Activity times, tolls, public transit, the utility function, and economic evaluation: where we stand and what we need

KN, (ab)using work by many people, but in particular by Yu Chen

1 A “standard” setup

1.1 Standard scoring function ...

... for most of our practical experiments

$$U = \sum_i U_{perf,i} + \sum_i U_{trav,i} \tag{1}$$

Note: ***Penalty for being late not enabled.*** Time structure given by initial demand, facilities opening times.

$$U_{trav,i}(x) = \beta_{mode} x \tag{2}$$

$$U_{perf,i}(x) = \beta_{perf}\, t_{*,i}\, \ln(x/t_{0,i}) \tag{3}$$

1.2 Other elements of setup for following results

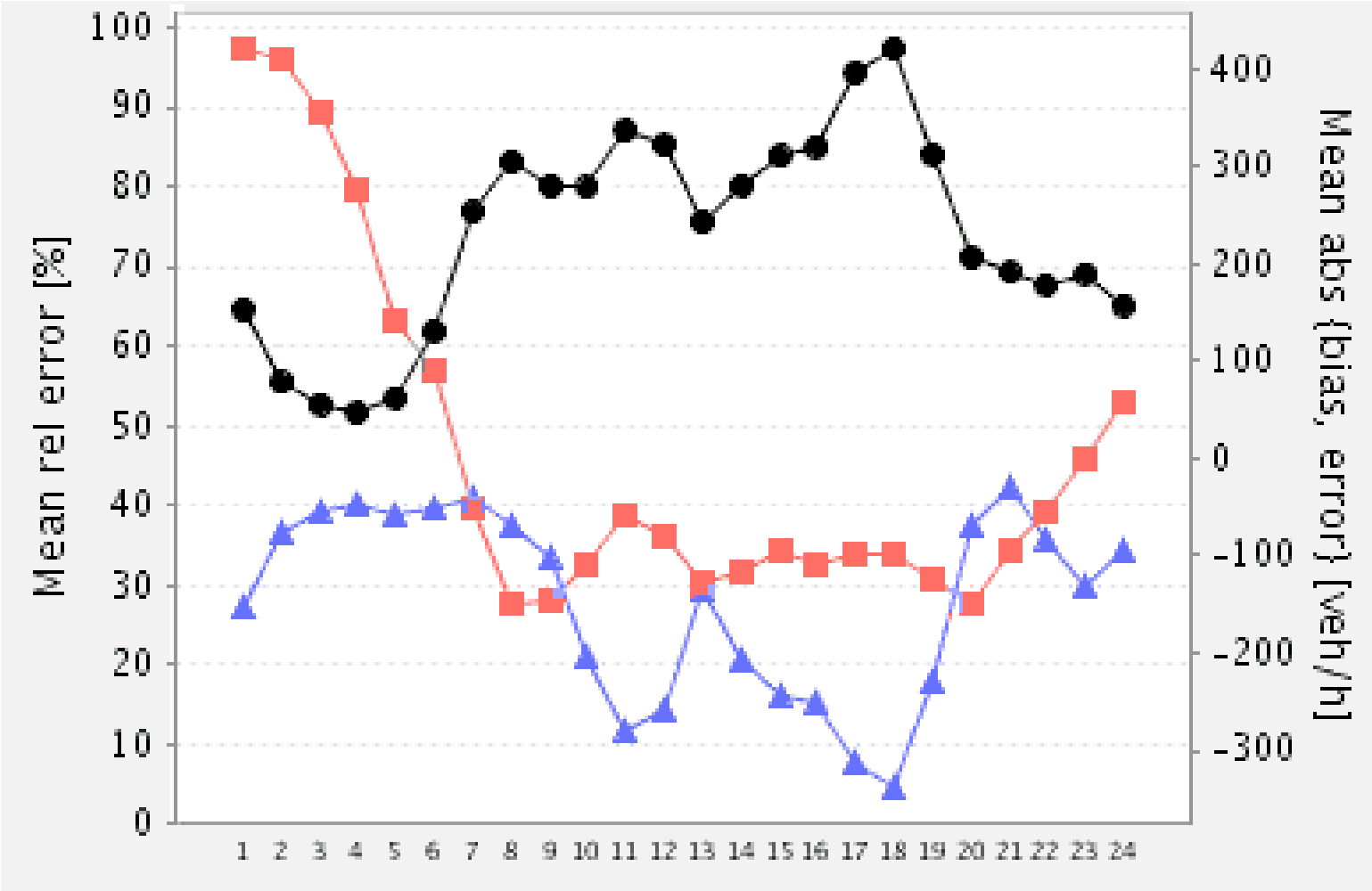
Network: ARE, with corrections from openstreetmap (work by Yu Chen)

Public transit: “pseudo” [[for experts: “old”, i.e. ignoring first/last link]]

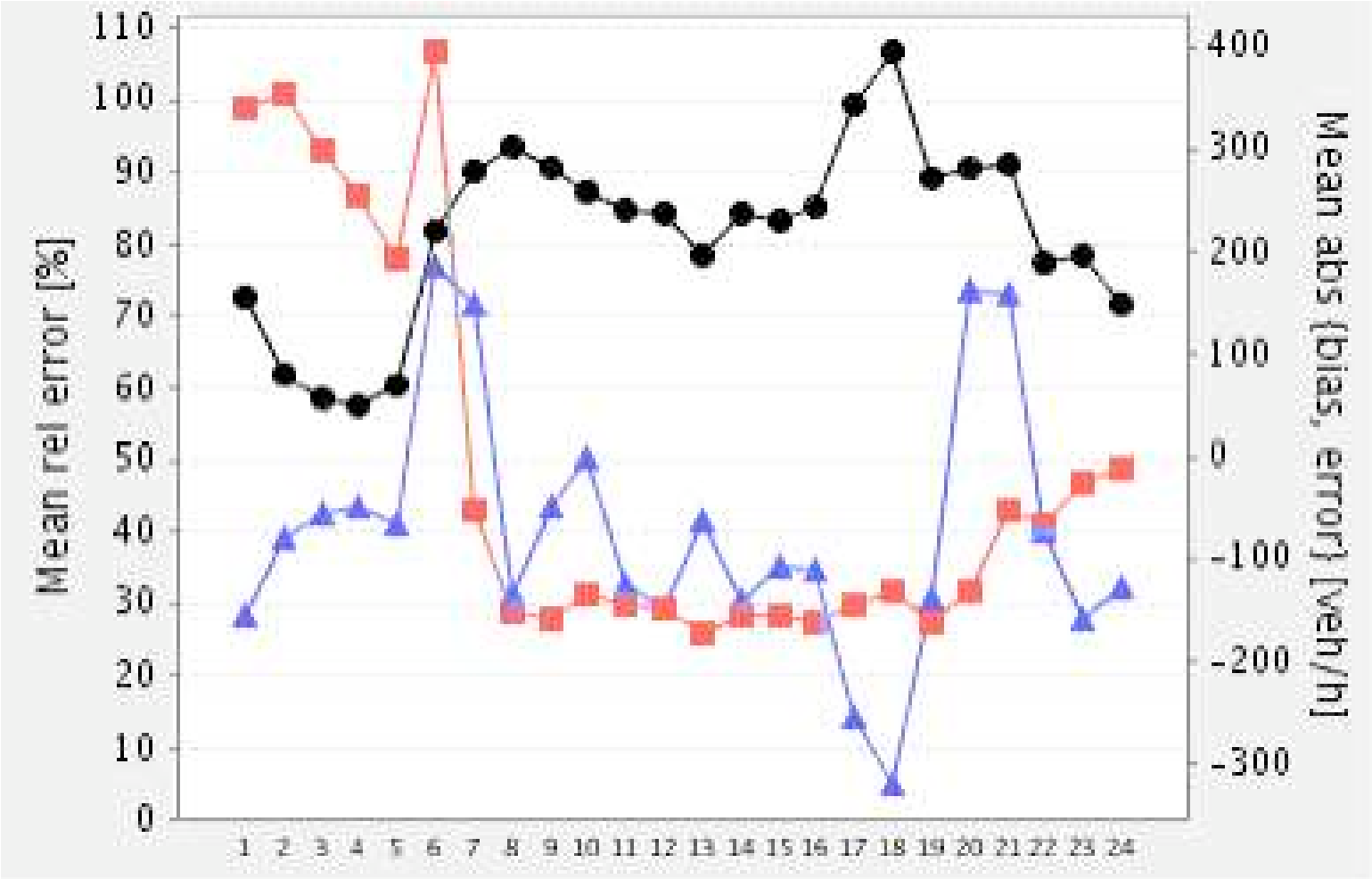
Essentially car vs. “other”.

Choice dimension of the adaptation: routes, times, mode.

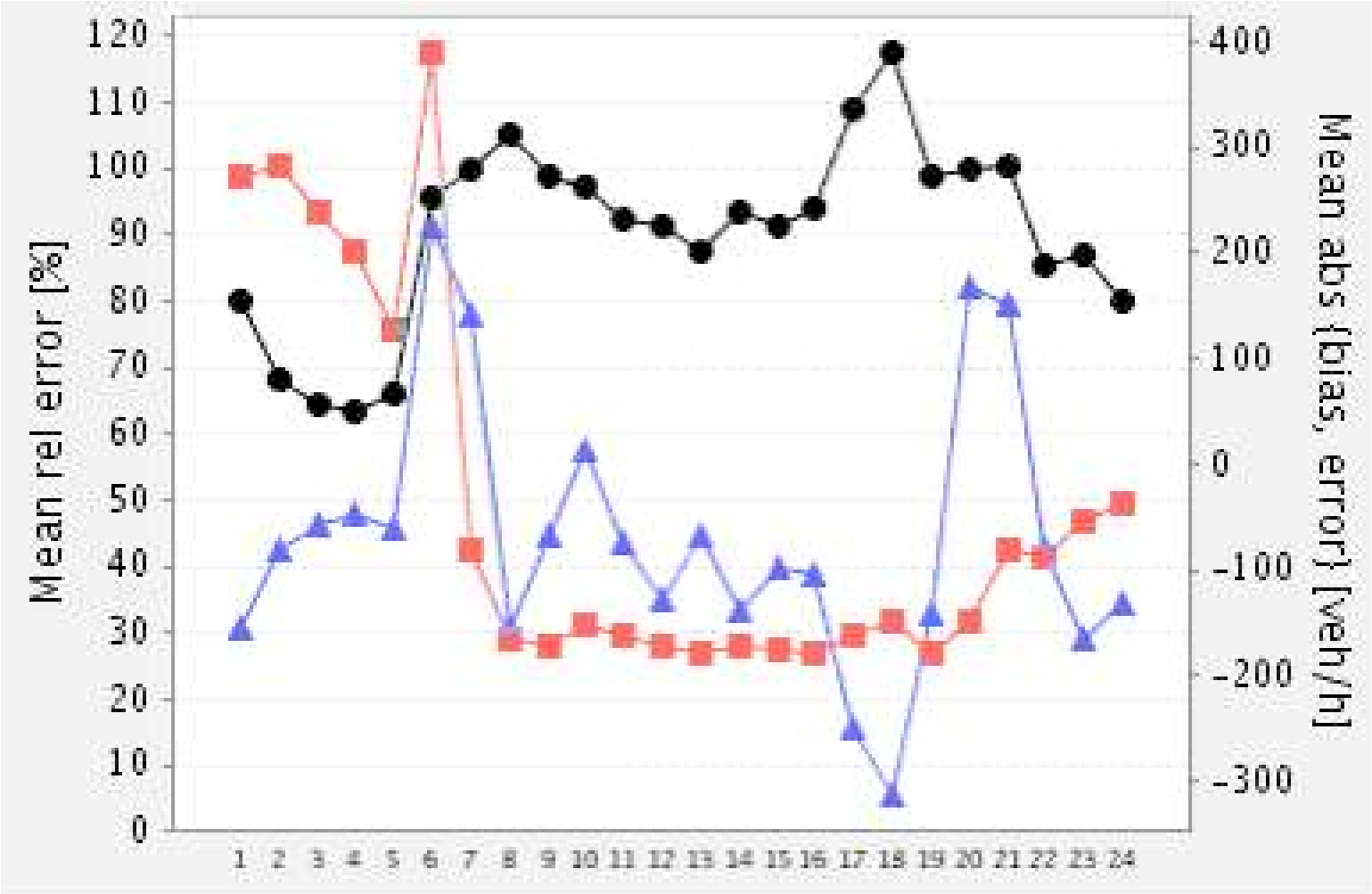
1.3 Validation with “standard” setup: it.100



1.4 Validation with “standard” setup: it.500



1.5 Validation with “standard” setup: it.1000



1.6 Remarks at this point

- Additional iterations seem to help the quality of the results.

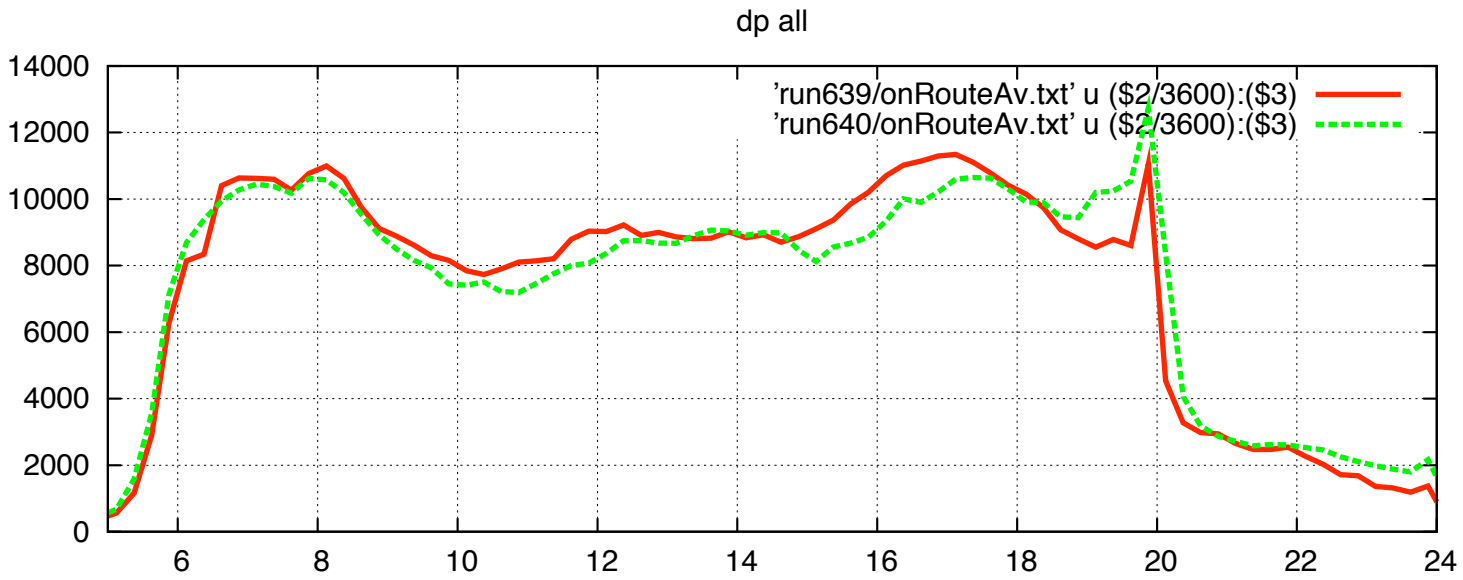
  (This is in contrast to earlier results that we had.)

  (There are problems in morning/evening ... but I think they are conceptually clear: opening times.)

- This also probably implies that MB's initial time structure is good, but the simulation can still improve upon it.

  (or is it an effect of route adaptation only?)

1.7 Toll reaction with “standard” setup



To note: There is a time reaction. (Details do not matter at this point; will come back to that.)

1.8 Economic interpretation of toll reaction

Get something like (numbers are from different scenario):

- Average score before toll: 102.66
- Average score after toll: 92.47 (i.e. a loss, due to toll payments, *which are part of the utl fct*)
- Average score after toll after redistribution: 104.03 (i.e. a gain)

I.e.: 1.37Eu $*$ 260'000 agents $=$ 356'200Eu/day $\approx$ **100 mio Eu / year**.

To which extent can score *differences* (!) be interpreted as utility gains/losses?

- Marginal utl $U'_{perf,i} \approx \beta_{perf}$ (see below) is utl that you gain if you save time (e.g. by taking faster route by paying toll).
- Utl is converted to Eu via (something like) "willingness-to-pay".

[[The latter is currently quite ad-hoc, but can be coupled to willingness-to-pay-for-more-leisure-time and/or to marginal wage rate (minus marginal (dis)utility of work-time): If you work one more hour, you

- lose one our of leisure time (opportunity cost of leisure time): $\beta_{leisure}$
- have to suffer your boss for one more our (disutl of work time): β_{work}, often assumed to be negative
- gain wage for one more hour: w

At the optimum:

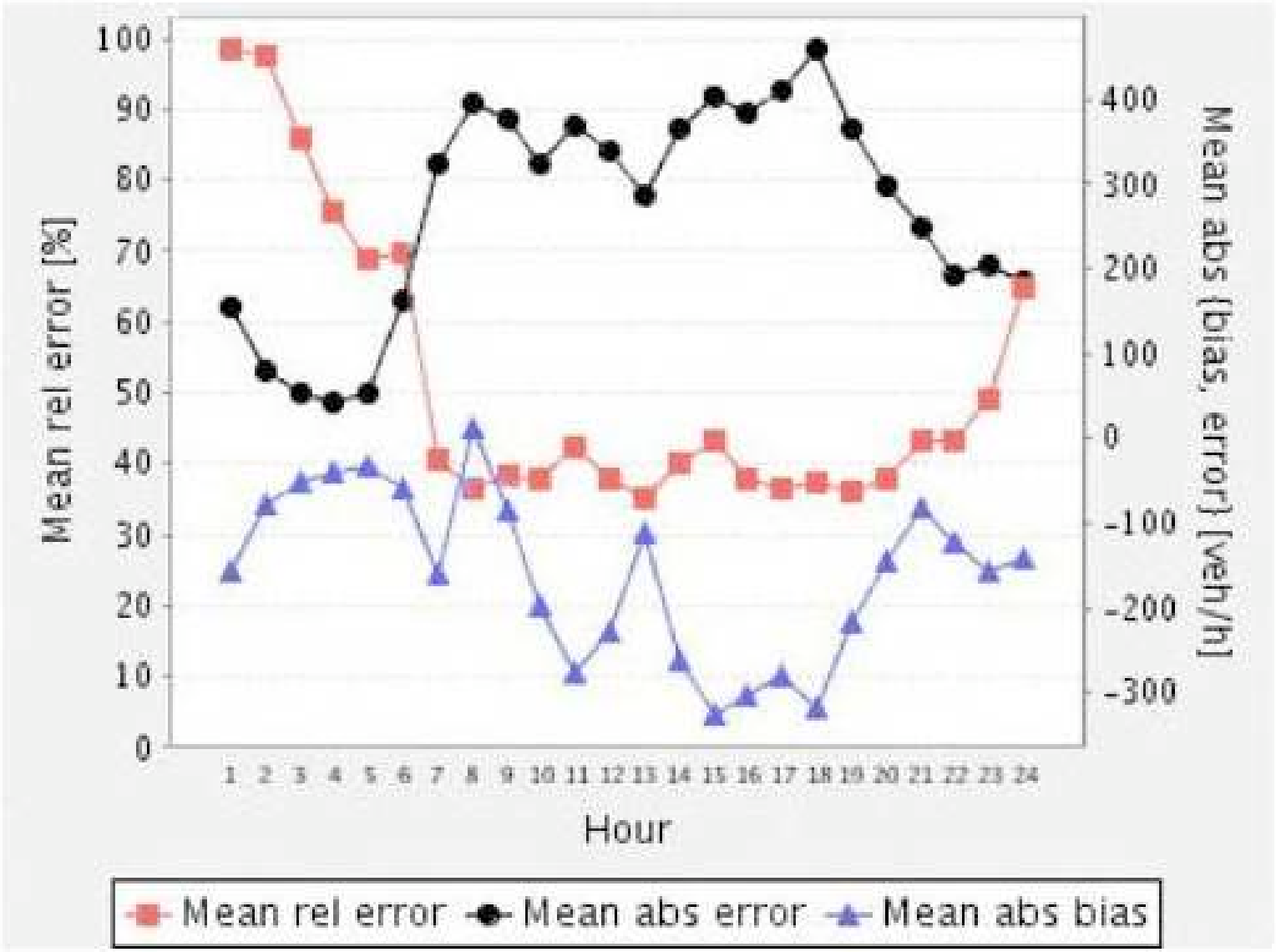
$$\beta_{leisure} = \beta_{work} + w \; . \tag{4}$$

Source: Jara-Diaz et al]]

2 Choice dimensions

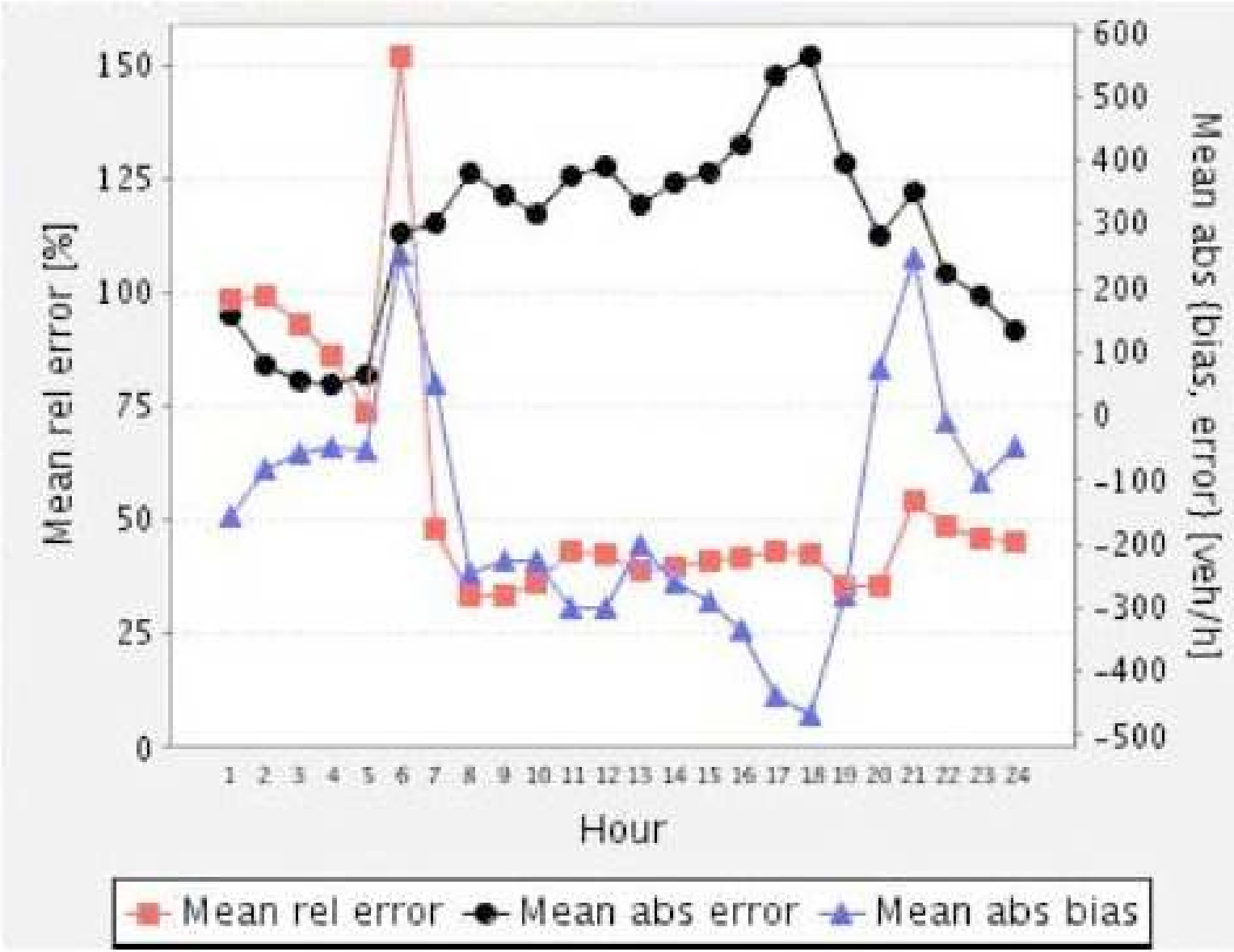
Look at different choice dimensions after starting with the initial plans.

2.1 Routes only



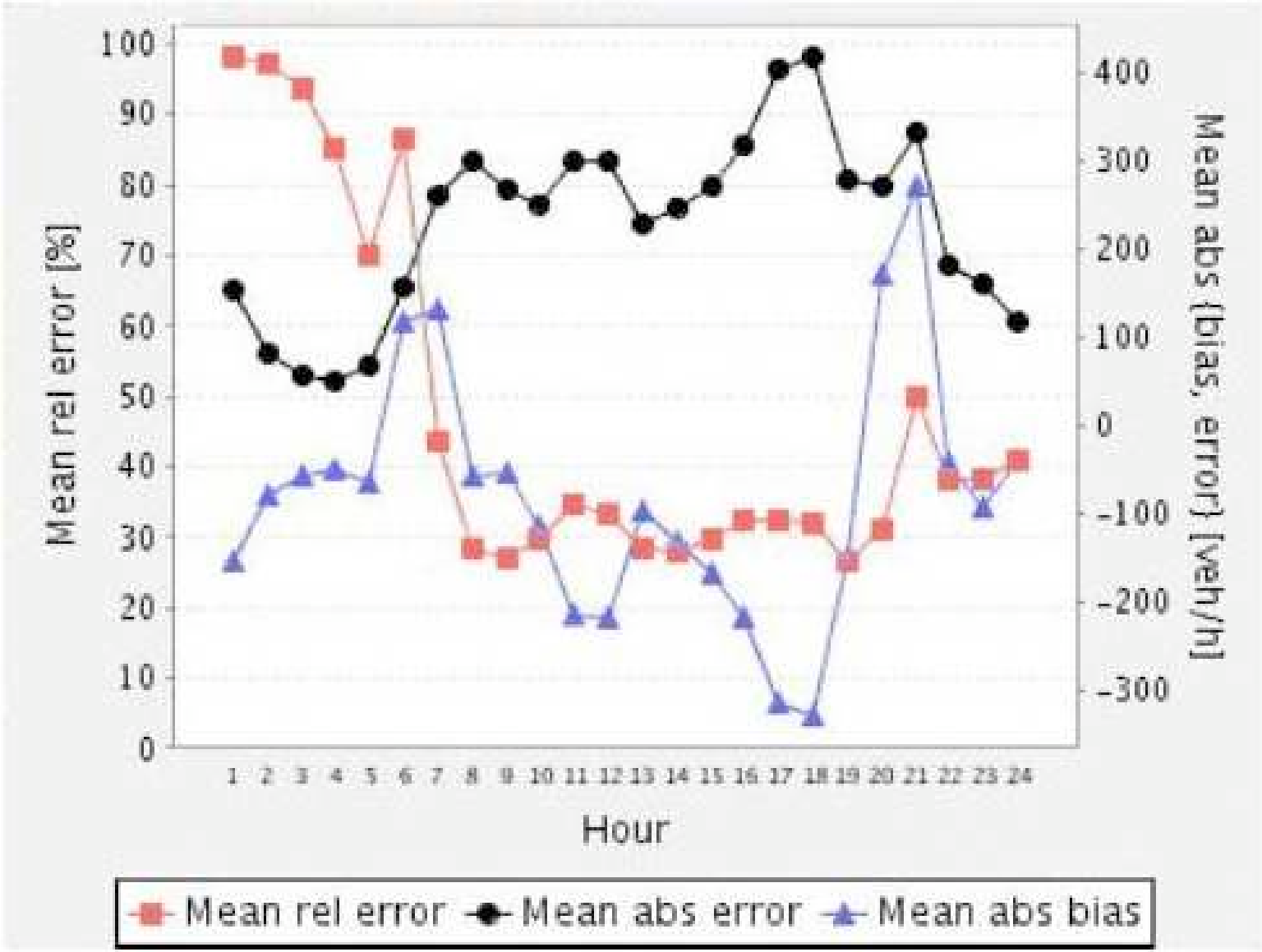
(a) route choice only

2.2 Routes and times



(b) route and time choice

2.3 Routes and times and mode



(c) route, time and mode choice

2.4 Consequences

Adding choice dimensions seems to make the results more realistic.

IMPORTANT: The economic appraisal depends on that: A toll where you do route adaptation only ...

... results in a ***totally*** different economic appraisal ...

... then one where you also adapt times and/or mode choice.

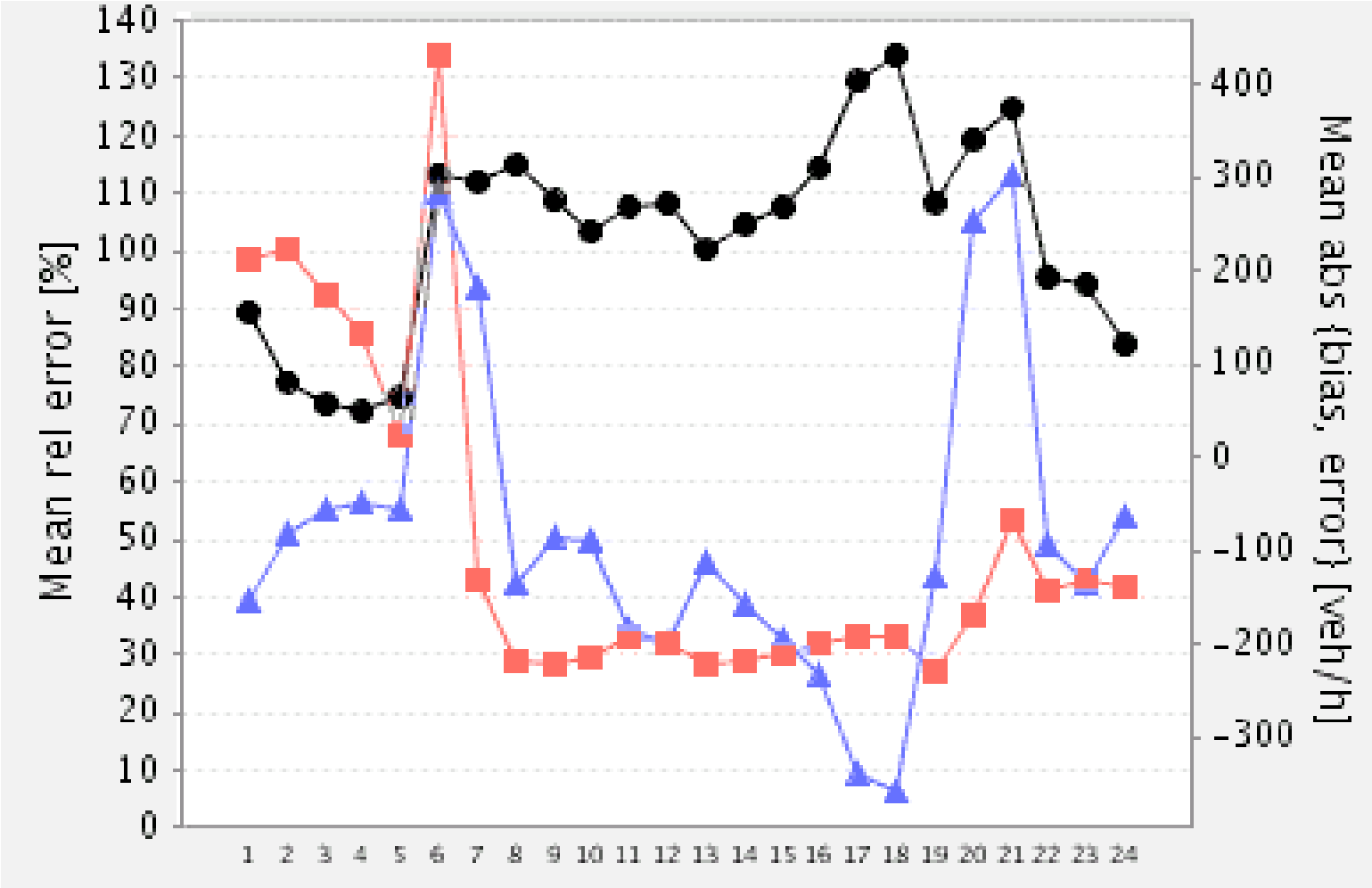
3 Adding “minimum activity duration”

Activities with durations x_i less than the typical duration $t_{*,i}$ receive penalty

$$\beta_{md}(t_{*,i} - x_i) \ . \tag{5}$$

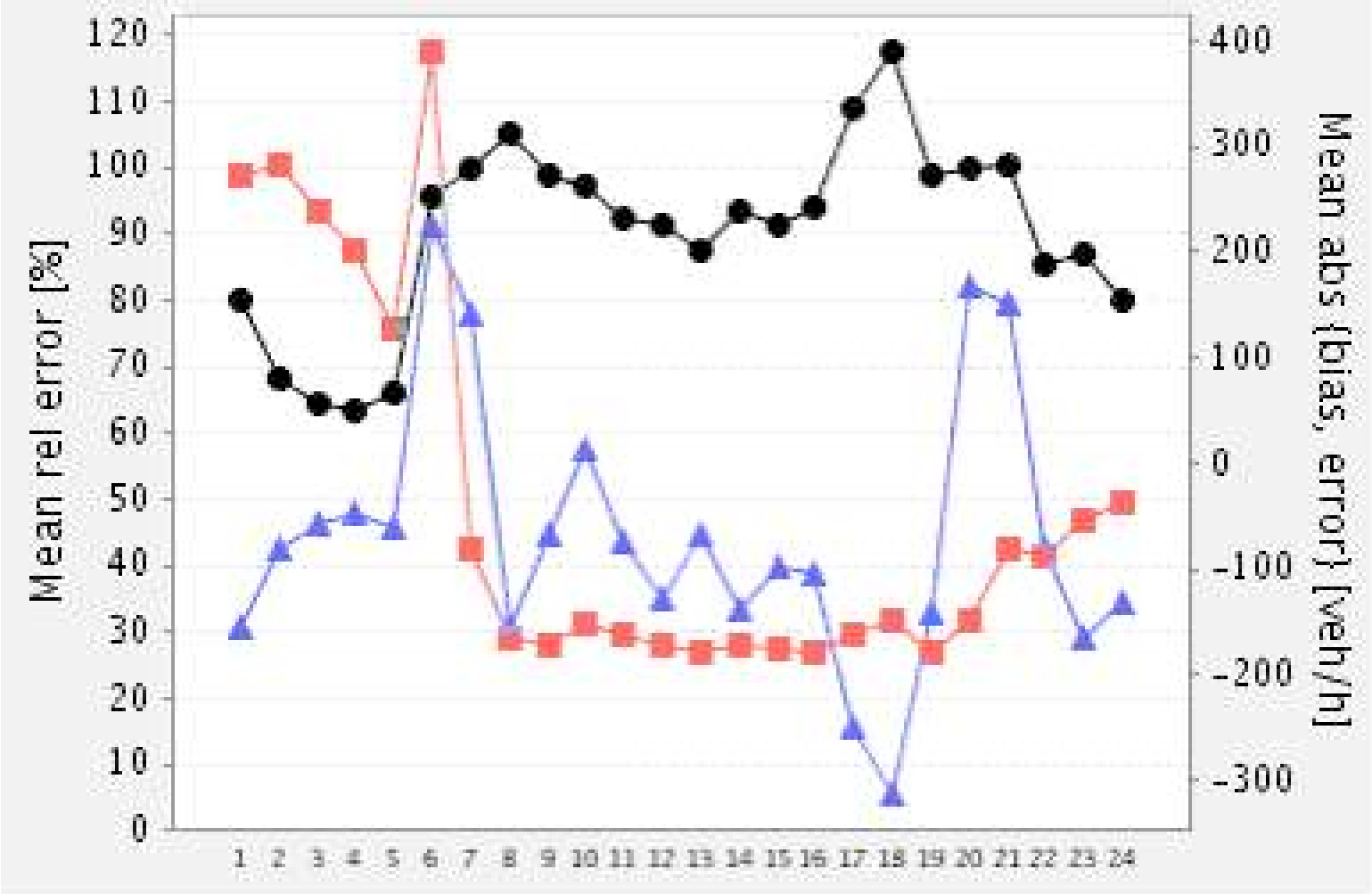
(β_{md} for example $-18 Eu/h$.)

3.1 Validation with “minimum activity duration”

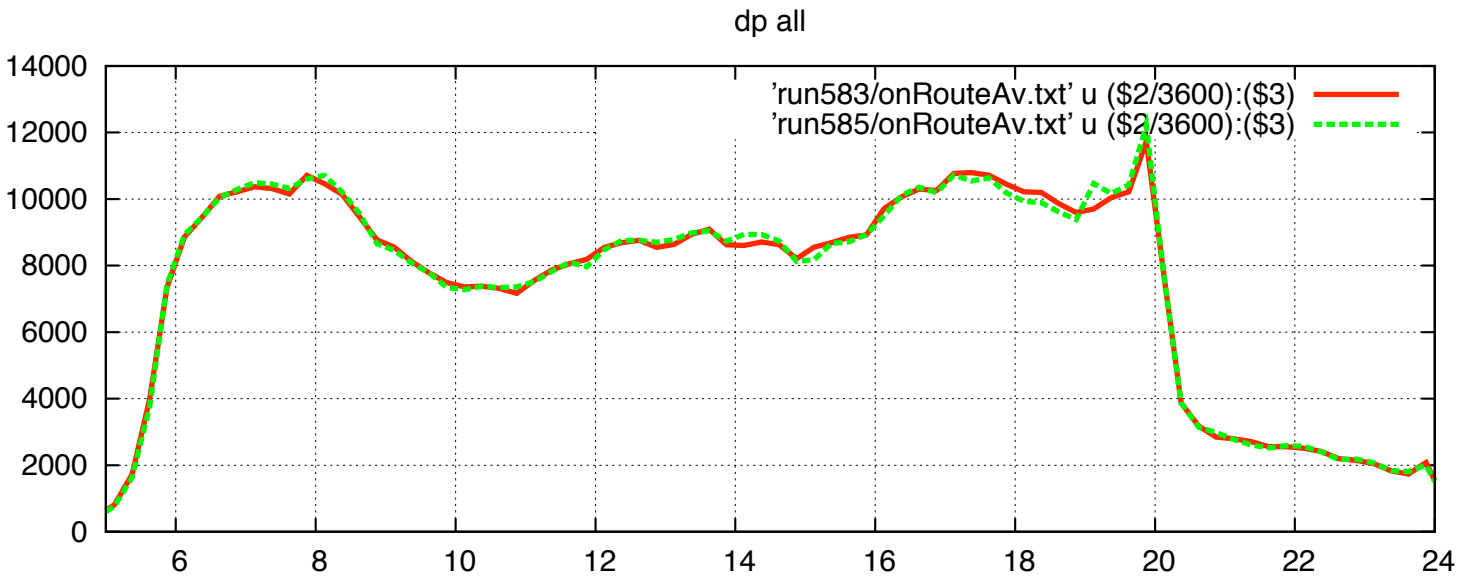


I.e. no (discernible) time reaction.

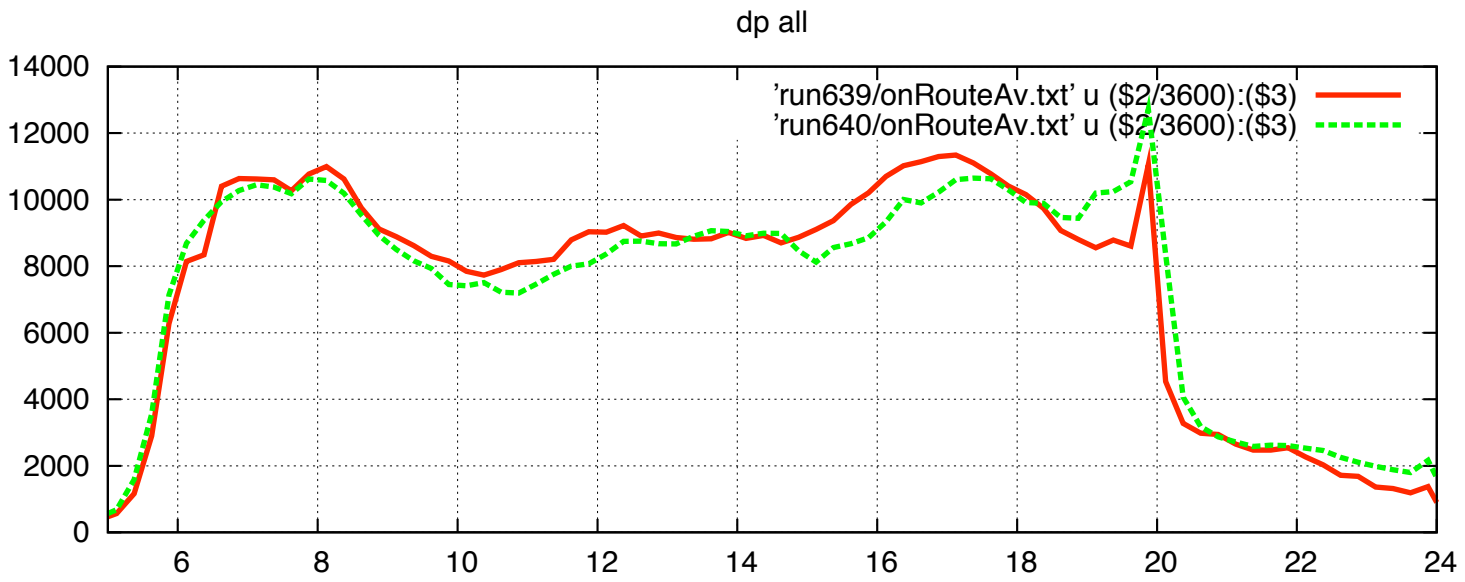
3.2 (Compare to “standard” setup)



3.3 Toll reaction with “minimum activity duration”



3.4 (Let's go back to "standard" setup)



I don't think that this is more stretched ...

... but instead durations are not strongly anchored.

4 Consequence

So which one is correct?

Which one should be analyzed for economic appraisal?

Need to anchor utl fct more firmly in reality.

But what is the exact nature of the problem?

4.1 Marginal utl of time (= slope)

Should be same for all acts (no constraints, constant travel times). Marginal utl:

$$U'_{perf,i} = \beta_{perf}\, t_{*,i}/x \tag{6}$$

Same for two acts:

$$\beta_{perf}\, t_{*,i}/x_i = \beta_{perf}\, t_{*,j}/x_j \tag{7}$$

$$x_i/x_j = t_{*,i}/t_{*,j}\ . \tag{8}$$

Thus the interpretation of $t_{*,i}$ as **typical durations**: They regulate the shares of time of the activities.

At the typical duration,

$$U'_{perf,i}(t_{*,i}) = \beta_{perf}\ , \tag{9}$$

thus the interpretation of β_{perf} as (roughly) the marginal utility of any activity.

4.2 Curvature

tells us something about resistance of act to time changes. E.g. strong curvature:

- Small reduction in time $\Rightarrow$ marginal utl much increased
- Large reduction in time $\Rightarrow$ marginal utl much *de*creased

$$U''_{perf,i} = -\beta_{perf}\, t_{*,i}/x^2 \tag{10}$$

$$U''_{perf,i}(t_{*,i}) = -\beta_{perf}/t_{*,i} \tag{11}$$

The unfortunate truth: *There is no free parameter left* to calibrate the curvature at the typical duration.

Problem becomes clearer if you re-write:

$$\beta_{perf}\, t_{*,i} \ln(x/t_{0,i}) = \beta_{perf}\, t_{*,i} \ln x - \beta_{perf}\, t_{*,i} \ln t_{0,i} \tag{12}$$

That is, once β_{perf} (marginal utl of time) and $t_{*,i}$ (typical duration) are given, then $t_{0,i}$ does nothing more but a vertical shift of the curve.

4.3 How to continue?

Two issues:

- **Would like to control both slope and curvature at typical duration.**

  2nd degree polynomial would nicely do that.

  Note: As long as I cannot drop utilities, the absolute height at the typical duration does not matter.

- **Would like to include money in a systematic way.** I find most convincing to have a utility of money, i.e. something like

$$U = \beta_{perf} * ... + \beta_{mon} \ln M \tag{13}$$

That is, utl no longer expressed directly in monetary units.

(By the way, difference between two utilities then

$$\Delta U \approx \beta_{perf} * ... + \beta_{mon} \frac{\Delta M}{M} \tag{14}$$

that is, the linearized utl of money is proportional to $1/M$ where M ends up being the income.

But that may be non-standard, and not much consistent theo seems available.

4.4 Direct vs. indirect utl

Our utl fct is a *direct* utl function. E.g.: How is the utl changed if a toll is introduced but your plan remains unchanged?

Alternativ is *in*direct utl function. E.g.: How is the utl changed if a toll is introduced and you can adjust your plans optimally?

Random utl theo typically measures the latter.

Matsim needs the former as input, and computes the latter as output. PLUS: It depends on the choice dimensions. (Utility gains are generally the higher, the more choice dimensions there are.)

There is also Gunnar's work ...

... which can be seen as a method to calibrate the *direct* utl fct.

5 Summary

Need utl fct

- where both slope and curvature at typical duration can be controlled
- where the relation to money is clear (possibly express utility of money in terms of utility of time)
- which is as much as possible anchored in existing theory (Jara-Diaz; “utl of money”)

An issue: Estimation of RUM from revealed/stated preference data gives us utl functions of the wrong type (indirect instead of direct utl fct).