Uncovered capacity in Incremental Allocation

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Abstract: This paper summarizes the work to estimate the value of uncovered capacity when using Incremental Allocation, including how it was calculated. The estimation was performed as part of the commercial valuation of Incremental Allocation. This valuation was made within the PENG framework. The aim is to estimate the value of new traffic that can be served by the uncovered capacity. The calculations are based on the UIC406 standard, but instead of analysing the traffic executed on a typical day the planned train paths are analysed. More precisely, the input data is a snapshot from planning tool TrainPlan from 2011-04-08, including AdHoc train paths. The results show that a large portion of the available capacity is hidden from use by the current planning methods and scheduling rules.

Introduction

This paper describes the method used to evaluate the value of uncovered capacity in an Incremental Allocation (IA) setting. The calculations are based on the standard UIC406 [1] applied to planned train paths for each individual day of a running week. The data for the planned train paths were taken from the planning system used at Trafikverket (i.e. TrainPlan). The aim was to evaluate the benefit of the IA timetable flexibility and day-by-day optimization. The value of additional traffic is used to assess the benefit of uncovered capacity, but the capacity could also be used for e.g. possessions or improved quality in terms of better punctuality.

UIC406

UIC406 [1] is a standard for measuring railway capacity. It was developed by UIC, "Union Internationale des Chemins de fer". UIC currently has 197 members in 5 continents. Railway capacity is quit hard to measure, and is e.g. dependent on the design of the infrastructure, the homogeneity of the traffic and the traffic time distribution. UIC406 assigns a capacity usage value for a real or imagined traffic,but it is not a universal tool for calculating a line's potential production capacity. That is, it is not a tool for scheduling traffic, but rather a tool for evaluating traffic patterns.

Short description of UIC406

To calculate the capacity usage according to UIC406 we need a timetable for the line segment to be investigated and the timetabling rules such as the minimum safety distance between trains. Given this information the shortest make span (i.e. the shortest time to execute the plan) is calculated. UIC406 does not allow for train orders on individual atomic line segments to be changed, and as a consequence it is not possible to move a train meeting or train overtaking to another station than the planned one. The make span is calculated by compressing the timetable by moving each train as early as possible[1].The ratio between the compressed timetable duration and the original timetable duration is the capacity usage.

In the figures below a simplified graphical timetable is given, with time on the X-axis and stations on the Y-axis. The grey horizontal bars show the time that can be "gained" by compressing the timetable, leading to figure 2. The light dotted line marks the earliest starting time for the green train at station S2 according to the timetabling rules. Note that the stop at S3 by the green train is not needed this particular day and can be removed. This stop has been planned for a meeting with a train that runs other days.

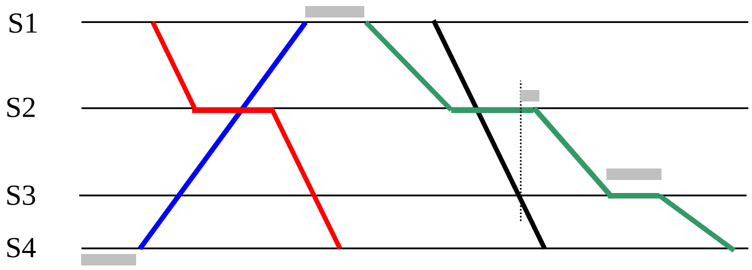


Figure 1 Original timetable

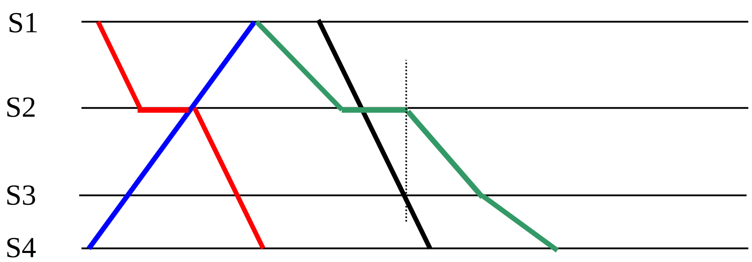


Figure 2 Compressed timetable

[1] There are many algorithms for this, one is Critical Path Method, used in project planning. Another one for calculating the shortest cycle time in a periodic timetable is MaxPlus Algebra.

Capacity calculations performed by Trafikverket

Each year Trafikverket calculates the capacity usage of the Swedish railway based on the UIC406, together with manual assessments. The result is published in a report [2]. The timetable segments to be analysed using UIC406 are decided based on two criteria:

1) Each line investigated shall be free from major joints. This is because otherwise the compression of the timetable is hard to perform.
2) Two different time frames are used, one typical 24 hour time frame and one 2 hour time frame representing the typical peak hours of the day.

Data for the yearly calculations are collected from Trafikverket's monitoring systems. That is, the calculated capacity usage value is for the executed traffic rather than for the planned train paths. This is different from the approach used in this paper, where the planned train paths are the input data. New trains and possessions are added to spare capacity in the planned timetable, and therefore the value of uncovered capacity in the planning process should be calculated based on the planned train paths rather than on the executed traffic.

The output of the yearly capacity analysis is a classification of the different lines into "red" (large capacity problems), "yellow" (some capacity problems) and "green" (small or no capacity problems). Different lines can get different classifications depending on the time frame, so a line may be yellow or green in the 24 hour period and at the same time be red in the 2 hour time period.

Figure 3 Part of the Swedish railway network, coloured according to capacity usage. From the yearly capacity analysis carried out at Trafikverket [1].

The annual train timetable

The annual timetable is created and managed in the tool TrainPlan. During the long term planning process a annual timetable is created from the operators applications. The timetable is finalised in September each year, and after finalisation it is fixed. That is, all train paths and possessions are fixed in time at all timetable points (stations, major points and many important signals), and they can not be changed. However, trains and possessions may be cancelled, and new trains and possessions added to any remaining free capacity. New trains and possessions are also fixed. The applications for new trains are processed in a first-come first-served order during the so called AdHoc process. Note that no replanning of finalised (i.e. fixed) trains is performed.

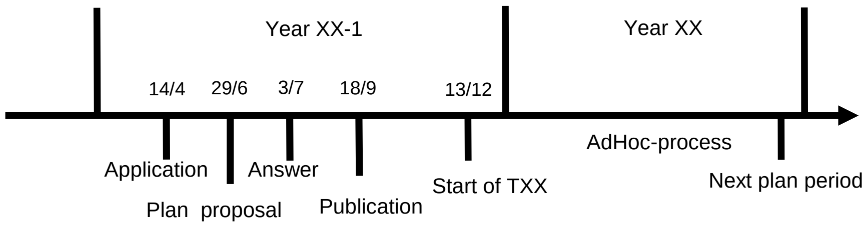


Figure 4 The Timetable Process

At any point in time during the AdHoc process a snapshot of the planned traffic can be taken, containing all planned traffic from the current point in time to the end of the current annual timetable.

Incremental Allocation

Incremental Allocation (IA) is an alternative way of planning and managing the timetable. In IA the times are not fixed at all timetable points, but only where there are major events such as e.g. passenger stops, freight loading or driver changes. These important points and their timetable times are called delivery commitments and are subject to contractual agreements. The train paths are allowed to change as long as the delivery commitments are honoured. This increase in flexibility uncovers capacity that is (unnecessarily) occupied by fixed train paths in the current process. This opens up for daily optimization of the entire timetable, as well as increased possibilities for constructing attractive train paths for AdHoc trains. The daily optimization can e.g. be used to increase the robustness of the timetable and thereby enabling a more punctual traffic. However, this paper focuses on the value of using the uncovered capacity to run more trains.

A method for calculating uncovered capacity in Incremental Allocation

To estimate the value of uncovered capacity when implementing IA compared to the traditional method an approximation method has been developed. In short, the method consists of applying the UIC406 calculation on a snapshot of the train paths from the planning tool TrainPlan, where all currently planned traffic is included. The time frame investigated can be a day, a week or the rest of the timetable period. Following the description in UIC406 the network is split into “straight lines”, i.e. no major joints are allowed on a line to be analysed. For each defined line and each defined time period a UIC406 capacity usage value is calculated by compressing the timetable segment and compare it to the base case.

In our calculations, if the investigated timeframe contains several days the calculation is performed with the days overlaid and there is only one train path for each train even if the train runs multiple days. If a train travels over midnight it is split into a before-midnight and an after-midnight part before the compressing starts. The two train-parts will be compressed separately.

The figures below illustrate how trains travelling over midnight into the next day are handled. The red train that passes over 24:00 is “cut” and the second part is added to the beginning of the day. When compressing the timetable we get the train paths shown in figure 6. As it is the last arrival time that is used in IUC406, the long stop connecting the two train parts is not included.

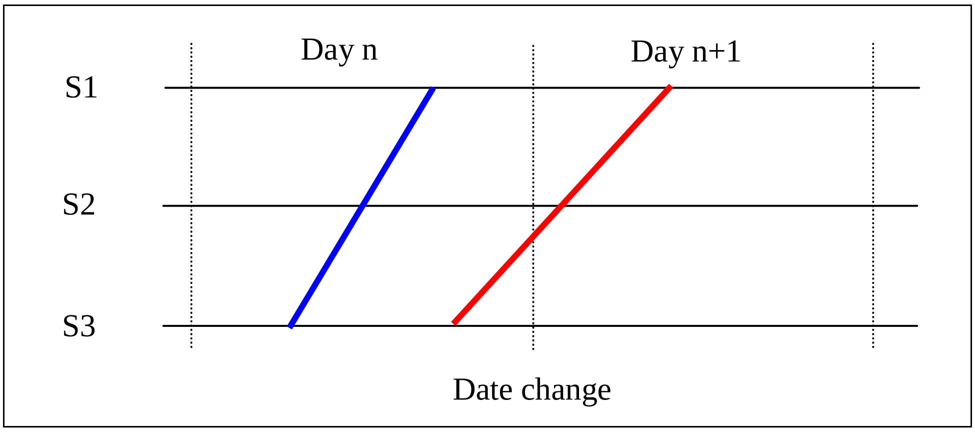


Figure 5 Overlaying days when the time frame contains several days

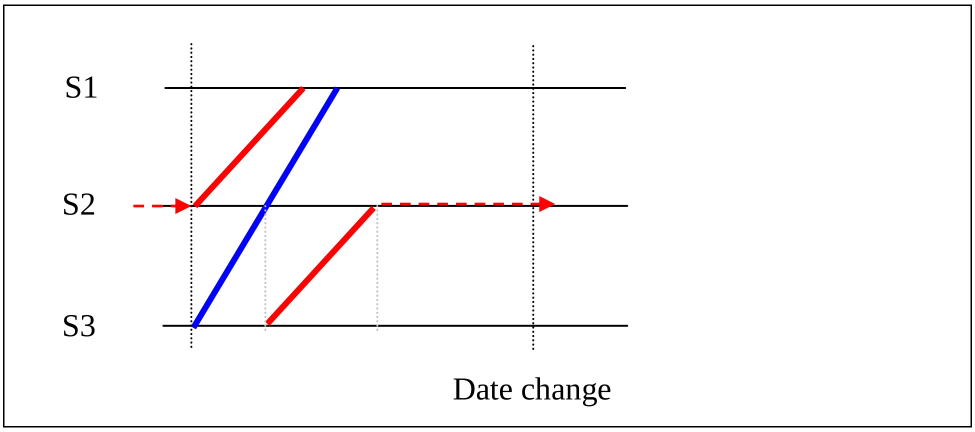


Figure 6 The red train travelling over midnight has been split in two, and after compressing the timetable it has a long "stop" at station S2

Calculations

To estimate the uncovered capacity resulting from IA several calculations are performed on individual days. The UIC406 capacity usage for the individual days is compared with a base case capacity usage which is calculated by using UIC406 on the remaining timetable period, 274 days. The base case represents the current planning process, where daily train path variations are not allowed. As an example, figure Figure 7 shows the uncompressed timetable for an individual day, and figure Figure 8 the compressed timetable for the same day. Figure Figure 9 shows the compressed timetable for the remaining timetable period (the base case).

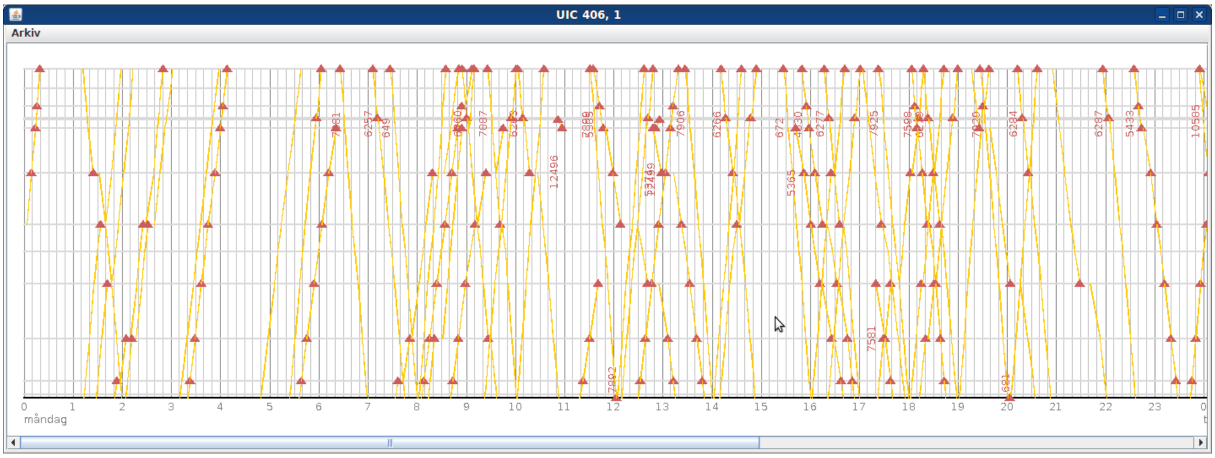


Figure 7 An individual day, original timetable.

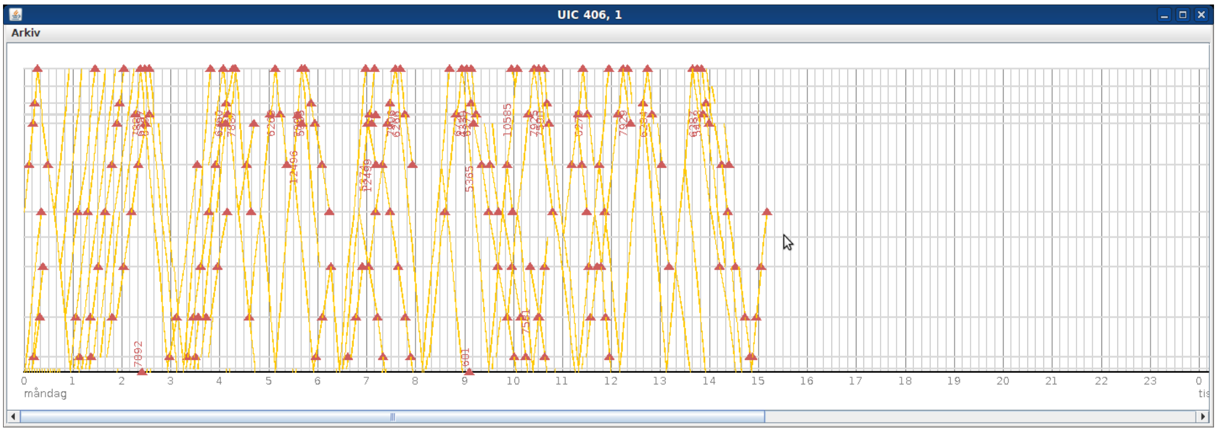


Figure 8 An individual day, compressed timetable.

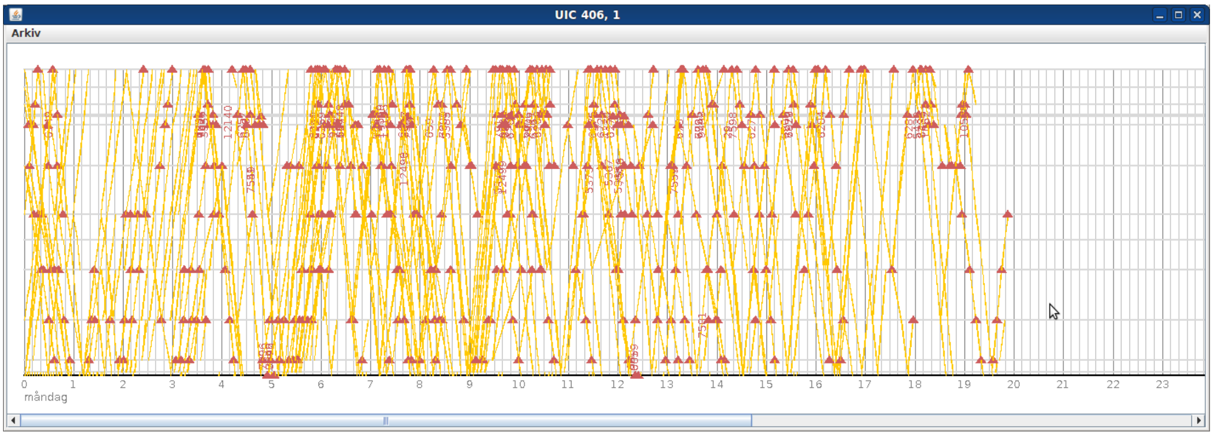


Figure 9 Remaining timetable period (base case), compressed.

Individual calculations were made for each day of the first week in the snapshot from TrainPlan, for all investigated lines. Individual days are used as this reflects the daily train path variations allowed by IA. The day with the largest capacity usage is chosen and compared with the base case, for each line. The difference between the individual day with the largest capacity usage and the base case is taken as the *IA uncovered capacity***.** Figure 10 shows the capacity usage for each of the 7 days for the line between Gävle and Söderhamn. For this line Friday has the largest capacity usage.

Gävle-Söderhamn		76 km		used time	occupation	# trains	Time per train
Start Day		End Day	Weekday	86400	100%		
	117	117	Thursday	54589	63%	61	895
	118	118	Friday	58340	68%	60	972
	119	119	Saturday	34657	40%	29	1195
	120	120	Sunday	29167	34%	23	1268
	121	121	Monday	54660	63%	53	1031
	122	122	Tuesday	57931	67%	61	950
	123	123	Wednesday	56822	66%	57	997
				max	68%	average	1044
	117	364	Rest of the year	71506	83%	243	294

Figur 10 Example of capacity usage calculations for each day of the first week

The next step is to estimate how many new train paths the IA uncovered capacity might serve. This is a rough estimate based on averages and a scaling factor that controls how much capacity that might be used by new train paths. The roughness of the method is caused by at least two factors: 1) the demand for new train paths is unknown and 2) the anticipated new train paths are not planned in detail, and therefore we do not know how much capacity they require, or if there is a feasible timetable solution. The latter is due to the former. As we do not know which train paths that would be demanded we do not know what kind of train to plan for. The valuation is therefore key value based and gives a rough estimate of the values involved.

To go from capacity usage to the number of train paths the scaled down uncovered capacity is divided by average capacity consumption of a train. The average capacity consumption is calculated by taking the compressed timetable segment's duration and dividing it by the number of trains in the timetable segment. The number of train paths that fit on the scaled down uncovered capacity is then multiplied with the length of the line to get the number train kilometers per day. An example is given in figure Figur 11. The calculated difference between the worst individual day and the base case, i.e. the uncovered capacity, is scaled down with a factor of 30%. Note that capacity removed by this scaling may be useful for other activities such as e.g. possessions or timetable robustness.

	83%	Capacity usage whole year
-	68%	Max cap. usage in chosen week
	15%	% new, uncovered capacity
*	86400	One day in seconds
	12960	IA uncovered capacity in seconds
*	30%	Part possible to realize in additional traffic
	3888	Potential additional traffic, in seconds
/	1044	Average time per train
	3.72	# new trains
*	76	Length of the line segment
	283	Additional train kilometers, from IA

Figur 11 Example of calculation of estimated number of new train paths

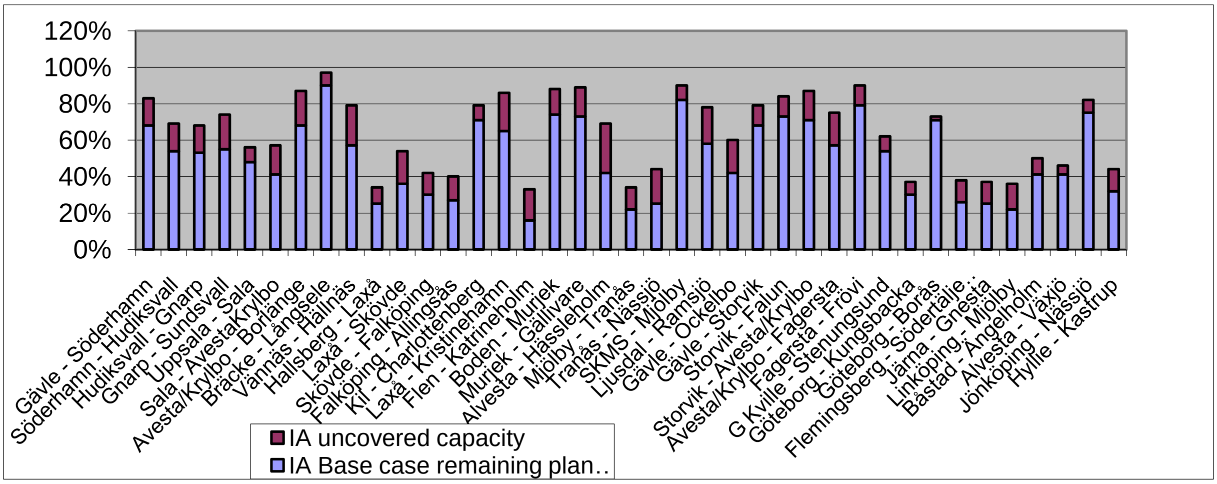
To get a monetary value for the new trains served by the uncovered capacity the number of train kilometers per day is multiplied with the number of anticipated running days. This total number of train kilometers is multiplied with the key value 139kr. This key value was provided to us by Trafikverket.

Result

We restricted the calculations to the "yellow" line segments from the 2011 yearly capacity report (excluding some small, manually dispatched lines). This resulted in an IA uncovered capacity of 457056 seconds per day in total. With a scaling factor of 30% and a whole year (counting weekdays, not Saturdays and Sundays, resulting in 250 days) we get 4958541 train kilometers of potential new traffic. With the key value of 139 kronor / kilometers we get a total monetary potential estimation of 689 000 000 kronor for a complete year. The result shows that there is a large hidden potential in today's way of planning.

Note that this is a potential, we do not know the actual demand for additional traffic. The calculations were performed to give a hint of the magnitude of the value of the hidden capacity, and as an indication of the extent to which the already available infrastructure can be used.

The diagram below summarizes the result for all "yellow" line segments. The blue bars are the maximum capacity usage from the individually compressed days, and the red bar on top is the IA uncovered capacity when compared to the base case consisting of the remaining timetable period.



Figur 12 Uncovered capacity for all yellow line segments

Note that the rest capacity already available in the base case is not considered to be uncovered by IA. This is because we do not know why this capacity "reserve" is present. Rather, we only attribute the capacity uncovered by planning for each individual day to IA.

References

[1] UIC CODE 406, 1st edition, June 2004

[2] *Kapacitetsutnyttjande och kapacitetsbegränsningar hösten 2011, TRAFIKVERKET, Dnr: TRV 2012/5114*, Magnus Wahlborg, Magdalena Grimm, Samhälle Planering Kapacitetscenter, 2012-01-25