003.

In 2.2.1-2.2.6 Kjell Jansson has translated part of this note into Swedish. This note should be of interest both since it is written by the procurer and since one may compare the descriptions of problems in 2003 with the description of the problems in 2009, which were presented in section 2.1.

In 2.2.7 Kjell Jansson briefly tries to interpret part of the note on Sampers developments carried out in 2004.

2.2.1 Distribution of effects

The models for private intercity journeys give an extremely large share of newly generated journeys and very small shifts between journeys.

2.2.2 Network distribution

Already when we procured the Sampers-system we were aware that the headway based Emme/2-model is not appropriate for long-distance public transport. So, there is no surprise that we still have serious problems concerning network distribution for long-distance public transport.

The problems with the Emme/2 approach are several. It is obviously unrealistic to assume that the travellers do not know the departure times for long-distance journeys and that they are assigned only in proportion to frequency. This implies that fast lines (such as X2000) may get too few passengers. Furthermore, the model ignores that various connections have different prices, which is also unrealistic. In addition one cannot take into account that different passenger groups have different willingness to pay for fast modes, which also makes it difficult to describe travelling with X2000, which was launched as a high-quality mode for business travellers with high willingness to pay.

2.2.3 High-speed rail

Sampers calculates an increase of number of journeys between Stockholm and Gothenburg when a new track (Götalandsbanan) is assumed. Then, when also the link Jönköping-Copenhagen is assumed, Sampers calculates that the number of journeys Stockholm-Gothenburg decreases, to a level even below the original one when Götalandsbanan was not assumed! The effect depends on that the link Jönköping-Copenhagen is so attractive that people choose other destinations at such a degree that travelling between Stockholm and Gothenburg decreases. The effect is not unbelievable but the magnitude of the effect is difficult to accept.

2.2.4 Elasticities

The cross-elasticities according to Sampers are very low compared to cross-elasticities according to international studies.

2.2.5 Measures

The problems related to Emme/2, combined with the unrealistically low cross-elasticities in Sampers long-distance models, the weights used and our definition of mode alternatives, together can give unreasonable results relatively frequently.

It is not reasonable to continue using Emme/2 for long-distance transport. We should as soon as possible launch a pilot study on possible alternatives and strategies for and consequences of a change of network model.

Several changes of various kinds are worth to consider:

Change to a new network model that works for both public and private transport.

Use Sampers/Emme/2 for car and let the system generate matrices for long-distance public transport, and use another program for public transport assignment.

Change to a new network model in Sampers and use the new system for public transport and for generation of matrices for car travelling, and use Emme/ for car assignment.

There may even be other hybrid forms where a new system is employed even for generation of travel times for long-distance public transport for demand calculations, while Emme/2 is used for car. A variant of this is used by the Stockholm county Public Transport authority (SL) in applications of their model SIMS.

It is not trivial to choose what to do. It is probably important that the travel times used in model estimation are consistent with those used for assignment. It is thus not unproblematic to employ Emme/2 travel times for model estimation and another model for assignment. One may therefore have to re-estimate the models when one changes to a new network model.

2.2.6 Possible development steps

Evaluate alternative network models.
Conduct a pilot study concerning requirements for a partial or total exchange of Emme/2 in Sampers.

2.2.7 Interpretations of development of Sampers in 2004

The problems mentioned in 2.2.1 were addressed in a development effort in 2004; see Transek (2004) (in Swedish).

The new version includes the following three mayor model developments:

1. Estimation of a new national model where the train types IC and X2000 (faster train) are regarded as the same train type,
2. Estimations of new regional models where train and bus are regarded as one public transport mode,
3. Tests of alternative model structures, which aimed to try to yield model specifications that solve part of the weaknesses with respect to low cross-elasticities in the current model.

The reason for change 1 was that when the two train types were separated, a certain amount of travellers were still demanding the worst alternative even when the supply was virtually zero.

Certain statements in the report

The substitutability between destinations increases somewhat compared to the substitutability between modes.

Any clear pattern concerning cross-elasticities is not found – sometimes cross-elasticities are higher after implementation, in other case lower (IC-train and car cost with respect to X2000 and air).

The tables below show some own- and cross-elasticities with the old and the new model.

Table 2.2.7.1 Cross-elasticities with old and new model

Mode	**Model**	**Elasticities**	
		Ride time train	**Price train**
Car	Old model	0,02	0,01
	New model	0,05	0,08
Bus	Old model	0,03	0,01
	New model	0,05	0,08
Train	Old model	-0,67	-0,26
	New model	-0,43	-0,66
Air	Old model	0,03	0,01
	New model	0,05	0,08

Comments by Kjell Jansson

Even in the new model cross-elasticities seem very low. If train ride time would be reduced by for example 50 %, e.g., by introduction of high-speed trains, air demand would be reduced by only 2.5 %. (cross-elasticity0.05). If the price of rail travel would decrease by for example 50 %, demand for air, car and bus would be reduced only by 4 % each (cross-elasticity 0.08).International experience indicates much larger effects on air demand when high-speed trains have been introduced.

One may also wonder about the relationships between price elasticity and ride time elasticity. In the table below I have derived ride time elasticity based on price elasticity using the relationship that these elasticities should be proportional to the cost of each, in this case in terms of SEK. I have derived the ride time elasticity assuming the VoT SEK 100 for private journeys and SEK 275 for business journeys. The derived elasticity for private journeys coincides fairly well with the value in the table above, but the derived elasticity for business journeys is much larger than in the table above. It is unclear to me whether the elasticities in the table above refers to private or business journeys or if they are the same for both groups.

Table 2.2.7.2 Estimations of ride time elasticities

Private journeys				**Price elasticity**	**Ride time elasticity**
Price, SEK	Time, h	VoT	Time, SEK		
500	3	100	300	-0,66	-0,396
Business journeys				**Price elasticity**	**Ride time elasticity**
Price, SEK	Time, h	VoT	Time, SEK		
500	3	275	825	-0,66	-1,089

Concerning the critical note by Widlert it seems that at least the following problems still prevail after the developments in 2004:

- Emme/2 is still employed,
- Cross-elasticities still seem very low.

3 Overview of the models

Important definitions:
By mode we mean train, (or different types of trains with different comfort or price in Vips), air, coach and car.
By line we mean a service from one start terminal to an end terminal, each with a specific itinerary and specific stop pattern.
By routes or travel paths we mean for each origin-destination (O-D) pair, the various combinations of lines and modes that are feasible.

3.1 Representation of lines and modes in the models

3.1.1 Overview

Below we describe the representation (mapping) of lines and modes in the two models.

Vips has 192 rail lines and Sampers 126.
Vips has 101 airlines and Sampers 63.
Vips takes into consideration 511 regional bus lines, Sampers none.

Vips takes into consideration all combinations of lines and modes while Sampers deals with main modes only. This means for example that use of airline + rail line or rail line + regional bus are not handled by Sampers.

Vips specifies separate prices for a number of lines, implying that the price for the whole journey origin to destination is calculated endogenously by taking into consideration all acceptable travel paths. Sampers uses an exogenous price matrix for each main mode, where the price is the average price of all lines per mode in the respective O-D pair.

Vips takes into consideration that lines within a mode may have separate ride times and prices while Sampers uses only the average ride time of all lines per mode in the respective O-D pair.

Number of departures per day differs a little. This mainly depends on the definition, where Sampers maps the number per Tuesday and Vips the average per week.

Emme/2 does not distinguish between different airports, where there are two in Stockholm, neither between different airlines with different prices.

Vips regards that there are two competing airports in Stockholm, Arlanda and Bromma, and that there are several competing airlines at various airports.

3.1.2 Access to lines and modes

Neither in Sampers nor in Vips are local bus lines coded.

From each origin travellers have in Vips several commuter train lines, regional buses or coach lines to choose among to reach a rail or air service. They may in addition have several rail services to choose among to reach an airport etc. In addition there are access/egress links that represent going by car/taxi to a railway station or an airport. The time for these is a linear combination of ride time and price, together expressed in minutes by use of a value of time. So, there is a choice between lines plus walk links to these and access/egress links representing car/taxi.

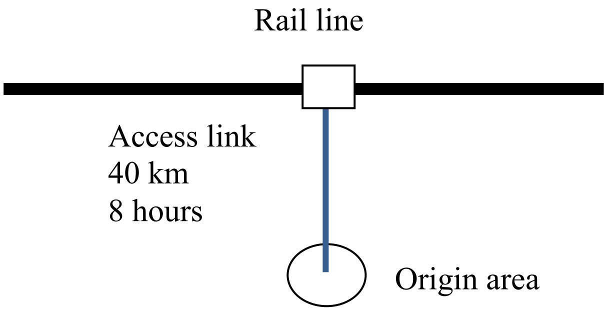
To/from the main modes Sampers instead only uses access/egress links, each with a specified time, i.e., no public transport lines. The model assumes very low speed, 5 km/hour, for these egress/access links in order to prevent too extensive use of access/egress links. If for example one can go by train to a city for which there are two possible alighting stations, Sampers only accepts the egress link with the shortest time. One reason for this is to avoid too many alternatives. The other is that Emme/2 from the origin only accepts the perceived best stop (and one mode), but when approaching the destination accepts several stops and modes. Thus, the long access/egress links are used in order to achieve fairly similar paths in the two directions.

The figures below illustrate the representations in Sampers and Vips respectively. The black line illustrates a rail line with a station. The blue lines illustrate access links in Sampers and Vips and the red line a regional bus in Vips.

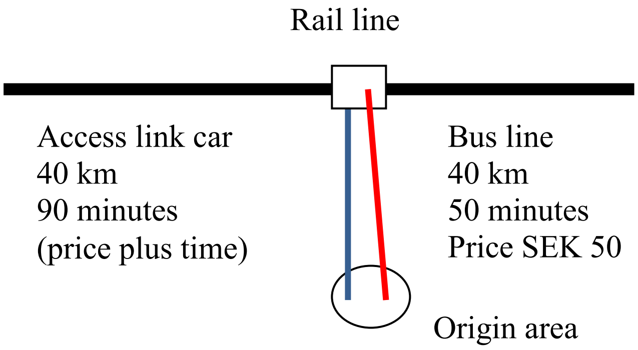
Times and prices in the figures are examples only.

Figure 3.7.2 Representations of access to a rail line

Sampers' representation



Vips representation

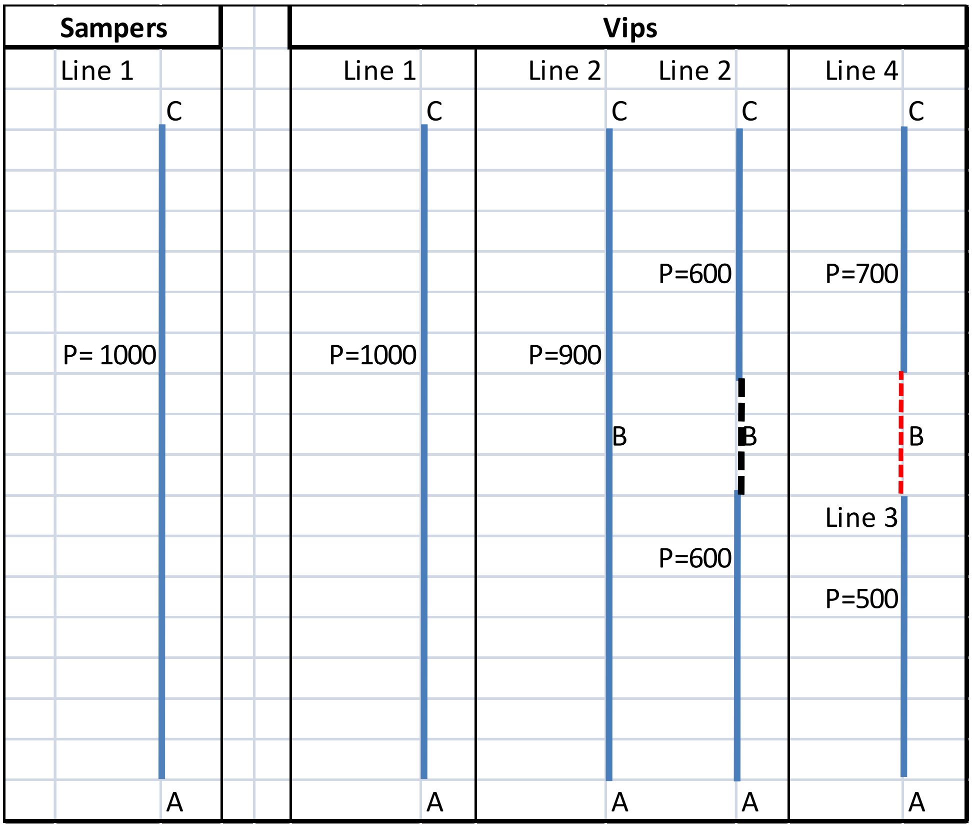


Examples of consequences of using only access/egress links in Sampers are found in section 5.3.

3.1.3 Line variants

Vips takes into consideration that there may be both direct lines and various combinations of lines. An example for air lines is given below. Vips considers direct air connections in an O-D pair and air connections with transfers, while Sampers only deals with one single direct air connection. The diagram below illustrates this.

Diagram 3.1.3 Example of representations of airlines in the models



In Sampers there is one price for air, 1 000, for going between A and C, for line 1.

According to Vips the price may also be 1 000 for this line 1.

According to Vips there may be another line 2, with two prices from A to C. The price for going all the way A to C may be 900. But this line makes a stopover at airport B. The sum of the prices for going A to B and the price for going B to C can be different compared to the price for going all the way A to C.

There may also be lines 3 and 4 with a transfer between these at B. Again, the price for going all the way A to C may differ from the price with transfer between airlines.

4 Theoretical background to the models

4.1 Introduction

Both the logit model in Sampers and Vips/Visum have the same theoretical background in the sense that each individual is assumed to choose the alternative with minimum generalized cost (G). (In the main reports generalised cost was denoted GC instead og G).This G is, however, not the same for each individual due to the variation of individual preferences – stochastic influence, but this stochastic influence reflects different aspects in the two models.

In Sampers there is a variation among individuals due to taste, measurement errors, omitted variables etc. In Vips/Visum there is a uniform variation among individuals due to ideal departure or arrival time in relation to actual departure or arrival time. It is also assumed that departure times of alternative lines are uniformly distributed. Both the departure times of travellers and lines are thus assumed randomly (uniformly) distributed, which has given rise to the term RDT (Random Departure Times).

In order to deal with the issues addressed in this paper it is sufficient to distinguish between on the one hand wait time, V, which depends on frequency of service, and on the other hand all other travel time components and price, R. The sum of V and R is called generalised cost, G. All elements are expressed in minutes by use of values of time (VoT). For convenience R is here often referred to as travel time only.
In order to simplify notation and calculations, without affecting the general aspects, we assume that there are two alternatives, 1 and 2.

4.2 Basic micro-economic model

The generalised cost of alternative j (j=1, 2) for each individual i is composed of the following elements. Travel time R^j (including all travel time components plus price, except wait time) plus a stochastic variable, t^j_i, that varies among individuals with taste, measurement errors etc. plus a stochastic variable, x^j_i, that varies among individuals with ideal departure or arrival time in relation to actual time. We define x^j_i as time to departure from the ideal departure time, i.e., the difference between actual and ideal departure time. The generalised cost of alternative j is then:

(1) $$G^j = R^j + t_i^j + x_i^j$$

When each individual chooses the alternative with the minimum generalised cost the realised "joint" (or combined) generalised cost of individual i is:

(2) $$G_i = \min\left[R^1 + t_i^1 + x_i^1, R^2 + t_i^2 + x_i^2\right]$$

The average joint generalised cost of both alternatives over all individuals in a segment is then:

(3) $$G = E\left[\min\left[R^1 + t_i^1 + x_i^1, R^2 + t_i^2 + x_i^2\right]\right]$$

where E denotes the expected value corresponding to the distribution of individuals.

We have thus defined one single G for a journey from door to door when there are several alternatives to choose among. The deviation εi from the joint G for an individual could be composed of t i and/or x i. The generalised cost G of individual i is then defined by:

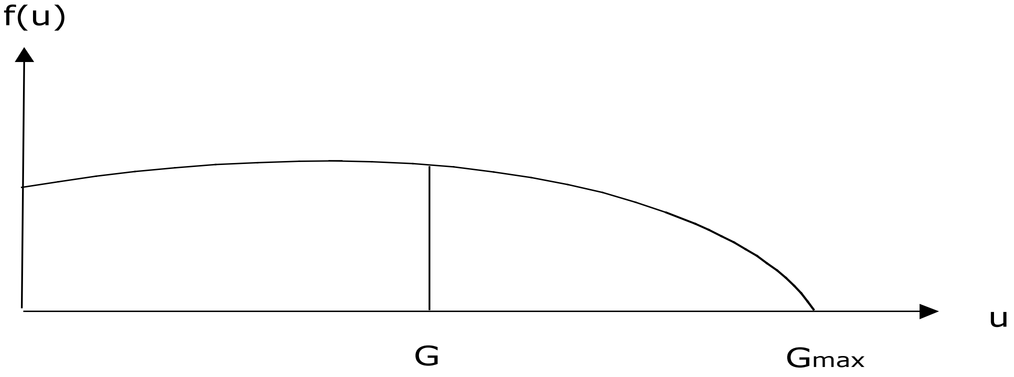
$$(4) \qquad G_i = G + \varepsilon_i$$

Each individual is assumed to have a utility of travelling from origin to destination, i.e., the utility of the journey itself, which is denoted vi.
The net utility for individual i, when taking G into account, is:

$$(5) \qquad v_i - G_i = v_i - \varepsilon_i - G \equiv u_i - G$$

Let f(u) be the density function over u_i among the individuals. The individual chooses to travel if u i ≥ G, where u i has a distribution f(u) over all individuals. The choice is illustrated in the figure below.

Figure 4.2 Distribution of utility



The aggregate demand, X, is the integral over f(u) between G and the reservation price Gmax.

$$(6) \qquad X = \int_{G}^{G_{max}} f(u)\,du = X(G)$$

The consumer surplus, S, is thus:

$$(7) \qquad S = S(G) = \int_{G}^{G_{max}} (u - G)\,f(u)\,du$$

It then follows that:

$$(8) \qquad \frac{\partial S}{\partial G} = -(G - G)f(G) + \int_{G}^{G_{max}} -f(u)\,du = -X$$

Observe that the aggregate consumer surplus is a function of the joint generalised cost, which in turn is a function of the generalised cost of both alternatives, where G^1 is also a function of G^2 and vice versa.

$$(9) \qquad S = S\left[G^1\left[G^2\right], G^2\left[G^1\right]\right]$$

5 Principles of the Sampers model

The Sampers model uses 3 steps: i) the network model Emme/2 for assignment on lines within each mode and for estimation of travel time components for each mode, ii) a multinomial logit model for demand projections concerning modes, destinations, and travel frequency, iii) Samkalk for calculation of consumer surplus, revenues, costs etc. for cost-benefit analysis.

5.1 Emme/2

The Emme/2 model is based on average frequencies of services. The travellers are assumed to know the travel time components and headway of all lines, but not the timetable (the actual departure times) or behave as if they do not. The basic behavioural assumption is that travellers choose a strategy that minimizes the weighted travel time components, i.e., generalised cost except price, which is not specified. The price variable is specified exogenously as an O-D matrix in the multinomial logit model described later; this way of handling the price variable has the effect that price differentials between different services within one mode cannot be considered.

The assumption that traveller do not know the time tables, only frequencies, implies: i) that travellers go to the stop with the shortest expected total travel time, which typically has only one main mode, ii) that travellers are assigned to lines at this stop in proportion to frequency only, without concern for ride time and price. This decision rule is correct given the assumption that departure times are not known.

5.2 The logit model

For each defined main mode the Emme/2 assignment gives level of services (LOS) variables that are weighted averages for the alternatives that the network model picks for each OD-pair. Subsequently parameters are estimated for the different LOS-variables that enter the utility functions of each main mode in the logit model. Each estimated utility function, less one, will then also get an alternative specific constant. The utility functions also include other variables that do not concern us here.

The logit model in Sampers assumes stochastic variation with respect to preferences etc., t, as a deviation from G. When each individual is assumed to choose the alternative with the minimum generalised cost the realised generalised cost of individual the joint generalised cost in (3) is (see for example Ben-Akiva and Lerman (1985) and Louviere et al., (2000)):

$$(10) \qquad \mathrm{G} = \mathrm{E}\left[\min\left[G^1 + t_{\mathrm{i}}^1, G^2 + t_{\mathrm{i}}^2\right]\right]$$

The logit model thus produces not only measures for probabilities but also for joint generalised cost, which is supposed to be represented by the logsum.

The difference in consumer surplus between two alternative public transport scenarios is represented by the difference between the logsums of these scenarios.

Assume that originally there is only one alternative, 1, where the joint G equals G^1. In this original situation the joint G according to the logsum is simply:

$$(11) \qquad G = -\frac{1}{\mu}\ln\left(e^{-\mu G^1}\right) \equiv \frac{1}{\mu}\mu G^1 \equiv G^1$$

Assume now that we double the number of alternatives so that there are two alternatives with the same G.

The new joint G* is then:

$$(12) \qquad G^* = -\frac{1}{\mu}\ln\left(2e^{-\mu G^1}\right) \equiv -\frac{1}{\mu}\ln 2 + \frac{-1}{\mu}\ln\left(e^{-\mu G^1}\right) \equiv G^1 - \frac{1}{\mu}\ln 2$$

The change of the joint G is thus (1/μ)ln2. If we have k alternatives with the same G the joint G would be (1/μ)lnk.

Note that this change of joint G is the same irrespective of whether we are dealing with doubling of a service that takes 5 minutes or 2 hours. The change of the joint G is also the same irrespective of whether we are dealing with doubling of a service that has the interval 5 minutes or two hours. Doubling of service could either mean doubling of the same service or addition of another mode that has, more or less, the same generalised cost. This example also tells us that

- As there is unobserved utility, increasing the number of alternatives implies a better chance to find an alternative with a higher total utility
- The increase by increasing the number of alternatives is depending on the variance of the unobserved utilities – the larger the variance, the smaller the scale factor μ and the higher the increase of expected maximum utility
- If there is no unobserved utility, then the scale parameter μ will approach infinity, and there will be no gain by increasing the number of such alternatives
- The increase is not depending on the observed utility G^1 – the variance is homoskedastic

The logit model in Sampers is characterised by the following features, which are a consequence of the IID characteristic of the logit model (independent and identical distribution).

- The cross elasticity, ε^{ij}, with respect to generalised cost, G, or any component in G, is uniform, i.e., the cross elasticity of the probability of alternative i with respect to a change of G^j are equal for all alternatives i≠j. $\varepsilon^{ij} = \Pr(j)\mu G^j$. This means for example that if the generalised cost of rail is reduced, then the demand of the other modes air, bus and car is reduced by the same percentage.

- The direct elasticity, ε^i, with respect to generalised cost, G, or any component in G, is proportional to the level of G or any other component, and proportional to the scale. $\varepsilon^i = -(1- Pr(i))\mu G^i$. This means for example that the elasticity is 10 times higher for a journey that is 1 000 km than for a journey that is 100 km.

5.3 Samkalk

Samkalk uses "rule of the half" (ROH) for calculating changes in consumers' surplus of a change of one main mode. ROH works as follows. Assume that an improvement of rail services reduces GC in an O-D pair with 10 minutes. There are 100 travellers in this O-D pair and the improvement makes the demand increase to 110. The existing 100 travellers gain in total 1 000 minutes. The new 10 travellers gain on average half of the 10 minutes, in total 50 minutes. The total change in consumes surplus is then 1 050 minutes. ROH is an approximation of the change of logsum.

This ROH principle for calculation of consumers´ surplus works when travel times or price are changed, *but not if headways are changed*. Consumer surplus calculations are discussed in depth in section 9

6 Principles of Vips/Visum and the RDT approach

The models Vips and Visum work in one simultaneous step for lines and modes, where all feasible combinations of lines and modes are taken into account, and where each line has a specific ride time and price (kilometre, zone, or stop-stop based). Each passenger segment can then have a specific price structure for each mode and service within mode. The price in each O-D pair for a specific group is then calculated endogenously by the program as the weighted average of the prices of all combinations of lines and modes.

The travellers in each origin zone are assigned to various stops with various services and modes.

The RDT principle in Vips and Visum[1] assumes that travellers know the timetables and estimates assignment on lines and modes and calculates all travel time components. RDT assumes no stochastic variation with respect to preferences. In practical applications instead the model allows a) substantial segmentations for traveller categories with respect to different values of time, b) that services and modes are given specific characteristics in terms of comfort, price etc., which may differ between traveller categories.

Since the model takes into consideration a number of combinations of services and modes, the number of travel paths (each with a combination of services and modes from origin to destination) can be very large for the Swedish national network, tens or hundreds.

Some details of the implemented Vips model are found in Jansson and Ridderstolpe (1992) and details of principles in Jansson, Lang, Mattsson and Mortazavi, R. (2008).

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[1] We refer to the model Visum for the RDT principle, since we know that this is implemented in the Visum software. There may, however, be other softwares we do not know of that include this principle.

7 Calibration and segmentation

7.1 Sampers

After implementation, the models will result in a somewhat different travel pattern as contained in the travel survey (RVU or RES), which was used for estimation. This depends on the fact that the model is driven by another set of trip generating data, that the supply data is related to a specific year and that simplifications are made. In order to match the RVU trip pattern, some adjustments of the model – calibration - has been carried out.

7.1.1 Calibration method

The adjustments that are made for the Standard Model are related to the general level of trip making, the distribution on modes and the distribution on trip length. The adjustments take the form of correction constants that are added to the utility functions. The correction constants are computed in an estimation process for each of the travel purposes. First, a calibration target is defined in terms of the desired criteria, like mode and distance or aggregate OD distributions. For this calibration target, an aggregate model with a full set of alternative specific constants is estimated (the alternatives being modes and trip length classes or OD groups). A similar estimation is performed for the current model output, resulting in a different set of constants.

The difference between the constants is what we need to put into our model to obtain the target distribution. So, the differences between the constant are then added to the model. Because of the simple nature of the computation (alternative availability is not taken into account for instance), the operation may have to be iterated once or twice to converge closely enough. This type of additional adjustment in the utility functions ensures consistency between the estimated and the implemented models. Only the market shares of the different alternatives are affected.

7.1.2 Calibration process

In context with the re-estimation and implementation of the 2.1 version models, the models were calibrated to match the travel survey by mode and tour length distribution.

The information that was put to disposal for calibration purpose was in the form of the number of trips in 8*8 matrices (A regional subdivision of Sweden). So, the new calibration targets were in the form of 8*8 OD pairs for each mode (for car and bus, the previous results were defined as calibration targets). Using the same approach, an additional set of calibration constants was estimated. It turned out to be sufficient to hold down the number of constants to 8 origin and 7 destination constants, instead of a full set of 63 constants.

The full description of the Sampers calibration is found in appendix 9.

7.2 Vips

In Vips parameters are not estimated by use of any statistical method. Basically the values of time for the various travel time components are used, originating from ASEK 4. These values are not changed. But in the calibration process other parameters may be changed. This calibration process may also be seen as a “manual” estimation process, since one is searching by trial and error the parameters that give demand for lines and modes as close as possible to empirically based demand.

Basically weights for public transport modes have been specified without further changes. Various mode constants were tested, which did not affect the demand pattern very much.

Vips has been calibrated against:

- The Swedish airport administrations (LFV) statistics on number of passengers between airports,
- The Swedish railways (SJ) statistics on number of passengers on specific links,
- Number of passenger km per passenger segment according to the national survey (RES).

The parameters for calibration of Vips have been:

Prices for rail lines and air lines. These prices are originally taken for the various passenger segments (employed, pensioners, students, and business travellers) from the web home pages of the operators. These prices are, however, highly differentiated, since prices shift between times of day and from day to day. It is therefore difficult to calculate a “true” average price. For this reason price changes by some plus or minus 10 per cent were tested. It appeared that variation of prices had a significant effect on demand for lines and modes.

Prices for car use. The price was assumed to include fuel price plus an additional 30 per cent more or less. It is genuinely difficult to know how people believe the true prices to be. Some people probably only take fuel price into account, other people include all variable costs. Various prices were tested for the different segments. It appeared that the model is very sensitive for assumptions on car use prices.

Comfort of car. Travellers may perceive car as more or less comfortable than public transport modes. The ride time weight of car in relation to the norm 1 (ordinary intercity train) that was found most suitable was above 1,i.e., that travellers in general seem to regard car as less comfortable than train. It appeared also that the model is very sensitive for assumptions on these comfort weights.

The full Vips calibration report is found in appendix 8.

7.3 Estimation of values and calibration

One basis for estimation of values is the stated-preference studies carried out several times.

A large value-of-time study was made in 1998 and the latest one is due to be finished in 2010.

These studies give values of time for ride time, wait time, and transfer time for various modes.

The values constitute the basis for Emme/2 in Sampers and for Vips.

In parallel the values used in the logit model in Sampers are based on logit estimations of these values, based on travel time components from Emme/2. This estimation seeks the parameters that will on the average come as close as possible to measured demand between areas in Sweden.

A problem in this context is that the values from this estimation differ substantially from those obtained by state preference studies. This means an inconsistency in the Sampers model since the values for line choice in Emme/2 and the mode choice in the logit model are far from the same.

Neither in Emme/2 nor in Vips applications there is no statistical procedure for calibration of various parameters, such as mode specific constants, convenience factors for various modes etc. This calibration is carried out “manually” as mentioned earlier, by trying various magnitudes of parameters with the aim to find those that seems to make model demand in accordance with actual measured demand on air links and rail links. In this sense the calibration of Emme/2 and Vips is sort of a manual estimation of parameter values. This method is anyway a shortcoming and one should try to find a more general statistical approach to calibration. One should probably restrict this calibration just to mode specific constants, prices and convenience factors for various modes. To calibrate other parameters such as value of ride time of various modes etc. should probably be avoided since one may then end up with inconsistencies in relation to the official values that typically originate from stated-preference studies.

7.4 Segmentation in Vips

The table below shows the most used segmentations applied in the Vips applications. In this project, however, we have simplified the segmentation in order to gain time. We have thus eliminated the differentiation between convenience factors, normal and low.

Table 7.4 Segmentation applied in Vips

Segmentation in Vips calculations	Availability car and appreciation of car	Number of travellers	Value of time per mode			Price per mode	Mode constant
			Ride	Wait	Transfer		
DOMESTIC							
PRIVATE							
Working	avail. car, normal factor car						
	avail. car, low factor car						
	no avail. car						
Pensioners	avail. car, normal factor car						
	avail. car, low factor car						
	no avail. car						
Students	avail. car, normal factor car						
	avail. car, low factor car						
	no avail. car						
BUSINESS	avail. car, normal factor car						
	avail. car, low factor car						
INTERNATIONAL							
PRIVATE < 500 KM	avail. car, normal factor car						
	avail. car, low factor car						
	no avail. car						
PRIVATE > 500 KM	avail. car, normal factor car						
	avail. car, low factor car						
	no avail. car						
BUSINESS	avail. car, normal factor car						
	avail. car, low factor car						

8 Logit models and the logsum as a measure of generalized cost

Sections 8.1-8.4 are written by Reza Mortazavi, University of Dalarna and
Odd Larsen, Molde University College, Norway.

8.1 Introduction

Discrete choice situations are often modelled based on the random utility framework in which it is basically assumed that the consumers compare different alternatives based on the characteristics of the alternatives and their own preferences and choose the alternative that gives maximum amount of utility. Since all the relevant information is not observed by the analyst and also due to the existence of randomness the choice models used to predict consumer behaviour are probabilistic in nature. In a travel to work context, for instance, the following specification based on the random utility framework is often used:$U_{in} = V_{in} + \varepsilon_{in}$. Here i is the index for the alternative and n is the index for the individual traveller. V_{in} is the systematic part of the utility function and ε_{in} is the random unobserved part. The individual traveller is then assumed to choose among different alternatives so as to maximize his utility. Assuming different distributions for ε will lead to different models. For instance, when ε is assumed to be IID (Independently and Identically Distributed) Gumbel we get the multinomial logit model (MNL). It is well known, however, that the IID assumption regarding the distribution of the error terms of the multinomial logit model is restrictive. In the utility function above, the systematic part, V_{in}, may be written as a linear function of the attributes of the alternative, $V_{in} = x'\beta$, where, x_{in} is a vector of observable characteristics of the alternatives and β is a set of parameters, which, in reality may vary over individuals. But, if these vary among individuals then it would mean that we cannot maintain the constant error variance assumption. The variance would vary over alternatives and individuals. This type of pattern may be even more apparent in more complex situations when the alternatives themselves are not independent.

8.2 Non-constant error variance and the logit model

Suppose we have a situation where the schedule delay (difference between the desired and actual departure time) is unobserved. In the above random utility framework then this would make a part of the random error, ε_{in}, or the non-systematic part of the utility function. One can then imagine that in this case the variance of this error term may be different from individual to individual. For instance those with a flexible starting working time may exhibit larger variance than those with a fixed starting working time. To simplify, assume that we can divide people into two distinct categories (1 and 2) in our example. Then we have: $U_{in} = x'_{in}\beta + \varepsilon_{in}^{k}$ where $k = 1, 2$ and $Variance(\varepsilon_{in}^{1}) \neq Variance(\varepsilon_{in}^{2})$. Assume for instance that $Variance(\varepsilon_{in}^{1}) > Variance(\varepsilon_{in}^{2})$. This would mean that the observed factors explain the choice better for group 2 than group 1 relative to the unobserved factors. Not accounting for possible heteroskedasticity may have severe implications. Zeng (2000, p.120) referring to Horowitz (1981) writes: "the damage of the specification error is often serious enough to destroy the practical value of the model". In general there are two basic approaches to deal with heteroskedastic errors in logit based discrete choice models. One is to apply the basic philosophy of the GLS (Generalized Least Squares) in ordinary regression, i.e., to reweigh the observations so that one gets a homoskedastic error term. See Bhat (1995) for dealing with heteroskedasticity across alternatives and Zeng (2000) for a more general approach that also includes heteroskedasticity across individuals. A problem is to find the correct specification in explicitly modelling the heteroskedasticity by using the observed characteristics. Another approach is to use more sophisticated models, like the Mixed Logit Model, which permits different parameter values for different individuals by assuming a distribution of these over the individuals (Train, 2003). However, even here one needs to make distributional assumptions that may or may not represent reality well. Another type of problem that remains is the fact that in many practical situations the set of alternatives may be very large, for instance in a public transportation choice context.

Note also that the heteroskedasticity issues discussed above mainly concerned non-constant error variance due to individual differences. In cases when observed factors are correlated with the error term the problem is even more severe. Larsen and Sunde (2008), for instance, discuss the problem when headway or estimated waiting time is correlated with unobserved factors implying that the error variance varies with them. They suggest a heuristic logit model that to some extent gets around the problem.

8.3 Logsum as a measure of generalized cost

A by-product of the standard logit model, often used as a measure of welfare or consumer plus, is the so called logsum. Suppose that there are two alternatives, 1 and 2 and let us ignore the individual index n. Utility functions can be written as: $U_i = V_i + \varepsilon_i$ where $i = 1, 2$. Again V_i is the representative utility (function of observables) associated to alternative i and ε_i = random term (unobservable). Consumer surplus (CS) is defined to be the maximum of U_1 and U_2. Because of the random error term we have to take the expectation over all possible values for the random error term. So $E(CS) = E\big(Max(U_1 = V_1 + \varepsilon_1, U_2 = V_2 + \varepsilon_2)\big)$. This measure is in the units of utils so to have it in money terms it must be divided by marginal utility of income, say, λ,which is often assumed to be a constant. For the case of the logit model the probability associated to the alternatives are:$P_1 = \frac{e^{V_1}}{e^{V_1}+e^{V_2}}$ and $P_2 = \frac{e^{V_2}}{e^{V_1}+e^{V_2}}$ respectively. Then, the expected consumer surplus can be written as: $E(CS) = \frac{1}{\lambda}\ln(e^{V_1} + e^{V_2}) + C$. Where, the term $\ln(e^{V_1} + e^{V_2})$ is the log of the denominator in the probability expressions. Also since preference ordering is not changed by addition and/or multiplication of constants to the utility function the unidentifiable term C is added. This then would give a measure of welfare for the representative consumer. For policy analysis we are often interested to calculate the change in consumer surplus brought about by a change in the attributes of an alternative. Suppose for instance that we have had a change in the representative utility for alternative 1. So we have a before (b) and after (a) situation. Then the change in expected consumer surplus is given by: $\Delta E(CS) = \frac{1}{\lambda}\ln[\frac{(e^{V_{1a}}+e^{V_2})}{(e^{V_{1b}}+e^{V_2})}]$. Note that the additive constant, C, vanishes when calculating the change in consumer surplus. (De Jong et al, 2005, Small 1995). A question is whether this measure, i.e. logsum, is a suitable measure of consumer welfare. The literature seems to point to the fact that whenever a logit model is used to estimate the choice probabilities one also should use logsum as the welfare measure (De la Barra, 1989). This actually is seen as an advantage since then the estimation and evaluation parts are done in one step. However, this also implies that whenever the logit model is not representing the real situation under consideration well then the calculated logsum is also wrong. For instance if we have individual variation that is not captured by the logit model because of simplifying assumptions (for instance ignoring possible heteroskedasticity as discussed above) then the logsum will also give unreasonable results.

8.4 The mixed logit model

The description of the mixed logit model here is basically a condensed summary of Chapter 6 in Train, K. (2009).

Mixed logit model can be derived from utility maximizing behaviour in two ways;
i) Random coefficients ii) Error components, which are formally equivalent but with different interpretations.

Random coefficients:
$U_{nj} = \beta_n' x_{nj} + \varepsilon_{nj}$
U_{nj}, utility of individual $n = 1,...,N$ choosing alternative $j = 1,...,J$ is assumed to be a linear function of the vector of observed variables x. Here β_n is assumed to follow some distribution, $\beta_n \sim f(b,W)$, with b as the mean value and W as the covariance. The goal is to estimate these distributional parameters. In applications different distributions such as normal, lognormal (for coefficients with definite sign), uniform, triangular have been used. ε_{nj} are assumed to be distributed iid extreme value. The choice probabilities conditional on β_n is given by the logit formula:

$$L_{ni}(\beta_n) = \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}}$$

The problem is that β_n are not known so the unconditional choice probability $P_{ni} = \int L_{ni} f(\beta) d\beta$ must be calculated. This integral is approximated through simulation and for estimation the so called simulated log likelihood is maximized.
In a random parameter interpretation it seems that one has to be cautious about how many parameters that should be treated as random. Train (2009, p.140) writes: "Expecting to estimate the distribution of 26 coefficients is unreasonable, yet thinking in terms of random parameters instead of error components can lead the researcher to such expectations. It is important to remember that the mixing distribution, whether motivated by random parameters or by error components, captures variance and correlations in unobserved factors. There is a natural limit on how much one can learn about things that are not seen."

Error components:
In this formulation utility is specified as $U_{nj} = \alpha' x_{nj} + \mu_n' z_{nj} + \varepsilon_{nj}$. Here x_{nj} and z_{nj} are observables related to alternative j and α is a vector of fixed coefficients. The random part has been decomposed into two components, i.e., the total random part is $\eta_{nj} = \mu_n' z_{nj} + \varepsilon_{nj}$. Here ε_{nj} is again assumed to be iid extreme value while μ is a vector of random terms with zero mean. This formulation allows for correlation between

alternatives and thereby a relaxation of the IIA property (restrictive substitution patterns) of the standard logit. The covariance can be written as $Cov(\eta_{ni},\eta_{nj}) = E((\mu_n' z_{ni} + \varepsilon_{ni})(\mu_n' z_{nj} + \varepsilon_{nj})) = z_{ni}' W z_{nj}$ where W is the covariance of μ_n.

An expression for the percentage change in the probability of one alternative given a percentage change in the m^{th} attribute of another alternative is: $E_{nix_{nj}^m} = -x_{nj}^m \int \beta^m L_{nj}(\beta) \left[\frac{L_{ni}(\beta)}{P_{ni}} \right] f(\beta) d\beta$. This elasticity is different for each alternative *i*.

Advantages of the mixed logit model:

- It has been shown that any random utility model can be approximated as closely as desired by the mixed logit model.
- Mixed logit model is more flexible than the standard logit because it relaxes a number of restrictive assumptions. Within a standard logit model framework it is possible to account for some preference heterogeneity based on observed factors but not preference heterogeneity that stems from unobserved factors often called random taste variation. Within a mixed logit framework, however, one may specify coefficients of the utility function to vary randomly over the individuals in the population.

- Also, the standard logit implies the so called IIA (independence from irrelevant alternatives) property, i.e., the relative odds between two alternatives is independent of other alternatives (red and blue buss paradox). This is particularly implausible when alternatives are similar. Mixed logit model allows model specifications that do not have the IIA implication.

- Also in contrast to the standard logit, the mixed logit model accounts for possible correlation between several choices made by the same individual (relevant when Stated preference data or panel data are used).

Disadvantages of the mixed logit model:

- Assumptions have to be made about the distributions of the random parameters. The usual distributions assumed are normal, lognormal, uniform and triangular, which may or may not be a good approximation to reality. Train (2008) discusses problems in this regard and describes alternative nonparametric approaches.

- Problems with large choice sets have traditionally been solved by sampling of alternatives. This solution is however based on utilizing the IIA property of the logit model, i.e. assuming iid errors. (Ben-Akiva and Lerman, 1985)

- Samples must be sufficiently large to avoid wrong conclusions drawn about the correlation patterns.

8.5 Some views on the logit model and the logsum

Larsen (2010) expresses the problems related to logit models as follows: "Travellers compare itineraries both within and across modes. They don't base mode choice on the mean level of service offered by different modes. This means that the observed choices will not be generated by a standard logit model and the conditions for the use of such a model are violated. This also invalidates the logsum as a measure of consumers' surplus. At best it will be a rough approximation with unknown properties and unsuitable for comparison of different situations."

Larsen (2009) expresses the following viewpoints:

> "The current logit model approach will in general be acceptable if we deal with high frequency services as in dense urban areas. Then travellers may base their decision of mode choice on expected values and forego the use of time tables. Thus the Level Of Service (LOS) - variables in the utility functions is in this case also represents the magnitudes of what affects the decisions of travellers. When dealing with long distance travel and people who use timetables and in addition are concerned with preferred arrival or departure time they do not base their decisions on mean values for each mode, say for bus, train and airplane, but consider the arrival and departure time as well as cost and onboard time for the options available under each mode.
>
> What are the consequences of such behaviour in relation to logit models where the mean values of different variables enter as arguments in the utility function for the different modes, directly or with some non-linear transformation?
>
> In the estimation phase the modeller certainly gets a problem with the IID (independent and identical distributed) assumption for random terms.
>
> For each observation one uses in the estimation, the implicit random term will absorb the deviation between the mean values of the LOS-variables used for a mode and the actual values experienced by the traveller. Especially for the headway variable in scheduled transport modes we must also expect that the distribution of deviations from the mean depends on the headways and the number of alternatives available for travelling with main modes between an origin and a destination.
>
> But the situation is even worse, for this particular variable the deviations from the mean for one mode will in general also depend on the deviations from the mean for the other modes. Thus the implicit random terms of the model that one estimates will have a special component in the error term that is heteroskedastic and cross-correlated over modes. Or to state it in another way, we apply "standard assumptions" to estimate a model with random measurement errors where at least some measurement errors in addition are heteroskedastic and correlated across alternatives. This may have quite severe and unknown implications for estimated parameters (Larsen and Bhatta, 2007). In any estimation process, different specifications are usually tested. Some specification of the model might correct somewhat for the initial misspecification of the model and become the accepted specification, but out of

> sample predictions and demand predictions related to changes in the transport system may still be far off the mark.
>
> These problems will be present whichever assignment model is used to produce Level-of Service (LOS)-variables for the estimation of a logit model as long as the travellers have preference for arrival and/or departure time that reaches across modes. However, any problems in estimation and later application of the model may be amplified by the use of an assignment model that is not suited for the task.
>
> The seriousness of the problems pointed out here will depend on several factors. If a "standard" (IID) error term is the dominating component in the implicit composite error terms of the utility functions, the impact of the other error components may be less severe."

In an E-mail dialogue in an earlier research work Andrew Daly (2004) wrote:

> "One problem is that a model of choice among lines may yield a logsum that is not a representation of the total quality of the combined service – this is a standard feature of hierarchical models."

Larsen, O. I. and Sunde, Ø. (2008). write:

> "Logit models have been proposed and discussed as an alternative assignment principle both for transit systems and more generally for choice between different public transport modes. We will not attempt a review of the different approaches in this paper, but a recent example is Nguyen et al. (1998). In our opinion a satisfactory scheme for use of logit models has so far not been demonstrated…… A major problem by using the logit model is caused by the fact that the main component in the random term of an alternative will be due to the random waiting time even if we allow for heterogeneous transit users. Headways that vary between lines then imply that we will have heteroskedastic error terms in the utility function."

However, in the article they propose a heuristic logit-formulation that seems to overcome some of the problems inherent in the use of logit models for choice among alternatives where one or more of the alternatives are scheduled services.

Ben-Akiva and Lerman (1987) write (pages 108-109) that the core of the problem with the IIA property is

> "the assumption that the disturbances are mutually independent.", and that "In some instances it can give rise to somewhat odd and erroneous predictions."

Greene (2008, pages 852-854) describes a study on a logit model for travel choice between Sydney and Melbourne based on 210 choice observations, with four modes available, air, train, bus and car. The IIA property was rejected.

Then a nested logit model was examined. The first choice level was FLY and GROUND. The next level was AIR under FLY, and TRAIN, BUS and CAR under GROUND. The null hypothesis of homoskedasticity was rejected below the level 0.5 per cent.

One may wonder whether mixed logit or HEV (Heteroskedastic extreme value) could solve some of the problems. Even if IIA is relaxed in terms of heteroskedastic random parameters, the model would probably still suffer from an independence problem. This problem occurs if, as we assume, that travellers have different ideal departure or arrival times in relation to actual departure or arrival times. A discrete choice model ignores that alternative lines or modes are dependent via their headways and the subsequent implication for choice. One can also see it from the operators′ point of view. The higher frequency they choose, the larger is the possibility that their departures will suit the travellers compared to the competitors′ departures.

Note finally that the set of values of time used is not consistent since the set used in the Emme/2 step is not the same as the set of values that are estimated by the logit model and subsequently used when the model is run.

The logit model thus produces not only measures for probabilities but claims also to calculate joint generalised cost. The difference in generalised cost between two alternative public transport scenarios should thus be represented by the difference between the logsums of these scenarios.

In an E-mail dialogue in an earlier research work Andrew Daly (2004) wrote:

> "…the coefficients of a vehicle run choice model can be estimated from quite simple data, perhaps just simple counts of travellers on competing services. However, the logsum from such a model cannot be used directly as the composite cost measure. An obvious defect is that variables may be omitted, for example in the Netherlands Railways case there is no competition on fares, fares do not therefore appear in the service choice model but they obviously do need to be incorporated in a mode choice model. Further, the variables describing frequency appear in the wrong form in this logsum: the greater the interval before the departure of a service, the more likely it is to attract travellers, so the lower the frequency the lower the 'cost'. In the table of the previous Section, the coefficients of the variables relating to headways have a ***negative*** sign in the generalised cost, which is incorrect for mode choice modelling although correct in the service choice model. Obviously, for mode choice purposes it is necessary to arrange that lower-frequency services have a higher generalised cost.
>
> The fundamental problem here is that a model predicting only choice among vehicle runs gives a logsum which could differ by an arbitrary amount from the correct generalised cost, since that arbitrary amount can be added to the generalised cost of each of the vehicle runs without changing the choice among them. The correct procedure to solve the problem is to estimate the model of choice among vehicle runs ***simultaneously*** with the mode choice model. In this way the coefficients of the generalised cost components can take account of both the choice among vehicle runs and the mode choice issues. However, this type of simultaneous modelling with disparate data sets presents problems of computer processing which can be addressed only by very specialised software.
>
> The calculation of a composite cost measure thus presents a number of difficulties, whichever measure is adopted. Some steps can be taken to reduce

these difficulties and analysts need to be aware of the problems and solutions when deriving mode choice and other models on schedule-based assignments.

One problem is that a model of choice among lines may yield a logsum that is not a representation of the total quality of the combined service – this is a standard feature of hierarchical models. This is the problem we have tried to solve in Promise, but it remains to be seen whether there are any other problems that are not solved by that structure.”

9 Assessment of consumer surplus

The way Samkalk assesses consumer surplus (CS) is wrong (overestimates CS) if headways are changed. See mathematical proofs in Jansson, Lang and Mattsson (2008). In fact, when headways are changed there is nothing like existing or new travellers, since changes of headways make people move around between departures. The wait time in total and the wait time per line/mode are endogenous and depend on the headway of all complementary or competing lines/modes. This issue is discussed in this section.

Section 9.1 is written by Harald Lang, Department of Mathematics, the Royal Institute of Technology (KTH), Stockholm

9.1 Theory for consumer surplus assessment for long-distance public transport

9.1.1 Features of long distance public transport

One important property with long distance public transport, as opposed to short distance (or urban) transport, is that departures take place with a low frequency, which implies that it is reasonable to assume that travellers find out the actual frequency delay (“generalised” cost for the fact that the departure doesn’t take place at the ideal time) rather than the expected frequency delay. The implication of this is that the generalised cost (G) for a particular choice of travel alternative (modes, lines) is endogenous in the sense that it depends not only on the ticket price, time schedule etc. for that particular choice, but on the time schedules for all substitute alternatives.
My concern is the assessment of consumer surplus in this situation. There seems to be a rather relaxed attitude among many transport economists on this issue; the view is that standard methods like “log sums” or “rule of a half” will take care of this once we have calibrated our demand model. I am convinced that this confidence is unwarranted. The danger is that erroneous assessments of consumer surplus will escape detection, since there are rarely directly observable data on consumer surplus (as opposed to data on demand, for example.)

In this section I will test two common ways to assess consumer surplus in the current context (i.e., where travellers consult time schedules prior to deciding on mode or route.) I will perform the test in a similar way that the efficiency of estimation procedures on small samples are conducted. It is done by simulation: the tester decides on a stochastic process with parameter values set by him, and then he simulates data from this stochastic process. He then pretends that the parameters are unknown, and estimates them from the simulated data, using the various estimation procedures he wants to evaluate.

I will specify a very simple demand model for public transport between two destination points. This test model is “reality”. I will then use the logit model and the “rule of a half” procedure to estimate the (known) shift in consumer surplus when one of the headways is changed. We can then see how well or bad these procedures perform in this context. The important feature of “reality” is again that travellers consult time schedules.

9.1.2 The test model

- Travellers want to go from destination P to destination Q.
- There are two buses, Black and Red, which both go from P to Q,
- they both have the same ride time and fare.
- However, Black has headway of 60 minutes, Red 90 minutes. Black leaves at 12pm, 1pm, 2pm etc. Red leaves at 12:15pm, 1:45pm, and 3:15pm etc.
- There are 300 travellers, each with a personal ideal departure time. These departure times are uniformly distributed between 12pm and 3pm (note that the schedules will repeat in the same manner with a period of 3 hours.)
- Travellers have to be at their destination in time, so they take the bus that leaves at the latest time before (or exactly at) their ideal departure time.
- Travellers consult a time table to decide which line to chose.

The schedules are illustrated below:

Hence, travellers with ideal departure time between 12pm and 12:15pm will chose Black at 12pm, travellers with ideal departure time between 12:15pm and 1pm will chose Red at 12:15pm, etc.

Let us denote the time from actual departure to ideal departure “waste time”, which is a kind of generalised cost, G. It is now easy to see, that

- 200 travellers will chose Black, with a mean waste time, i.e. “mean generalised cost” MGC=24.375 minutes.
- 100 travellers will chose Red, with a MGC 18.75 minutes.

Now let us consider a change of headway for the Red buses. Assume that they too leave with an interval of one hour: 12:15pm, 1:15pm, 2:15pm etc.

Similar calculations show:

- 75 travellers will chose Black, with a mean generalised cost MGC=7.5 minutes.
- 225 travellers will chose Red, with a MGC 22.5 minutes.

Hence,

- the demand for Black goes down from 200 to 75, MGC goes down from 24.375 min. to 7.5 min.
- the demand for Red goes up from 100 to 225, MGC goes up from 18.75 min. to 22.5 min.

Note three important features

1. The MGC for travellers *with Black* goes down by 69%, although the change in schedule is for done for *Red*.
2. MGC and demand goes in the *same direction* i both cases: when price (MGP) goes up, demand also goes up; when demand goes down, demand goes down.
3. An apparent *improvement* in the Red schedule—a reduction of headway with 33%—leads to *higher* MGC for that mode.

In this example, we see that the total delay time for all passengers is

$$200 \cdot 24.375 + 100 \cdot 18.75 \text{ minutes} = 6'750 \text{ minutes}.$$

After the frequency change of Red, the total delay time for all passengers is

$$75 \cdot 7.5 + 225 \cdot 18.75 \text{ minutes} = 5'625 \text{ minutes}.$$

The reduction of delay time is thus 6’750−5’625 minutes = <u>1’125 minutes</u>

9.1.3 The Logit model: Consumer Surplus as Logsums

We specify the deterministic part of the utility of travelling by bus *i* by

$$v_i = u - c \cdot h_i$$

where $c=\ln(2)/30$, h_i=headway, and u is some fixed level of utility for the journey. When h=90 for Red and 60 for Black, this gives a probability for Black equal to

$$P(\text{Black}) = \exp(u - c \cdot 60)/[\exp(u - c \cdot 60) + \exp(u - c \cdot 90)] = 2/3$$

which is in accordance with the example, and, by the same token, P(Red)=1/3. Notice that I have scaled the utility (the parameter c) such that the probabilities are correct, and the assumed Gumbel random terms are normalised (0,1), i.e., the “scale factor” =1. The model is thus calibrated to the observed demand. The consumer surplus per traveller is now given by the “logsum”:

$$CS_0 = \ln[\exp(u - c \cdot 60) + \exp(u - c \cdot 90)] = u - 0.980829$$

After the change of headway for Red, the CS is

$$CS_1 = \ln[\exp(u - c \cdot 60) + \exp(u - c \cdot 60)] = u - 0.693147$$

The increase of CS per traveller is thus $\Delta CS = 0.980829 - 0.693147 = 0.287682$, which corresponds to a total reduction of delay time of

$$300 \cdot 0.287682 / c \text{ minutes} = \underline{3'735 \text{ minutes}}$$

The logit model hence exaggerates the gain in CS by 230 %. The model will also erroneously predict the change in demand. Indeed, after the reduced headway of Red the two alternatives are symmetrical (equal headways,) so the predicted probability for Black, say, is

$$P(\text{Black}) = \exp(u - c \cdot 60)/[\exp(u - c \cdot 60) + \exp(u - c \cdot 60)] = 1/2$$

rather that the true value P(Black) = 1/4.

9.1.4 Employing the “Rule of a Half”

The “traditional” way to compute (changes in) consumer surplus (CS) is to employ the rule that CS is the “area under the demand curve”. But in the current context it is unclear what the definition of “demand curve” is. The very notion of “demand curve” is that price is exogenous to the consumer (he is price taker) whereas he chooses the quantity to buy according to a utility maximising scheme. In the current context this is still true, but the actual “price” differs among travellers (because of their heterogeneity as to ideal departure time,) and since they have full information of all alternatives (substitutes,) they will allocate themselves in such a way that on the aggregate, the mean generalised cost is not exogenous, but endogenous, to the aggregate of travellers.

In the example above, what would the “demand curve” for Red be? What would the “demand curve” for Black be? Wouldn’t any candidate for such a curve be *upward sloping* according to the points 1−3 made earlier?

It has been suggested that the MGC (in terms of frequency delay, in this case) for each of the two buses be defined as the mean cost for all 300 travellers, i.e. both those who choose the bus under consideration *and* those who choose the other bus. In this case, the MGC is simply half the headway. Maybe, with this definition the gain in surplus (total reduction in “cost”, i.e., frequency delay time) can be computed by comparing areas under a “demand curve”, i.e., by the “rule of a half” as an approximation? Let us investigate this possibility.

What would the “rule of one half” give? The MGC for Red has decreased from 45 to 30 minutes. The demand has gone up from 100 to 225. The reduction of cost would then be, according to this rule:

$$0.5\cdot(225+100)\cdot(45-30) \text{ minutes} = \underline{2'437.5 \text{ minutes}}$$

This is an exaggeration by 117 %.

9.1.5 A Composite Good

It is indeed possible to employ the “rule of a half” to assess the CS if we consider the two bus modes as a composite good. It is imperative, though, that we then assess the correct generalised price to of this good. First we compute the total cost in terms of frequency delay. It is equal to 6’750 minutes, i.e., 22.5 minutes per passenger. After the reduction of headway of Red, the cost is 5’625/300 = 18.75 minutes. If we define 22.5 minutes and 18.75 minutes as “generalised prices”, then the “rule of a half” gives the gain in CS:

$$0.5\cdot(300+300)\cdot(22.5-18.75) = 1'125 \text{ minutes}$$

which is the correct value. This comes as no surprise, of course, since we have just made a circular computation. In order to assess the “correct” generalised prices, we have to *first* calculate the CS, and then use these prices to compute the very same CS. However, this procedure could be commendable in the case when total demand is elastic. Assume, for instance, that the reduction of headway of Red attracts another 25 travellers. Then a reasonable approximation of the gain in total CS would be

$$0.5\cdot(300+325)\cdot(22.5-18.75) = 1'172 \text{ minutes.}$$

However, this correct way of using “rule of a half” is infeasible for computing CS, since it assumes that we *already know* the CS in order to calculate the “correct” generalised prices.

9.1.6 “Integrating over all instances”

A possible problem with the “true” model is that the analyst needs to know the time schedules of the two buses. In a realistic situation with many O-D pairs, this may require an infeasible amount of information. A common approach is to “integrate over all incidents” which means that the analyst knows the headways, but not the actual phasing of departure times. There is hence a continuum of possible schedules pertaining to these headways. The procedure is then to take an average over all possible schedules, with a "diffuse" prior, i.e., all possible schedules are given the same weight. If h_1 and h_2 are the headways of Black and Red, respectively, then the proportion of travellers choosing Black is calculated as

$$\text{P(Black)} = \frac{1}{h_1 h_2} \int_0^{h_2} \int_0^{h_1} \text{step}(y - x)\,dx\,dy$$

(*step* is the Heaviside function, defined as *step(x)* = 1 if $x>0$ and = 0 if $x<0$) and so on. In the current example the demand for Black, prior to the change in headway for Red, is 200, and the demand for Red is 100. The total delay time for those choosing Black is 5'000 minutes, and for those choosing Red 2'000 minutes. The initial total cost is thus 7'000 minutes.

After the reduction of Red's headway, the demand for either bus is 150 passengers, and the average delay time (per passenger) is 20 minutes. Note that this is 1/3 of the headway, *not* 1/2, as would be the case if passengers did not consult time schedules! Hence the total delay time is 300· 20 = 6'000 minutes. The gain in CS is thus

$$\Delta\text{CS} = 7'000\text{-}6'000 = 1'000 \text{ minutes}$$

This is an underestimate of the true value by 11 %. It is not perfect, but at least in the same ballpark. If the phasing of departure times varies over the day or week, then this averaging procedure could be expected to perform even better.

9.1.7 The Mathematics of Consumer Surplus

The problem in the current context is the fact that "generalised prices" are *endogenous* when travellers consult time tables. Let me explain. First, look at the general setting in which the result *Consumer surplus is the area under the demand curve* is typically derived.

Let x and y be the demand for two goods, whose prices are p and q, respectively. The net utility, or consumer surplus, of this consumption can be written as

$$u(x,y) - px - qy$$

where u is the utility function (in pecuniary units.)

Since consumers maximise the net utility, we have the first order conditions

(1) $u_x(x,y) - p = 0$ and $u_y(x,y) - q = 0$

These relations determine the demands $x = x(p,q)$ and $y = y(p,q)$. Now we differentiate the Consumer Surplus $S = u(x,y) - p\,x - q\,y$:

$$\begin{aligned} dS &= S_x dx + S_y dy + S_p dp + S_q dq \\ &= (u_x(x,y) - p)\,dx + (u_y(x,y) - q)\,dy - x\,dp - y\,dq \\ &= -x\,dp - y\,dq \end{aligned}$$

The last equality follows from (1). *If only the price p is changed,* then $dS = -x\,dp$, which implies that the "consumer surplus is the area under the demand curve". This shows that we can ignore the fact that the demand for good y will change as a result of a price change on x (if these goods are substitutes of complements.) But we cannot ignore a *price* change on y, and this is what happens when travellers consult time schedules and one headway is changed. The "prices" (generalised costs) of *all* alternative lines change as well. Hence, the change in consumer surplus is the value of a *line integral* in this case.

9.1.8 Conclusions

When travellers are assumed to consult time schedules, computing consumer surplus is considerably more demanding than when they make their decision based only on headways (and other characteristics unrelated to departure / arrival times). The often overlooked feature is that *when the headway is changed for one mode, the average delay time will be affected also for other modes.* A problem is that erroneous estimates of consumer surplus may pass undetected. A plain vanilla logit model cannot handle the situation, nor can a simple "rule of a half". The RDT (Random Departure Time) model seems to be the best suited for the task. However, in its simplest form that model does not take individual preferences into account, but Odd Larsen has shown how the RDT model can reasonably easily be combined with a "discrete choice" specification so as to remedy this limitation; see his report *"A note on discrete choice and assignment models"*

9.2 Example

When travellers are assumed to use timetables it was proven in section 9.1 that the logsum and ROH principles overestimates change of consumer surplus when headway is changed. See also a proof in Jansson, Mattsson, Lang (2008).

First we illustrate this overestimation in the case with a pure comparison where the wait time for logsum and ROH is assumed to half the headway of the mode that is changed.

Then we illustrate the case where the stepwise function for wait time weight applied in the logit model and Samkalk. In this case Samkalk does not necessarily overestimate the change of consumer surplus, since the value of wait time is reduced. However, if the same weight for wait time would be applied in Vips, the same overestimation would occur.

For both cases we assume that the scale factor in the logit model is 0.014, which is the logit parameter from the estimated models (business trips).

In the schematic examples for the two cases there are two alternative modes where the headway of a mode 1 is halved, for various ride times from 120 to 280 minutes, while mode 2 is unchanged.

The different results from Vips, logsum and ROH are illustrated by these schematic examples, constructed in the following way:

In a first step, a base Vips situation is defined for the two modes by headway, in-vehicle time (ride time) and access time for two modes. Then, a logit model is calibrated to that situation by adjusting a mode specific constant so that the logit model gives the same probabilities as the Vips assignment does.

In a second step, a new Vips situation is defined for one of the modes, mode 1, by a headway change from 240 minutes to 120 minutes. Then, the calibrated logit model is used to describe the new situation in the logit case.

New situations are repeatedly constructed by adding in vehicle time (RM1) to mode 1, 120, 180, 240 and 280 minutes, and recalibrating the logit model to give the same choice probabilities as the Vips assignment.

Mode 2 is unchanged with headway 180 minutes and ride time 200 minutes.

Then, the changes in CS are compared between for the three principles.

9.2.1 Pure comparison Vips, logsum, ROH

The first table below shows the calculations of probabilities for choice of mode 1 and 2 respectively and the estimated changes of generalised cost (GC), for various ride times of
mode 1.

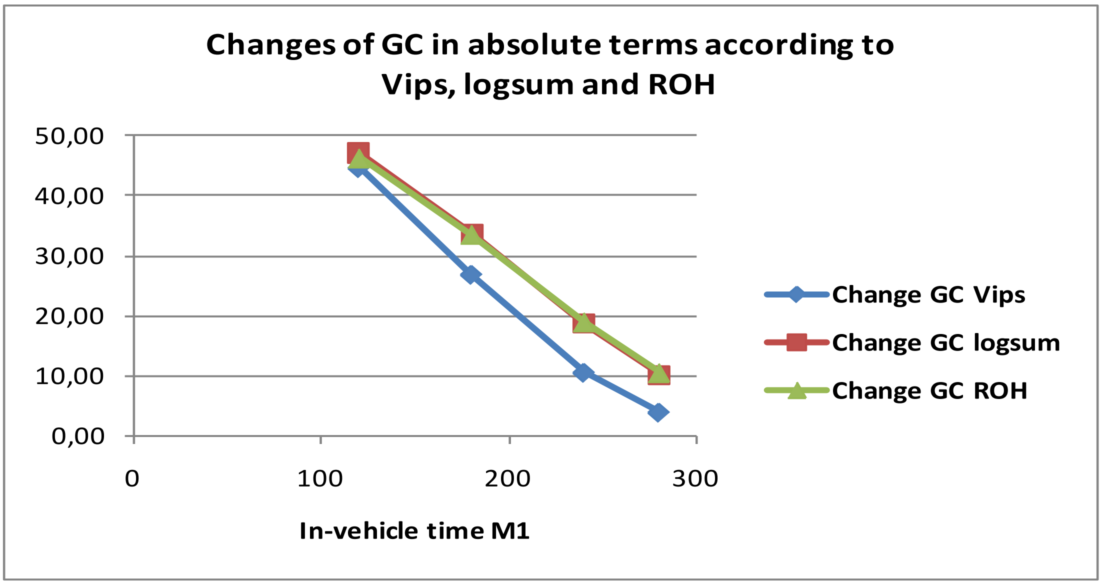
	HM1	RM1	HM2	RM2	Prob M1 Vips	Prob M1 logit	ΔGC Vips	ΔGC logsum	ΔGC ROH	ΔGC logsum/Vips	ΔGC ROH/Vips
Sit 1	240	120	180	200	0,7037	0,7037					
Sit 2	120	120	180	200	0,9629	0,8426					
Sit 2-sit 1							-44,69	-47,13	-46,39	1,05	1,04
Sit 1	240	180	180	200	0,4583	0,4583					
Sit 2	120	180	180	200	0,7685	0,6621					
Sit 2-sit 1							-26,88	-33,72	-33,61	1,25	1,25
Sit 1	240	240	180	200	0,2269	0,2269					
Sit 2	120	240	180	200	0,5926	0,4048					
Sit 2-sit 1							-10,52	-18,67	-18,95	1,77	1,80
Sit 1	240	280	180	200	0,1157	0,1157					
Sit 2	120	280	180	200	0,2315	0,2325					
Sit 2-sit 1							-3,87	-10,12	-10,45	2,62	2,70

We note that the logit model estimates a lower increase in demand of mode 1 except for the longest in-vehicle time, 280 minutes.

We can also see the overestimation of change of generalised cost (GC) made by the logsum and ROH in relation to Vips, between 1.04 and 2.70 times.

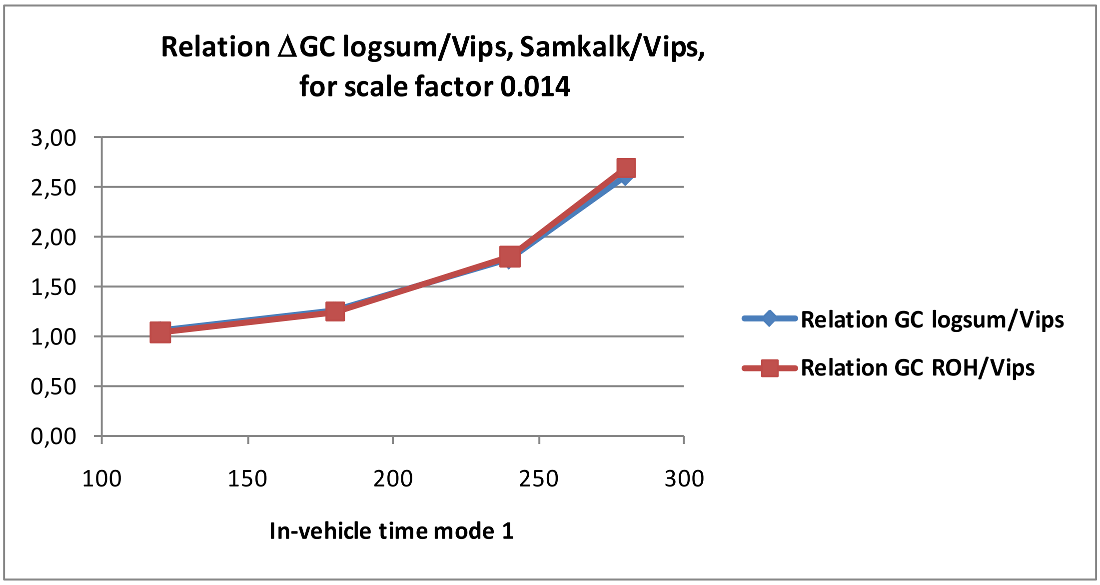
As can also be seen from the table, logsum and ROH estimates of the CS are the same, which is not surprising since the logit parameter is small enough to be well approximated by ROH. In both cases, the ΔCG becomes smaller when the in-vehicle time is increased for mode 1 (and hence the choice probability decreased). The main difference is then that the effect of the headway change decreases faster for Vips than in the logit case. This is expected as the logit model is less sensitive, because of the influence of random terms.

Next we show the changes in GC in absolute terms according to the three principles.



The overestimation of GC in absolute terms by logsum and ROH are not very large.

Below we show the relative changes of GC according to the three principles.



The overestimation in relative terms by logsum and ROH is much larger than the absolute overestimation and is a function of the ride times and of the choice probabilities. The smaller the choice probability for mode 1 is in the original situation and the longer the ride time of mode 1 is, the larger is the overestimation by the logsum and ROH.

Below we show the calculations by RDT in Vips and by the logsum and ROH in some more detail, for the situation that the ride time of mode 1 is 280 minutes.

RDT	**Assumptions**						**RDT results**						
	HM1	HM2	RM1	RM2	GCM1	GCM2	PM1	PM2	Comp R	Comp W	W1	W2	Comp GC
Sit 1	240	180	280	200	537,94	473,24	0,1157	0,8843	219,26	76,88			326,150
Sit 2	120	180	280	200	492,06	473,24	0,2315	0,7685	228,52	63,77			322,280
Sit 2 - Sit 1	-120	0	0	0			0,1158	-0,1158	9,26	-13,11			-3,87

Logit calculation and result				d		-ln(d)/μ					**Samkalk result**		
	μ	GCM1	GCM2	$(e^{-\mu GC1}+e^{-\mu GC2})$	ln(d)	Comp GC	$e^{-\mu GC1}$	$e^{-\mu GC2}$	PM9	PB7	ΔGC		
Sit 1	0,014	537,94	388,39	0,005746869	-5,16	379,35	6,6E-04	5,1E-03	0,1157	0,8843	Exist	New	Sum
Sit 2	0,014	492,06	388,39	0,006322852	-5,06	372,32	1,2E-03	5,1E-03	0,1962	0,8038			
Sit 2 - Sit 1		-45,88	0,00			-7,02			0,0806	-0,0806	-5,31	-1,85	-7,16

From the RDT results we can see the separate composite effects on ride time (Comp R) and wait time (Comp W). The composite wait time is reduced by 13.11, while at the same time the ride time increases by 9.26. This increase in ride time depends on that mode 1 has a longer ride time than mode 2, so the shift of mode causes a longer composite ride time.

These separate effects the logit model cannot calculate. We can see that according to the logit model the generalised cost of mode 2 (GCM2) is the same in situation 1 and 2, equal to 388.39. In fact, the wait time for mode 2 will be reduced when its market share decreases, which is not taken into consideration by the logit model.

9.2.2 Comparison between Vips and Samkalk

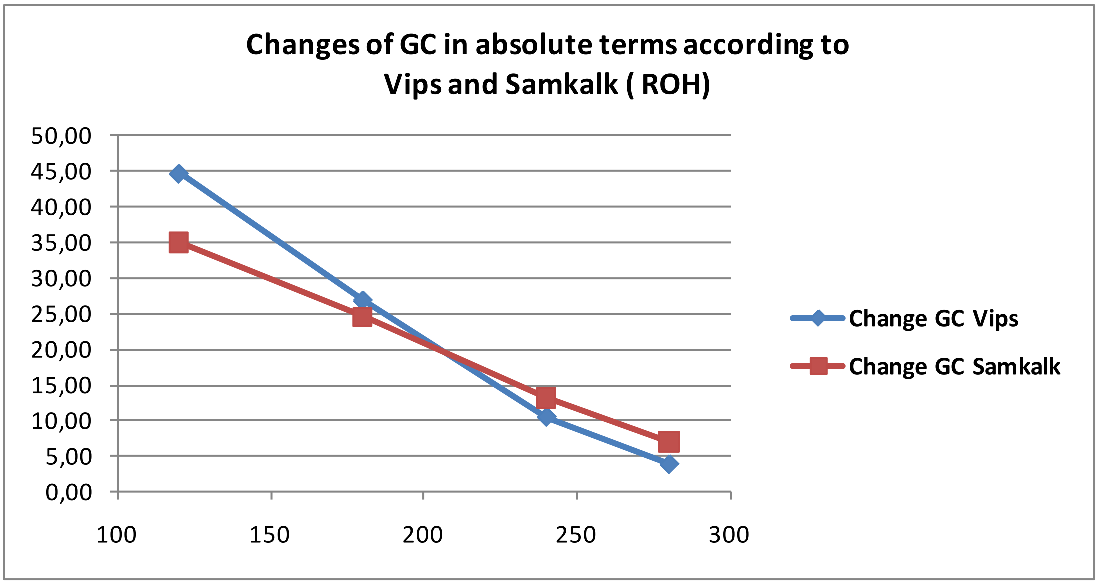
Note that the Samkalk results are the same as the results of ROH since Samkalk applies ROH.

Here the step-wise wait time weights are used in the logit model and in Samkalk.

The basic results are the following according to the models.

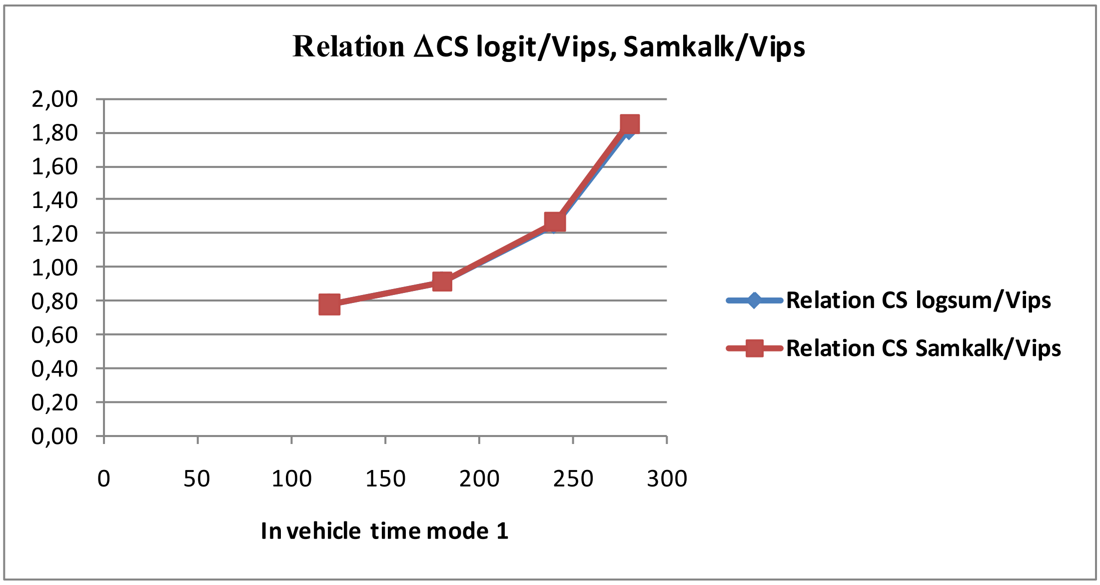
Headways M1		**Time**	**ΔGC**	**ΔGC**	**ΔGC**	**ΔGC**	**ΔGC**
Sit 1	**Sit 2**	**R1**	**Vips**	**Samkalk**	**ROH**	**logit/Vips**	**ROH/Vips**
240	120	120	-44,69	-35,00	-34,86	0,78	0,78
240	120	180	-26,88	-24,59	-24,56	0,91	0,91
240	120	240	-10,52	-13,19	-13,32	1,25	1,27
240	120	280	-3,87	-7,02	-7,16	1,81	1,85

Now we observe that the ΔCG is smaller in the logit case in the first two situations, implying that the differences between the systems are no longer necessarily in one direction. Other results could be obtained by using other parameters, so this is not necessarily a general property. A comparison of the results in absolute terms is illustrated in the figure below.



Again, the differences in changes of GC in absolute terms seem fairly small.

Below we show the differences in relative terms.

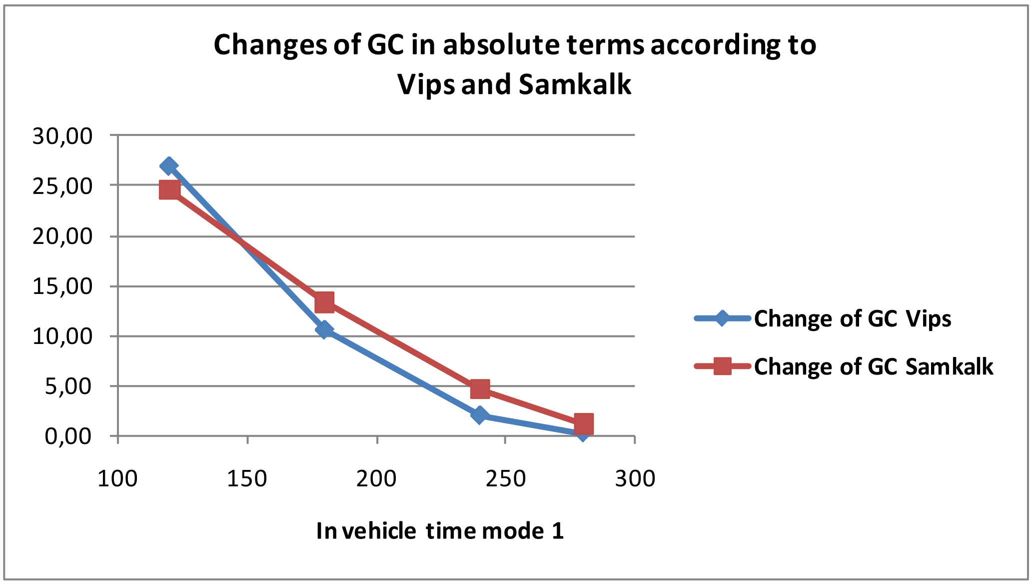


In a second example, the same pattern is repeated. The main difference is now that the initial choice probabilities are lower for mode 1. The results are presented in the table below:

Headways M1		Time	ΔGC	ΔGC	ΔGC	ΔGC	ΔGC
Sit 1	Sit 2	R1	Vips	logit	ROH	logit/Vips	ROH/Vips
240	120	120	-26,88	-24,59	-24,56	0,91	0,91
240	120	180	-10,52	-13,20	-13,32	1,25	1,27
240	120	240	-1,97	-4,56	-4,66	2,31	2,37
240	120	280	-0,24	-1,17	-1,21	4,89	5,04

Again, the logsum is well approximated by ROH in Samkalk.

A comparison of the results in absolute terms is illustrated in the figure below.



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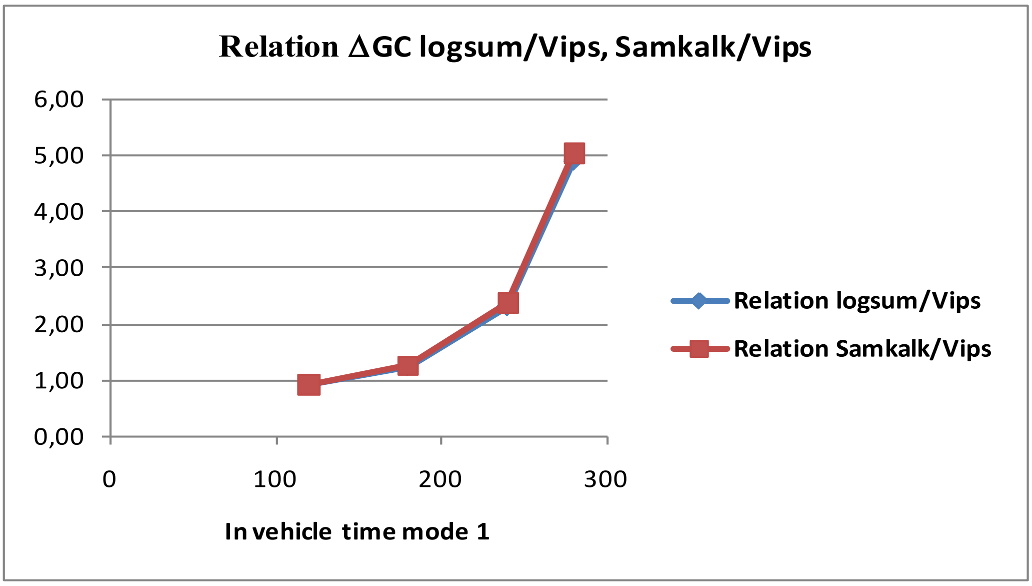
Below we show the differences in relative terms.



In this example with lower initial probability for choice of mode 1 the relative differences between the models are much larger than when the initial probability for choice of mode 1 was larger.

9.2.3 Conclusions

The examples illustrate one of the main differences between the RDT algorithm and the logit model, namely that in the logit model the distribution of individual preferences is implicitly considered, implying that a mode may be chosen even if its generalized cost is much lower than for the other mode. In the extreme or, rather, if the in vehicle time of mode 1 in the first example becomes larger than 380 (in vehicle time plus headway of mode 2), then there will be no gain at all in the Vips case, but still some gain in the logit case (as mode 1 will still be chosen by a few). In the other extreme, where mode 1 is chosen by almost everybody, then ΔGC will be almost equal to (half) the headway change in Vips as well as in the logit case. When initial choice probabilities are lower for mode 1, then the ΔGC will be lower in both cases, but the ratio between the logit result and the Vips result will increase (at least in last example).

From the RDT results we can see the separate composite effects on ride time and wait time. These separate effects the logit model cannot calculate.

With the same weights for wait time in Vips and Sampers, the logsum and ROH will overestimate the consumer surplus effects of headway changes. Since the step-wise weight of wait time is applied in Sampers, there is no general rule that the logsum or ROH will overestimate the consumer surplus effects of headway changes, but all results are sensitive to the case and the parameter choices.

See also some complementary results of headway change from *real runs* with Vips and Sampers in sections 11.4 and 12.

The generalised cost and the consumer surplus effects when headway is changed certainly needs deeper studies.

9.3 Discussion on methods for consumer surplus assessment

Larsen (2009a) writes: “The most important feature of a RDT-model is the ability to handle properly the combined waiting time.”

Larsen (2009b) specifies that the generalized travel cost of line “i” for an arbitrary traveller (j) belonging to a particular segment in the framework of a RDT-model be written as:

$$GC_{ij}=\alpha_i T_i + C_i + \mu_i H_i v_{ij} + \xi AET_i + \Omega_i \qquad \text{for all } i \qquad (1)$$

Where
GC_{ij} = generalized cost
T_i = on-board time
C_i = cost
H_i = headway
AET_i = access + egress time
v_{ij} = a random variable on the unit interval <0,1> that varies by departure time and incident

Larsen (2009b) writes:

> “If we – as observers – know the incident (i.e. the specific timetable) and the preferred arrival or departure time of an individual, we will also know the values of vij and we can predict the choice of line for the individual with certainty. …..
>
> When we don’t know the incident and the preferred arrival or departure time, the best we can do is to predict probabilities or market shares for each mode, i.e.

> we assume a uniform distribution of preferred arrival or departure times and integrate over all incidents. The only stochastic element that enters the model is vij which is generated by the mixture of incidents and random arrival/departure times."

In "Notes on the RDT Model" (2009) John Bates agrees with the first paragraph, but thinks something is missing in the argument, and this is the relationship between early and late departures (or arrivals – for convenience we will work with preferred departure times [PDT]). Bates note in full is here in appendix 1.

Larsen (2010) expresses the problems related to logit models as follows: "Travellers compare itineraries both within and across modes. They don't base mode choice on the mean level of service offered by different modes. This means that the observed choices will not be generated by a standard logit model and the conditions for the use of such a model are violated. This also invalidates the logsum as a measure of consumers' surplus. At best it will be a rough approximation with unknown properties and unsuitable for comparison of different situations."

For scheduled public transport where travellers consider the schedules of various lines for various modes, the "standard" conditions for the logit model are thus violated.

It may be worthwhile, however, in order to clarify the issue, to discuss the differences between consumer surplus calculations according to the logsum, rule-of-the half (ROH) and RDT by use of schematic examples.

It has been argued that ROH is a good approximation of the difference in logsum between two scenarios. This is not generally true, but for scheduled public transport the deviations may be large and serious.

We have already shown that ROH is an erroneous measure of consumer surplus change if headway is changed.

However, even if ride time or price is changed, the difference in logsum may differ from ROH, and both can differ from the change in CS according to RDT.

If we assume that the demand level of alternatives in an initial situation are the same according to the logit model and RDT, then a change in ride time will give the same change in generalised cost according to the difference in logsum, ROH and RDT.

But, when the demand levels are calculated by the logit model the three measures of change in CS may differ, dependent on what the implicit scale factor (unknown part of the parameters) in the logit model happens to be.

10 Frequency-based or timetable-based assignment

One important issue is whether average frequency-based assignment or schedule-based assignment is preferable.

One advantage with timetable-based assignment as Daly (2004) points out is that transfer times at interchanges can be calculated correctly. One is not dependent on transfer time as half the interval.

Concerning the problems related to timetable-based (or in other words schedule-based) assignment we can quote Daly (2004) in this respect, who is pointing both at the advantages of schedule-based assignment and the problems.

Daly writes:

> ” the use of schedule-based assignment is certainly more costly in terms of computer time and the requirements for data input can be prohibitive.”…” Further, particularly when testing alternative network designs for the future, it is often the case that the operator itself is unable to prepare detailed running schedules for a wide range of network designs. This means that either schedule-based assignment has to be abandoned or that approximations have to be made. However, the use of approximations for such forecasts can introduce systematic inconsistencies relative to forecasts in which schedules are available.”… The difficulty of obtaining good information about passengers’ preferences for times of travel is a significant limitation on the improvement that can be obtained from schedule-based assignment.”

The increased level of detail needed for the schedule-based approach comes with the cost of need for more detailed data e.g. desired departure (arrival) times and exact timetables and considerable effort for data processing. For forecasting it is also required to have information about the future timetables.

Neither Preston (2004) is convinced, writing:

> “The computational challenges faced by timetable/schedule approaches are enormous but should be manageable if one is to believe the hype of the IT revolution.”

It is worth mentioning the Vips/Visum models can handle transfer times where convenient transfers are deliberately arranged by specifying ”matched transfer time” between any pair of services in both directions. This means that up to 8 matched transfers can be specified between any pair of services at each transfer point. One is not constrained to transfer time as half the headway. This is thus one way to deal with convenient transfers without using timetable-based assignment, but of course much more approximate.

Even if there are several problems related to schedule based assignment we suggest that one should look deeper into possible solutions for this kind of models in further research.

Visum´s timetable based assignment regards all departure and arrival times of all lines and modes for the whole day. Travellers in each of one hour time slice compares departures in several slices each with different ride times, fares etc. The choice also depends on the assumed cost for late versus early arrival.

For the assignment on the different departures Visum applies a logit model, Box-Cox transformation, the Kirchoff principle etc. It may be questioned whether these assignment principles are the most appropriate since they may give certain probabilities for choice of departure that are unrealistic. The logit model for example will give a probability for choice of a departure that takes longer time and is more expensive than other departures. One may here consider the RDT principle for the choice of departure. This would mean that the travellers within each one hour time slice are uniformly distributed. The consequence is that departures with ride time longer than the ride time plus the time till departure for the best option will be rejected. Such issues, however, need much more consideration and are left for future research.

Since the worries expressed by Daly 2004, it may be that the possibility through the “hype of the IT revolution” foreseen by Preston may be more or less in place. In Germany the timetable-based version is already dominating. In the near future it may be that also for the whole of Sweden all timetables for all lines and modes can be exported to Visum or some other timetable based software.

11 Changes of two modes – Examples from real runs of the national network

11.1 Introduction

Here we present results from real runs of the Swedish network by Sampers and Vips respectively, where we have simulated two sequential transport measures for two modes.

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We have analysed demand and consumer surplus effects of measures assumed for rail and air for journeys between Sollentuna (15 km north of Stockholm) and central Gothenburg.

The distance between Stockholms central station and Gothenburgs central station is around 450 km. Today train departures take 3 hours ride time or slightly more from Stockholm central station and air takes 1 hour from the two Stockholm airports, Bromma and Arlanda.

The distance from Sollentuna to Bromma airport is about 12 km and to Stockholm central station about 14 km. The distance from Sollentuna to Arlanda airport is about 29 km. The distance from the Gothenburg airport Landvetter to central Gothenburg is about 25 km. The walking distance from the Gothenburg central station to central Gothenburg is less than 1 km.

Sampers only regards Arlanda airport with one “average airline”, while Vips takes a choice between both airports with their respective airlines into account.

According to both models one can reach Arlanda by car/taxi. Ride time and price expressed in minutes takes according to the Vips coding 33.1 minutes from Sollentuna to Bromma and 84.2 minutes to Arlanda. According to Sampers it takes x minutes to reach Arlanda. Sollentuna to Stockholm central station takes 43.2 minutes according to Vips and x minutes according to Sampers. In the Vips coding there is also an option to go by commuter train to Stockholm central station but this alternative is not chosen by business travellers, due to the high value of time. Sampers only regards the car/taxi access. The link to central Gothenburg takes 18 minutes from the Gotehnburg railway station and 26.6 minutes from the Gothenburg airport (Landvetter). According to Sampers these links take x and y minutes respectively.

We have analysed the following measures:

- Ride time for Speed trains X2000 between Stockholm and Gothenburg halved from approximately 3 hours to approximately 1.5 hours, denoted Ride Time Down (RTD),

- Airlines frequency Stockholm-Gothenburg decreased by 80 %, denoted Air Frequency Down (AFD).

- Airlines Stockholm-Gothenburg get ride time increased by 100 %, denoted Air Time Up (ATU).

The last measure is certainly not realistic in practice. It is used in order to illustrate change of air ride time as an alternative to reduced frequency. We could equally well have assumed the double price for air transport. This would have given more or less the same results and could me more realistic if for example higher taxation of air travel is considered.

We have analysed the following sequences of the measures:

1. First RTD, then AFD
2. First AFD, then RTD

The reason in real life for the decrease of air frequency could be that the airlines have to adapt to demand decrease because of the introduction of faster rail services.

3. First RTD, then ATU
4. First ATU, then RTD

Note that for Vips we have not applied its forecast method. This method is based on assumed elasticity with respect to composite generalized cost of all alternatives. Since this is not used here we do not present any demand changes in total according to Vips.

11.2 Demand and demand changes for rail time down and air frequency down

11.2.1 Base situation

The two tables below show calculated demand according to Vips and Sampers for the base situation.

Table 11.2.1.1 Demand according to Vips for base situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	20,5	1611	+60a	14011	43,2	38,8	672	172	959,4	18
St C stn.	198,3	1611	+60b	14011	43,2	38,8	88,5	182	959,4	18
St C stn.	57	1611	+60d	14011	43,2	38,8	197,5	182	959,4	18
St C stn.	39,5	1611	+60j	14011	43,2	38,8	280	182	959,4	18
St C stn.	15,8	1611	+60c	14011	43,2	38,8	672	182	959,4	18
St C stn.	45,9	1611	+60f	14011	43,2	38,8	240	187	959,4	18
Bromma	186,5	1691	Malmö Av	13191	33,1	38,8	59	55	1252	26,6
St C stn.	7,1	1611	+57x2	14011	43,2	38,8	672	222	996	18
Arlanda	13,1	2491	SAS	13191	84,2	38,8	48,5	60	804	26,6□
Sum Rail	384,1									
Sum Air	199,6									
Total	583,7									
% Rail	66									

Note that Vips assigns travellers on a number of rail lines and two airlines, one from Bromma and one form Arlanda airport. The rail lines have to some extent different ride times due to different stop patterns.

Table 11.2.1.2 Demand according to Sampers for base situation

	Rail	Air	Total	% Rail
Base	213	293	506	42

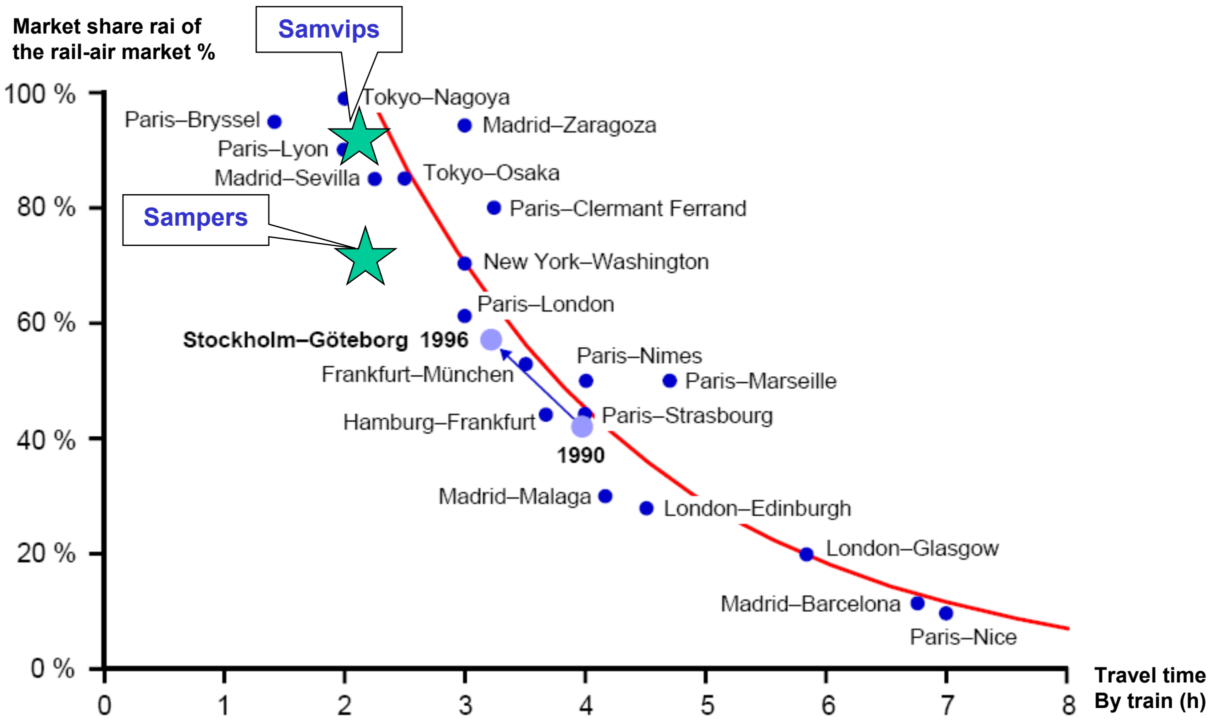
Vips calculates higher demand for air than Sampers. This depends on the parameters chosen in the two models so we cannot draw any significant conclusions of this. We neither have real figures to compare with for this particular O-D pair for business journeys.

However, it may be interesting to look at some real statistics for rail shares in more general terms. We can for example look at general statistics for all journey purposes for rail and air between Stockholm and Gothenburg. When the fast trains (X2000) were introduced between Stockholm and Gothenburg and train travel time was reduced from 4 to 3 hours, the market share for rail grew from 40 to around 60 per cent. In December 2009 rail had a share of 70 % and air 30 % (of these two modes), according to the Swedish Tourist data base (TDB).

Diagram 11.2.1 below shows the international experience of rail market share, of rail and air, depending of rail travel times.

There is a very stable relation between travel time by train and the rail market share. At 3 hours travel time rail will have higher market share than air and at 2 hours travel time rail will totally dominate the market and sometimes the airlines close down. The diagram also shows the calculated rail share Stockholm-Gothenburg from a recent high-speed rail study, according to Samvips (around 90 %) and Sampers (around 70 %) respectively. Note that experience from other countries indicates that the rail share with rail time 2 hours is between 85 and 100 per cent.

Diagram 11.2.1.1 Examples of rail and air shares



11.2.2 Base and rail time down (RTD) situation

The table below shows demand for rail lines and airlines in the base situation for this particular O-D pair according to Vips. Note that only one of the air lines still has demand, but only 3 %, after the rail time reduction.

Table 11.2.2.1 Demand according to Vips for RTD situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	30,4	1611	+60a	14011	43,2	54,7	672	86,5	959,4	18
St C stn.	293,8	1611	+60b	14011	43,2	54,7	88,5	96,5	959,4	18
St C stn.	84,5	1611	+60d	14011	43,2	54,7	197,5	96,5	959,4	18
St C stn.	58,5	1611	+60j	14011	43,2	54,7	280	96,5	959,4	18
St C stn.	23,4	1611	+60c	14011	43,2	54,7	672	96,5	959,4	18
St C stn.	68,1	1611	+60f	14011	43,2	54,7	240	101,5	959,4	18
St C stn.	4,8	1611	+57x2	14011	43,2	54,7	672	175	996	18
Bromma	20,2	1691	Malmö Av	13191	33,1	54,7	59	55	1252	26,6□
Sum Rail	563,5									
Sum Air	20,2									
Total	583,7									
% Rail	97									

The tables below show the results of Vips and Sampers when moving from the base to the RTD situation. The RTD situation means that rail takes 1.5 hours and air 2 hours. In addition the distances to/from the railway stations are much shorter than the distances to/from the airports.

Table 11.2.2.2 Demand according to Vips for base to RTD situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
RTD	564	20	584	97
Gained/lost	179	-179	0	
% change	47	-90	0	

Table 11.2.2.3 Demand according to Sampers for base to RTD situation

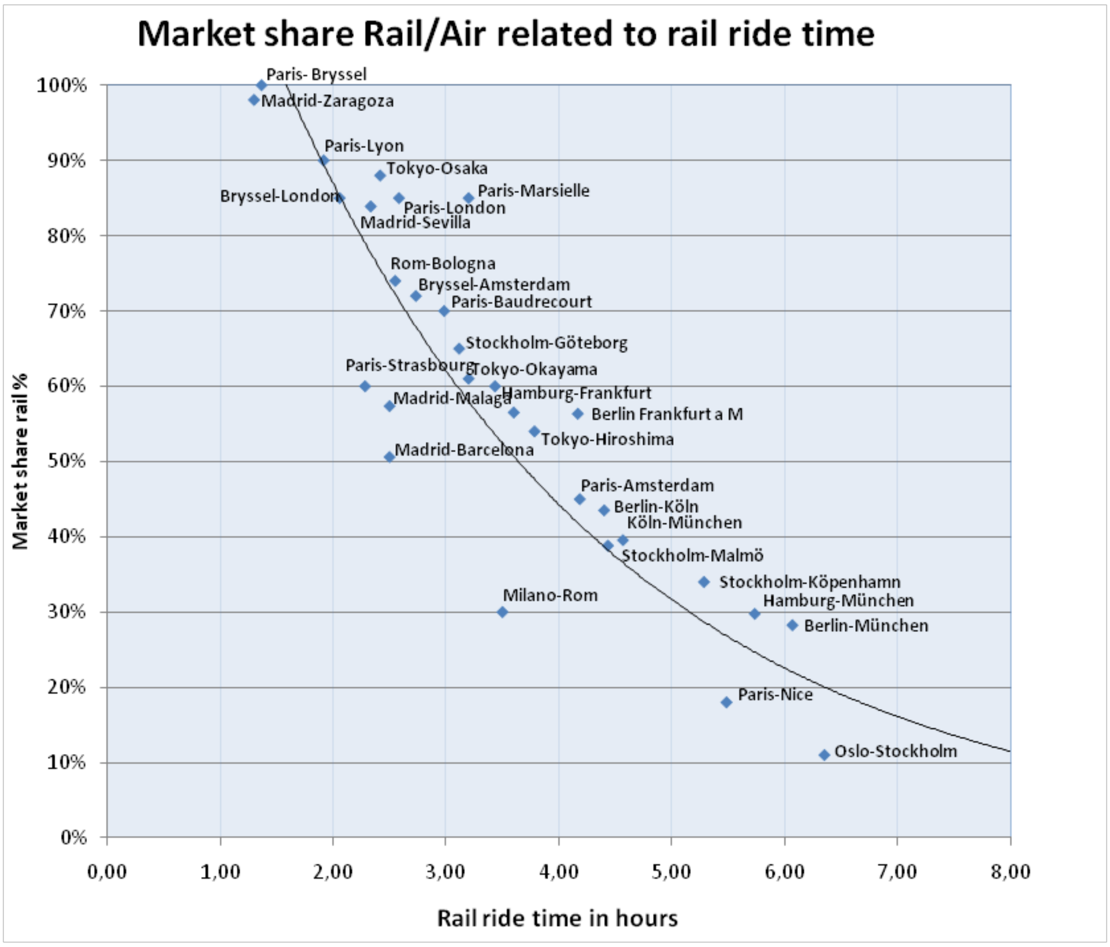
	Rail	Air	Total	% Rail
Base	213	293	506	42
RTD	509	237	746	68
Gained/lost	296	-56	240	
% change	139	-19	47	

With half ride time for rail services Sampers calculates a much smaller decrease of air demand than Vips, 19 compared to 90 %. That is, according to Sampers air should still have a market share of 32 % but according to Vips only 3 %.

Let us now look at a recent diagram by Lundberg (2010).

We see that for 2 hour rail ride time the rail market share is around 90 %. For rail ride time 1.5 hours the rail market share is around 100 %. Also taking into consideration the shorter distances to/from the railway stations than to/from the airports, the market share according to Sampers seems excessively high.

Diagram 11.2.2.1 Rail market shares for various rail ride times.



11.2.3 Base and air frequency down (AFD) situation

The table below shows demand for rail lines and airlines in the AFD situation for this particular O-D pair according to Vips. In the AFD situation both airlines still have demand but they have lost much.

Table 11.2.3.1 Demand according to Vips for AFD situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	28,6	1611	+60a	14011	43,2	52,7	672	172	959,4	18
St C stn.	276,8	1611	+60b	14011	43,2	52,7	88,5	182	959,4	18
St C stn.	79,6	1611	+60d	14011	43,2	52,7	197,5	182	959,4	18
St C stn.	55,1	1611	+60j	14011	43,2	52,7	280	182	959,4	18
St C stn.	22,1	1611	+60c	14011	43,2	52,7	672	182	959,4	18
St C stn.	64,1	1611	+60f	14011	43,2	52,7	240	187	959,4	18
Bromma	37,3	1691	Malmö Av	13191	33,1	52,7	295	55	1252	26,6
St C stn.	10,9	1611	+57x2	14011	43,2	52,7	672	222	996	18
Arlanda	9,2	2491	SAS	13191	84,2	52,7	242,5	60	804	26,6□
Sum Rail	537,2									
Sum Air	46,5									
Total	583,7									
% Rail	92									

The tables below show the results of Vips and Sampers when moving from the base to the AFD situation.

Table 11.2.3.2 Demand according to Vips for base to AFD situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
AFD	537	47	584	92
Gained/lost	153	-153	0	
% change	40	-77	0	

Table 11.2.3.3 Demand according to Sampers for base to AFD situation

	Rail	Air	Total	% Rail
Base	213	293	506	42
AFD	227	167	395	58
Gained/lost	14	-126	-112	
% change	7	-43	-22	

With 80 % fewer air departures services Sampers calculates a much smaller decrease of air demand than Vips, 43 compared to 77 %. After reduction of air services by 80 % Sampers calculates that air still has a 42 % markets share while it is only 8 % according to Vips.

11.2.4 Base and rail time down (RTD) plus air frequency down (AFD) situation

The table below shows demand for rail lines and airlines in the RTD plus AFD situation for this particular O-D pair. Now only one airline still has small demand left.

Table 11.2.4.1 Demand according to Vips for RTD plus AFD situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	31,3	1611	+60a	14011	43,2	57,3	672	86,5	959,4	18
St C stn.	302,2	1611	+60b	14011	43,2	57,3	88,5	96,5	959,4	18
St C stn.	86,9	1611	+60d	14011	43,2	57,3	197,5	96,5	959,4	18
St C stn.	60,2	1611	+60j	14011	43,2	57,3	280	96,5	959,4	18
St C stn.	24,1	1611	+60c	14011	43,2	57,3	672	96,5	959,4	18
St C stn.	70	1611	+60f	14011	43,2	57,3	240	101,5	959,4	18
St C stn.	5	1611	+57x2	14011	43,2	57,3	672	175	996	18
Bromma	4	1691	Malmö Av	13191	33,1	57,3	295	55	1252	26,6□
Sum Rail	579,7									
Sum Air	4									
Total	583,7									
% Rail	99									

The diagrams below show the results of Sampers and Vips when moving from the base to the RDT plus AFD situation.

Table 11.2.4.2 Demand according to Vips for base to RTD plus AFD situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
RTD+AFD	580	4	584	99
Gained/lost	196	-196	0	
% change	51	-98	0	

Table 11.2.4.3 Demand according to Sampers for base to RTD plus AFD situation

	Rail	Air	Total	% Rail
Base	213	293	506	42
RTD + AFD	538	131	668	80
Gained/lost	324	-163	162	
% change	152	-55	32	

When rail time is reduced from 3 to 1.5 hours and 80 % of rail departures are withdrawn Sampers calculates an air demand decrease by only 55 % while the decrease according to Vips is 98 %. In this situation Sampers calculates that air still has a 20 % markets share while it is only 1 % according to Vips.

Sampers seems to calculate an unrealistically low effect for demand shifts between the modes.

11.2.5 Conclusions from demand and demand changes

Samkalk seems to severely underestimate the demand reduction for air when rail ride time is reduced to half.

When both rail ride time is halved and air frequency is reduced by 80 %, Sampers calculates that air still has a market share of 20 %. This seems unrealistic and underpins the viewpoints by users of Sampers presented in section 2.1.

The reasons for these results of Sampers have to do with the main mode concept and the features of the logit model.

11.3 Demand and demand changes for rail time down and air time up

11.3.1 Base situation

The two tables below repeat the calculated demand according to Vips and Sampers for the base situation.

Table 11.3.1.1 Demand according to Vips for base situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	20,5	1611	+60a	14011	43,2	38,8	672	172	959,4	18
St C stn.	198,3	1611	+60b	14011	43,2	38,8	88,5	182	959,4	18
St C stn.	57	1611	+60d	14011	43,2	38,8	197,5	182	959,4	18
St C stn.	39,5	1611	+60j	14011	43,2	38,8	280	182	959,4	18
St C stn.	15,8	1611	+60c	14011	43,2	38,8	672	182	959,4	18
St C stn.	45,9	1611	+60f	14011	43,2	38,8	240	187	959,4	18
Bromma	186,5	1691	Malmö Av	13191	33,1	38,8	59	55	1252	26,6
St C stn.	7,1	1611	+57x2	14011	43,2	38,8	672	222	996	18
Arlanda	13,1	2491	SAS	13191	84,2	38,8	48,5	60	804	26,6□
Sum Rail	384,1									
Sum Air	199,6									
Total	583,7									
% Rail	66									

Table 11.3.1.2 Demand according to Sampers for base situation

	Rail	Air	Total	% Rail
Base	213	293	506	42

11.3.2 Base and rail time down (RDT) situation

The tables below repeat the results of Vips and Sampers when moving from the base to the RDT situation.

Table 11.3.2.1 Demand according to Vips for base to RTD situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
RTD	564	20	584	97
Gained/lost	179	-179	0	
% change	47	-90	0	

Table 11.3.2.2 Demand according to Sampers for base to RTD situation

	Rail	Air	Total	% Rail
Base	213	293	506	42
RTD	509	237	746	68
Gained/lost	296	-56	240	
% change	139	-19	47	

Note again. With half ride time for rail services Sampers calculates a much smaller decrease of air demand than Vips, 19 compared to 90 %. That is, according to Sampers air should still have a market share of 32 % but according to Vips only 3 %.

11.3.3 Base and air time up (ATU) situation

The table below shows demand for rail lines and airlines in the air time up (ATU) situation for this particular O-D pair. In the ATU situation only one airline still has demand.

Table 11.3.3.1 Demand according to Vips for ATU situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	29,8	1611	+60a	14011	43,2	53,6	672	172	959,4	18
St C stn.	288,3	1611	+60b	14011	43,2	53,6	88,5	182	959,4	18
St C stn.	82,9	1611	+60d	14011	43,2	53,6	197,5	182	959,4	18
St C stn.	57,4	1611	+60j	14011	43,2	53,6	280	182	959,4	18
St C stn.	23	1611	+60c	14011	43,2	53,6	672	182	959,4	18
St C stn.	66,7	1611	+60f	14011	43,2	53,6	240	187	959,4	18
St C stn.	11,6	1611	+57x2	14011	43,2	53,6	672	222	996	18
Bromma	24	1691	Malmö Av	13191	33,1	53,6	59	110	1252	26,6□
Sum Rail	559,7									
Sum Air	24,0									
Total	583,7									
% Rail	96									

The tables below show the results of Vips and Sampers when moving from the base to the ATU situation.

Table 11.3.3.2 Demand according to Vips for base to ATU situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
ATU	560	24	584	96
Gained/lost	176	-176	0	
% change	46	-88	0	

Table 11.3.3.3 Demand according to Sampers for base to ATU situation

	Rail	Air	Total	% Rail
Base	213	293	506	42
ATU	227	171	398	57
Gained/lost	14	-123	-108	
% change	7	-42	-21	

With double air ride time (2 hours) Sampers calculates a much smaller decrease of air demand than Vips, 42 compared to 88 %. With air ride time 2 hours instead of 1 hour Sampers calculates that air still has a 43 % markets share while it is only 4 % according to Vips.

11.3.4 Base and rail time down (RTD) plus air time up (ATU) situation

The table below shows demand for rail lines and airlines in the rail time down (RTD) plus the air time up (ATU) situation for this particular O-D pair. Now airlines have lost all demand according to Vips.

Table 11.3.4.1 Demand according to Vips for RTD plus AFD situation

Start stop	Trips	Stop	Route	Stop	Walk time	Composite wait time	Route wait	Ride time	Fare	Walk time
St C stn.	31,5	1611	+60a	14011	43,2	58	672	86,5	959,4	18
St C stn.	304,3	1611	+60b	14011	43,2	58	88,5	96,5	959,4	18
St C stn.	87,5	1611	+60d	14011	43,2	58	197,5	96,5	959,4	18
St C stn.	60,6	1611	+60j	14011	43,2	58	280	96,5	959,4	18
St C stn.	24,3	1611	+60c	14011	43,2	58	672	96,5	959,4	18
St C stn.	70,5	1611	+60f	14011	43,2	58	240	101,5	959,4	18
St C stn.	5	1611	+57x2	14011	43,2	58	672	175	996	18,0□
Sum Rail	583,7									
Sum Air	0									
Total	583,7									
% Rail	100									

The diagrams below show the results of Vips and Sampers when moving from the base to the rail time down (RDT) plus the air time up (ATU) situation.

Table 11.3.4.2 Demand according to Vips for base to RTD plus ATU situation

	Rail	Air	Total	% Rail
Base	384	200	584	66
RTD and ATU	584	0	584	100
Gained/lost	200	-200	0	
% change	52	-100	0	

Table 11.3.4.3 Demand according to Sampers for base to RTD plus ATU situation

	Rail	Air	Total	% Rail
Base	213	293	506	42
RTD + ATU	537	133	669	80
Gained/lost	323	-160	163	
% change	152	-55	32	

When rail time is reduced from 3 to 1.5 hours and air gets double ride time, 2 hours, Sampers calculates an air demand decrease by only 55 % while the decrease according to Vips is 100 %. In this situation Sampers calculates that air still has a 20 % markets share while it is zero according to Vips.

Sampers seems to calculate an unrealistically low effect for demand shifts between modes.

11.3.4 Conclusions from demand and demand changes

When both rail ride time is halved and air rail ride time is doubled, Sampers calculates that air still has a market share of 20 %. This seems unrealistic and underpins the viewpoints by users of Sampers. The reasons for these results of Sampers have to do with the main mode concept and the features of the logit model.

11.4 Generalised cost and consumer surplus for rail time down and air frequency down

11.4.1 Rail time down (RTD) first and then air frequency down (AFD)

For “Rail Time Down” calculation according to the principles assumed to be used by Samkalk and Vips gives nearly the same result. The similar results for ride time change mainly depend on that rule of the half is an approximation of the integral used by Vips. A complementary reason is that Sampers uses average ride times of all rail services in each O-D pair from Emme/2. while Vips uses individual ride times of each line. The reason is that the logit model takes the average ride times for a mode from Emme/2, since this model does not take differences in ride times into account.

For the other assumed traffic supply change alternatives, Air Frequency Down (AFD) and Air Time Up (ATU) our calculations indicate that there may be significant differences between the outcomes using on one hand the Vips way of calculating CS changes and calculation according to the principles assumed to be used by Samkalk on the other.

We can see some interesting differences due to the calculation principles in Vips and Samkalk, illustrated in the table below. Note that the results here are based on real runs with the two systems for business journeys, with the actual parameters used, including the step-wise function in Sampers for wait time.

First we look at the case where of Air Frequency Down (AFD) is assumed *before* Rail Time Down (RTD)

Order: first air frequency down 80 % (AFD), then ride time down 50 % (RTD)										
Sampers/Samkalk					**Vips**			Samkalk	Vips	Relation
	Rail trips	Rail GC	Air trips	Air GC		Total trips	Total GC	**ΔCS**	**ΔCS**	ΔCS Samkalk/ ΔCS Vips
RA	213,1	497,7	293,1	386,7	RA	583,8	522,9			
AFD	227,3	497,7	167,2	430,3	AFD	583,8	531,1			
AFD+RTD	537,5	404,1	130,5		AFD+RTD	583,8	469,5			
Δ First AFD		0,0	-125,9	43,6	Δ First AFD	0,0	8,1			
			ΔGC	**ΔCS**		**ΔGC**	**ΔCS**			
Remaining			43,6	-7 291						
Lost			21,8	-2 745						
Sum				-10 035		8,1	-4 746	-10 035	-4 746	2,11
Δ Then RTD	310,2	-93,6			Δ Then RTD	0,0	-61,5			
	ΔGC	**ΔCS**				**ΔGC**	**ΔCS**			
Existing	-93,6	21 267								
New	-46,8	14 512								
Sum		35 779				-61,5	35 933	35 779	35 933	1,00
Total sum				**ΔCS**			**ΔCS**			
				25 744			31 187	25 744	31 187	0,83

When the effect of Air Frequency Down (AFD) is calculated *before* Rail Time Down (RTD), Samkalk calculates an effect on generalized cost that is 5 times higher than that of Vips (43.6/8.1). However, the effect for air travellers concerns the remaining ones only. In order to calculate the effects for consumer surplus according to Samkalk we must multiply the loss in GC with the number of remaining air passengers and with half of this loss for the lost passengers. The overestimation in terms of CS by Samkalk is then about 2 times. This is also a complementary illustration of the generalized cost effects of a headway change that were discussed on the basis of schematic examples in section 3.5.4.

Next we look at the case where of Air Frequency Down (AFD) is assumed *after* Rail Time Down (RTD).

Order: first rail ride time down 50 % (RTD), then air frequency down 80 % (AFD)												
Sampers/Samkalk					**Vips**			Samkalk	Vips	Relation
	Rail trips	Rail GC	Air trips	Air GC		Total trips	Total GC	**ΔCS**	**ΔCS**	ΔCS Samkalk/ ΔCS Vips
RA	213,1	497,7	293,1	386,7	RA	583,8	522,9			
RTD	508,6	404,1	237,4	386,7	RTD	583,8	469,2			
RTD+AFD	537,5		130,5	430,3	RTD+AFD	583,8	469,5			
Δ First RTD	295,5	-93,6	-55,7	0,0	Δ First RTD	0,0	-53,7			
	ΔGC	**ΔCS**				**ΔGC**	**ΔCS**			
Existing	-93,6	19 939								
New	-46,8	13 824								
Sum		33 763				-53,7	31 350	33 763	31 350	1,08
ΔThen AFD			-106,9	43,6	ΔThen AFD	0,0	0,3			
			ΔGC	**ΔCS**		**ΔGC**	**ΔCS**			
Remaining			43,6	-5 690						
Lost			21,8	-2 331						
Sum				-8 021		0,3	-163	-8 021	-163	49,07
Total sum				**ΔCS**			**ΔCS**			
				25 742			31 187	25 742	31 187	0,83

When the effects of Air Frequency Down (AFD) is calculated *after* Rail Time Down (RTD), Samkalk calculates an effect on generalized cost that is 156 times higher than that of Vips 43.60.3. Again, this Samkalk effect for air travellers concerns the remaining ones only. In order to calculate the effects for consumer surplus according to Samkalk we must multiply the loss in GC with the number of remaining air passengers and with half of this loss for the lost passengers. The overestimation by Samkalk is then here 49 times. One reason is the mentioned one, that Samkalk overestimates the effect on consumer surplus when headway is changed. The reason is that change of headway of one mode affects wait time for this mode but also for other competing modes. Altogether Samkalk calculates a gain in CS that is 17 % lower than Vips.

That Samkalk calculates a much larger decrease in consumer surplus than Vips when the effects of reduced frequency of air services were assumed after introduction of high-speed rail services was also noticed in the mentioned Governmental inquiry on high-speed rail in Sweden.

But there are complementary reasons for this large overestimation.

One reason is that Sampers/Samkalk takes into consideration the effect of rail ride time in a different way than Vips. Vips explicitly calculates the composite change of ride time besides the effect on composite wait time. In the logit model the effect on ride time is implicit in the change of the logsum, which cannot be shown.

The main reason, however, depends on the different demand calculations in Sampers and Vips. We note that Sampers calculates a fairly large share of remaining air journeys when rail ride time has been halved.

We have therefore made the Samkalk calculations based on the following "harmonization" of demand calculations. As the basis we take air demand from Vips in the reference alternative (RA) and for the other scenarios. We then assume for Samkalk that rail gets the additional demand calculated by Vips in the scenarios, plus the demand changes according to Sampers for car/coach. Then we have the following results.

Order: first air frequency down 80 % (AFD), then ride time down 50 % (RTD)											
Sampers/Samkalk						**Vips**			Samkalk	Vips	Relation
	Car/coach trips	Rail trips	Rail GC	Air trips	Air GC		Total trips	Total GC	**ΔCS**	**ΔCS**	ΔCS Samkalk/ ΔCS Vips
RA	77,6	213,1	497,7	293,1	386,7	RA	583,8	522,9			
AFD	80,9	434,6	497,7	68,3	430,3	AFD	583,8	531,1			
AFD+RTD	77,6	500,3	404,1	5,9		AFD+RTD	583,8	469,5			
Δ First AFD			**0,0**	-224,8	43,6	Δ First AFD	0,0	8,1			
				ΔGC	**ΔCS**		**ΔGC**	**ΔCS**			
Remaining				43,6	-2 977						
Lost				21,8	-4 901						
Sum					-7 879		8,1	-4 746	-7 879	-4 746	1,66
Δ Then RTD		65,7	-93,6			Δ Then RTD	0,0	-61,5			
		ΔGC	**ΔCS**				**ΔGC**	**ΔCS**			
Existing		-93,6	40 665								
New		-46,8	3 074								
Sum			43 739				-61,5	35 933	43 739	35 933	1,22
Total sum					**ΔCS**			**ΔCS**			
					35 860			31 187	35 860	31 187	1,15

Order: first rail ride time down 50 % (RTD), then air frequency down 80 % (AFD)											
Sampers/Samkalk						**Vips**			Samkalk	Vips	Relation
	Car/coach trips	Rail trips	Rail GC	Air trips	Air GC		Total trips	Total GC	**ΔCS**	**ΔCS**	ΔCS Samkalk/ ΔCS Vips
RA	77,6	213,1	497,7	293,1	386,7	RA	583,8	522,9			
RTD	68,5	485,6	404,1	29,7	386,7	RTD	583,8	469,2			
RTD+AFD	77,6	500,3		5,9	430,3	RTD+AFD	583,8	469,5			
Δ First RTD		272,5	-93,6	-263,4	0,0	Δ First RTD	0,0	-53,7			
		ΔGC	**ΔCS**				**ΔGC**	**ΔCS**			
Existing		-93,6	19 939								
New		-46,8	12 750								
Sum			32 689				-53,7	31 350	32 689	31 350	1,04
ΔThen AFD				-23,8	43,6	ΔThen AFD	0,0	0,3			
				ΔGC	**ΔCS**		**ΔGC**	**ΔCS**			
Remaining				43,6	-256						
Lost				21,8	-519						
Sum					-775		0,3	-163	-775	-163	4,74
Total sum					**ΔCS**			**ΔCS**			
					31 914			31 187	31 914	31 187	1,02

Now we see that the overestimation by Samkalk when air frequency is changed is much smaller. When the effects of Air Frequency Down (AFD) is calculated *after* Rail Time Down (RTD) the original calculation of relation between CS according to Samkalk and Vips was 49.07 and when demand is harmonized it is 4.74.

We can now also see that the gain in CS is actually higher according to Samkalk than according to Vips.

In practice one has to live with the demand calculations according to each model, meaning that the original Sampers and Vips results are more realistic from comparison point of view. The latter results based on demand harmonization illustrate the divergence from the original different demand calculations.

12 Combinations of modes - Examples from real runs of the national network

12.1 Three O-D pairs in Sweden

We have run three O-D pairs where the travellers need combinations of modes to reach the destination:

- Sundsvall-Göteborg
- Luleå-Örebro,
- Luleå-Karlskoga

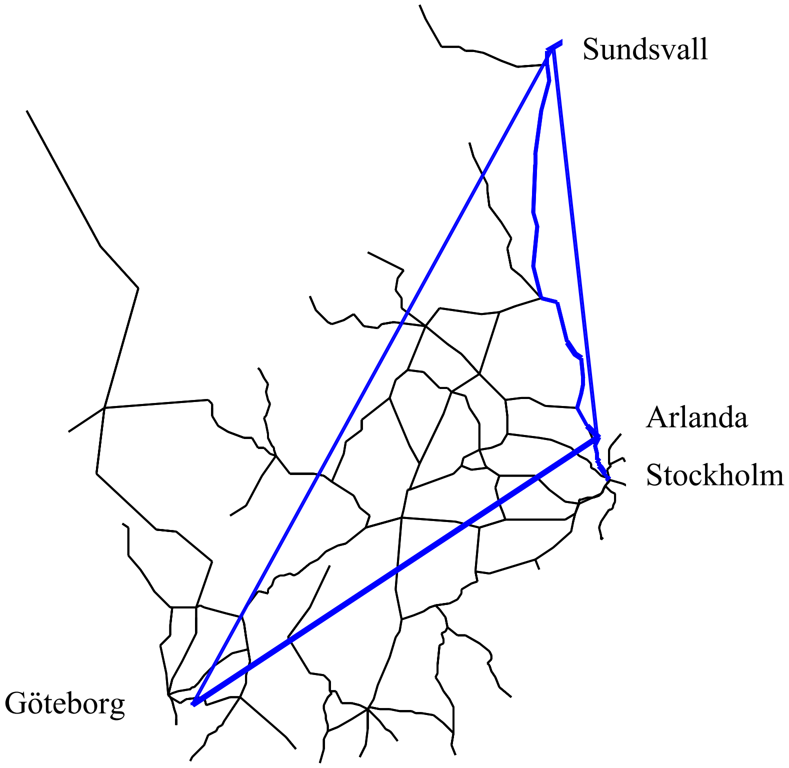
In appendices 4-6 some more details of the results are copied from Excel-format:

12.1.1 Sundsvall-Göteborg

The straight lines in the figure below represent airlines Sundsvall-Göteborg, Sundsvall-Arlanda (Stockholm) and Arlanda-Göteborg. The curved line represents the rail lines 41a and 42f between Sundsvall and Stockholm. The existing network is denoted RA.

We investigated the results of a new alternative network (NA) meaning half ride time of the rail lines 41a and 41f between Sundsvall and Stockholm.

Figure 12.1.1 Network Sundsvall-Stockholm-Göteborg



Vips assigns travellers on the following travel paths and lines in RA and NA respectively:

Table 12.1.1 Vips assignment on travel paths and lines

RA			
Operator	Itinerary	Route	Trips
SJ X2000	Sundsvall-Sthlm	+41a	145,3
SAS	Arlanda-Gbg	+sk1NY	
Skyways	Sundsvall-Gbg	-jz17NY	98,4
SAS	Sundsvall-Arlanda	-sk6NY	39
SAS	Arlanda-Gbg	+sk1NY	
SJ X2000	Sundsvall-Sthlm	+41a	18,7
FlyNordic	Arlanda-Gbg	+lf1NY	
SJ X2000	Sundsvall-Sthlm	+41a	14,7
FlyMe	Arlanda-Gbg	+fly1NY	
SJ X2000	Härnösand-Sthlm	+41f	13,7
SAS	Arlanda-Gbg	+sk1NY	
SJ regtrain	Sundsvall-Östersund	-42cLT	5,4
SJ X2000	Sundsvall-Sthlm	+41a	
SAS	Arlanda-Gbg	+sk1NY	
SAS	Sundsvall-Arlanda	-sk6NY	3,3
FlyNordic	Arlanda-Gbg	+lf1NY	
SAS	Sundsvall-Arlanda	-sk6NY	2,3
FlyMe	Arlanda-Gbg	+fly1NY	

NA			
Operator	Itinerary	Route	Trips
SJ X2000	Sundsvall-Sthlm	+41a	181,5
SAS	Arlanda-Gbg	+sk1NY	
Skyways	Gbg-Sundsvall	-jz17NY	73,3
SJ X2000	Sundsvall-Sthlm	+41a	23,4
FlyNordic	Arlanda-Gbg	+lf1NY	
SJ X2000	Härnösand-Sthlm	+41f	18,8
SAS	Arlanda-Gbg	+sk1NY	
SJ regtrain	Sundsvall-Östersund	-42cLT	15,4
SJ X2000	Sundsvall-Sthlm	+41a	
SAS	Arlanda-Gbg	+sk1NY	
SJ X2000	Sundsvall-Sthlm	+41a	18,4
FlyMe	Arlanda-Gbg	+fly1NY	
SAS	Sundsvall-Arlanda	-sk6NY	5,5
SAS	Arlanda-Gbg	+sk1NY	
SJ X2000	Härnösand-Sthlm	+41f	2,4
FlyNordic	Arlanda-Gbg	+lf1NY	

Note that Vips calculates that the majority of travellers choose combinations rail/air. For these combinations the number of transfers is between 1 and 2.

Vips calculates a reduction of direct air travellers with Skyways and a substantial reduction of those choosing airline between Sundsvall and Arlanda and then change to another airline between Arlanda and Göteborg. Instead more travellers choose the speeded up train 41a between Sundsvall and Stockholm, and then airlines Arlanda-Göteborg.

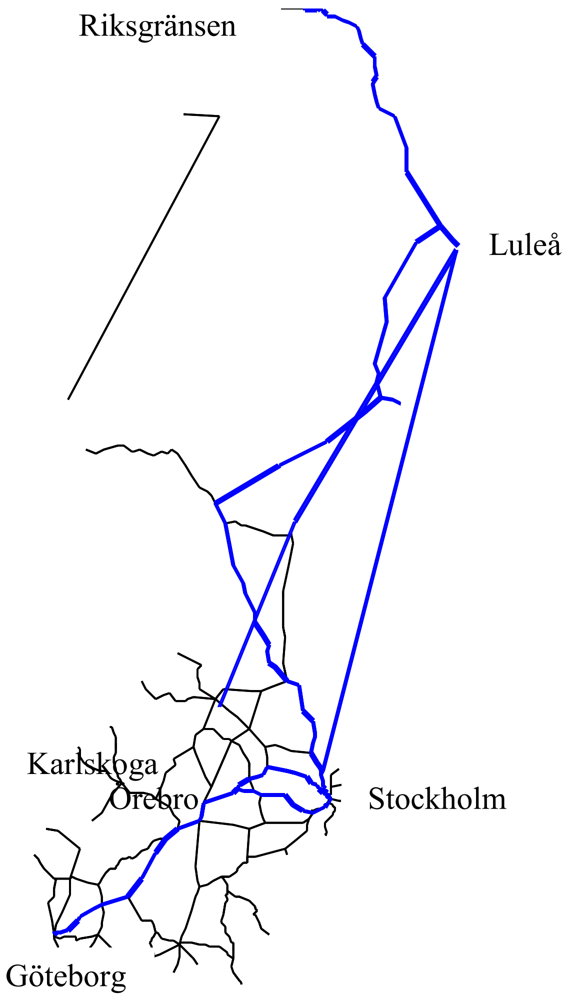
Vips gave a change in CS by 14 000 and Samkalk by 3 000 only. The reason is that Sampers calculates that few travellers choose rail Sundsvall-Stockholm *and* Stockholm-Göteborg. Samkalk then bases the CS change on the ride time reduction for existing travellers on train plus half that again for new travellers. Since few choose train this is one reason why the gain is small according to Samkalk. The other reason is that Sampers does not handle combinations of modes, in this case rail Sundsvall-Arlanda airport and then airline Arlanda-Göteborg.

Note here that Vips handles several airlines, which also charge different prices, something that Sampers cannot take into consideration. The following prices have been coded in Vips. Most expensive is the direct airline Skyways Sundsvall-Göteborg (2 603), followed by SAS+Fly Nordic and SAS+FlyMe (1 990) and then SAS+SAS (1 669). Cheapest is the combination rail+SAS (1 580), which Sampers cannot take into consideration.

12.1.2 Luleå-Örebro and Luleå-Karlskoga

The straight lines in the figure below represent airlines Luleå-Arlanda (Stockholm) and Luleå-Borlänge. The curved line represents the rail lines 57a, 57b, 57e and 57x2 between Stockholm and Örebro and the night trains Riksgränsen-Stockholm and Luleå-Göteborg.

Figure 12.1.2 Network Luleå-Stockholm-Örebro and Karlskoga



We investigated the results of a new alternative, (NA), meaning half ride time of the rail lines 57a, 57b, 57e and 57x2 between Stockholm and Göteborg, via the destination Örebro.

Vips assigns travellers on the following lines in RA and NA respectively for Luleå-Örebro:

Table 12.1.2.1 Vips assignment on travel paths and lines for Luleå-Örebro

RA			
Operator	Itinerary	Route	Trips
Fly Nordic	Luleå-Arlanda	-lf4NY	16
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	7,6
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb	+57e	
Fly Nordic	Luleå-Arlanda	-lf4NY	6,3
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	-57b	
Fly Nordic	Luleå-Arlanda	-lf4NY	3,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	+61b	
SAS	Luleå-Arlanda	-sk3NY	2,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
Reg. Bus	Örebro-Hallsberg	-T701a	
Direktflyg	Luelå-Borlänge	-hs6NY	1,9
SJ	Gävle-Örebro	+53aLT	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,6
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Stockholm-Hallsberg	+61a	
Reg. Bus	Örebro-Hallsberg	-T701a	
Direktflyg	Luelå-Borlänge	-hs6NY	1,5
Air coach	Borlänge-Borlänge	-FB1	
SJ	Gävle-Örebro	+53aLT	
Air coach	Luleå-Luleå	+FB7	1,5
Fly Nordic	Luleå-Arlanda	-lf4NY	
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,2
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Göteborg	+57x2	
Air coach	Luleå-Luleå	+FB7	1,1
SAS	Luleå-Arlanda	-sk3NY	
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	

NA			
Operator	Itinerary	Route	Trips
Fly Nordic	Luleå-Arlanda	-lf4NY	21,9
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	9,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb	+57e	
Fly Nordic	Luleå-Arlanda	-lf4NY	7,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	-57b	
Fly Nordic	Luleå-Arlanda	-lf4NY	3,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	+61b	
SAS	Luleå-Arlanda	-sk3NY	3
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	2,2
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Karlstad	+70c	
SJ	Gävle-Hallsberg	-54cLT	
Air coach	Luleå-Luleå	+FB7	2
Fly Nordic	Luleå-Arlanda	-lf4NY	
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,8
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Göteborg	+57x2	
Air coach	Luleå-Luleå	+FB7	1,6
SAS	Luleå-Arlanda	-sk3NY	
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach	Sthlm-Oslo	+Sä150a	
Direktflyg	Luelå-Borlänge	-hs6NY	1,5
SJ	Gävle-Örebro	+53aLT	
Direktflyg	Luelå-Borlänge	-hs6NY	1,3
Air coach	Borlänge-Borlänge	-FB1	
SJ	Gävle-Örebro	+53aLT	
SAS	Luleå-Arlanda	-sk3NY	1,3
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb	+57e	
SAS	Luleå-Arlanda	-sk3NY	1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	-57b	

Note that Vips calculates that all travellers choose combinations rail/air since there is no direct airline. For these combinations the number of transfers is between 2 and 3.

Vips gave a change in CS by 2 500 and Samkalk by 2 only. The reason is that Sampers calculates that very few travellers choose rail Luleå-Örebro. In fact, only the night train Luleå-Göteborg, via Örebro is taken into account. The combinations airline Luleå-Arlanda, Arlanda express train Arlanda-Stockholm plus the rail lines Stockholm-Örebro are not taken into account.

Vips assigns travellers on the following lines in RA and NA respectively for Luleå-Karlskoga:

Table 12.1.2.2 Vips assignment on travel paths and lines for Luleå-Karlskoga

RA			
Operator	Itinerary	Route	Trips
Fly Nordic	Luleå-Arlanda	-lf4NY	1,4
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Karlstad	+70c	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,2
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Sthlm-Oslo	+Sä150a	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,2
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Kil	+70b	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb	+57e	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	-57b	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,8
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Swebus	Sthlm-Oslo	+Sw888a	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,7
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Karlstad	+70e	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,7
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Göteborg-Karlstad	+Sä150b	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,6
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Sthlm-Grums	+Sä100d	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,6
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Sthlm-Karlstad	+Sä100e	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	+61b	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Swebus	Sthlm-Karlstad	+Sw845a	

NA			
Operator	Itinerary	Route	Trips
Fly Nordic	Luleå-Arlanda	-lf4NY	2,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb-Gbg	+57a	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,3
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Karlstad	+70c	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,3
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Hallsb	+57e	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,2
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Kil	+70b	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	-57b	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	1,1
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Göteborg-Karlstad	+Sä150a	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,7
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sthlm-Karlstad	+70e	
Reg. Bus	Degerfors-Karlskoga	-T502	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
SJ	Sth-Örebro	+61b	
Reg. Bus	Örebro-Karlskoga	+T504	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Göteborg-Karlstad	+Sä150b	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Sthlm-Grums	+Sä100d	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Sä bus	Sthlm-Karlstad	+Sä100e	
Fly Nordic	Luleå-Arlanda	-lf4NY	0,5
Arl exp	Arlanda-Sthlm	+46Arlexp	
Coach Swebus	Sthlm-Oslo	+Sw888a	

Note that Vips calculates that all travellers choose combinations rail/air since there is no direct airline. For these combinations the number of transfers is between 2 and 3.

Vips gave a change in CS by 280 and Samkalk by 0! The reason is that Sampers calculates that no travellers choose rail Luleå-Karlskoga. As for Luleå-Örebro, only the night train Luleå-Göteborg, via Örebro is taken into account. The combinations airline Luleå-Arlanda, Arlanda, then express train Arlanda-Stockholm, then rail lines Stockholm-Örebro are not taken into account. In this case, in addition, Sampers does not allow travellers to alight in Örebro for regress to Karlskoga. Instead the travellers have to alight in Degerfors, but the assumed faster trains do not pass via Degerfors. The reason why travellers cannot alight in Örebro is that Sampers only takes into consideration the shortest regress link to the destination and that is Degerfors-Karlskoga and not Örebro-Karlskoga.

In general Sampers does not take into consideration combinations, neither between air and rail, nor between rail and bus.

12.2 Stockholm-Hamburg

This analysis was only carried out by Vips since networks outside Sweden are not coded in Sampers. The example is described since it illustrates the emphasized importance of taking combinations into consideration for international journeys.

The high-speed rail project includes high-speed rail lines Stockholm-Gothenburg and Stockholm-Malmö-Copenhagen-Hamburg and higher rail frequencies than today.

However, in the high-speed rail project on behalf of the Swedish Government calculations were made by Samkalk, taking demand and level of service data from the Vips analyses. Samkalk, however, only takes into consideration rail demand both without and with high-speed rail. This meant that one from the Vips results had to extract journeys made by rail only, to suit the Samkalk approach. The consequence was that all journeys that need both air and rail were dismissed.

Such a mission is of course impossible. The problems are:

1 The rule-of-half principle is wrong when frequency is changed,
2 Only rail travellers are taken into account, which is aggravated by point 1,
3 Combinations are not taken into account.

Here the problem in point 3 is illustrated by the O-D pair Stockholm-Hamburg. The analysis concerns business journeys from the city centre in Stockholm to Hamburg.

High-speed trains (HST) are introduced in new alternative (NA).

Denotation: HST high-speed train, F airlines, FB airport bus.

The tables below present the results from Vips. Travel paths presented are the ones with most travellers.

Table 12.2 Vips assignment on travel paths and lines for Stockholm-Hamburg

	Origin	Dest	Trips	Ride dist	Ride time	Wait time	Walk time	Transfer time	Transfer ratio	Fare	Gen cost	Mode split
RA	971804	161	1 159	853,05	127,23	27,00	110,89	97,62	0,75	1 687,28	1 171,61	1,00
NA	971804	161	1 037	895,67	226,97	31,65	72,02	22,95	0,28	1 382,99	1 131,60	1,00
NA-RA	971804	161	-122	42,62	99,74	4,64	-38,87	-74,67	-0,48	-304,29	-40,02	0,00

Travel paths RA	Origin Sthlm	Dest Hamburg	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Combinations	Share
	971804	161	609,97	1654	+FB19	2455	22,5	27	4,5	45	56,2		air bus +	0,526
				2491	-FuA-Ham	30306	1,2	131,1	186,5	95	1600	60	airline	
			416,89	2491	-FuA-Ham	30306	99,3	27	186,5	95	1600	60	airline direct	0,360
			132,1	1654	+FB19	2455	22,5	27	4,5	45	56,2		air bus +	0,114
				2491	-FuA-K	30203	1,2	131,1	31	70	1550		airline +	
				30203	-FuK-Ham	30306		120	120	55	500	60,0□	airline	
		Sum	1158,96											1,0

Travel paths NA	Origin Sthlm	Dest Hamburg	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Combinations	Share
With high-speed rail Stockholm-Hamburg	971804	161	442,32	1611	+80a1HST	30305	30,5	31,6	66	280	1204,3	6	HST direct	0,429
			160,95	1654	+FB19	2455	22,5	31,6	4,5	45	56,2		air bus +	0,156
				2491	-FuA-Ham	30306	1,2	93,7	186,5	95	1600	60	airline	
			237,95	2491	-FuA-Ham	30306	99,3	31,6	186,5	95	1600	60	airline direct	0,231
			36,87	1654	+FB19	2455	22,5	31,6	4,5	45	56,2		air bus +	0,036
				2411	+45bLT	1611	6	93,7	26,4	24	25,5		train +	
				1611	+80a1HST	30305		20	20	280	1204,3	6	HST	
			115,21	1611	+80cHST	30305	30,5	31,6	66	326	1243,1	6	HST direct	0,112
			36,76	1654	+FB19	2455	22,5	31,6	4,5	45	56,2		air bus +	0,036
				2411	+80cHST	30305	6	93,7	66	351	1269,6	6	HST	
		Sum	1030,06											1,0

We note:

- That in RA 100 % go by air but in NA only 39 % go by air (0.156+0.231).
- The very few rail travellers in RA. In fact for business journeys it was 0, but a small amount for other groups. This means that very few will gain according to Samkalk,
- The large number of combinations, which Samkalk ignores,
- The substantial shift from air to HST, which Samkalk ignores.

  Consequently it is apparent that Samkalk severely underestimates consumer surplus effects.

13 Conclusions and final discussion

13.1 Characteristics of the Sampers model

- The currently used headway based Emme/2 model assumes no knowledge of timetable. The consequence is that travellers are assigned to one stop only, and at this stop assigned on lines in proportion to frequency only, without regard for time and price.

- With respect to representation of the network only “main modes” are regarded where the average of ride times and prices are used for each main mode, not times and prices for individual lines.

- The main mode concept in Sampers causes that no combinations of modes for an O-D pair can be handled, for example regional bus plus train or air plus train.

- The Samkalk approach for assessment consumer surplus, the rule-of-half principle, is wrong where frequencies are changed; it overestimated the effects. However, the application of a step-wise weight for wait time in Samkalk mitigates this problem.

- Since long-distance travellers compare itineraries both within and across modes they don't base mode choice on the mean level of service offered by different modes. This means that the observed choices will not be generated by a standard logit model and the conditions for the use of such a model are violated. This also invalidates the logsum as a measure of consumers´ surplus. At best it will be a rough approximation with unknown properties and unsuitable for comparison of different situations.

- Sampers does not take into consideration that different traveller groups may have specific valuations of ride time with different modes.

- The values of time components differ substantially between the Emme/2 step and the logit model, which means an inconsistency.

- Sampers may give unreasonably small demand shifts between modes when ride time or frequency changes are simulated.

13.2 Characteristics of the Vips and Visum models

- Vips and Visum assume that the travellers know the timetable. This is realistic for long-distance transport, with the consequence that travellers are assigned to all acceptable stops with various lines and modes.
- With respect to representation of the network all feasible lines and modes are taken into consideration, with line specific ride times and fares.
- The RDT approach in Vips/Visum assumes that the differences between the travellers´ ideal departure or arrival times and actual time are uniformly distributed and that the departure times of alternative lines are uniformly distributed.
- Vips/Visum takes into consideration that different traveller groups may have specific valuations of ride time with different modes.
- The RDT approach in Vips/Visum does not take into consideration any stochastic element that varies with taste differences among individuals, measurement errors etc.
- In the calibration process Vips has appeared being too sensitive to parameters for car use price and car comfort.
- The calibration process in Vips is made manually by an iterative process where various parameters are evaluated against passenger loads on trains and airlines and against the survey RES. This method seems too crude.

13.3 Final discussion

Let us recall the prerequisite that travellers use timetables, meaning that they “already at home” compare various combinations of lines and modes not only with respect to price, ride time, transfer time etc. but also with respect to how well departure or arrival times fit their ideal departure or arrival times.

The RDT principle in Vips/Visum accords with this prerequisite, given the approximations that neither real timetables are represented in detail in the model nor that ideal departure or arrival times are known by the modeller and given that uniform distributions are the best assumption.

With respect to Sampers it would suffice that only one of the three steps, Emme/2, logit model, to make Sampers violate the basic prerequisite. The Sampers model in fact violates this prerequisite in *each* of the steps Emme/2, logit model, Samkalk. Emme/2 fails by definition since the assumption is no knowledge of timetables. The applied logit model fails because no concern is taken for ideal departure or arrival times in relation to actual times. Samkalk fails because only one mode is taken into consideration instead of all lines and modes, which is erroneous for consumer surplus calculations when headways are changed.

One possibility to consider is to use generalized cost from Vips/Visum as the estimate of composite generalized cost instead of the logsum. This is an issue for further research.

There is a shortcoming of Vips and Visum that they do not take into consideration taste variation over individuals, variation with respect to preferences for modes and for measurement errors by use of a random term

With respect to preferences for modes these can be handled in four ways:

1. Mode specific constants,
2. Different weights of ride time for different modes,
3. Segmentation of travellers with respect to different valuations of travel time components and prices,
4. A random term for taste, measurement errors etc.

Way 1 is handled by both models, way 2 by Vips/Visum only. Way 3 is optional in both models, but currently more applied in Vips. (In practical use of Vips for the Swedish national network, travellers are segmented in 14 groups, each with assumed specific homogenous valuations of time for different modes, price for different lines, weights for travel time components car availability etc.). Way 4 is only handled by Sampers.

That Vips/Visum can take into consideration certain distributions of valuations of modes by mode specific constants and segmentation is not considered sufficient, for example shown by the sensitivity for car use and car comfort parameters that have appeared in the calibration process.

In addition to segmentation, one would want to add to the RDT approach randomness with respect to taste, measurement errors etc., given that one shall *simultaneously handle both lines and modes*.

With respect to way 4 Larsen and Sunde (2008) employs Monte-Carlo simulation in order to combine RDT with random terms. However, as they put forward, this technique is not possible in a real model due to extreme run times.

Harald Lang and Odd Larsen have also proposed a simpler statistical method for this combination; see first thoughts in appendix 1 in the main report “Towards a model for long distance passenger travel in the context of infrastructure and public transport planning”.

Finally one should realize that none of the models examined here tells the full truth.

The crucial question is the relative importance of deviations from preferred departure/arrival times as opposed to mode specific aspects and preferences. If we use RDT for assignment within modes and the mode specific aspects are dominating, logsums and ROH will come closer to the truth than RDT-calculations, but if the arrival/departure time aspect is dominating, simultaneous RDT-calculations across modes will come closer to the “truth”. There are two important empirical questions here: The parameter for and an average minute of schedule delay and the variance/scale of the discrete choice random term.

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Appendix 1 Notes on the RDT Model

By John Bates, 29 September 2009.

Opening Remarks

In his note "Estimating market shares and consumer benefits with random departure time (RDT) model or discrete choice model – some unsolved issues" (dated 14 Aug 09), Odd Larsen specifies that the generalized travel cost of line "i" for an arbitrary traveller (j) belonging to a particular segment in the framework of a RDT-model be written as:

$$GC_{ij}=\alpha_i T_i + C_i + \mu_i H_i v_{ij} + \xi AET_i + \Omega_i \qquad \text{for all } i \qquad (1)$$

Where

GC_{ij} = generalized cost

T_i = on-board time

C_i = cost

H_i = headway

AET_i = access + egress time

v_{ij} = a random variable on the unit interval <0,1> that varies by departure time and incident

As I understand it, an "incident" is here defined as a particular instance of a timetable with fixed headway H.

My concern in this note is entirely with the "waiting time" component represented by $H_i v_{ij}$.

Development

Odd goes on to say:

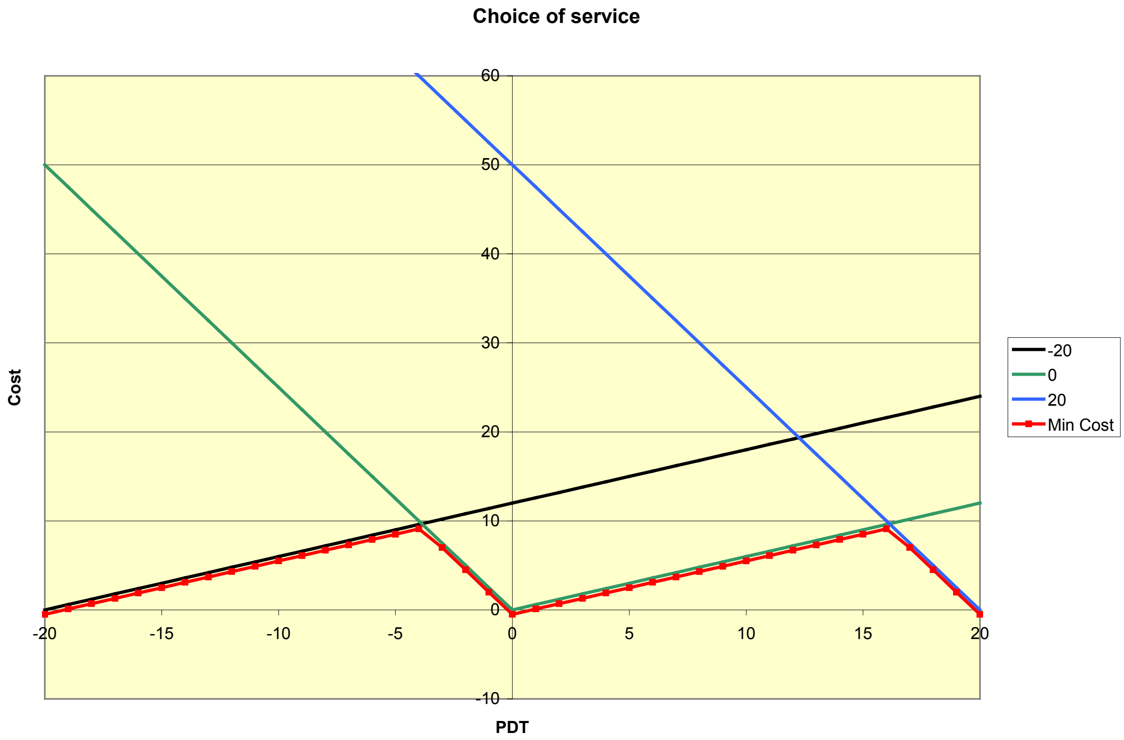
If we – as observers – know the incident (i.e. the specific timetable) and the preferred arrival or departure time of an individual, we will also know the values of vij and we can predict the choice of line for the individual with certainty. .....

When we don't know the incident and the preferred arrival or departure time, the best we can do is to predict probabilities or market shares for each mode, i.e. we assume a uniform distribution of preferred arrival or departure times and integrate over all incidents. The only stochastic element that enters the model is vij which is generated by the mixture of incidents and random arrival/departure times.

I agree with the first paragraph, but I think something is missing in the argument, and this is the relationship between early and late departures (or arrivals – for convenience we will work with preferred **departure** times [PDT]).

Consider a single line i, with headway H_i, and an “incident” which can be described as an “offset” ω_i, and where for simplicity we define $\omega_i = 0$. This means that services depart at times 0 ± k.H. Now consider an individual j with preferred departure time PDT_j in the range [–H, + H]. In considering line i, unless PDT_j = –H or 0 or +H, in which case the service departs precisely at his desired time, traveller j has a choice of service which can be effectively restricted to the latest service which departs earlier than desired, and the earliest service which departs later than desired. Since all other elements of the journey are the same, the choice of departure time between these two options is entirely dependent on the scheduling weights, relating to earlier and later than desired departure. It is conventional to denote these by β and γ respectively, in line with the scheduling model proposed by Kenneth Small, and it is usually expected that $\beta < \gamma$.

We can represent this by a version of the “rooftop” model, as in the Figure below, where H is taken as 20 minutes. Services are shown departing at –H, 0 and +H, and the schedule cost of using each of these services is plotted for all PDTs in the range [–20,+20]. The red line shows the minimum cost at each PDT, which indicates which of the three services will be used. It is clear that the cost pattern repeats in intervals of H.



Considering the PDT range [0, H], it is easy to show that the traveller will choose the earlier service (0) as long as:

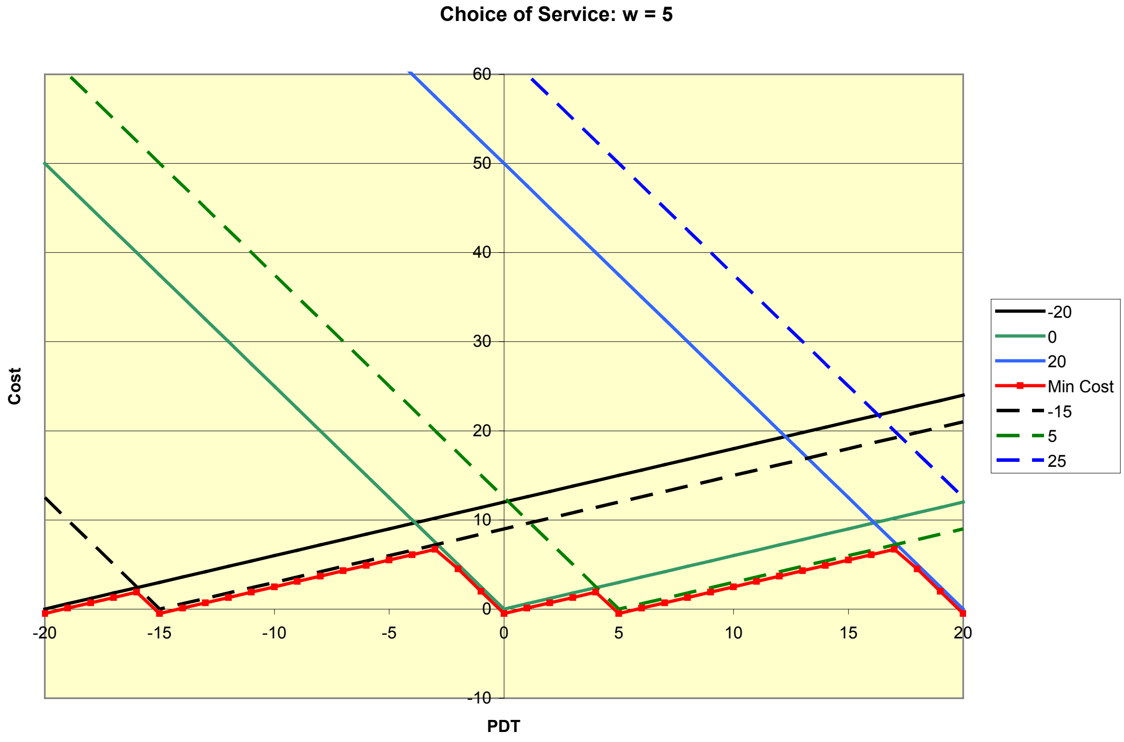
$\beta.PDT_j < \gamma.(H - PDT_j)$ in other words, if $PDT_j < \dfrac{\gamma}{\gamma + \beta}.H_i$ = t*, say

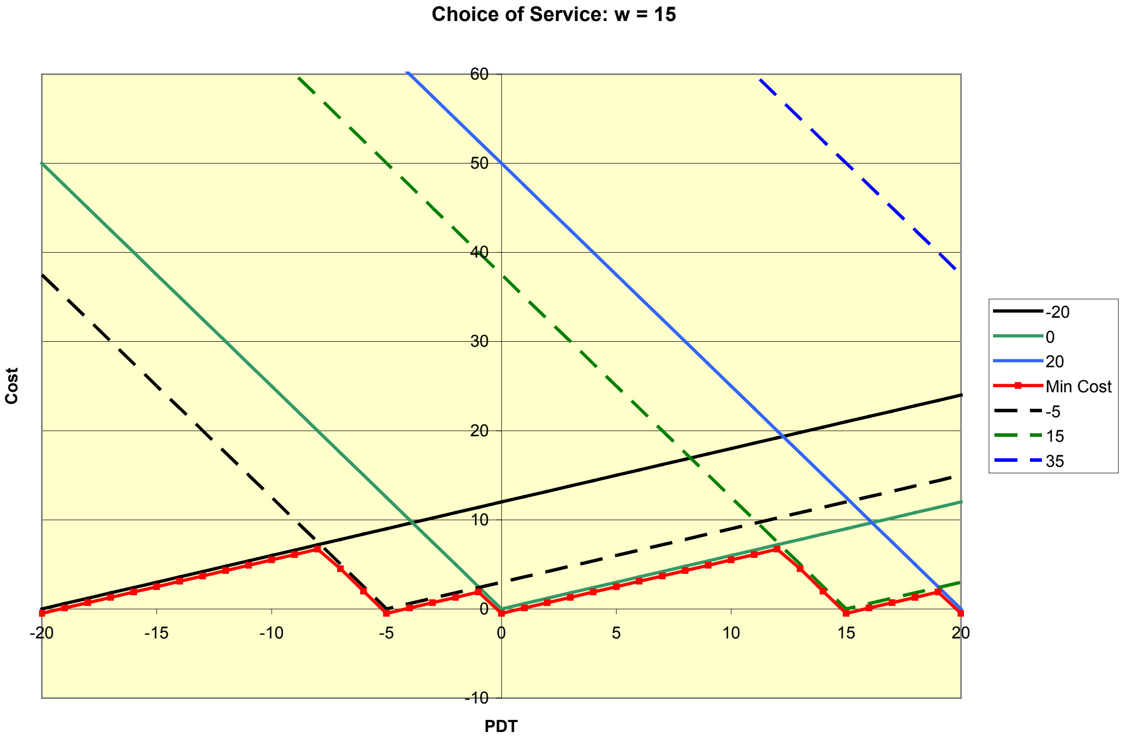
On the assumption that PDT is uniformly distributed, and that the travellers know the timetable, we can calculate the average schedule cost as:

$$\frac{1}{H_i}\left[\int_0^{t^*_i} \beta.(t).dt + \int_{t^*_i}^{H_i} \gamma.(H_i - t).dt\right]$$

This can be shown to have the value $\frac{\beta.\gamma}{2(\gamma+\beta)}.H_i$ Note that typical values for β and γ (e.g. those reported by Kenneth Small [0.613, 2.396, in units of in-vehicle time]) imply that the multiplier on H_i is about 0.24.

Now consider a second line, with identical features including headway, but timed with an offset ω_i in the range $0 < \omega_i < H_i$. It is clear that having the choice of a second line will generally reduce the average schedule cost, and that the extent to which this happens depends on the offset ω_i. The first diagram below shows the case where ω_i = 5 minutes, and the second where ω_i = 15 minutes: the 2nd line uses the same colour scheme as the first for the different services, but dashed rather than solid lines are used.





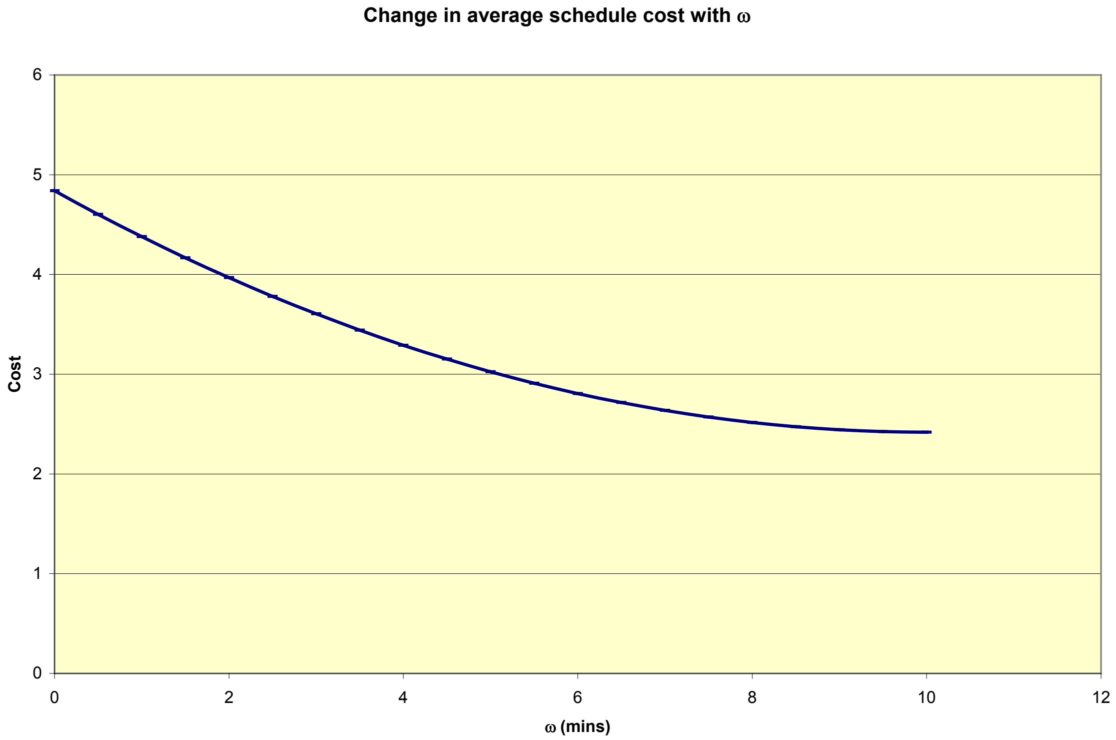
It can be seen that within the PDT range [0, H] there are now four services which are used. Initially line 1 is used, with travellers departing early, but when point t_1 is reached, travellers switch to line 2, departing late. At point ω_i they can depart on time with line 2, and thereafter they remain with line 2, departing early, until point t_2 is reached, when they switch back to line 1, departing late. As before, the pattern repeats at intervals of H.

Points t_1, t_2 are calculated as follows:

$$\beta.t_1 = \gamma.(\omega_i - t_1) \quad \text{so} \quad .t_1 = \frac{\gamma.\omega_i}{(\beta+\gamma)}$$

$$\beta.(t_2 - \omega_i) = \gamma.(H - t_2) \quad \text{so} \quad .t_2 = \frac{\gamma.H + \beta.\omega_i}{(\beta+\gamma)}$$

The average schedule cost can be calculated by summing the integrals over the four linear sections. In this simple case we can see that (by similar triangles) the total area is equal to the total area with only one line, multiplied by a factor $F = [\theta^2 + (1-\theta)^2]$, where $\theta = \omega_i/H_i$, so that, as expected, the schedule cost is a function of ω_i. The cost is at a maximum at $\omega_i = 0$, when there is no advantage in having the second line, and falls at a decreasing rate to a minimum (equal to half the maximum) when $\omega_i .= H/2$, as illustrated in the diagram below:



If we assume also that we have no knowledge of ω_i, then the average schedule cost is the average of these values, over the range ω_i.= 0, H/2. This involves integrating the schedule cost calculated for each value of ω_i over possible values of ω_i. This can be shown, on the assumptions given, to have the value 2/3 of the value at ω_i.= 0. (Note that the curve is symmetric around ω_i = H/2, so the same average cost is obtained whether we integrate from 0 to H/2 or to H.)

With some effort, this approach can be extended to allow for differences between the lines in a) other attributes (cost, journey time etc.), and b) headways, as well as generalizing to more than 2 lines.

Thus, this gives a principled way of incorporating the notions behind a timetabled assignment, but making the simplifying assumptions a) that desired travel times are uniformly distributed and b) that the exact "offset" between competing services is not known (to the modeller) and is therefore again assumed to be uniformly distributed.

Questions

It is unclear to me whether what I have set out above is compatible with any of the following:

- Odd's formulation for v_{ij}, which seems to me to "collapse" two independent uniform random distributions into one
- Harald's discussion of average waiting time, based on random arrivals of two independent lines
- The actual Vips RDT formulation, for which I have seen no technical documentation.

It may be that these are all different ways of saying the same thing (or at least that the mathematics gives the same answer!). However, given my understanding (from the meeting) that we are agreed that:

all lines i operate according to a regular pattern (every H_i minutes)
travellers know the timetable of all lines
travellers' ideal departure(/arrival) times are uniformly distributed
Modellers know the headway H_i (as well as other line characteristics – fare, travel time etc) but they do **not** know the timetable (in the sense of how the different lines are timed relative to each other (i.e., in my example, the offset ω is not known);

then I think we should be able to set out the consequences clearly for the approach used in Vips.

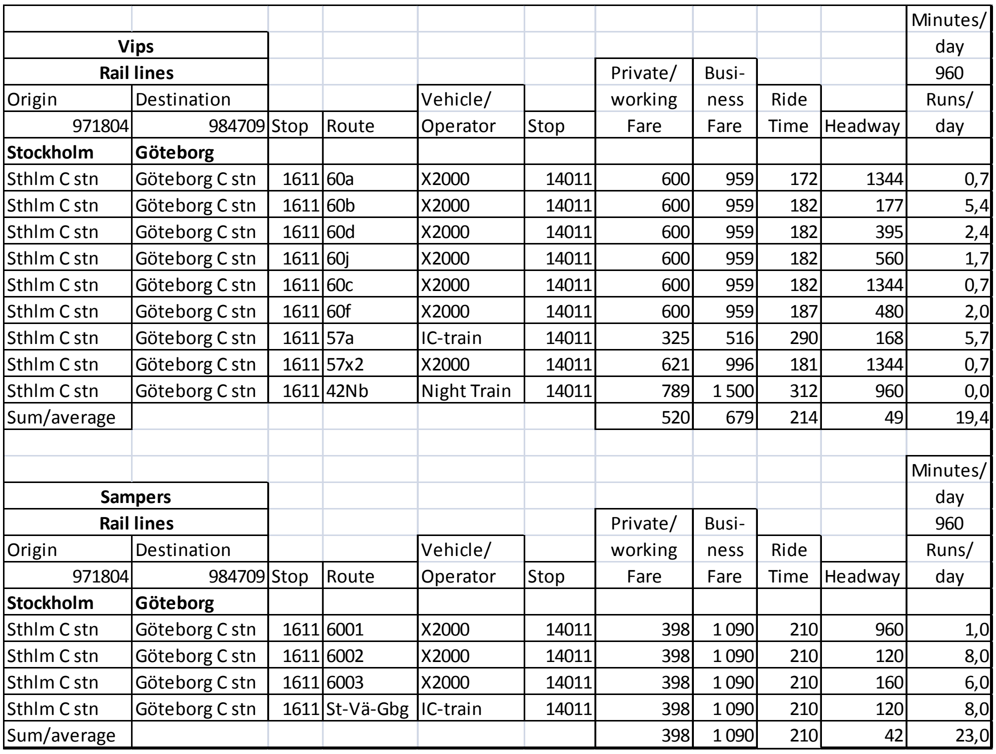
I do not think we need to concern ourselves with variations in fare, journey time etc. but we do need to consider the effect of varying headways between competing lines.

I welcome comments!

Appendix 2 Representations of network

By Kjell Jansson, Royal Institute of Technology (KTH), Stockholm

The tables below illustrate representations of lines and modes, with operators, fares, ride times and headways in Vips and Sampers, for three O-D pairs.

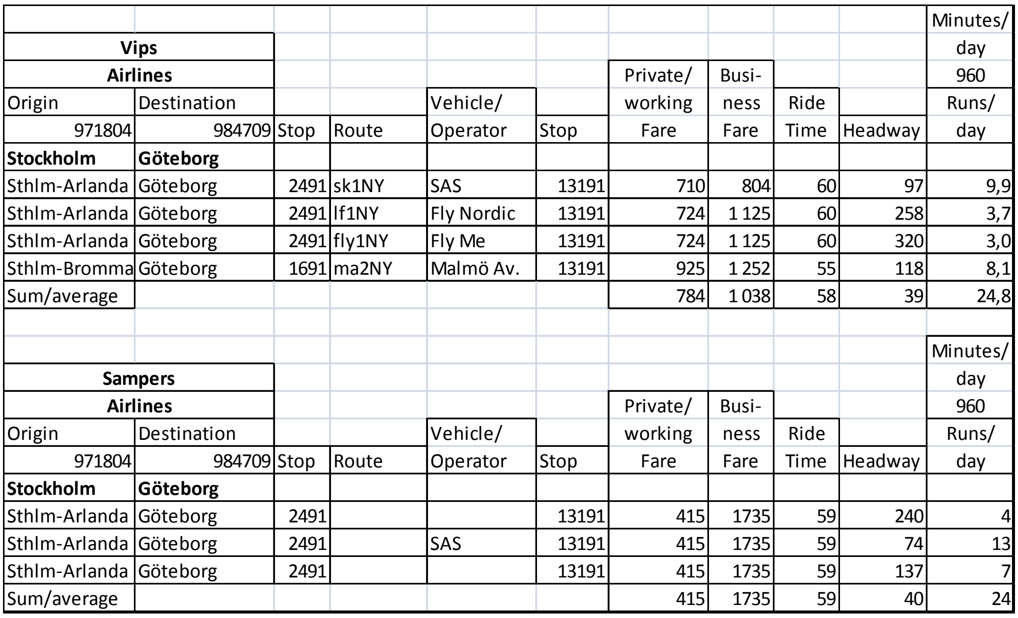


Vips
Rail lines

Origin 971804	Destination 984709	Stop	Route	Vehicle/ Operator	Stop	Private/ working Fare	Busi- ness Fare	Ride Time	Headway	Minutes/ day 960 Runs/ day
Stockholm	**Göteborg**									
Sthlm C stn	Göteborg C stn	1611	60a	X2000	14011	600	959	172	1344	0,7
Sthlm C stn	Göteborg C stn	1611	60b	X2000	14011	600	959	182	177	5,4
Sthlm C stn	Göteborg C stn	1611	60d	X2000	14011	600	959	182	395	2,4
Sthlm C stn	Göteborg C stn	1611	60j	X2000	14011	600	959	182	560	1,7
Sthlm C stn	Göteborg C stn	1611	60c	X2000	14011	600	959	182	1344	0,7
Sthlm C stn	Göteborg C stn	1611	60f	X2000	14011	600	959	187	480	2,0
Sthlm C stn	Göteborg C stn	1611	57a	IC-train	14011	325	516	290	168	5,7
Sthlm C stn	Göteborg C stn	1611	57x2	X2000	14011	621	996	181	1344	0,7
Sthlm C stn	Göteborg C stn	1611	42Nb	Night Train	14011	789	1 500	312	960	0,0
Sum/average						520	679	214	49	19,4

Sampers
Rail lines

Origin 971804	Destination 984709	Stop	Route	Vehicle/ Operator	Stop	Private/ working Fare	Busi- ness Fare	Ride Time	Headway	Minutes/ day 960 Runs/ day
Stockholm	**Göteborg**									
Sthlm C stn	Göteborg C stn	1611	6001	X2000	14011	398	1 090	210	960	1,0
Sthlm C stn	Göteborg C stn	1611	6002	X2000	14011	398	1 090	210	120	8,0
Sthlm C stn	Göteborg C stn	1611	6003	X2000	14011	398	1 090	210	160	6,0
Sthlm C stn	Göteborg C stn	1611	St-Vä-Gbg	IC-train	14011	398	1 090	210	120	8,0
Sum/average						398	1 090	210	42	23,0



Vips
Airlines

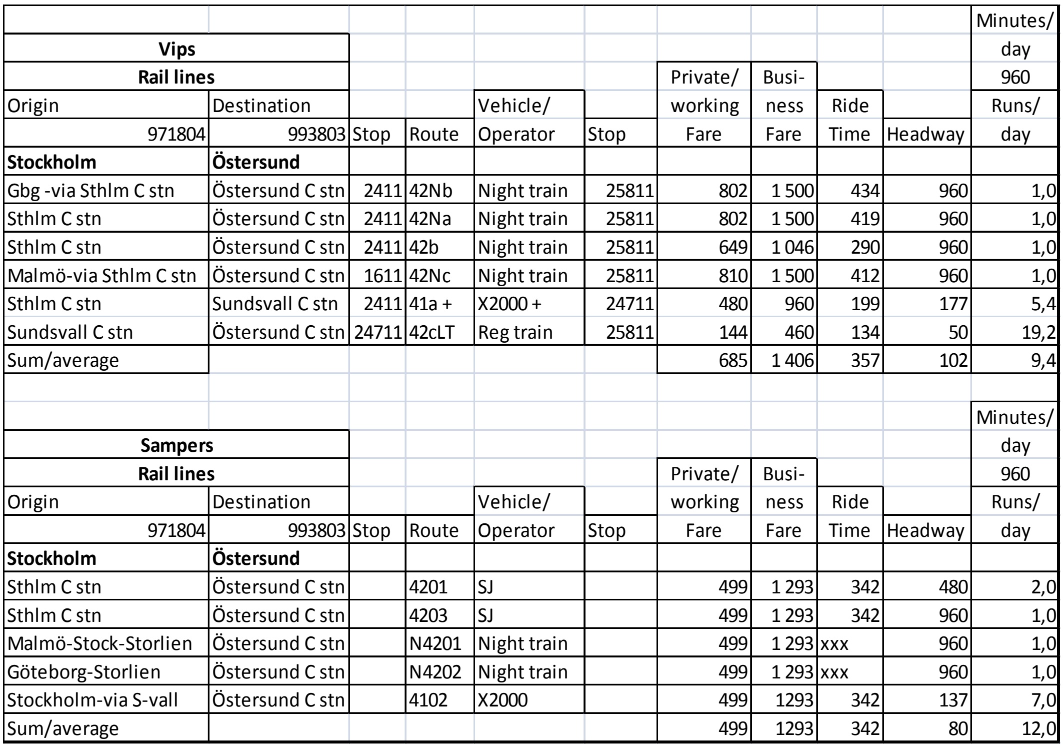
Origin 971804	Destination 984709	Stop	Route	Vehicle/ Operator	Stop	Private/ working Fare	Busi- ness Fare	Ride Time	Headway	Minutes/ day 960 Runs/ day
Stockholm	**Göteborg**									
Sthlm-Arlanda	Göteborg	2491	sk1NY	SAS	13191	710	804	60	97	9,9
Sthlm-Arlanda	Göteborg	2491	lf1NY	Fly Nordic	13191	724	1 125	60	258	3,7
Sthlm-Arlanda	Göteborg	2491	fly1NY	Fly Me	13191	724	1 125	60	320	3,0
Sthlm-Bromma	Göteborg	1691	ma2NY	Malmö Av.	13191	925	1 252	55	118	8,1
Sum/average						784	1 038	58	39	24,8

Sampers
Airlines

Origin 971804	Destination 984709	Stop	Route	Vehicle/ Operator	Stop	Private/ working Fare	Busi- ness Fare	Ride Time	Headway	Minutes/ day 960 Runs/ day
Stockholm	**Göteborg**									
Sthlm-Arlanda	Göteborg	2491			13191	415	1735	59	240	4
Sthlm-Arlanda	Göteborg	2491		SAS	13191	415	1735	59	74	13
Sthlm-Arlanda	Göteborg	2491			13191	415	1735	59	137	7
Sum/average						415	1735	59	40	24

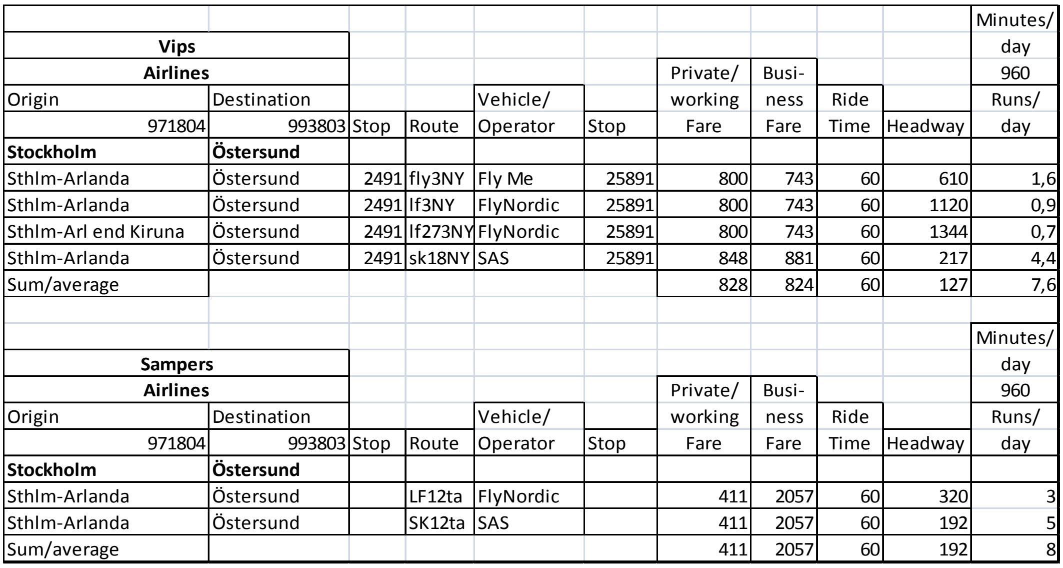
										Minutes/
Vips										day
Rail lines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	982802	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Malmö**									
Sthlm C stn - Cph	Malmö C stn	1611	80a	X2000	14011	720	1 171	265	517	1,9
Sthlm C stn	Malmö C stn	1611	80b	X2000	14011	720	1 171	266	97	9,9
Sthlm C stn	Malmö C stn	1611	80e	IC-train	14011	394	554	333	3 360	0,3
Sthlm C stn	Malmö C stn	1611	80na	Night train	14011	820	1 500	492	960	1,0
Sum/average						721	1 182	285	74	13,0
										Minutes/
Sampers										day
Rail lines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	982802	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Malmö**									
Sthlm C stn - Cph	Malmö C stn	1611	8001		14011	503	1 301	269	480	2
Sthlm C stn	Malmö C stn	1611	8002		14011	503	1 301	269	960	1
Sthlm C stn	Malmö C stn	1611	8003		14011	503	1 301	269	240	4
Sthlm C stn	Malmö C stn		8004			503	1 301	269	240	4
Sthlm C stn	Malmö C stn	1611	N8001	Night train	14011	503	1 301	269	960	1
Sum/average						503	1 301	269	80	12

										Minutes/
Vips										day
Airlines				Vehicle/		Private/	Busi-			960
Origin	Destination			Operator		working	ness	Ride		Runs/
971804	982802	Stop	Route		Stop	Fare	Fare	Time	Headway	day
Stockholm	**Malmö**									
Sthlm-Arlanda	Malmö	2491	sk2NY	SAS	13191	790	1 398	65	103	9,3
Sthlm-Arlanda	Malmö	2491	fly2NY	Fly Me	13191	899	684	65	280	3,4
Sthlm-Bromma	Malmö	1691	ma1NY	Malmö Av.	13191	786	1 458	65	124	7,7
Sum/average						807	1 301	65	47	20,5
										Minutes/
Sampers										day
Airlines				Vehicle/		Private/	Busi-			960
Origin	Destination			Operator		working	ness	Ride		Runs/
971804	982802	Stop	Route		Stop	Fare	Fare	Time	Headway	day
Stockholm	**Malmö**									
Sthlm-Arlanda	Malmö	2491	NB01ta		13191	413	1891	59	240	4
Sthlm-Arlanda	Malmö	2491	SK01ta	SAS	13191	413	1891	59	74	13
Sthlm-Arlanda	Malmö	2491	TF01ta		13191	413	1891	59	137	7
Sum/average						413	1891	59	40	24



										Minutes/
Vips										day
Rail lines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	993803	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Östersund**									
Gbg -via Sthlm C stn	Östersund C stn	2411	42Nb	Night train	25811	802	1 500	434	960	1,0
Sthlm C stn	Östersund C stn	2411	42Na	Night train	25811	802	1 500	419	960	1,0
Sthlm C stn	Östersund C stn	2411	42b	Night train	25811	649	1 046	290	960	1,0
Malmö-via Sthlm C stn	Östersund C stn	1611	42Nc	Night train	25811	810	1 500	412	960	1,0
Sthlm C stn	Sundsvall C stn	2411	41a +	X2000 +	24711	480	960	199	177	5,4
Sundsvall C stn	Östersund C stn	24711	42cLT	Reg train	25811	144	460	134	50	19,2
Sum/average						685	1 406	357	102	9,4

										Minutes/
Sampers										day
Rail lines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	993803	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Östersund**									
Sthlm C stn	Östersund C stn		4201	SJ		499	1 293	342	480	2,0
Sthlm C stn	Östersund C stn		4203	SJ		499	1 293	342	960	1,0
Malmö-Stock-Storlien	Östersund C stn		N4201	Night train		499	1 293	xxx	960	1,0
Göteborg-Storlien	Östersund C stn		N4202	Night train		499	1 293	xxx	960	1,0
Stockholm-via S-vall	Östersund C stn		4102	X2000		499	1293	342	137	7,0
Sum/average						499	1293	342	80	12,0



										Minutes/
Vips										day
Airlines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	993803	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Östersund**									
Sthlm-Arlanda	Östersund	2491	fly3NY	Fly Me	25891	800	743	60	610	1,6
Sthlm-Arlanda	Östersund	2491	lf3NY	FlyNordic	25891	800	743	60	1120	0,9
Sthlm-Arl end Kiruna	Östersund	2491	lf273NY	FlyNordic	25891	800	743	60	1344	0,7
Sthlm-Arlanda	Östersund	2491	sk18NY	SAS	25891	848	881	60	217	4,4
Sum/average						828	824	60	127	7,6

										Minutes/
Sampers										day
Airlines						Private/	Busi-			960
Origin	Destination			Vehicle/		working	ness	Ride		Runs/
971804	993803	Stop	Route	Operator	Stop	Fare	Fare	Time	Headway	day
Stockholm	**Östersund**									
Sthlm-Arlanda	Östersund		LF12ta	FlyNordic		411	2057	60	320	3
Sthlm-Arlanda	Östersund		SK12ta	SAS		411	2057	60	192	5
Sum/average						411	2057	60	192	8

Appendix 3 Headway changes for various assumptions

By Kjell Jansson

Here we examine whether results of changes of headway could be affected by different original ride times, prices and headways of the alternatives

Notation:

U, M	modes
P	price
T	ride time
RU, RM	hours ride time
IU, IM	headway
1	original situation
2	new situation
VoT	value of time
P+T	sum of ride time and price, in minutes
DG	change in generalised cost

The following cases were calculated:

- Reduce interval for mode with the same price + time (P+T) and longer interval
- Reduce interval for mode with the same P+T and shorter interval
- Reduce interval for mode with longer P+T and longer interval
- Reduce interval for mode with longer P+T and shorter interval
- Reduce interval for mode with shorter P+T and shorter interval
- Reduce interval for mode with shorter P+T and longer interval

Mode M always has the same or lower P+T than mode U.

For all cases Samkalk gives a larger change in generalised cost than Vips, but the ride times and intervals matter for the difference.

Ride time, price and headway are all expressed in minutes and for conversion of price into minutes the value of time 60 SEK/hour is used.

The weight for wait time is assumed to be 1 (equal to ride time)

Note that in practice Vips uses a lower wait time weight than 1 when headways are over 12 minutes since people then are waiting "at home". Note also that in practice

Sampers uses a stepwise weight for wait time, where the weight stepwise becomes smaller with longer headways. These remarks on weights for wait time do not change the principle character of the results of the examples below.

Note that effects for existing and new passengers according to Samkalk are irrelevant concepts, since passengers shift modes between the two situations (see appendices 1 and 2).

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
5	500	3	620
RU2 hours	RU2 price	RM2 hours	RM2 price
5	500	3	620
Results			
Reduce interval for mode with same P+T and longer interval			
RU1, P+T	RM1, P+T	IM1	IU1
800	800	180	200
RU2, P+T	RM2, P+T	IM2	IU2
800	800	180	120
PR U1	PR M1		
0,4500	0,550	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,6667	0,333	1,37	
VIPS		**SAMKALK**	
DG	-16,33	DG	-22,33
of which T	9,67	exist	-18,00
of which P	-26,00	new	-4,33

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
5	500	3	620
RU2 hours	RU2 price	RM2 hours	RM2 price
5	500	3	620
Results			
Reduce interval for mode with same P+T and shorter interval			
RU1, P+T	RM1, P+T	IM1	IU1
800	800	180	200
RU2, P+T	RM2, P+T	IM2	IU2
800	800	120	200
PR U1	PR M1		
0,4500	0,550	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,3000	0,700	1,25	
VIPS		**SAMKALK**	
DG	-15,00	DG	-18,75
of which T	-33,00	exist	-16,50
of which P	18,00	new	-2,25

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
7	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
7	500	3	600
Results			
Reduce interval for mode with longer P+T and longer interval			
RU1, P+T	RM1, P+T	IM1	IU1
920	780	180	200
RU2, P+T	RM2, P+T	IM2	IU2
920	780	180	120
PR U1	PR M1		
0,0222	0,978	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,0370	0,963	6,00	
VIPS		**SAMKALK**	
DG	-0,20	DG	-1,19
of which T	1,28	exist	-0,89
of which P	-1,48	new	-0,30

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
6	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
6	500	3	600
Results			
Reduce interval for mode with longer P+T and longer interval			
RU1, P+T	RM1, P+T	IM1	IU1
860	780	180	200
RU2, P+T	RM2, P+T	IM2	IU2
860	780	180	120
PR U1	PR M1		
0,1389	0,861	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,2315	0,769	2,40	
VIPS		**SAMKALK**	
DG	-3,09	DG	-7,41
of which T	6,17	exist	-5,56
of which P	-9,26	new	-1,85

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
7	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
7	500	3	600
Results			
Reduce interval for mode with			
longer P+T and shorter interval			
RU1	RM1	IM1	IU1
920	780	180	120
RU2	RM2	IM2	IU2
920	780	180	60
PR U1	PR M1		
0,0370	0,963	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,0741	0,926	3,38	
VIPS		**SAMKALK**	
DG	-0,49	DG	-1,67
of which T	3,21	exist	-1,11
of which P	-3,70	new	-0,56

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
7	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
7	500	3	600
Results			
Reduce interval for mode with			
shorter P+T and shorter interval			
RU1	RM1	IM1	IU1
920	780	170	180
RU2	RM2	IM2	IU2
920	780	160	180
PR U1	PR M1		
0,0147	0,985	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,0069	0,993	1,01	
VIPS		**SAMKALK**	
DG	-4,90	DG	-4,95
of which T	-5,68	exist	-4,93
of which P	0,78	new	-0,02

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
7	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
7	500	3	600
Results			
Reduce interval for mode with shorter P+T and longer interval			
RU1	RM1	IM1	IU1
920	780	240	120
RU2	RM2	IM2	IU2
920	780	180	120
PR U1	PR M1		
0,1736	0,826	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,0370	0,963	1,09	
VIPS		**SAMKALK**	
DG	-24,71	DG	-26,84
of which T	-38,36	exist	-24,79
of which P	13,66	new	-2,05

Prerequisites			
VoT	60		
RU1 hours	RU1 price	RM1 hours	RM1 price
5	500	3	600
RU2 hours	RU2 price	RM2 hours	RM2 price
5	500	3	600
Results			
Reduce interval for mode with shorter P+T and longer interval			
RU1	RM1	IM1	IU1
800	780	240	120
RU2	RM2	IM2	IU2
800	780	180	120
PR U1	PR M1		
0,6667	0,333	RATIO DG	
PR U2	PR M2	SAMPERS/VIPS	
0,5556	0,444	2,21	
VIPS		**SAMKALK**	
DG	-5,28	DG	-11,67
of which T	-16,39	exist	-10,00
of which P	11,11	new	-1,67

Appendix 4 Sundsvall-Göteborg, faster trains

By Kjell Jansson, Royal Institute of Technology (KTH), Stockholm

Sundsvall (north Sweden) - Göteborg (south-west Sweden)

Speed trains X2000 between Sundsvall and Stockholm half ride time

Vips:Composite values

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	CS
O-D	Sundsvall	Göteborg		dist	time	time	time	time	ratio		cost, min.	share	minutes
RA	992817	984709	345	703,36	179,34	68,19	61,19	29,07	0,73	1 924,49	902,90	1,00	
NA	992817	984709	345	718,36	142,42	68,28	56,48	32,74	0,84	1 849,17	862,51	1,00	
NA-RA	992817	984709	0	15,00	-36,92	0,09	-4,71	3,67	0,11	-75,32	-40,39	0,00	**13 952,3**
NA/RA %	992817	984709	1,000	1,021	0,794	1,001	0,923	1,126	1,148	0,961	0,955	1,000	

Note: Reduction in ride time and reduction in fare, transfer ratio below 1.

Sampers: Average values

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	Gen	Convert to GC per min with VoT 450 SEK/h
O-D	Sundsvall	Göteborg		dist	time	time	time	time	ratio		cost, min.	share	cost, SEK	0,357
RA	992817	984709	345,4		219,4	35,2	31,7	17,3	0,7	2 098,0	1 207,7	0,9	3 382,6	1 207,7
NA	992817	984709	316,0		220,6	38,1	29,9	21,5	0,8	2 046,5	1 197,7	0,9	3 354,8	1 197,7
NA-RA	992817	984709	-29,4		1,1	2,9	-1,8	4,2	0,1	-51,5	-9,9	0,0	-27,9	-9,9
NA/RA %	992817	984709	0,91		1,01	1,08	0,94	1,24	1,12	0,98	0,992	1,00	0,99	0,99

Note: Reduction in trips, increase in <u>long</u> ride time (in spite of halved times for rail lines), small decrease in generalised cost and decrease in fare, transfer ratio below 1.

Reason: ?

Samkalk: Only rail and rail changes. SAMKALK CALCULATION

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	Gen	CS, minutes		
O-D	Sundsvall	Göteborg		dist	time	time	time	time	ratio		cost, min.	share	cost, SEK	Exist/left	New/lost	Sum
RA	992817	984709	27,0	12,4	390,0	60,0		75,6	3,0	1 548,4	851,4	0,8	3 902,2			
NA	992817	984709	42,8	12,4	294,0	68,6		75,6	3,0	1 548,4	759,6	0,8	3 481,4			
NA-RA	992817	984709	15,8	0,0	-96,0	8,6		0,0	0,0	0,0	-91,8	0,0	-420,8	2 478,9	725,3	**3 204,2**
NA/RA %	992817	984709	1,59	1,00	0,75	1,14		1,00	1,00	1,00	0,892	1,01	0,89			

Note: Very small change in CS compared to Vips, only 23 %

Reasons: Only rail is taken into account, no combinations and very few use rail all the way, no concern for reduction of price

Travel paths according to Vips

Travel paths RA	Origin Sundsvall	Dest Göteborg	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
No. Of trips over 2 only	992817	984709	145,3	24711	+41a	2411	18	68,2	88,5	178	776		SJ X2000	Sundsvall-Sthlm	145,3
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
			98,4	24591	-jz17NY	13191	49,7	68,2	280	90	2603	26,6	Skyways	Sundsvall-Gbg	
			39	24591	-sk6NY	2491	49,7	68,2	88,5	50	865		SAS	Sundsvall-Arlanda	
				2491	+sk1NY	13191		40,8	45	60	804	26,6	SAS	Arlanda-Gbg	
			18,7	24711	+41a	2411	18	68,2	88,5	178	776		SJ X2000	Sundsvall-Sthlm	18,7
				2491	+lf1NY	13191	6	39,8	129	60	1125	26,6	FlyNordic	Arlanda-Gbg	
			14,7	24711	+41a	2411	18	68,2	88,5	178	776		SJ X2000	Sundsvall-Sthlm	14,7
				2491	+fly1NY	13191	6	39,8	160	60	1125	26,6	FlyMe	Arlanda-Gbg	
			13,7	24711	+41f	2411	18	68,2	480	178	776		SJ X2000	Härnösand-Sthlm	13,7
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
			5,4	24716	-42cLT	24711	18	68,2	112	2	61,3		SJ regtrain	Sundsvall-Östersund	5,4
				24711	+41a	2411		24,7	25	178	776		SJ X2000	Sundsvall-Sthlm	
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
			3,3	24591	-sk6NY	2491	49,7	68,2	88,5	50	865		SAS	Sundsvall-Arlanda	
				2491	+lf1NY	13191		40,8	129	60	1125	26,6	FlyNordic	Arlanda-Gbg	
			2,3	24591	-sk6NY	2491	49,7	68,2	88,5	50	865		SAS	Sundsvall-Arlanda	
				2491	+fly1NY	13191		40,8	160	60	1125	26,6	FlyMe	Arlanda-Gbg	
		Sum	338,5												197,8

Travel paths NA	Origin Sundsvall	Dest Göteborg	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
Rail routes 41a, 41f half ride time Sundsvall-Stockholm	992817	984709	181,5	24711	+41a	2411	18	68,3	88,5	97,5	776		SJ X2000	Sundsvall-Sthlm	181,5
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
			73,3	24591	-jz17NY	13191	49,7	68,3	280	90	2603	26,6	Skyways	Gbg-Sundsvall	
			23,4	24711	+41a	2411	18	68,3	88,5	97,5	776		SJ X2000	Sundsvall-Sthlm	23,4
				2491	+lf1NY	13191	6	39,8	129	60	1125	26,6	FlyNordic	Arlanda-Gbg	
			18,8	24711	+41f	2411	18	68,3	480	97,5	776		SJ X2000	Härnösand-Sthlm	18,8
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
No. Of trips over 2 only			15,4	24716	-42cLT	24711	18	68,3	112	2	61,3		SJ regtrain	Sundsvall-Östersund	15,4
				24711	+41a	2411		24,7	25	97,5	776		SJ X2000	Sundsvall-Sthlm	
				2491	+sk1NY	13191	6	39,8	48,5	60	804	26,6	SAS	Arlanda-Gbg	
			18,4	24711	+41a	2411	18	68,3	88,5	97,5	776		SJ X2000	Sundsvall-Sthlm	18,4
				2491	+fly1NY	13191	6	39,8	160	60	1125	26,6	FlyMe	Arlanda-Gbg	
			5,5	24591	-sk6NY	2491	49,7	68,3	88,5	50	865		SAS	Sundsvall-Arlanda	
				2491	+sk1NY	13191		40,8	45	60	804	26,6	SAS	Arlanda-Gbg	
			2,4	24711	+41f	2411	18	68,3	480	97,5	776		SJ X2000	Härnösand-Sthlm	2,4
				2491	+lf1NY	13191	6	39,8	129	60	1125	26,6	FlyNordic	Arlanda-Gbg	
		Sum	336,3												257,5

Note: Vips RA 58% use train, NA 77% use train- increase 31%. Sampers: RA 11,5% use train, NA 16,9% use train - increase 46%

Appendix 5 Luleå-Örebro, faster trains

By Kjell Jansson, Royal Institute of Technology (KTH), Stockholm

Examples on half ride time for certain rail routes

Half time for speed trains between Stockhom and Örebro, not trains Stockholm-Oslo

RA is reference alternative, NA is new alternative (half ride times)

Gen cost is expressed in minutes, Value ot ime is SEK 450/hour

In travel paths each rectangel limited by lines show the routes/modes from origin to destination

Luleå väst (north Sweden) - Örebro (180 km west of Stockholm)

Vips

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	CS
O-D	Luleå väst	Örebro		dist	time	time	time	time	ratio		cost, min.	share	
RA	995805	988805	81	927,70	221,81	87,40	57,19	60,43	2,34	1 527,84	1 054,09	1,00	
NA	995805	988805	81	926,58	184,13	86,30	55,96	63,73	2,27	1 534,37	1 022,51	1,00	
NA-RA	995805	988805	0	-1,12	-37,68	-1,10	-1,23	3,30	-0,08	6,52	-31,58	0,00	**2 542,5**
NA/RA %	995805	988805	1,000	0,999	0,830	0,987	0,979	1,055	0,967	1,004	0,970	1,000	

Note: Reduction in ride time and increase in fare, transfer ratio over 2.

Sampers: Average valus for all modes

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	Gen	Convert to GC per min with VoT 450 SEK/h
O-D	Luleå väst	Örebro		dist	time	time	time	time	ratio		cost, min.	share	cost, SEK	0,357
RA	995805	988805	81		717,40	47,40	10,44	397,82	1,87	1 347,98	2 359,67	0,87	6 609,27	2 359,67
NA	995805	988805	80		717,75	47,45	10,44	398,26	1,87	1 346,86	2 360,71	0,87	6 612,17	2 360,71
NA-RA	995805	988805	-1		0,35	0,05	0,00	0,43	0,00	-1,12	1,03	0,00	2,89	1,03
NA/RA %	995805	988805	1		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Note: increase in <u>long</u> ride time (in spite of halved times for rail lines) and decrease in fare, transfer ratio below 2. Gen cost goes up in spite of faster trains

REASON: Sampers does only take into account night train Luleå-Örebro-Gothenburg.

Since airline Luleå-Stockholm and then train Stockholm-Örebro is not taken into account the speeding up of trains Stockholm-Örebro
is neither taken into account.

See below under travel paths according to Vips that these paths are accepted.

Samkalk: Only rail and rail changes. SAMKALK CALCULATION

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	GC	CS, minutes		
O-D	Luleå väst	Örebro		dist	time	time	time	time	ratio		cost, min.	share	SEK	Exist/left	New/lost	Sum
RA	995805	988805	0,1	12,40	917,00	120,00		189,50	1,10	1 996,70	1 609,31	0,80	7 376,01			
NA	995805	988805	0,1	12,40	896,40	120,00		195,00	1,10	1 996,70	1 594,31	0,80	7 307,26			
NA-RA	995805	988805	0,0	0,00	-20,60	0,00		5,50	0,00	0,00	-15,00	0,01	-68,75	1,5	0,0	**1,5**
NA/RA %	995805	988805	1,0	1,00	0,98	1,00		1,03	1,00	1,00	0,99	1,01	0,99			

Note: Very small change in CS compared to Vips, only 0,06 % in spite of faster trains,

Reasons: Only rail is taken into account, no comb inations and very few use rail all the way 0,00059

Travel paths according to Vips

Travel paths RA	Origin Luleå väst	Dest Örebro	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
No. Of trips over 1 only	995805	988805	16	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	16
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		38,3	84	124	236	3	SJ	Sth-Hallsb-Gbg	
			7,6	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	7,6
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57e	20211		38,3	186,5	120	236	3	SJ	Sth-Hallsb	
			6,3	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	6,3
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	-57b	20211		38,3	224	97	236	3	SJ	Sth-Örebro	
			3,1	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	3,1
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+61b	20211		38,3	336	130	254,8	3	SJ	Sth-Örebro	
			2,1	28391	-sk3NY	2491	48	87,4	66	80	2276		SAS	Luleå-Arlanda	2,1
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				19852	-T701a	20258	3	20,5	40	24	21,8	3	Reg. Bus	Örebro-Hallsberg	
			1,9	28391	-hs6NY	22991	48	87,4	1120	100	1100		Direktflyg	Luelå-Borlänge	1,9
				22911	+53aLT	20211	40,5	27	112	130	66,8	3	SJ	Gävle-Örebro	
			1,6	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	1,6
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+61a	19811		38,3	210	107	232,7		SJ	Stockholm-Hallsberg	
				19852	-T701a	20258	3	27,3	40	24	21,8	3	Reg. Bus	Örebro-Hallsberg	
			1,5	28391	-hs6NY	22991	48	87,4	1120	100	1100		Direktflyg	Luelå-Borlänge	1,5
				22954	-FB1	22952	1,2	27	15	13	26,2		Air coach	Borlänge-Borlänge	
				22911	+53aLT	20211	3	51,2	112	130	66,8	3	SJ	Gävle-Örebro	
			1,5	28355	+FB7	28356	16,3	87,4	15	8	20,2		Air coach	Luleå-Luleå	1,5
				28391	-lf4NY	2491	6	70,5	140	80	951		Fly Nordic	Luleå-Arlanda	
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		38,3	84	124	236	3	SJ	Sth-Hallsb-Gbg	
			1,2	28391	-lf4NY	2491	48	87,4	140	80	951		Fly Nordic	Luleå-Arlanda	1,2
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57x2	20211		38,3	672	109	452,8	3	SJ	Sthlm-Göteborg	
			1,1	28355	+FB7	28356	16,3	87,4	15	8	20,2		Air coach	Luleå-Luleå	1,1
				28391	-sk3NY	2491	6	70,5	66	80	2276		SAS	Luleå-Arlanda	
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		38,3	84	124	236	3	SJ	Sth-Hallsb-Gbg	
		Sum	43,9												43,9

Note: All trvel part by train

Travel paths NA	Origin Luleå väst	Dest Örebro	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
Rail routes 57a,57b,57 Stockholm Örebro half ride time No. Of trips over 1 only	995805	988805	21,9	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	21,9
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		44,4	84	68	236	3	SJ	Sth-Hallsb-Gbg	
			9,5	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	9,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57e	20211		44,4	186,5	74	236	3	SJ	Sth-Hallsb	
			7,5	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	7,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	-57b	20211		44,4	224	51	236	3	SJ	Sth-Örebro	
			3,5	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	3,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+61b	20211		44,4	336	130	254,8	3	SJ	Sth-Örebro	
			3,0	28391	-sk3NY	2491	48	86,3	66	80	2276		SAS	Luleå-Arlanda	3,0
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		44,4	84	68	236	3	SJ	Sth-Hallsb-Gbg	
			2,2	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	2,2
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+70c	19811		44,4	197,5	92	449,8		SJ	Sthlm-Karlstad	
				19811	-54cLT	20211		20,5	25	25	21,1	3	SJ	Gävle-Hallsberg	
			2,0	28355	+FB7	28356	16,3	86,3	15	8	20,2		Air coach	Luleå-Luleå	2,0
				28391	-lf4NY	2491	6	70	140	80	951		Fly Nordic	Luleå-Arlanda	
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		44,4	84	68	236	3	SJ	Sth-Hallsb-Gbg	
			1,8	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,8
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57x2	20211		44,4	672	56,5	452,8	3	SJ	Sthlm-Göteborg	
			1,6	28355	+FB7	28356	16,3	86,3	15	8	20,2		Air coach	Luleå-Luleå	1,6
				28391	-sk3NY	2491	6	70	66	80	2276		SAS	Luleå-Arlanda	
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		44,4	84	68	236	3	SJ	Sth-Hallsb-Gbg	
			1,5	28391	-lf4NY	2491	48	86,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä150a	20258	12	44,4	160	140	97,2	3	Coach	Sthlm-Oslo	
			1,5	28391	-hs6NY	22991	48	86,3	1120	100	1100		Direktflyg	Luelå-Borlänge	1,5
				22911	+53aLT	20211	40,5	27	112	130	66,8	3	SJ	Gävle-Örebro	
			1,3	28391	-hs6NY	22991	48	86,3	1120	100	1100		Direktflyg	Luelå-Borlänge	1,3
				22954	-FB1	22952	1,2	27	15	13	26,2		Air coach	Borlänge-Borlänge	
				22911	+53aLT	20211	3	51,2	112	130	66,8	3	SJ	Gävle-Örebro	
			1,3	28391	-sk3NY	2491	48	86,3	66	80	2276		SAS	Luleå-Arlanda	1,3
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57e	20211		44,4	186,5	74	236	3	SJ	Sth-Hallsb	
			1,0	28391	-sk3NY	2491	48	86,3	66	80	2276		SAS	Luleå-Arlanda	1,0
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	-57b	20211		44,4	224	51	236	3	SJ	Sth-Örebro	
		Sum	59,6												59,6

Note: Vips RA 100% use train, NA 100% use train- increase 0 per cent. Sampers: RA 0,4% use train, NA 0,4% use train - increase 0%

Appendix 6 Luleå-Karlskoga, faster trains

By Kjell Jansson, Royal Institute of Technology (KTH), Stockholm

Luleå väst (north Sweden) - Karlskoga (250 km west of Stockholm) 1,4695652

Vips

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	CS
O-D	Luleå väst	Karlskoga		dist	time	time	time	time	ratio		cost, min.	share	
RA	995805	988831	19	979,03	272,63	85,55	69,96	66,52	2,82	1 561,41	1 186,78	1,00	
NA	995805	988831	19	979,06	252,54	85,29	69,13	68,34	2,86	1 567,47	1 171,77	1,00	
NA-RA	995805	988831	0	0,03	-20,09	-0,26	-0,82	1,82	0,03	6,06	-15,01	0,00	**280,7**
NA/RA %	995805	988831	1,00	1,00	0,93	1,00	0,99	1,03	1,01	1,00	0,99	1,00	

Note: Reduction in ride time and increase in fare, transfer ratio nearly 3.

Sampers

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	Gen	Convert to GC per min with VoT 450 SEK/h
O-D	Luleå väst	Karlskoga		dist	time	time	time	time	ratio		cost, min.	share	cost, SEK	0,357
RA	995805	988831	18,70		764,17	49,45	28,34	394,78	1,63	1227,10	2419,83	0,95	6777,77	2419,83
NA	995805	988831	18,60		762,81	49,40	28,45	394,00	1,63	1230,42	2417,62	0,95	6771,58	2417,62
NA-RA	995805	988831	-0,10		-1,36	-0,06	0,11	-0,78	0,00	3,32	-2,21	0,00	-6,19	-2,21
NA/RA %	995805	988831	0,995		1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Note: small decrease in long ride time and very small decrease in gen cost (in spite of halved times for rail lines) and increase in fare, transfer ratio below 2.

REASON: For regress links Sampers uses very long, not realistic, times and chooses the shortest of these. But from where the shortest is, Degerfors, the speeded up trains do not stop.

Sampers cannot make us of these speeded up trains.

The other aspect worth to notice is that Sampers assigns passengers on night train Luleå-Stockholm and then the train Stockholm-Degerfors.

Thus, Sampers cannot take into account airline Luleå-Stockholm and then train Stockholm-Örebro, where the speeded up trains stop.

See below according to Vips travel paths that these alternatives are taken into account.

Samkalk: Only rail and rail changes. SAMKALK CALCULATION

Level of ser	Origin	Dest	Trips	Ride	Ride	Wait	Walk	Transfer	Transfer	Fare	Gen	PT	GC	CS, minutes		
O-D	Luleå väst	Karlskoga		dist	time	time	time	time	ratio		cost, min.	share	SEK	Exist/left	New/lost	Sum
RA	995805	988831	0,00		913,70	120,00		233,30	2,70	1985,80	1660,03	0,95	7608,48			
NA	995805	988831	0,00		913,70	120,00		233,30	2,70	1985,80	1660,03	0,95	7608,48			
NA-RA	995805	988831	0,00		0,00	0,00		0,00	0,00	0,00	0,00	0,00	0,00	0,0	0,0	**0,0**
NA/RA %	995805	988831			1,00	1,00		1,00	1,00	1,00	1,00	1,00	1,00			

Note: No change in CS compared to Vips

Reasons: Only rail is taken into account, no comb inations and nobody uses rail all the way ########

Travel paths according to Vips

Travel paths RA	Origin Luleå väst	Dest Karlskoga	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
No. Of trips	995805	988831	1,4	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1,4
over 0,5 onl				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+70c	19911		33,7	197,5	122	587,8		SJ	Sthlm-Karlstad	
				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
			1,2	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1,2
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä150a	20551	12	33,7	160	179	111,5	12,2	Coach Sä b	Sthlm-Oslo	
			1,2	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1,2
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+70b	19911		33,7	186,5	171	294,8		SJ	Sthlm-Kil	
				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
			1,1	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1,1
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57e	20211		33,7	186,5	120	236		SJ	Sth-Hallsb	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			1,1	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1,1
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+57a	20211		33,7	84	124	236		SJ	Sth-Hallsb-Gbg	
				20258	+T504	20551	3	25	25	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			1	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	1
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	-57b	20211		33,7	224	97	236		SJ	Sth-Örebro	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			0,8	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,8
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sw888a	20551	12	33,7	160	196,5	156	12,2	Coach Swel	Sthlm-Oslo	
			0,7	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,7
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+70e	19911		33,7	280	147	294,9		SJ	Sthlm-Karlstad	
				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
			0,7	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,7
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä150b	20551	12	33,7	240	188	111,5	12,2	Coach Sä b	Göteborg-Karlstad	
			0,6	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,6
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä100d	20551	12	33,7	240	193	111,5	12,2	Coach Sä b	Sthlm-Grums	
			0,6	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,6
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä100e	20551	12	33,7	240	196	111,5	12,2	Coach Sä b	Sthlm-Karlstad	
			0,5	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1611	+61b	20211		33,7	336	130	254,8		SJ	Sth-Örebro	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			0,5	28391	-lf4NY	2491	48	85,6	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	17	124		Arl exp	Arlanda-Sthlm	
				1654	+Sw845a	20551	12	33,7	160	209	156,4	12,2	Coach Swel	Sthlm-Karlstad	
		Sum	11,4												11,4

Travel paths NA	Origin Luleå väst	Dest Karlskoga	Trips	Stop	Route	Stop	Walk time	Composed wait	Route wait	Ride time	Fare	Walk time	Operator	Itinerary	Of which part train
Rail	995805	988831	2,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	2,5
routes				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
57a,57b,57				1611	+57a	20211		34,9	84	68	236		SJ	Sth-Hallsb-Gbg	
Stockholm				20258	+T504	20551	3	25	25	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
Örebro			1,3	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,3
half				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
ride time				1611	+70c	19911		34,9	197,5	122	587,8		SJ	Sthlm-Karlstad	
No. Of trips				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
over 0,5 onl			1,3	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,3
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+57e	20211		34,9	186,5	74	236		SJ	Sth-Hallsb	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			1,2	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,2
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+70b	19911		34,9	186,5	171	294,8		SJ	Sthlm-Kil	
				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
			1,1	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,1
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	-57b	20211		34,9	224	51	236		SJ	Sth-Örebro	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			1,1	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	1,1
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä150a	20551	12	34,9	160	179	111,5	12,2	Coach Sä b	Göteborg-Karlstad	
			0,7	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,7
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+70e	19911		34,9	280	147	294,9		SJ	Sthlm-Karlstad	
				19955	-T502	20551	3	17,9	19	14	17	12,2	Reg. Bus	Degerfors-Karlskoga	
			0,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1611	+61b	20211		34,9	336	130	254,8		SJ	Sth-Örebro	
				20258	+T504	20551	3	30,1	31,5	57	28,7	12,2	Reg. Bus	Örebro-Karlskoga	
			0,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä150b	20551	12	34,9	240	188	111,5	12,2	Coach Sä b	Göteborg-Karlstad	
			0,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä100d	20551	12	34,9	240	193	111,5	12,2	Coach Sä b	Sthlm-Grums	
			0,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sä100e	20551	12	34,9	240	196	111,5	12,2	Coach Sä b	Sthlm-Karlstad	
			0,5	28391	-lf4NY	2491	48	85,3	140	80	951		Fly Nordic	Luleå-Arlanda	0,5
				2411	+46Arlexp	1611	6	5,5	5,5	16	124		Arl exp	Arlanda-Sthlm	
				1654	+Sw888a	20551	12	34,9	160	196,5	156	12,2	Coach Swel	Sthlm-Oslo	
		Sum	11,7												11,7

Note: Vips RA 100% use train, NA 100% use train- increase 0 per cent. Sampers: RA 0% use train, NA 0% use train - increase 0%

Appendix 7 Sampers model calibration – models for long distance tours

By Staffan Algers, Royal Institute of Technology (KTH), Stockholm

The purpose of this memo is to describe the calibration of the Sampers long distance models to partners in the Vinnova project "Samper Vips and Visum) project. It is based on the technical documentation of Sampers 2.1 and a later calibration report for the long distance trip models (Transek 2005).

The models

For long distance tours, nested logit models for mode and destination choice and trip frequency choice were estimated for business trips and private trips. In addition, a further sub categorisation was made with respect to the number of days of absence from home. The models were estimated on data from the national travel survey RES from the year 1994 to the year 2000.

Implementation

The two national models for long trips were divided into five submodels. Instead of looping over days of duration, the two models have been implemented as three private submodels (for 1, 2-5 and 6+ days spent on the destination) and two business submodels (for 1 and 2+ days spent on the destination). The models are run for each of a number of socioeconomic category combinations for each origin zone. The information on socioeconomic categories is partly independently, partly jointly available. Each socioeconomic category has therefore been implemented in one of three possible ways.

1. Correlation is fully taken into account between variables (joint distribution available),
2. The category is implemented as a loop-variable but no correlation is taken into account
3. The category is implemented only by average values

The total number of category combinations for which the model is run is the product of the number of classes in each category (category groups 1 and 2). Below the main socioeconomic variables are classified into one of the three groups listed above.

Category	Group	Comment
Party size	2	No geographical variation
Type of cost ("reslust", business etc)	2,3	No geographical variation
Car owner or not	2	Geographical variation
Car licence or not	2	No geographical variation
Age	1	With respect to employment and sex
Employed or not	1	With respect to age and sex
Sex	1	With respect to age and employment
Type of employment	3	No geographical variation
Seasonal variables	3	No geographical variation
Car density in households	3	Geographical variation
Income	2,3	Loop variable in business models

Season (summer and autumn) is a loop variable.

No availability restrictions

The alternatives in the estimated logit models are not always available. For the long distance models there is a general restriction for the length of the trips. Destinations less than 100 kilometres from the origin are not available. Below the additional restrictions are listed by mode.

Car modes are available alternatives if the in vehicle time is greater than 90 minutes (tour total) and by the existence of car in the household and the eligibility for car license (implemented by using age groups)

Public-transport-modes (bus, train and air) are restricted only by the values of in vehicle time. If in vehicle times for both the outgoing and the homebound trip legs are greater than zero and if the sum of these trip legs is greater than 60 minutes then the mode is an available alternative.

Calibration

After implementation, the models will result in a somewhat different travel pattern as contained in the travel survey (RVU or RES), which was used for estimation. This depends on the fact that the model is driven by another set of trip generating data, that the supply data is related to a specific year, and that simplifications are made. In order to match the RVU trip pattern, some adjustments of the model – calibration - has been carried out.

Calibration method

The adjustments that are made for the Standard Model are related to the general level of trip making, the distribution on modes and the distribution on trip length. The adjustments take the form of correction constants that are added to the utility functions. The correction constants are computed in an estimation process for each of the travel purposes. First, a calibration target is defined in terms of the desired criteria, like mode and distance or aggregate OD distributions. For this calibration target, an aggregate model with a full set of alternative specific constants is estimated (the alternatives being modes and trip length classes or OD groups). A similar estimation is performed for the current model output, resulting in a different set of constants.

The difference between the constants is what we need to put into our model to obtain the target distribution. So, the differences between the constant are then added to the model. Because of the simple nature of the computation (alternative availability is not taken into account for instance), the operation may have to be iterated once or twice to converge closely enough. This type of additional adjustment in the utility functions ensures consistency between the estimated and the implemented models. Only the market shares of the different alternatives are affected.

Calibration process

In context with the re-estimation and implementation of the 2.1 version models, the models were calibrated to match the travel survey by mode and tour length distribution. The results were as follows:

Table 1: Number of trips RVU (one way yearly average day)

	Business		Private		Total	
Bus	834	3,8%	7205	8,7%	8039	7,7%
Air	3862	17,7%	2488	3,0%	6350	6,1%
Train	2799	12,8%	9669	11,7%	12468	11,9%
Car	14384	65,7%	63293	76,6%	77677	74,3%
Sum	21879	100,0%	82655	100,0%	104534	100,0%

Table 2: Number of trips Sampers (one way yearly average day)

	Business		Private		Total	
Bus	840	3,8%	7179	8,7%	8019	7,7%
Air	3910	17,9%	2639	3,2%	6549	6,3%
Train	2788	12,7%	9624	11,6%	12412	11,9%
Car	14353	65,6%	63329	76,5%	77682	74,2%
Sum	21892	100,0%	82770	100,0%	104662	100,0%

Table 3: Ratio between Sampers and RVU, number of tours

	Business	Private	Total
Bus	1,01	1,00	1,00
Air	1,01	1,06	1,03
Train	1,00	1,00	1,00
Car	1,00	1,00	1,00
Sum	1,00	1,00	1,00

Obviously, the travel survey is based on a sample, and thus contains uncertainty and possible bias. The State Railways and the Swedish Aviation Authority have better information, and in a subsequent project, this information was utilised to obtain results that would match reality better. This information is however confidential to a certain aggregation level, and the information that was put to disposal for calibration purpose was in the form of the number of trips in 8*8 matrices (A regional subdivision of Sweden). So, the new calibration targets were in the form of 8*8 OD pairs for each mode (for car and bus, the previous results were defined as calibration targets). Using the same approach, an additional set of calibration constants was estimated. It turned out to be sufficient to hold down the number of constants to 8 origin and 7 destination constants, instead of a full set of 63 constants.

The results of the second calibration were as follows:

Trip totals

Table 4: Number of trips calibration target (one way yearly average day)

Mode	Business		Private		Total	
Bus	834	3,4%	7205	8,1%	8039	7,1%
Air	4369	18,0%	3161	3,6%	7530	6,6%
Train	4678	19,3%	15345	17,2%	20023	17,7%
Car	14384	59,3%	63293	71,1%	77677	68,6%
Sum	24265	100,0%	89004	100,0%	113268	100,0%

Table 5: Number of trips Sampers (one way yearly average day)

Mode	Business		Private		Total	
Bus	810	3,4%	6856	7,8%	7666	6,8%
Air	4236	17,6%	3043	3,5%	7279	6,5%
X2000	4962	20,6%	15086	17,1%	20048	17,9%
Car	14036	58,4%	63078	71,6%	77114	68,8%
Other mode	24044	100,0%	88063	100,0%	112107	100,0%
Sum	111388		185533			

Table 6: Ratio between Sampers and calibration target

Mode	Business	Private	Total
Bus	0,97	0,95	0,95
Air	0,97	0,96	0,97
X2000	1,06	0,98	1,00
Car	0,98	1,00	0,99
Sum	0,99	0,99	0,99

Results by OD pairs

Air

In the table below, the 8 main regions division is defined

Table 7: Definition of main regions

Main region	Included counties
R1	Stockholms län
R2	Uppsala, Södermanland, Östergötland, Örebro, Västmanland
R3	Jönköping, Kronobergs, Kalmar, Gotland
R4	Blekinge, Skåne
R5	Halland, Västra Götaland
R6	Värmland, Dalarna, Gävleborg
R7	Västernorrland, Jämtland
R8	Västerbotten, Norrbotten

The target matrix for air trips is shown in the table below:

Table 8: Target matrix for air trips between main regions (number of trips yearly average day)

	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**Sum**
R1	0	58	331	1410	1352	72	660	1078	4959
R2	75	21	116	254	167	20	158	237	1048
R3	326	111	27	52	87	103	109	149	964
R4	1426	243	57	12	20	76	62	441	2337
R5	1271	154	93	20	18	55	94	177	1882
R6	74	19	114	79	62	6	49	78	481
R7	677	135	119	64	97	50	8	77	1227
R8	1078	216	159	462	189	73	79	41	2297
Sum	4927	957	1017	2352	1993	453	1218	2278	15195

The fit between target and model output is illustrated in the scatter gram below:

Figure 1: Scatter gram for the number of air trips in Sampers and in the target matrix.

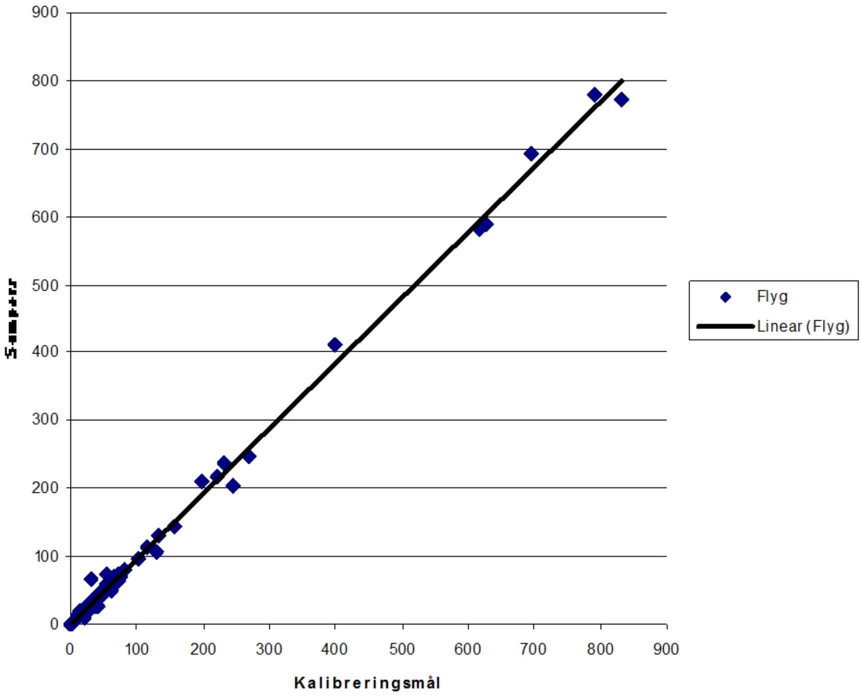


Table 9: Scatter gram regression parameters for air

Parameter	Value
Coefficient	1,038
Constant	-0,42
R-square	0,996

The fit is obviously quite good.

Train

The target matrix for train is not shown explicitly for confidentiality reasons. Instead, a scatter gram is shown as for air:

Figure 2: Scatter gram for the number of train trips in Sampers and in the target matrix

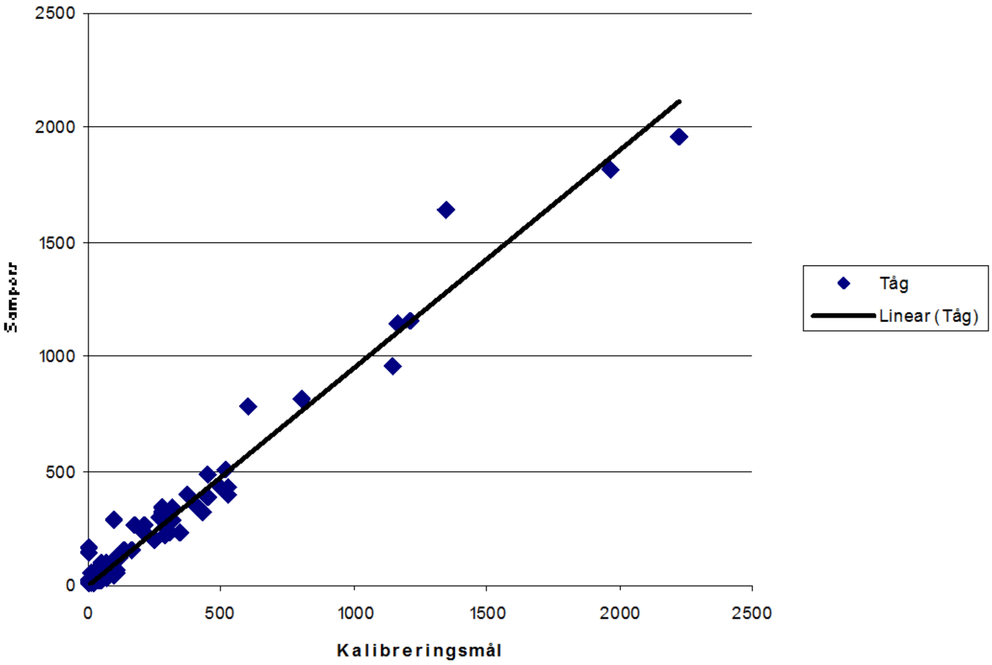


Table 10: Scatter gram regression parameters for train

Parameter	Value
Coefficient	1,041
Constant	-13,2
R-square	0,965

There is a good fit also for train, but not as good as for air.

Car

For car, the target was the result of the previous calibration. The resulting scatter gram for car is as follows:

Figure 3: Scatter gram for the number of car trips in Sampers and in the target matrix

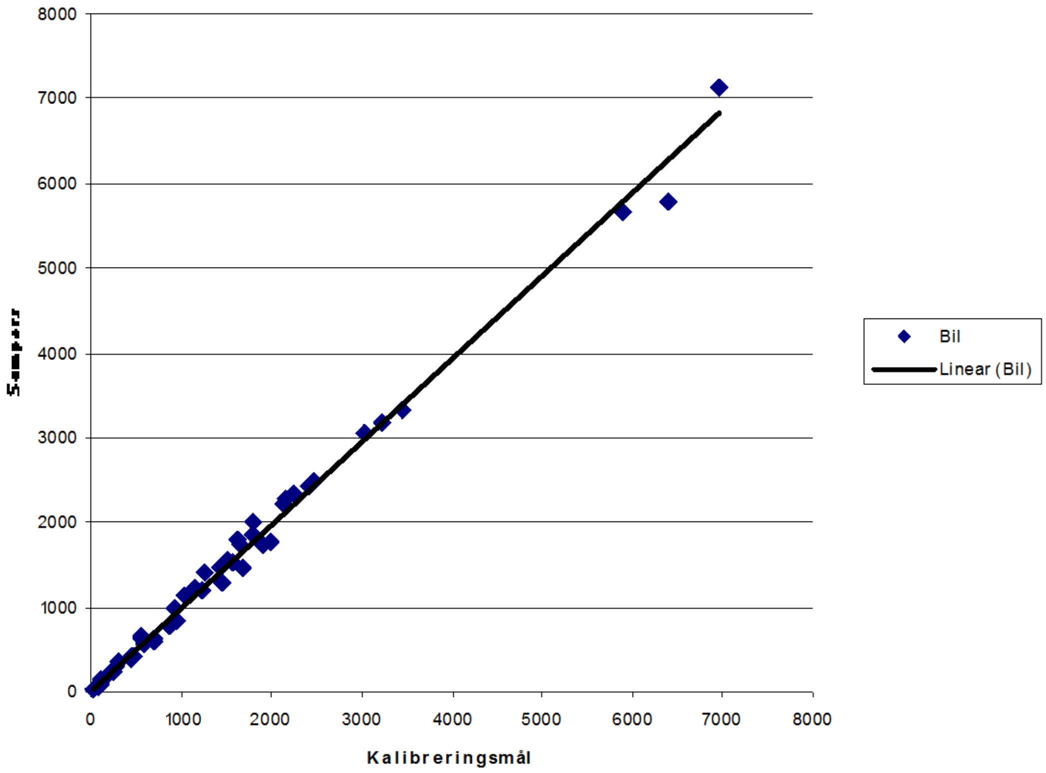


Table 11: Scatter gram regression parameters for car

Parameter	Value
Coefficient	1,017
Constant	-11,99
R-square	0,994

The fit is quite good also in this case, and reflects a small impact from the air and train calibration targets.

Bus

The corresponding scatter gram for bus looks as follows:

Figure 4: Scatter gram for the number of bus trips in Sampers and in the target matrix

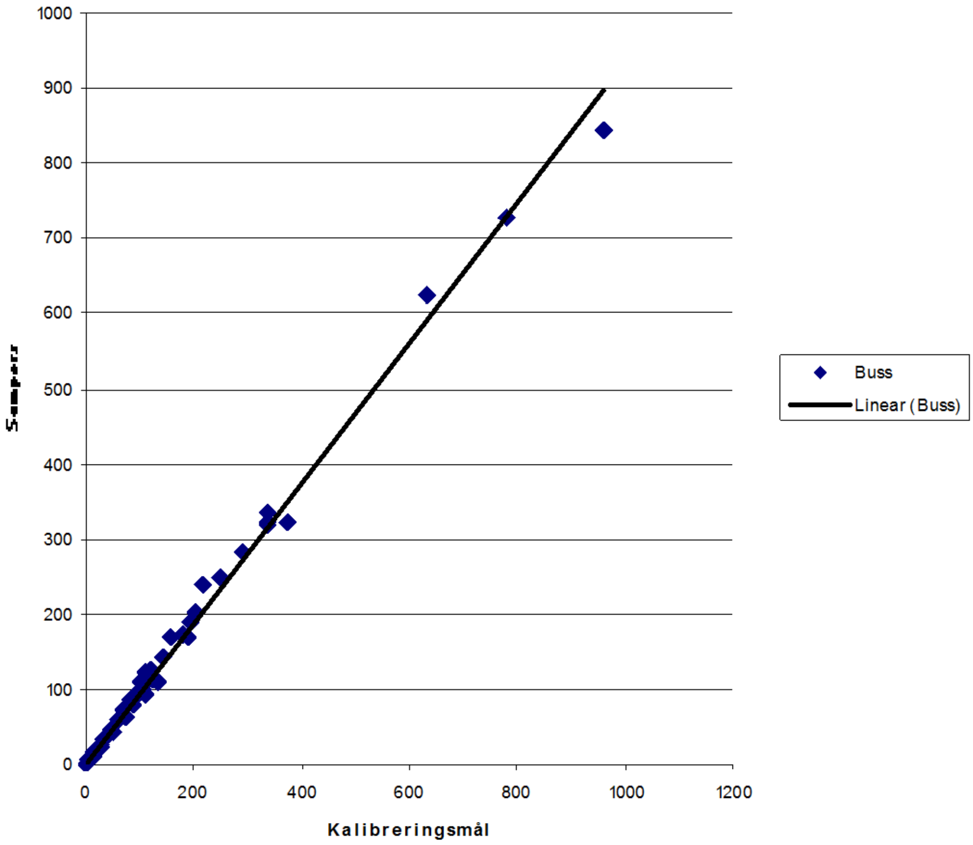


Table 12: Scatter gram regression parameters for bus

Parameter	Value
Coefficient	1,078
Constant	-4,12
R-square	0,995

Also bus seems to be only marginally affected by the new target matrices for train and air.

Kilometrage

It may also be of interest to compare the kilometrage between Sampers (after calibration) and the travel survey:

Table 13: Ratio between Sampers and travel survey (person kilometres)

Mode	Business	Private	Total
Bus	1,12	0,97	0,98
Air	1,14	1,28	1,20
Train	1,71	1,57	1,60
Car	0,98	1,01	1,01
Sum	1,15	1,12	1,12

The increased values for train and air correspond well to the increased number of trips in the new target matrices, whereas the kilometrage for car and bus is about the same as before the second calibration.

Appendix 8 Vips model calibration

By Kjell Jansson, Royal Institute of Technology (KTH), Stockholm

Distribution of travellers according to Vips has been calibrated against:

- The Swedish airport administrations (LFV) statistics on number of passengers between airports,
- The Swedish railways (SJ) statistics on number of passengers on specific links,
- Number of passenger km per passenger segment according to the national survey (RES).

Weights and costs

The table below shows assumptions on weights and costs per mode.

Weights and costs

Vehicle Type	Ride Time Weight	Capacity	# of Seats	Driver Cost/km	Driver Cost/h	Vehicle Cost/km	Crew Cost/h
F50	1,10	50	50	0,00	0	37,50	14 185
F100	1,10	107	107	0,00	0	80,25	22 518
FBA146	1,10	96	96	0,00	0	72,00	20 910
FJetstm	1,10	19	19	0,00	0	14,25	6 528
FSAAB34	1,10	36	36	0,00	0	27,00	9 013
FShorts	1,10	36	36	0,00	0	27,00	9 013
FSKDC9	1,10	112	112	0,00	0	84,00	23 249
FSKDC9u	1,10	112	112	0,00	0	84,00	24 499
FSKF28	1,10	71	71	0,00	0	53,25	17 255
FSKMD82	1,10	156	156	0,00	0	117,00	30 932
KBFlygbs	1,10	50	50	0,00	0	2,30	662
KBNynBus	1,10	50	50	0,00	0	2,30	662
KBRegbus	1,10	50	50	0,00	0	2,30	662
LBuss	1,10	50	50	0,00	0	2,30	662
NTL70BC	1,05	50	50	30,06	5 648	3,20	456
NTL80	1,00	35	35	11,99	3 383	8,69	548
NTL80RS	0,90	40	40	12,42	3 826	9,00	477
TICL60	1,05	55	55	11,70	2 663	5,50	960
TICL80	1,00	70	70	0,00	0	7,15	1 363
TICL80R	0,95	60	60	11,70	2 663	5,50	960
TICL90	0,95	80	80	11,70	2 663	5,50	960
TICX22	0,90	90	90	11,70	2 663	5,50	960
TICX31	0,95	60	60	11,70	2 663	5,50	960
TICX40	0,90	95	95	0,00	1 417	10,96	2 159
TICX50	0,90	85	85	0,00	1 466	8,40	1 884
TICY1	1,15	75	75	0,00	0	11,24	2 810
TICY2	0,85	45	45	6,50	1 647	5,95	1 092
TPX10	1,05	95	95	0,00	1 270	9,56	1 247
TPX60	1,00	90	90	0,00	2 159	9,31	843
TRegAEX	0,90	50	50	0,00	2 159	5,73	1 046
TRegL	1,00	70	70	11,70	2 663	5,50	960
TRegX12	1,00	60	60	0,00	0	11,51	1 392
TRegX14	1,00	80	80	0,00	0	11,51	1 392
TRegX22	0,90	95	95	0,00	1 270	9,56	1 247
TRegX31	0,95	60	60	0,00	1 270	8,27	1 173
TRegX40	0,95	95	95	0,00	1 270	9,56	1 247
TRegX50	0,95	95	95	0,00	1 270	9,56	1 247
TRegY1	1,15	75	75	0,00	0	11,24	2 810
TRegY2	0,85	45	45	0,00	1 221	7,57	772
TRegY5	0,95	70	70	0,00	1 221	11,19	1 202
TX21	0,80	80	80	0,00	1 612	9,89	2 270
TX24	0,80	63	63	0,00	1 417	9,95	2 193
TX25	0,80	60	60	0,00	1 417	10,03	2 137
TX2000	0,80	53	53	13,42	4 106	8,65	1 393
TX3000	0,80	60	60	0,00	1 466	12,71	2 302
UNT	1,00	35	35	0,00	0	9,62	897
UTIC	0,95	55	55	0,00	0	7,15	1 363
UTX2000	0,80	55	55	13,42	4 106	8,65	1 393
XGotbåt	1,00	1600	1600	0,00	0	50,00	0
XKatama	1,00	540	540	0,00	0	50,00	0

Networks and matrices

The table below specifies the networks used and the matrices with number of journeys.

Networks and matrices

Segment Nät	Matris namn	Matris antal/år	Andel per segment
Långväga inrikes privat			
JA05 P60_080329.VNT	Sum Mat P60.VMX	22 784 844	0,32
JA05 P100_080329.VNT	Sum Mat P100.VMX	22 784 844	0,32
JA05 PENS_080329.VNT (ej bil)	PENS,20%T,år.VMX	1 993 674	0,03
JA05 PENS_080329.VNT	PENS,80%T,årVMX	7 974 696	0,11
JA05 STUD_080329.VNT	Sum Mat stud.VMX	15 664 581	0,22
Summa långväga inrikes privat		71 202 639	1,00
Långväga inrikes tjänste			
JA05 T450_080329.VNT	Tjä summat.VMX	19 063 098	0,21
Summa långväga inrikes		90 265 737	1,00
Utrikes			
JA05 Tutl_080328.VNT	T2005T,år,båda.VMX	9 531 549	0,34
JA05 Putl,långa_080328.VNT	SNDTBHP00.pri,långa.VMX	6 164 321	0,22
JA05 Putl,korta_080328.VNT	SNDTBHP00.pri,korta.VMX	11 951 357	0,43
Summa utrikes		27 647 227	1,00
Regionalt			
JA05 REGarb_080328.VNT	RegARB2005T,år.VMX	1 973 444 992	0,37
JA05 REGövr_080328.VNT	RegÖVR2005T,årVMX	3 109 826 048	0,59
JA05 REGtjä_080328.VNT	RegTJÄ2005T,år.VMX	228 800 752	0,04
Summa regionalt		5 312 071 792	1,00

Values of time and weights

The table below shows assumed values of time and weights for travel time components.

Values of time and weights

Segment Nät	Tids- värde kr/h	Bil- vikt	Bil- pris kr/perskm	Väntetids- vikt, <12 min int.	Väntetids- vikt, >12 min int.	Byte- gång- vikt	Bytes- motstånd min.
Långväga inrikes privat							
JA05 P60_080329.VNT	60	1,7	0,8	3,0 + 12 min.	0,5	1,6	10
JA05 P100_080329.VNT	100	1,45	1,1	3,0 + 12 min.	0,5	1,6	10
JA05 PENS_080329.VNT (ej bil)	35			3,0 + 12 min.	0,5	1,6	10
JA05 PENS_080329.VNT	35	1	0,75	3,0 + 12 min.	0,5	1,6	10
JA05 STUD_080329.VNT	35	1,65	0,9	3,0 + 12 min.	0,5	1,6	10
Genomsnitt långväga privat	64						
Långväga inrikes tjänste							
JA05 T450_080329.VNT	450	2,25	1,3	3,0 + 12 min.	0,5	1,6	20
Utrikes							
JA05 Tutl_080328.VNT	800	3,0	2,0	3,0 + 10,80 min	1,2	2,0	90
JA05 Putl,långa_080328.VNT	200	2,5	1	3,0 + 12 min.	0,5	2	60
JA05 Putl,korta_080328.VNT	150	0,8	0,9	3,0 + 12 min.	0,5	2	30
Genomsnitt utrikes	385						
Regionalt							
JA05 REGarb_080328.VNT	50	1,9	1,2	3,0 + 12 min.	0,5	1,6	5
JA05 REGövr_080328.VNT	35	1,9	1,2	3,0 + 12 min.	0,5	1,6	5
JA05 REGtjä_080328.VNT	300	2,15	1,25	3,0 + 12 min.	0,5	1,6	20
Genomsnitt regionalt	52						

Parameters for calibration

Basically weights constants for public transport modes have been specified without further changes. We have tested various mode constants, which did not affect the demand pattern very much.

The parameters for calibration of Vips have been:

Prices for rail lines and air lines. These prices are originally taken for the various passenger segments (employed, pensioners, students, and business travellers) from home pages of the operators. These prices are, however, genuinely “unreliable”, since prices nowadays shift from time of day and from day to day. For this reason we have tested price changes by some plus or minus 10 per cent. It has appeared that variation of prices have a significant effect on demand for lines and modes.

Prices for car use. We have assumed a price that amount to combustion price plus an additional 30 per cent more or less. It is genuinely difficult to know how people believe the true prices to be. Some people probably only take combustion price into account, other people include all variable costs. We have tested various prices for the different segments and chosen the figures in table 2.3 above. It has appeared that the model is very sensitive for assumptions on car use prices. This fact means that there is a lack of randomness with respect to these prices.

Comfort of car. People may perceive car as more or less comfortable than public transport modes. In general we believe that people think that car is more uncomfortable. The ride time weight of car in relation to the norm 1 (ordinary intercity train) that we found most suitable are found in table 2.3 above. It has appeared that the model is very sensitive for assumptions on these comfort weights. This fact means that there is a lack of randomness with respect to these weights.

Results of calibration

Car and public transport

The table below shows calculated distribution between car and public transport for the segments.

Distribution between car and public transport for the segments according to Vips

Kategori	Kollresor	% koll	Bilresor
Årsvärden	Miljoner		Miljoner
Privat, 100kr	2,33	10%	20,45
Privat, 60kr	2,47	11%	20,31
Privat, stud	3,40	22%	12,27
Privat, pens	2,34	23%	7,63
Tjänste	7,15	38%	11,91
Summa långa	**17,7**	20%	**72,6**
Kortresor,arb	178,74	14%	1093,00
Kortresor,övr	140,69	9%	1394,51
Kortresor,tjä	21,00	14%	124,90
Summa korta	**365,3**	12%	**2696,9**
Summa, långa+korta	**383,0**	12%	**2769,5**
Utl. Privat	1,57	9%	16,55
Utl. Tjänste	4,54	81%	1,08
Summa utland	**6,1**	26%	**17,6**
Total summa	389,08	12%	2787,09

Journeys between airports

The table below shows number of journeys between some airports according to Vips and the Swedish airport administration (LFV).

Number of journeys according to the Swedish airport administration (LFV) and Vips

Boardings per route			LFV	Vips	Vips/
Airport	**Airport**	**Airline**	2005		LFV 2005
fArlanda	fÄngelholm		226 400	222 760	0,98
fArlanda	fBorlänge		17 100	5 317	0,31
fArlanda	fGällivare		14 100	94 535	6,70
fArlanda	fGöteborg		765 300	702 147	0,92
fArlanda	fHagfors		4 600	708	0,15
fArlanda	fHalmstad		113 900	96 550	0,85
fArlanda	fJönköping		64 900	41 477	0,64
fArlanda	fKalmar		114 300	91 853	0,80
fArlanda	fKarlstad		60 800	38 983	0,64
fArlanda	fKiruna		130 900	166 213	1,27
fArlanda	fKramfors		58 500	14 677	0,25
fArlanda	fKristians		60 600	53 556	0,88
fArlanda	fLuleå	sk3	827 600	831 450	1,00
fArlanda	fLycksele		52 400	59 393	1,13
fArlanda	fMalmö	sk2	632 600	643 837	1,02
fArlanda	fMora		8 700	3 938	0,45
fArlanda	fOskarsham		10 600	7 013	0,66
fArlanda	fÖrnskölds		130 000	100 205	0,77
fArlanda	fÖstersund		357 300	292 201	0,82
fArlanda	fRonneby		162 300	132 179	0,81
fArlanda	fSkellefte		219 700	222 066	1,01
fArlanda	fStoruman		21 400	17 546	0,82
fArlanda	fSundsvall	sk6	222 700	142 167	0,64
fArlanda	fTrollhätt		17 200	12 160	0,71
fArlanda	fUmeå		521 100	492 284	0,94
fArlanda	fVäxjö	sk8	101 600	77 855	0,77
fArlanda	fVisby		105 100	43 034	0,41
fBromma	fGöteborg	ma2	407 900	317 968	0,78
fBromma	fHalmstad		35	0	0,00
fBromma	fMalmö	ma1	492 000	548 041	1,11
fBromma	fRonneby		54 700	43 246	0,79
fBromma	fSundsvall		58 200	48 011	0,82
fBromma	fTrollhättan		37 700	34 369	0,91
fBromma	fUmeå		209 300	227 710	1,09
fBromma	fVäxjö		31 400	25 357	0,81
fBromma	fVisby		181 300	27 504	0,15
fGöteborg	fLuleå		21 154	21 272	1,01
fGöteborg	fMalmö		34 300	0	0,00
fGöteborg	fSundsvall		22 600	18 640	0,82
fGöteborg	fUmeå		576	14 251	24,74
fLinköping	fVisby		6 000	1 339	0,22
fLuleå	fKiruna		1 600	1 331	0,83
fMalmö	fÖrebro		9 400	7 619	0,81
fÖstersund	fKiruna		4 400	36 173	8,22
fÖstersund	fUmeå		13 200	2 824	0,21
fSundsvall	fLuleå		8 900	17 466	1,96
fSundsvall	fUmeå		45	0	0,00
fUmeå	fKiruna		7 300	22 146	3,03
		Sum	6 623 710	6 021 372	0,91

Journeys on railway links

The table below shows passengers load on certain links according to Vips and the Swedish state railways (SJ) statistics REDA.

Passenger load on railway links according to Vips and SJ

Några jvg-länkar för kalibrering		**REDA**	
Pass/år båda riktn	**Dstr**	**2006**	**VIPS**
FJÄRRTRAFIK			
Stockholm-Göteborg= Laxå-Skövde 17311- 17311-16912	**941**	3 207 115	3 490 838
Stockholm-Malmö= Sävsjö-Alvesta 6111-6811	**231**	1 914 085	2 577 842
Stockholm-Sundsvall= Gävle-Söderhamn 23913-24115	**2230**	749 629	1 178 163
Stockholm-Östersund= Bräcke-Östersund 25812-25214	**2345**	339 657	1 020 530
Stockholm-Dalarna= Alvesta-Borlänge 23111-23211	**2130**	727 593	461 981
Göteborg-Malmö Halmstad-Varberg 12811-12911	**530**	1 340 162	1 519 753
Stockholm-Karlstad Kristinehamn-Laxå 19713-19711	**1424**	613 346	431 394
Karlstad-Göteborg Öxnered-Säffle 16311-19611	**1115**	410 856	411 686
REGIONALTRAFIK			
Stockholm-Västerås= Enköping-Tillberga 3011-21413	**1920**	2 196 089	2 641 580
Stockholm-Eskilstuna= Läggesta-Eskilstuna 3912-3911	**1815**	1 300 996	1 235 913
Stockholm-Örebro= Arboga-Örebro 20211-21811	**1936**	1 333 639	2 063 032
Stockholm-Nyköping= Nyköping-Vagnhärad 3413-4011	**281**	902 667	403 086
Stockholm-Uppsala Märsta/Arlanda-Uppsala 2911-2912	**2210**	6 336 304	4 634 877
Stockholm-Södertälje Stockholm-Södertälje 811-812	**1900**	7 430 668	7 603 431

Passenger km per mode and segment

The table below shows number of passenger km (millions) according to Vips for each passenger segment per mode, for rail also per rain type.

Passenger km per mode and segment

Miljoner	Kortväga resor			Långväga resor					Utrikes resor		Totalt
Personkm/år	Arbete	Övrigt	Tjänste	Priv 100	Priv 60	Pens	Stud	Tjänste	Privat	Tjänste	inkl.utl
Flyg, inrikes	0	0	0	411	205	78	114	1 836	86	293	3 021
Flyg, utrikes	0	0	0	2	1	0	0	44	299	2 153	2 499
Summa flyg	**0**	**0**	**0**	**413**	**205**	**78**	**114**	**1 880**	**384**	**2 446**	**5 520**
Buss, kortväga	1 773	1 887	217	75	86	148	121	105	75	51	4 537
Buss, långväga	391	285	68	11	19	72	146	14	55	18	1 079
Summa buss	**2 164**	**2 172**	**285**	**86**	**105**	**220**	**267**	**118**	**130**	**68**	**5 616**
NTL80	0	0	0	3	19	1	51	5	2	1	83
NTL80RS	1	1	1	30	287	14	320	11	2	2	668
TICL80	75	28	6	11	17	14	26	22	2	10	210
TICL80R	89	123	17	87	107	61	91	81	15	42	713
TICX31	94	60	16	33	64	53	101	93	84	247	843
TICX40	14	15	2	0	0	1	0	2	0	2	37
TICX50	25	30	4	3	4	5	8	8	120	38	246
TICY1	0	1	0	0	0	0	0	0	0	0	2
TICY2	1	1	0	2	3	8	10	18	0	3	45
TPX10	862	232	115	7	5	7	8	19	6	15	1 278
TPX60	292	134	25	1	1	2	1	2	0	0	457
TRegAEX	0	0	4	0	0	0	0	70	0	41	115
TRegL	27	34	3	22	31	13	26	10	33	4	204
TRegX12	4	6	0	0	0	2	0	0	0	0	13
TRegX14	148	153	27	0	0	5	1	2	1	2	340
TRegX40	107	52	9	9	16	18	27	37	1	10	286
TRegX50	316	220	33	19	26	58	41	46	10	25	794
TRegY1	2	2	0	0	0	2	0	0	0	0	7
TRegY2	4	5	1	0	0	2	0	1	0	3	16
TRegY5	24	30	3	1	2	9	4	4	1	3	81
TX2000	52	3	13	543	509	195	611	836	69	236	3 068
Tåg i Sverige	**2 137**	**1 130**	**279**	**773**	**1 093**	**469**	**1 327**	**1 269**	**347**	**684**	**9 508**
UNT	0	0	0	0	0	0	0	0	0	1	1
UTIC	0	0	0	0	0	0	0	0	0	780	780
UTX2000	0	0	0	0	0	0	0	0	0	183	183
Tåg utrikes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**964**	**964**
Summa tåg	**2 137**	**1 130**	**279**	**773**	**1 093**	**469**	**1 327**	**1 269**	**347**	**1 648**	**10 472**
Båt	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**4**
Summa koll	**4 301**	**3 301**	**565**	**1 272**	**1 404**	**769**	**1 708**	**3 269**	**862**	**4 163**	**21 612**
Bil (milj. Resor)	1093,0	1394,5	124,9	20,5	20,3	7,6	12,3	11,9	16,5	1,1	2 703
Bil (reslängd km)	24,2	23,3	34,7	236,9	237,0	258,3	214,2	192,0	641	414	33,6
Bil (milj pkm)	**26 451**	**32 422**	**4 337**	**4 844**	**4 814**	**1 971**	**2 627**	**2 287**	**10 608**	**445**	**90 806**
Totalt	**30 752**	**35 724**	**4 901**	**6 116**	**6 218**	**2 739**	**4 335**	**5 556**	**11 470**	**4 608**	**112 419**

The table below summarises the results above and compares numbers from Vips with numbers (in red) by Wajsman and by SIKA in some cases (in parenthesis).

Passenger km per mode and segment according to Vips and other sources

Fordon/ Produkt	Kortv resor	Långv inrikes	Utrikes resor	Totalt
		2600 (3309)	900	3 400
Flyg, inrikes	0	2 643	378	3 021
Flyg, utrikes	0	47	2 452	2 499
Summa flyg	**0**	**2 689**	**2 831**	**5 520**
Buss, kortväga	3 877	534	126	4 537
Buss, långväga	744	262	73	1 079
Summa buss	**4 621**	**796**	**199**	**5 616**
	6 400	1 500	300	8 200
NTL80	0	80	4	83
NTL80RS	2	661	4	668
TICL80	108	90	12	210
TICL80R	229	427	57	713
TICX31	170	343	330	843
TICX40	31	4	2	37
TICX50	59	29	158	246
TICY1	1	1	0	2
TICY2	2	41	3	45
TPX10	1 210	48	21	1 278
TPX60	450	6	0	457
TRegAEX	4	70	41	115
TRegL	65	102	37	204
TRegX12	10	3	0	13
TRegX14	328	9	3	340
TRegX40	167	108	10	286
TRegX50	569	189	35	794
TRegY1	4	3	0	7
TRegY2	10	3	3	16
TRegY5	57	20	4	81
TX2000	68	2 694	305	3 068
Tåg i Sverige	**3 546**	**4 931**	**1 031**	**9 508**
	3800 (3961)	5000 (5101)	400 (580)	9200 (9642)
UNT	0	0	1	1
UTIC	0	0	780	780
UTX2000	0	0	183	183
Tåg utrikes	**0**	**0**	**964**	**964**
Summa tåg	**3 546**	**4 931**	**1 995**	**10 472**
Båt	**0**	**3**	**0**	**4**
Båt	**8 167**	**8 420**	**4 061**	**20 648**
Bil (milj. Resor)	2 612	73	18	2 703
Bil (reslängd km)	24,2	228,0	627,2	33,6
Bil (milj pkm)	63 210	16 543	11 053	90 806
	63 500	19 100	8 000	90 600
Totalt	**71 377**	**24 964**	**16 078**	**112 419**

Shares per segment and mode

The table below shows demand in passenger kilometres according to Vips and the national survey RES.

Table 3.5.1 Shares according to Vips and the survey RES

	Shares VIPS					Shares RES				
Mode	Working	Pens	Stud	Bus	Sum	Working	Pens	Stud	Bus	Sum
Air	0,07	0,04	0,05	0,25	0,10	0,09	0,04	0,05	0,29	0,11
Buss	0,02	0,07	0,11	0,01	0,04	0,04	0,11	0,13	0,04	0,07
Rail	0,16	0,11	0,21	0,23	0,18	0,12	0,08	0,21	0,18	0,14
Car	0,75	0,78	0,63	0,50	0,68	0,75	0,77	0,61	0,49	0,68
Sum	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Comments

The number of passenger km according to Vips is lower than measured amounts for bus, air, rail as well as car. This indicates that the matrix does not include all journeys.

Some deviations between calculated and measured amounts of travel will of course depend on shortcomings of the model, besides shortcomings of the matrix.

The fairly large deviations in demand towards north of Sweden probably depends on shortcomings of the matrix.

The Vips model seems too sensitive to assumptions on car use prices and car comfort parameters. This is certainly an argument for introducing a random term.

Appendix 9 Summary of points on Public Transport Models

By Andrew Daly, RAND Europe, 21 May 2010

Important note: ***None*** *of my work on this study has been subjected to Quality Assurance in the usual way for RAND Europe and it must not be represented as a RAND Europe product.*

This note summarises the more important points made in my notes on public transport models of 18 March and 28 April 2010.

Specification of Utility
It is important that the specification of average or representative utility should be consistent across the main modelling stages of demand forecasting, assignment and appraisal. Sources of variation around the average arise from variation in preference or taste, measurement error including that arising from the use of zone centroids to represent location and the distribution of departure times. For practical reasons it is necessary to specify these variations as homoskedastic, which they are not in reality and this may well imply that the best formulation of representative utility functions is non-linear.

Alternatives and aggregation
It is important to be clear whether the distribution of travellers over alternatives is controlled by their own choices or by exogenous and system mechanisms. In the former case a maximising procedure (typically a logsum) will be required to obtain aggregate utility; in the latter case an averaging procedure will be appropriate. In many cases it will not be entirely clear which process is operating.

Headway changes
If there is no preference variation or measurement error, then when headways change the distribution of travellers over services is determined by their departure time, which can be considered exogenous. Clearly, for the typical one-mode public transport network this is the appropriate description.

However, when there is variation in preferences, which corresponds closely to what we would normally consider multiple public transport modes, or when there are different boarding points, so that locational variation within zones plays a role, then we enter the area of utility maximisation by choice and a logsum or rule-of-a-half calculation becomes more appropriate.

Logsum and rule of a half
These are measures of consumer surplus and can be applied correctly to choice models. There is a substantial theoretical underpinning and there is no doubt that the measures are correct. They can be used to evaluate changes in multiple modes and there is generally little difference between them.

Knowledge of the timetable
Obviously it is not true that all travellers know the timetables, particularly for alternatives they do not use. Nevertheless it is necessary to assume that many travellers do have this knowledge, particularly when services are infrequent and/or reasonably reliable. This assumption affects waiting time and choice of boarding point (if travellers know the timetable before they start their journey) and choice of service (if travellers know the timetable when they are at the boarding point – a weaker assumption).

Detail of programs and networks
There seem to be some issues here but this is not a useful area for me to advice. EMME/2 is used extensively for long-distance rail modelling in the UK without apparent problems.

What is to be done?
A model is needed of choice of destination and mode (in the sense indicated above) and this model needs to include a random preference element, e.g. a Gumbel term. The only model of this type currently available in Sweden is SAMPERS, so this model will have to be used until it is replaced or improved; there are criticisms of the elasticities generated by this model.

An assignment model is also needed and it seems that the choice is between:

- VIPS/Visum which has accuracy in detail but seems to me to attempt to combine modes in an inappropriate way (i.e. without random preference);
- EMME/2 which seems to be lacking in detail and not to deal appropriately with access modes (for reasons I still don’t understand).

It seems that the best approach is likely to be the use of a main-mode assignment, perhaps based on VIPS/Visum, which can generate appropriate (averaged) costs for a re-estimation of SAMPERS. Issues concerning mixed-mode trips, e.g. car-air or even train-air, are difficult and should be studied further. There is experience in our work with Eurostar, the current GB Long-Distance modelling, in West Midlands and in Sydney which can be drawn on (three using EMME, one using Visum).

Another approach is to use random sampling for all of the modelling. A theorem by Harald Lang seems to make this prospect more attractive, while there is experience in the US (using activity-based models) and in Stockholm which suggests that the approach can be feasible on a large scale.

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