9th Urban Mobility India Conference & Expo 2016
Planning Mobility for City's Sustainability

TRAVEL TIME DYNAMICS

A study of Travel Time Budgets in an Indian city - the case of Chennai

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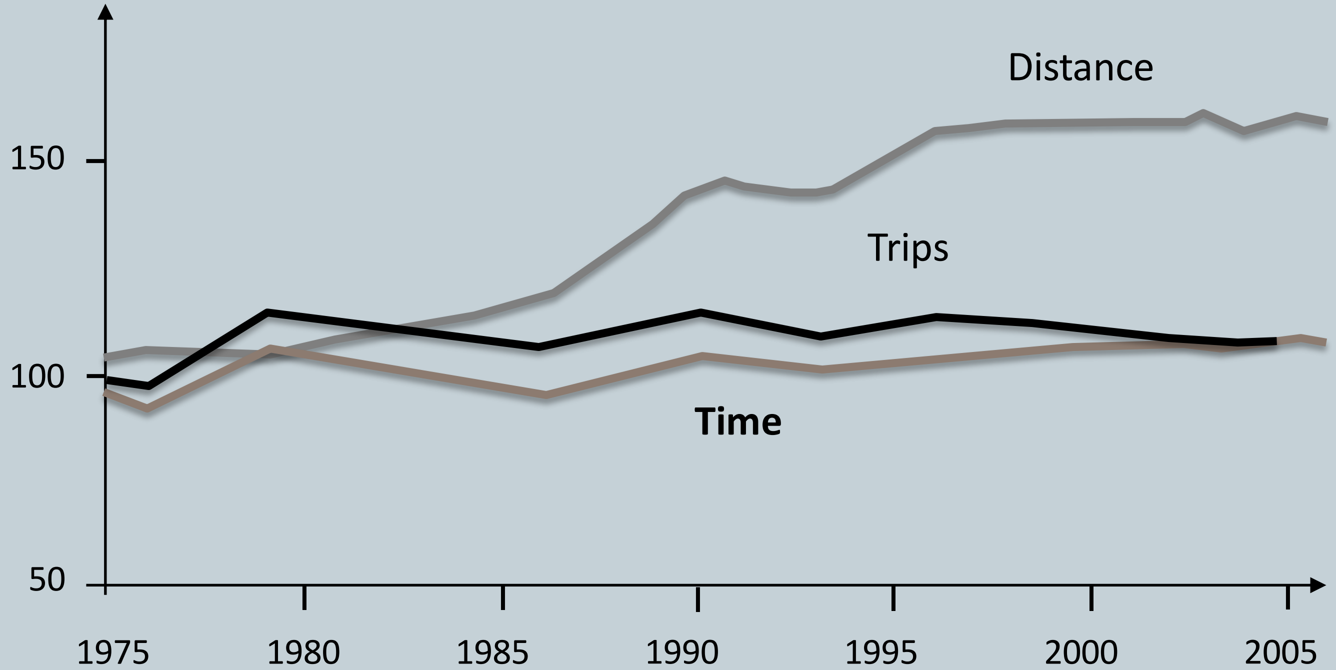
Perception of Growth Dynamics

Cities are dynamic entities. They constantly evolve with time.

The general perception of growth dynamics is that- **with growth, travel times increase.**

"For as much as world's cities have grown over the past few decades, commute times have remained oddly stable"



Trips / distance travelled / time spent travelling per person per year (1972/73 = 100) in London

Source: An analysis of urban transport, Nov 09, Cabinet office- strategy unit – Britain.

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Rationale behind the occurrence – Marchetti's constant

Among the most convincing ideas to explain this occurrence is the **idea of 'travel time budgets'** that any individual refuses to exceed.

Individual travel time budget (TTB) is **computed as the sum of the duration of all the trips realised in one day.**

Concept of TTB

*A **fixed portion** as the maximum amount of time out **of that day or week** that people would be willing ,on an average, to spend on travel.*

Marchetti → *1 hour wide cities*

Yacov Zahavi → ***Constant TTB* - 1 hour per day per capita**

The 2-fold constancy of TTB → 1 ***Spatial*** → 2 ***Temporal***

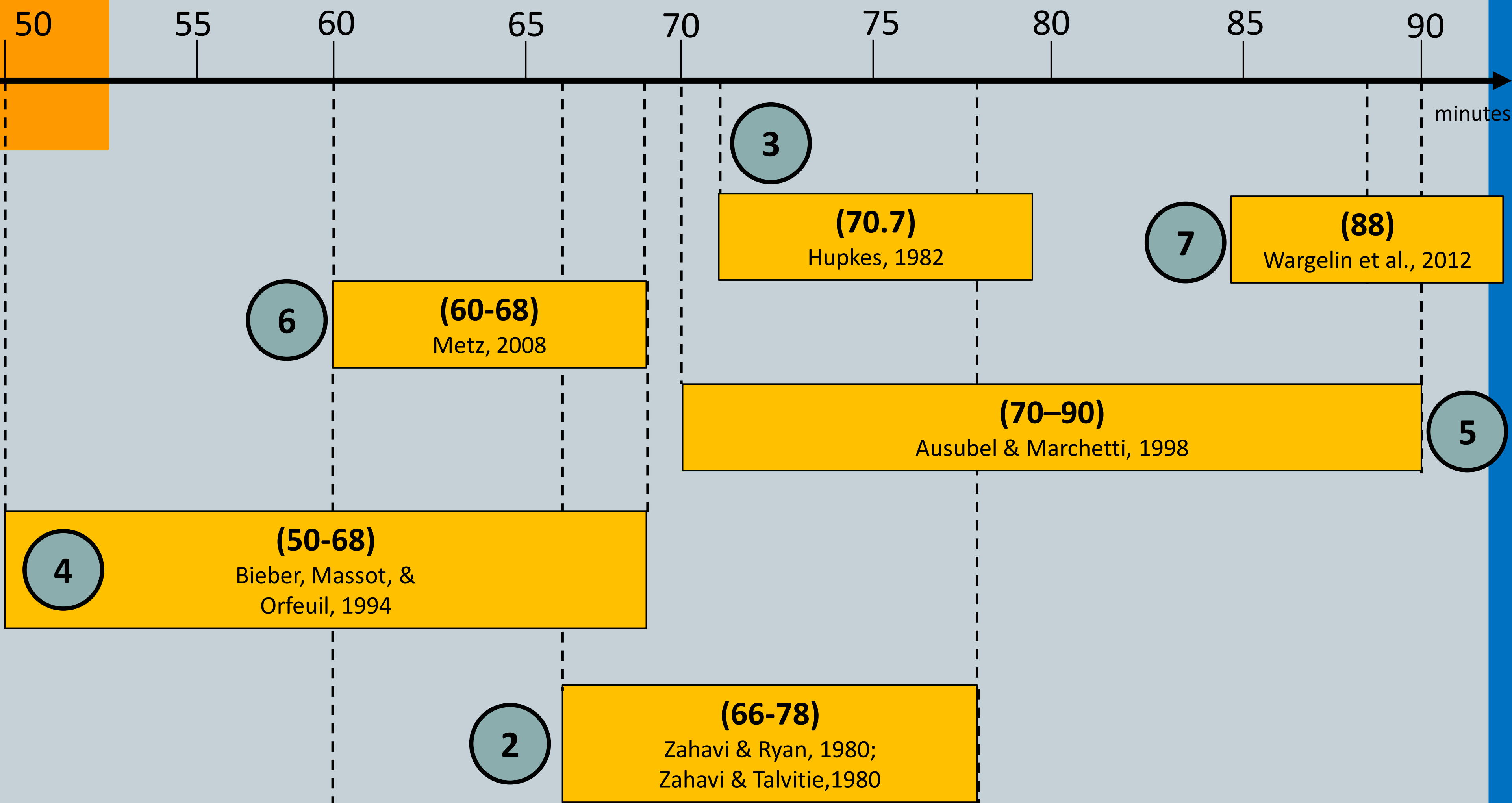
"TTB is constant over different cities and different time periods."

The 2 hypotheses

1 ***Strong hypothesis*** → ***Stability of TTB at an aggregate level***

2 ***Weak Hypothesis*** → ***Regularity of relationships between TTB and variables at a disaggregate level***

Researches in support of Constant TTB concept



TTB is almost seen as a universal constant at **1- 1.3 hours**

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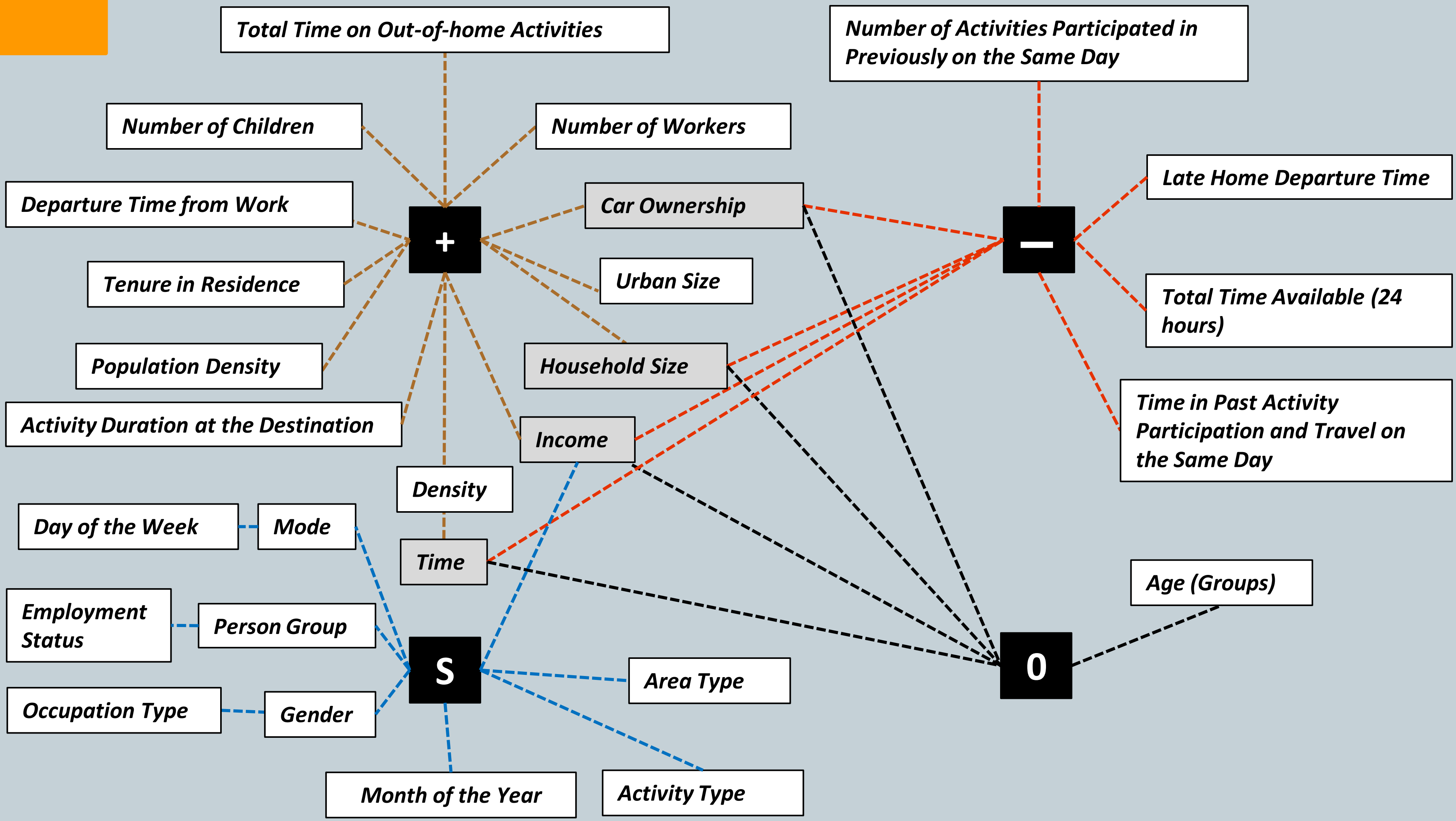
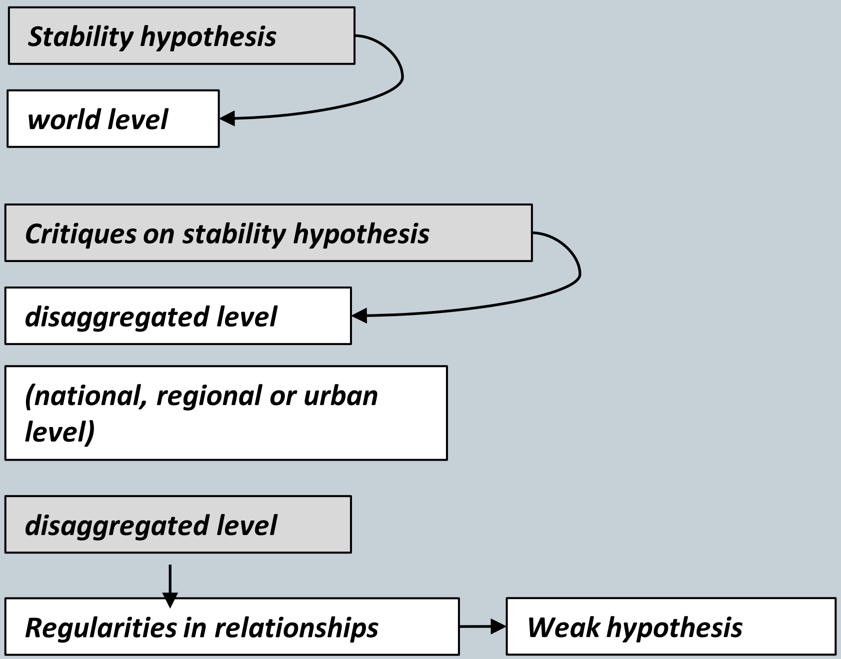
Critics of Zahavi's conjecture

The critics of Zahavi's conjecture have been **concerned with the influence of some socio-economic, activity-related and area specific variables.**



These multiple critiques are warnings to the abusive application of the constant TTB concept in a non-world level.

Level of observation and application



Two propositions

This ***research attempts to test these alternate theoretical propositions on an Indian city***. This thesis specially comments on two propositions:

Proposition 1

While travel time vary by size of city and over time, **there are certain thresholds (minimum and maximum), within which most people travel.**

Proposition 2

There are certain **travellers who travel beyond these thresholds** and we call them **'extreme travellers'.** For this group we explore who they are and Why do they accept such extreme traveling conditions?

Data Collection

Household mobility survey for Chennai – carried out

Socio-demographic and mobility characteristics of the 200
households and of each individual in the household

Each trip is described by
the **starting and stopping times,**
the types of activities at origin and at destination,
the travel mode.

Thus, the one-day out-of-home activities diary can be deduced, from the first trip to the last trip of the day.

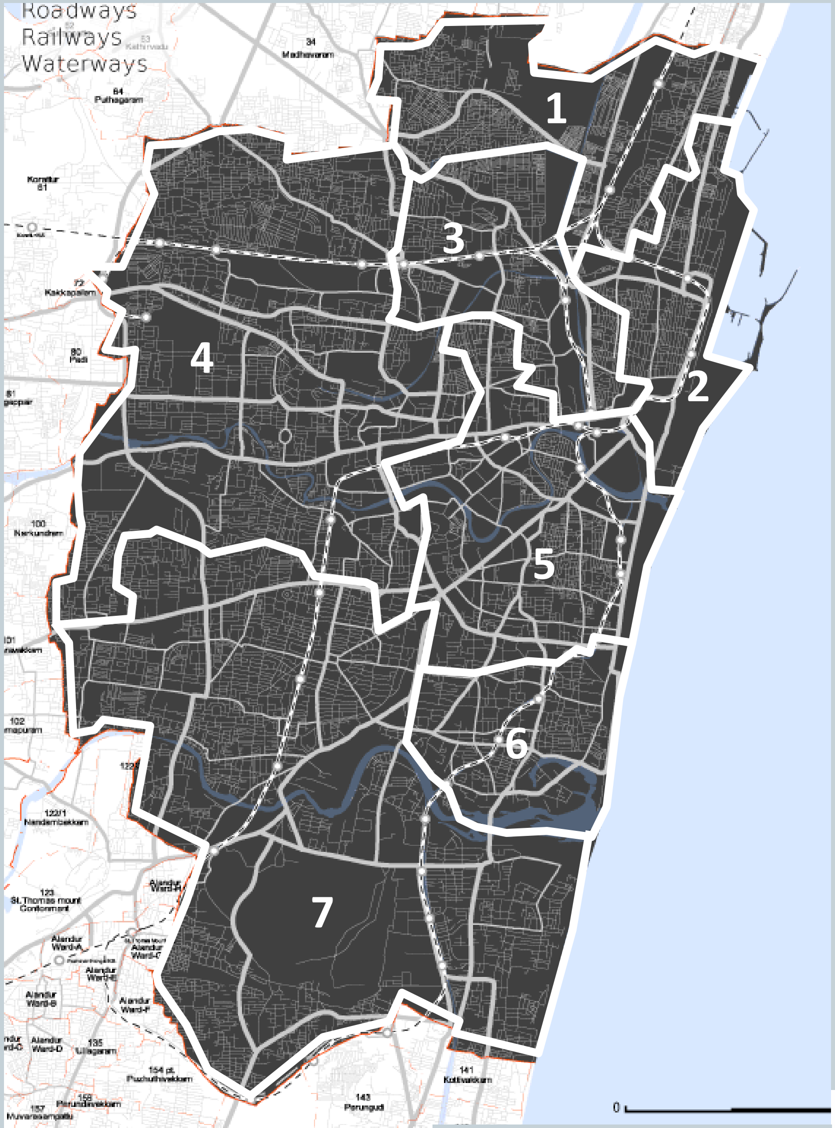
Mobile population : 533
Number of trips captured : 1277
Extreme travellers : 84

Perception surveys

Non-extreme travellers : 60

Extreme Travellers : 11

Life-story interviews for 11 extreme travellers



Zone aggregations

Estimation and Results

Summary statistics of TTBs (in mins)

Mean	69.39		**Std. Deviation**	59.60		**Range**	356
Median	50		**Minimum**	4		**Interquartile Range**	60
Variance	3551.67		**Maximum**	360			

Trip rate : 2.39

OLS Regression – TTB & influent variables

	Influent Variables	Estimates
	Intercept	86.83681
	Age	0.1929621 **
	Female	-16.24516 **
	Household size	-1.573521 **
	No of workers in the household	2.883696 **
	High income	-11.97689 **
S 1	Low income	3.6564
	No of vehicles in household	6.914162
	No of children below 10	-9.58019
	Worker	9.461773 **
	housewife	19.54848 **
	Student	10.94039 **
	Unemployed	34.62675 **
S 2	Purpose - education	7.578477 **
	Purpose- others	3.829528 **
	Mode- Car	14.77739 **
	Mode - Cycle	-61.28583 **
S 3	Mode - PT	14.24626 **
	Mode- Two Wheeler	-36.39105 **
	Mode - Walk	-63.69675 **
	R - Square	0.3

** 0.05 level of significance

The TTB is regressed, using a stepwise selection. The table shows the **weak results of the linear regression of the TTB on the household and individual characteristics**.

Despite the low R square (0.3), **classical variables are found to be significant**.

The influence of variables seems to be confirmed by the OLS regression. But the weak performance of the model indicates that **the relationships between these variables and the TTB may not be linear**.

Need for a multi-dimensional method to analyse TTB

Duration modelling

To perform a more flexible **multi-dimensional analysis** of the TTBs the **duration model methodology** is applied.

The usage of survival analysis in transportation is better known as duration modelling.

Duration dependence concept

1. Models the **conditional probability of the end-of-duration of a process** given that it has lasted to a specified time.

2. Permits the **likelihood of ending to be depending on the length of elapsed time**

3. Hence, this **probability can vary during the process**.

4. Indeed, the estimation of this conditional probability, **named hazard rate, will inform us on the temporal dynamics of TTB and help question the TTB stability hypothesis**.

Data need

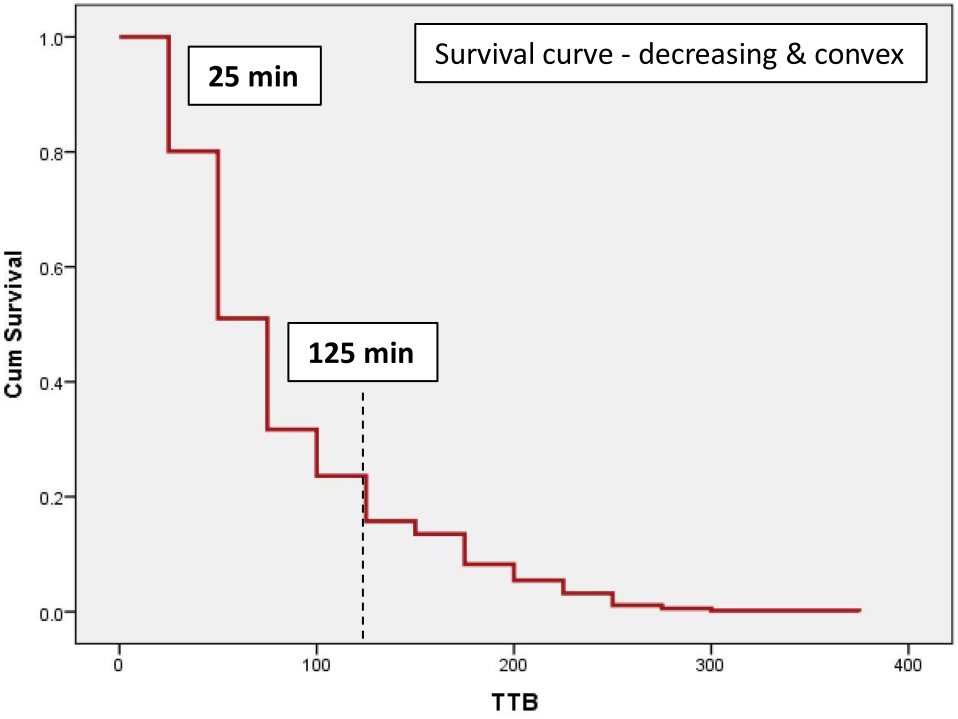
Duration data that is **non-negative**, can be censored and **time-varying**

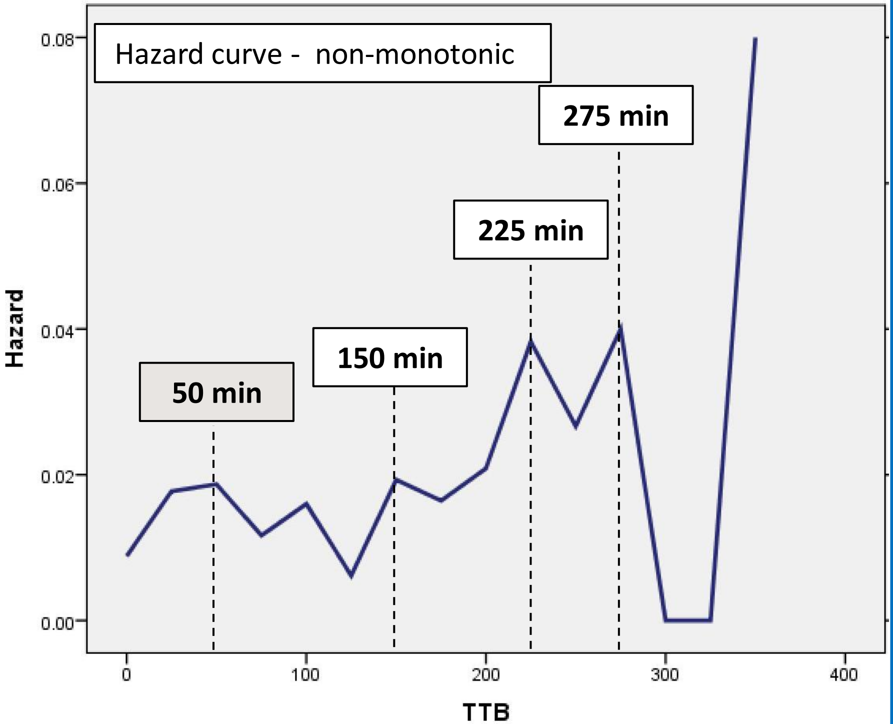
Non-parametric method

The lifetable method & Kaplan Meir

Exploration of the covariates' effects

Output of lifetable method - Survival and hazard curves for TTB in minutes





The survival curve

2 inflection points - The first, near 25 minutes, seems to indicate the existence of **minimum TTB level of 25 minutes**.

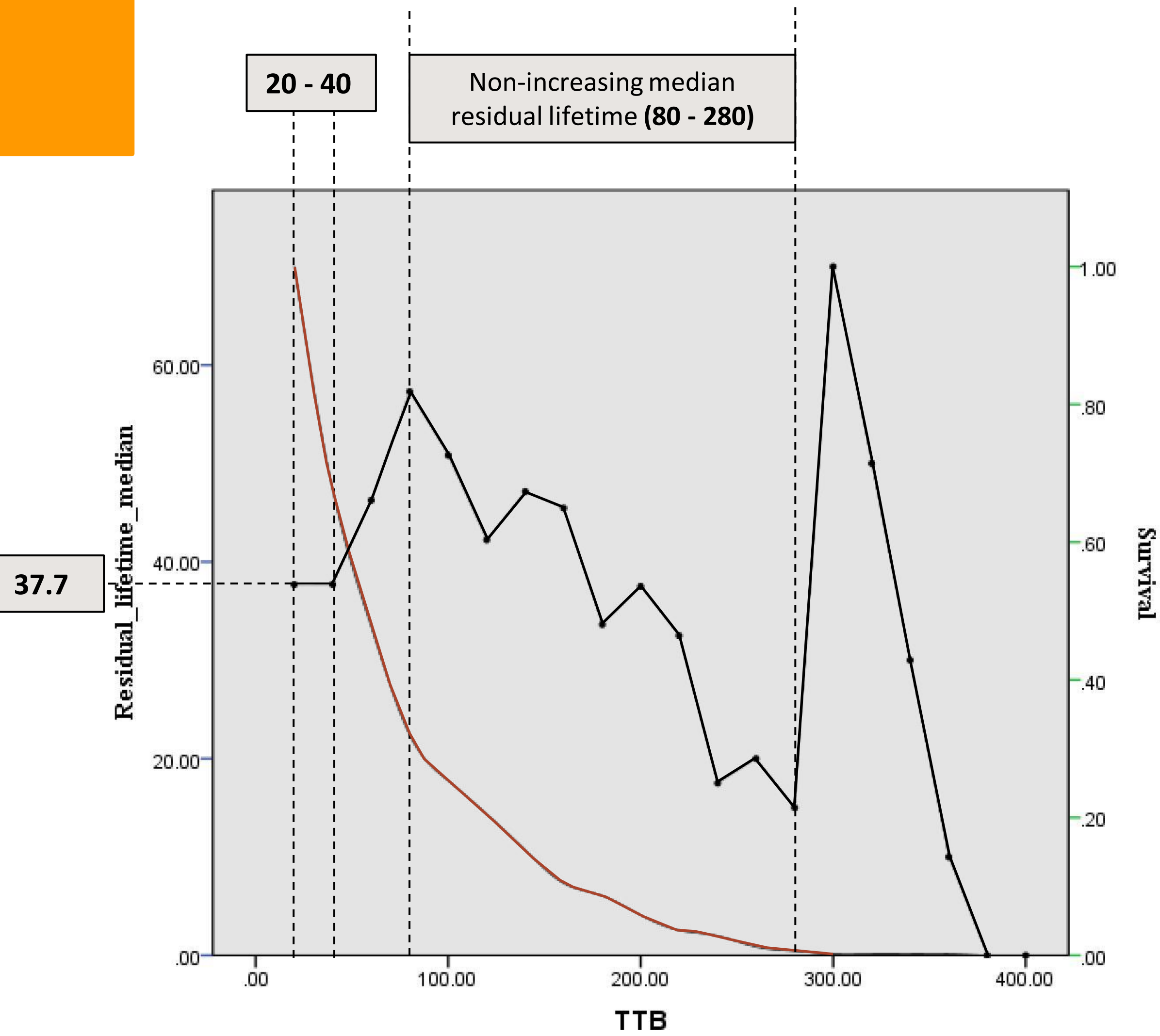
The second point, near **125 minutes corresponds to a diminishing probability of the ending after 2 hours of travel.**

The hazard curve

Characterised by **peaks for 150, 225 and 275 minutes**.

The **hazard is increasing until near 50 minutes**, and then decreasing.

Median survival lifetime



For each time *t*, it approaches the expected survival time given that the process has lasted to *t*.
(For a null TTB, the median survival time is **37.7 minutes**.)

The increasing part of the curve suggests that **travellers increase the travel times during the first hour.**

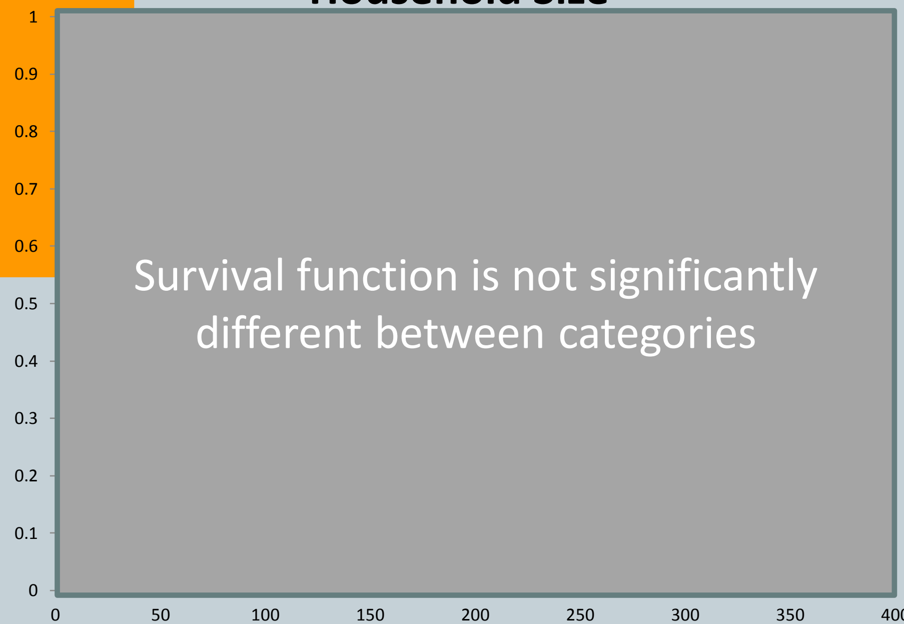
But from **20 to 40 minutes, the median survival time is stable**. Then, individuals that have already a 20 min TTB, are expected to pass 20 minutes more in travel.

And finally the **median survival time is decreasing after 80 minutes**.

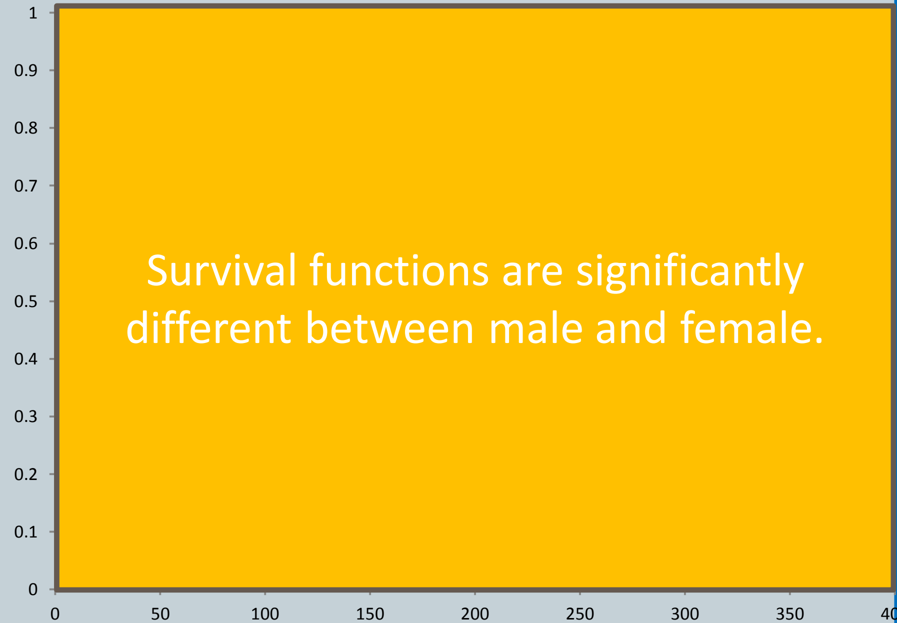
Kaplan Mier Survival curves

The non-parametric tests of **survival equivalence** is used to inform us about the relationship between TTB and the considered variables.

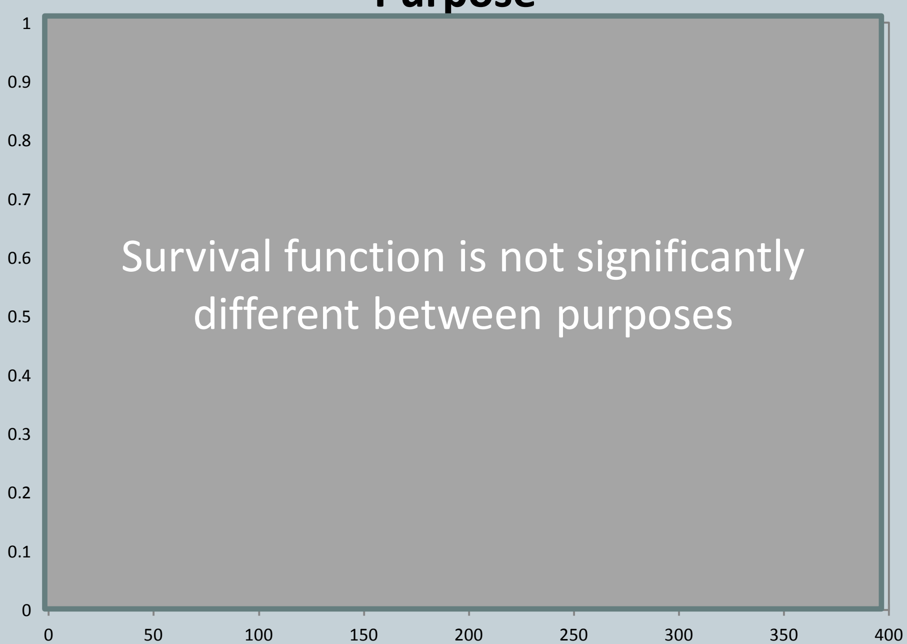
Household Size



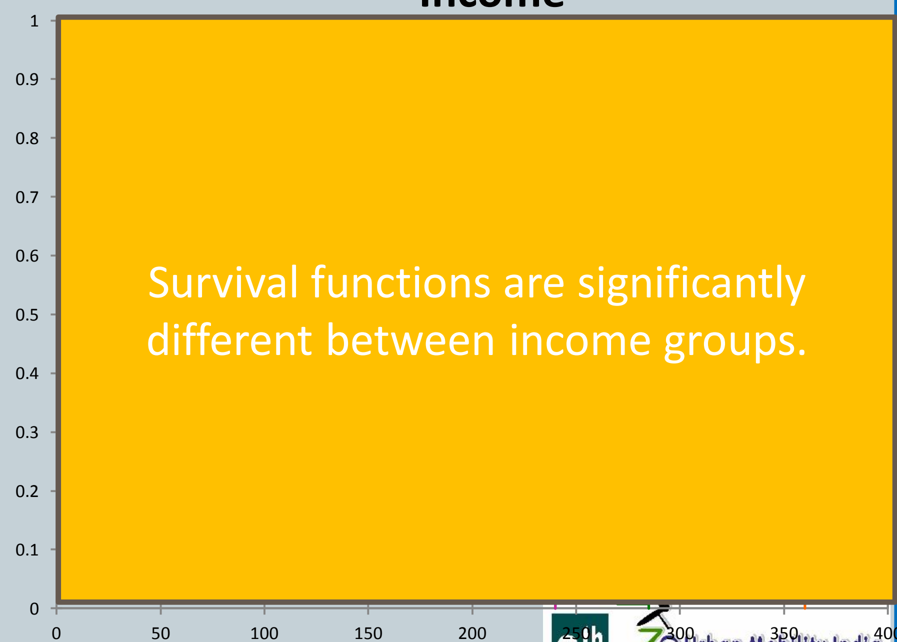
Gender



Purpose



Income



Professional status

Survival function is not significantly different between categories (Taron)

Age

Survival functions are significantly different between categories

Mode

Survival functions are significantly different for various modes used.

EMP IPT PT Walk

Children be

Survival functions a
different between categories

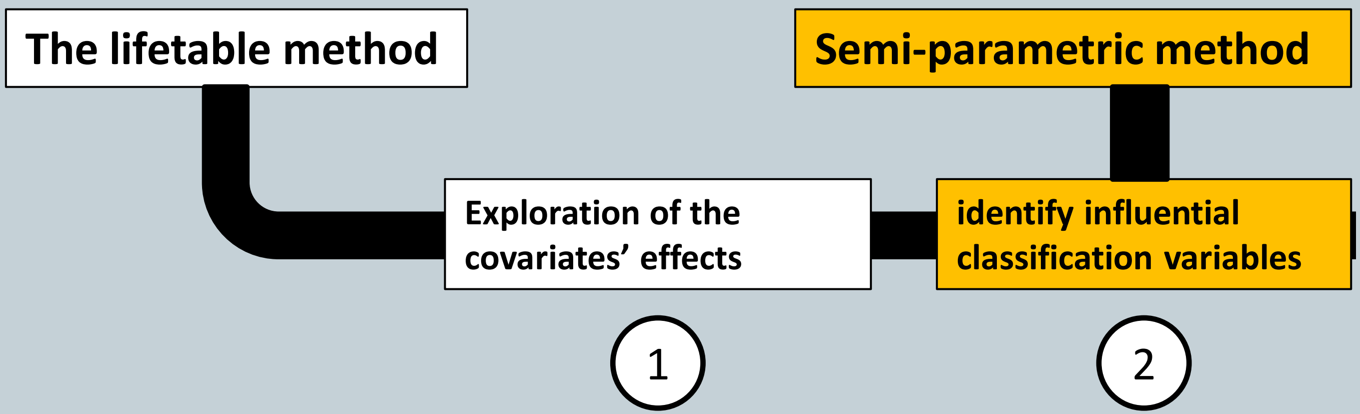
of vehicles

...ons are significantly
different between categories

1 2 3

Lifetable and Kaplan Mier tests are only unidimensional. The intuition given by these tests needs to be examined by considering the whole set of variables. Hence, we estimate the **semi-parametric Cox model, which is multidimensional**. The Cox method assumes a **proportional hazard model.**

Non-parametric method



Cox proportional hazard model

	Cox estimation	S1 : HH & individual characteristics		S2 : S1 + Trip purpose		S3 : S2 + Principal mode used	
	Variables	Estimates	Hazard ratio	Estimates	Hazard ratio	Estimates	Hazard ratios
	Age	-0.002867	**0.9971**	-0.00369	**0.9963**	-0.005388	**0.9946**
	Female	-0.141954	**0.8677**	-0.14375	**0.8661**	-0.17857	**0.8365**
	No of workers at HH	-0.029624	**0.9708**	-0.02846	**0.9719**	-0.035003	**0.9656**
	No of vehicles at HH	-0.112557	**0.8935**	-0.12202	**0.8851**	-0.083546	**0.9198**
S1	**No of children below 10**	0.25971	1.2966	0.246714	1.2798	0.210201	1.123
	Housewife	0.195992	1.2165	0.176781	1.1934	-0.088958	**0.9149**
	Student	0.135823	1.1455	0.010032	1.0101	-0.24134	**0.7856**
	Unemployed	0.234979	1.2649	0.174455	1.1906	0.38783	1.4738
	worker	0.105144	1.1109	0.098283	1.1033	-0.154101	**0.8572**
	Low income	-0.062696	**0.9392**	-0.06306	**0.9389**	0.079724	1.083
	High income	-0.003027	**0.997**	-0.00615	**0.9939**	-0.109338	**0.8964**
S2	**Trip Purpose - eductaion**			0.134901	1.1444	0.115966	1.123
	Trip purpose - others			-0.03716	0.9635	-0.003921	**0.9961**
	Walking					-0.911122	**0.4021**
	Bicycle					-0.62551	**0.535**
S3	**Motorcycle**					-0.378478	**0.6849**
	Public transport					0.054833	1.0564
	Car					0.036657	1.0373
	Log Likelihood	-2796.566		-2795.64		-2708.9779	

Cox model estimations

Cox model estimations

In the PH model, **estimates can be interpreted** with their corresponding **hazard ratios**.

hazard ratio < 1

The covariates with hazard ratio less than 1 will reduce hazard rate i.e., **increase survival and TTB**.

HH & individual characteristics

- Age
- Number of workers
- Female
- Number of vehicles
- Housewife
- High income
- Student
- worker

Trip purpose

- Trip purpose - others

Principal mode

- Motorcycle
- Bicycle
- Walking

Exhibit Positive relationship with TTB

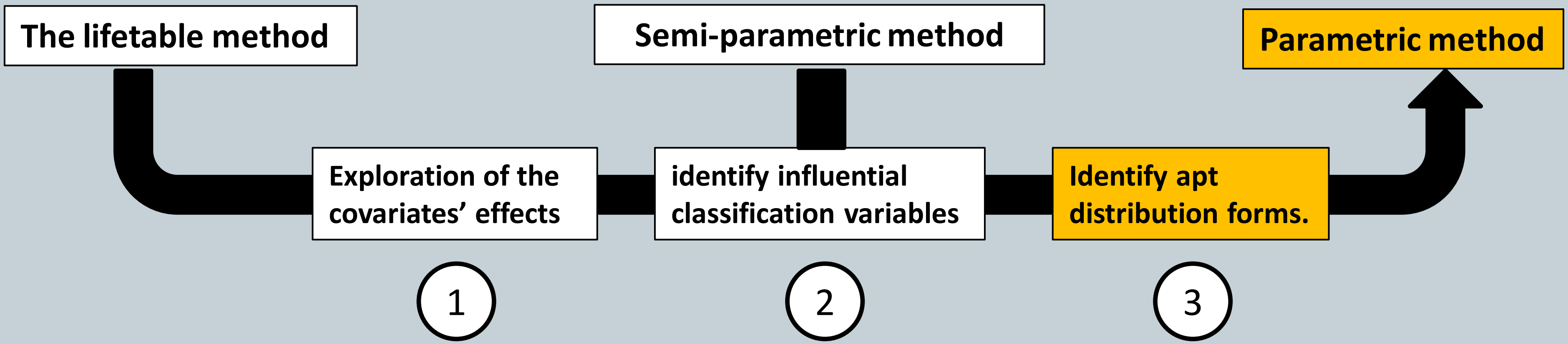
Effect of variables on TTB

1. **Males have lower hazard** and higher TTB.
2. TTB **increases with age.**
3. Workers have higher TTB. **Workers > Student > Housewife > Unemployed.**
4. The presence of children under 10 years of age decreases the TTB.
5. The number of working household members is positively linked to the TTB.
6. And **high household income** members have **higher TTB.**
7. If people making trips other than work or education, then their TTB increase significantly.
8. Modes of transport have both high and low hazard ratios. They can be ordered by increasing TTB:
   Walking > Bicycle > Motorcycle > Car > Public transport

The **Semi-parametric approach has confirmed the intuitions of the non-parametric approach** and has helped in the **selection of the most influential variables.**

But the hazard function is not estimated with this method, thus it gives **no information on the duration dependence**. The **full parametric** model allows to **estimate both covariates coefficients and the duration dependence** simultaneously.

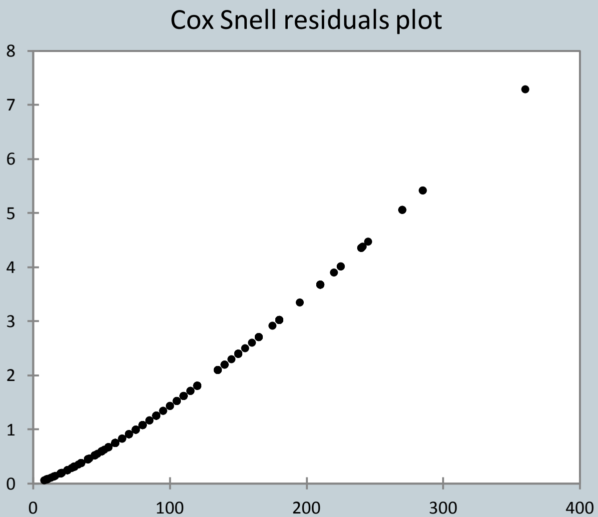
Non-parametric method



Parametric estimation

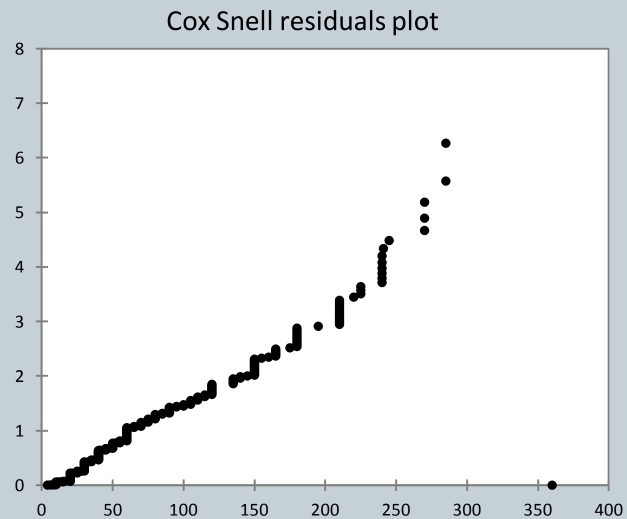
The **accelerated lifetime models with the log-normal and log-logistic distributions are estimated**.

We compare the goodness-of-fit of the log-normal and log-logistic model with **likelihood level and residuals of Cox-Snell**.



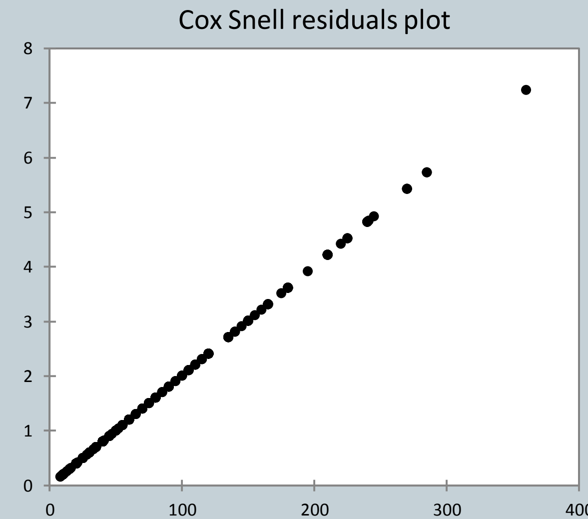
Weibull

- 5537.623



Log logistic

- 2750.589



Log normal

- 1312.499

The best goodness of fit is obtained with the log-normal distribution. The estimates of covariates for the log-normal model is made.

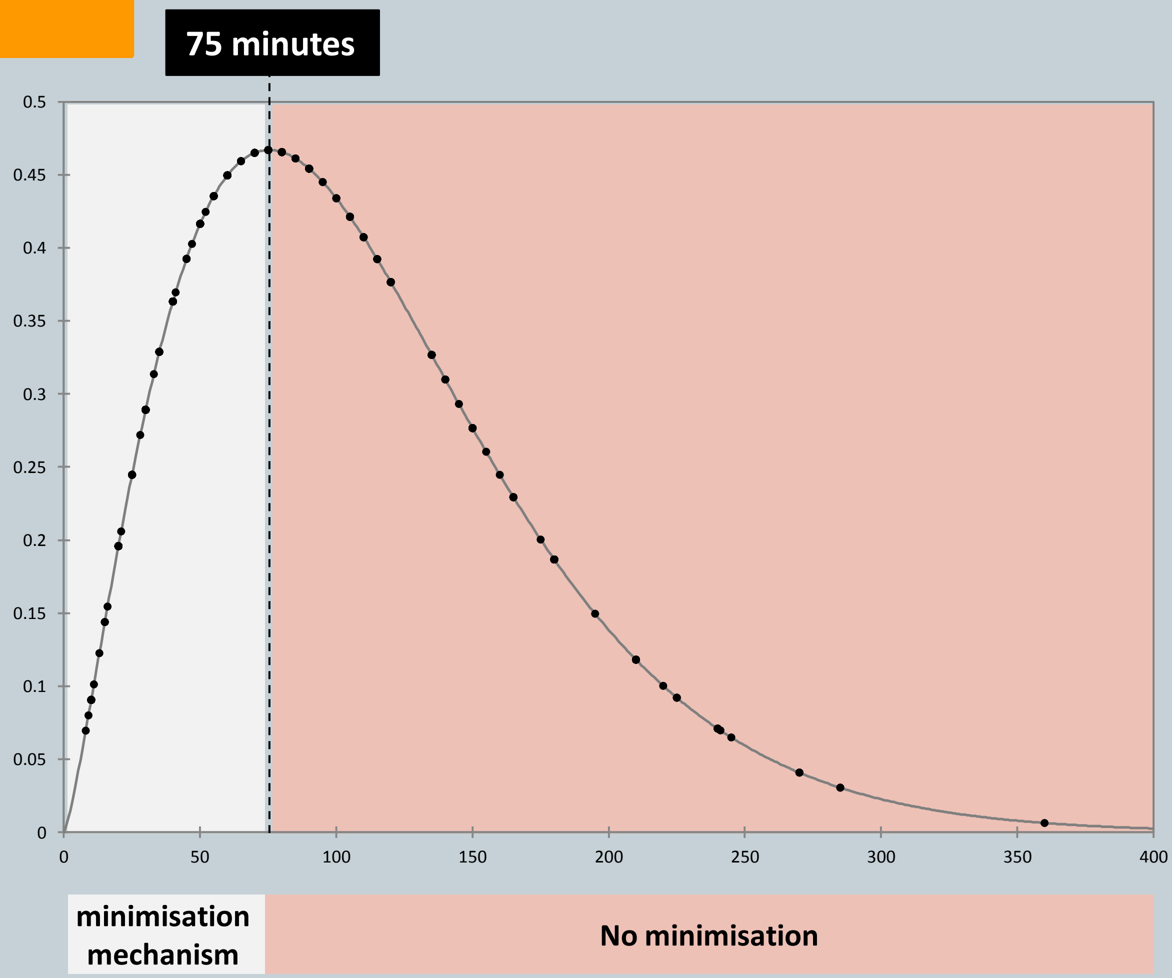
	Parametric lognormal estimation	S1 : HH & individual characteristics	S2 : S1 + Trip purpose	S3 : S2 + Principal mode used
	Variables	Estimates	Estimates	Estimates
	Age	-0.008	-0.008	-0.007
	Male	-0.036	-0.040	-0.010
	No of workers at HH	-0.076	-0.063	-0.055
	No of vehicles at HH	-0.008	-0.010	0.021
S1	**No of children below 10**	-0.059	-0.066	-0.064
	Housewife	-0.115	-0.126	-0.035
	Student	-0.032	-0.089	0.003
	Unemployed	-0.443	-0.530	-0.503
	worker	0.120	0.189	0.277
	Low income	-0.303	-0.300	-0.298
	Medium income	-0.037	-0.038	-0.003
S2	**Trip Purpose – Work**		-0.182	-0.181
	Trip purpose - Education		-0.012	-0.055
	Walking			0.022
	Bicycle			-0.224
S3	**Motorcycle**			-0.249
	Public transport			-0.427
	Car			-0.204
	Log Likelihood	**-2456.557**	**-2454.886**	**-2444.29**

Log-normal parametric model estimation

In an accelerated lifetime model, **exponential of the estimates can be interpreted in terms of expected time ratio**.

- Worker (full time, part time workers and students) have higher TTB. And young at school have lower TTB.
- The household responsibilities, represented by the number of children leads to lower TTB.
- And the number of household members increases the TTB.
- The individuals characterised by high household income have higher TTB.
- These results are classical findings of the other studies on travel times.

Estimated hazard for Log-normal model

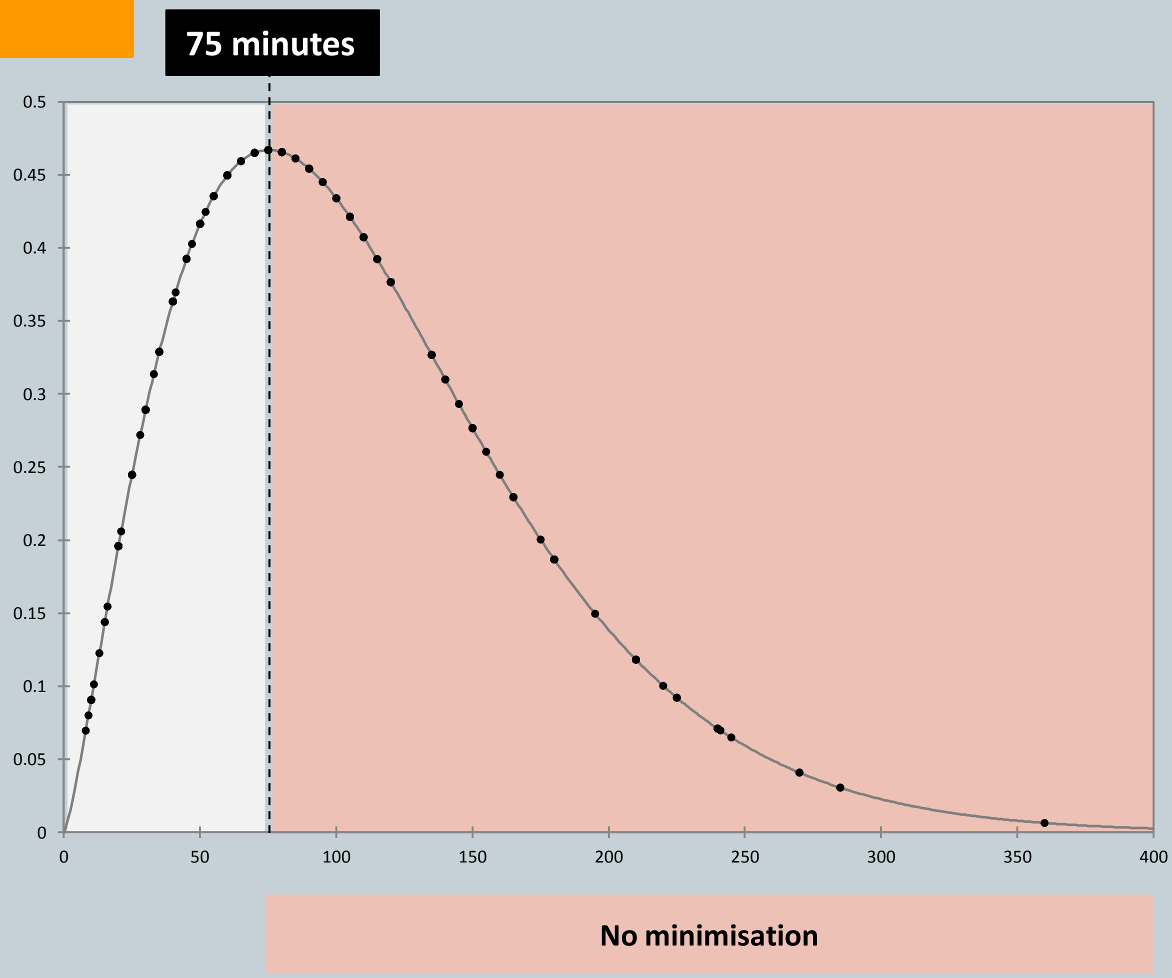


Non-monotonic inverted **U-shaped hazard with an inflection point near 75 min**.

The **non-monotonic hazard implies** that the **probability of ending daily transport**, given it has lasted to a specified time, **is not stable**.

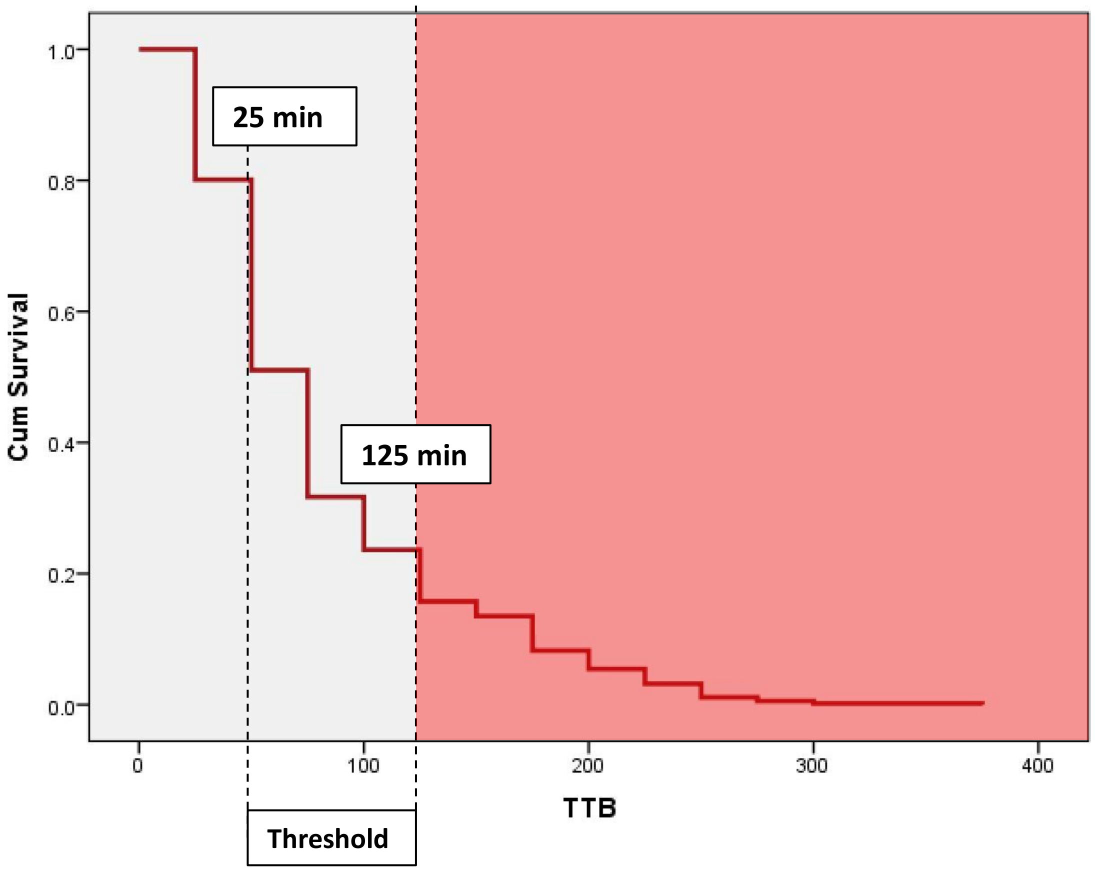
Under TTB stability hypothesis, or more generally **under travel time minimisation this conditional probability is expected to be monotonically increasing**. The monotonic hazard will characterise a duration that is generated by a minimisation process.

The estimated log-normal hazard seems to show that everything happens as if **two groups of travellers exist**. The behaviour of a **first group** of individuals can be represented by the **minimisation mechanism**. And a **second group** is composed of **individuals that can not or do not want to minimise their TTB.**



A **second group** is composed of **individuals that can not or do not want to minimise their TTB ?**

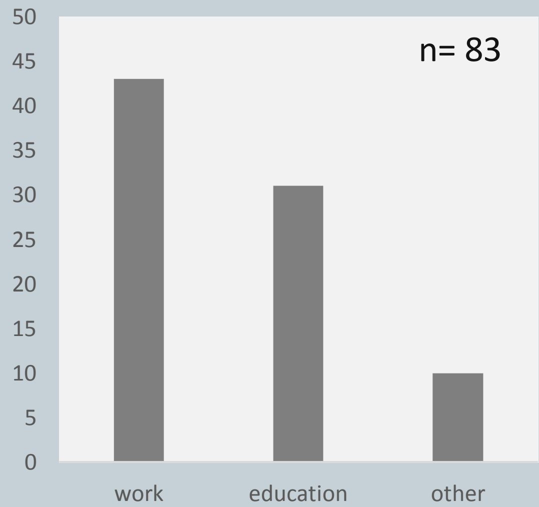
Extreme travellers are defined in this study as individuals who **travel more than 125 min per day**.

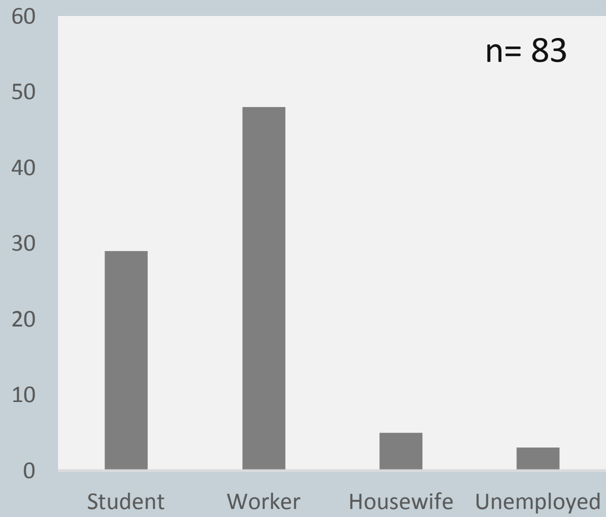


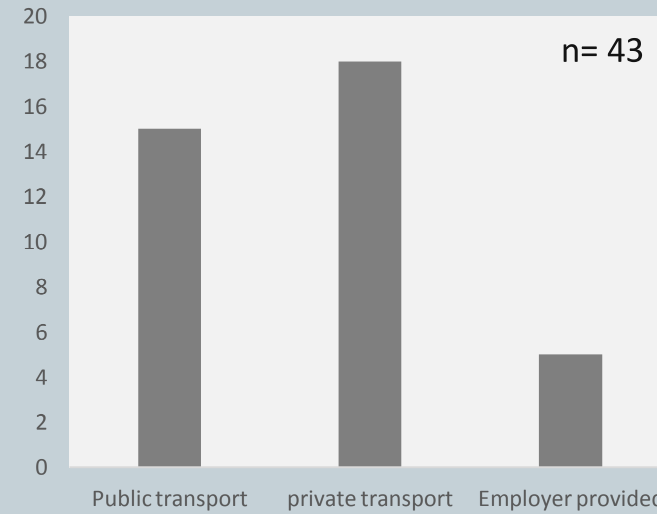
The excess traveller’s profile

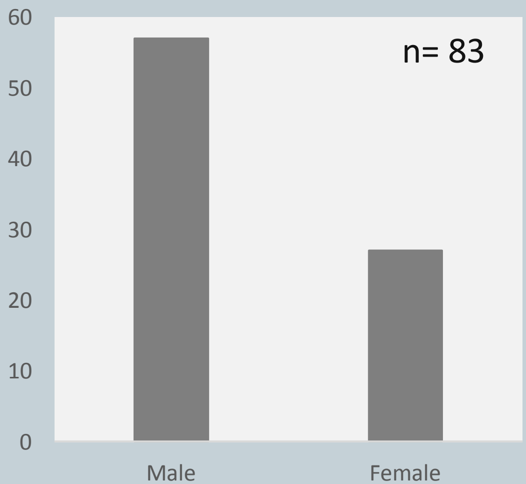
Excess travel is observed in work trips more than education trips. While a small ratio of other trips also feature excess travel.

An excess traveller is mostly a male worker who commutes ‘excessively’ to work **or a student** to his institution using private or public mode.









The most **popular transport mode to work** in this sample was **private transport** whereas only 5 excess travellers are travelling through employer provided modes. The other 15 excess travellers are using public transport.

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How different are the extreme travellers?

Age

No statistically significant difference between the means.
(p-value: 0.804)

	n	Mean	Std. Deviation	Std. Error Mean
Age (excess)	84	33.31	15.848	1.729
Age (non-excess)	533	33.50	17.624	.763

Income

Statistically **significant difference** between the means observed.
(p-value: 0.000)

	N	Mean	Std. Deviation	Std. Error Mean
Income (excess)	84	54908.73	46207.932	5041.699
Income (non-excess)	533	46423.14	41468.376	1796.195

Vehicles owned

Statistically **significant difference** between the means observed.
(p-value: 0.000)

	N	Mean	Std. Deviation	Std. Error Mean
Vehicles owned (excess)	84	1.57	1.195	.130
Vehicles owned (non excess)	533	1.24	1.024	.044

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Does the excess traveller show different preferences?

The questionnaire sought respondent's views in terms of the **importance of different factors in determining their commute mode** and in terms of their reactions to a set of questions designed to elicit attitudes to travel.

Attitudes towards factors influencing travel to work options and mean values (scale: 1—not important, 5—very important)

Importance of factors when choosing travel to work	Non-excess travellers (n=60)	Excess travellers (n=11)	p-value (2 tailed) for difference of means
Good accessibility	4.1	4.8	0.029
Good comfort	3.6	3.6	0.98
Short distance	3.7	3	0.309
High independence	4	3.8	0.802
Low price	4	4	0.956
Good safety	4.4	3.8	0.474
Short time	4.4	4.2	0.693
Good enjoyment	3.5	3	0.41

- When comparing the excess travellers to the non-excess travellers, there are many similarities but some key differences.
- It can be seen that **excess travellers' value of good accessibility is statistically significantly different** at the 5% level from the non-excess travellers and low price and comfort have the same value for the two groups.

Making use of travel time as a rationale for intensive travelling

In view of respondents' social histories, the life story interviews indeed show that
Extreme travelling falls somewhere between life choices (most notably family and residential) and career choice.

One extreme traveller, for instance, "*chooses to continue his intensive travelling so that he can keep on doing the research work about which he is so passionate. In such situations, intensive daily travelling seems to be an adjustment variable between the individual's personal and professional lives*"

Determinants of intensive travelling, be it short- or long-term

- Residential anchorage
- Social anchorage
- Pursuit of a career

Extreme travel a choice?

Statements characterising travel to work and mean values
(scale: 1—not at all true, 2—not very true, 3—fairly true, 4—very true)

Statement	Total sample (n=60)	Extreme travellers (n=11)	p-value (2 tailed) for difference of means
A travel time is a good time to relax	2.5	1.6	0.091
A travel time is a good time to think	3.1	3.6	0.122
My trip is a useful transition between home and work/destination	2.8	2	0.278
I like travelling alone	2.7	3	0.603
I think travel is boring	2.2	3	0.066
My trip is a real hassle	1.9	2.8	0.186
We need more public transportation, even if I have to pay for a lot of the costs	2.8	3.6	0.02
If I could find quicker and cheaper way I would use it	3.1	3.8	0.021

- **excess travellers feel more negative** about the travel to work than the whole sample.
- Significant difference of means:
- **finding a quicker and cheaper way to travel**
- **the relaxing and boring nature of travel**
- Excess travellers have a **higher mean score on the attitude 'If I could find quicker and cheaper way I would use it**' which suggests that **not all the excess travellers are excess travellers by choice**.

The extreme traveller’s profile

Respondent number	10	22	23	68
Transport mode	Car	Bus	Bus	Bus
Distance (km)	35.89	11.43	13.04	6.92
Time spent commuting	135	150	175	225
Identified alternate transport mode	Metro + walk	No response	No response	Train
No. of vehicles at home	2	1	0	0
Driving licence	Yes	No	Yes	No
Gender	F	F	M	F
Age	<23	41–64	41–64	24–40
Marital status	Single	Single	Married	Single
Economic activity	Student— full time	high- managerial	supervisor	student - full time
No of people in Household	4	2	3	1
If you could arrive at your work without commuting would you like to do it?	No	Yes	Yes	No
Activities when travelling	Music, observe, eat	Think, read, talk, observe	Think, relax	Think, music, read, talk, relax, observe
Amount of time spend travelling to work is	Too much	Too much	Far too much	About right
Ideal one-way commute time [mins] would be	30	30	15	30

Perception of Travel time among Extreme travellers

Activity optimisation

optimise their travel time by doing activities during their trip that could be done elsewhere, at another time.

Travel time as additional time

see it as additional time or time to enjoy.

Travel time - time to kill

travel time is simply time to kill
time is wasted and useless

Whilst the sample size is small, this study contributes by **confirming that excess travelling exists in the commute to work** and provides a start in the **understanding of differences between excess and non-excess travellers** in terms of the factors which are cited as important for the journey **and in their perceptions of travel.**

A better understanding of who the excess travellers are and why and how they behave in their daily commute is the foundation for exploring policy to encourage sustainable transport patterns of commuting.

Conclusions

1 Major part of analyses of TTB by researchers is unidimensional or limited to the linear model. **To overcome these limits, this research applies a survival analysis, which is suitable to investigate duration data.**

2 The log-normal distribution used in the parametric model implies a non-monotonic inverted U-shaped hazard, while Under TTB stability hypothesis a monotonically increasing hazard is expected.

Thus the influent variables show the **irrelevancy of the “strong TTB stability hypothesis” in the city of Chennai**.

3 The non-parametric model estimates the **minimum TTB at 25 minutes and the maximum at 125 minutes.**

4 The log-normal model shows **an inflection at 75 minutes**. The estimated log-normal hazard seems to show that everything happens as if **two groups of travellers exist**.

The behaviour of a **first group** of individuals can be represented by the **minimisation mechanism**. And a **second group** is composed **of individuals that can not or do not want to minimise their TTB**.

5

+

Vehicle Ownership

Income

–

Number of Workers

Number of Children

S

Mode

Gender

0

Employment Status

Household Size

Trip purpose

6

When people travel beyond the threshold of TTB- Extreme travelling falls **between life choices (most notably family and residential) and career choice.**

Excess travellers are mostly male workers and students who commute to work and college.

Excess travellers significantly differ from non-excess travellers by income and vehicles owned.

Not all the excess travellers **are excess travellers by choice**.

Excess travellers feel more negative about the travel.

Implications on modelling

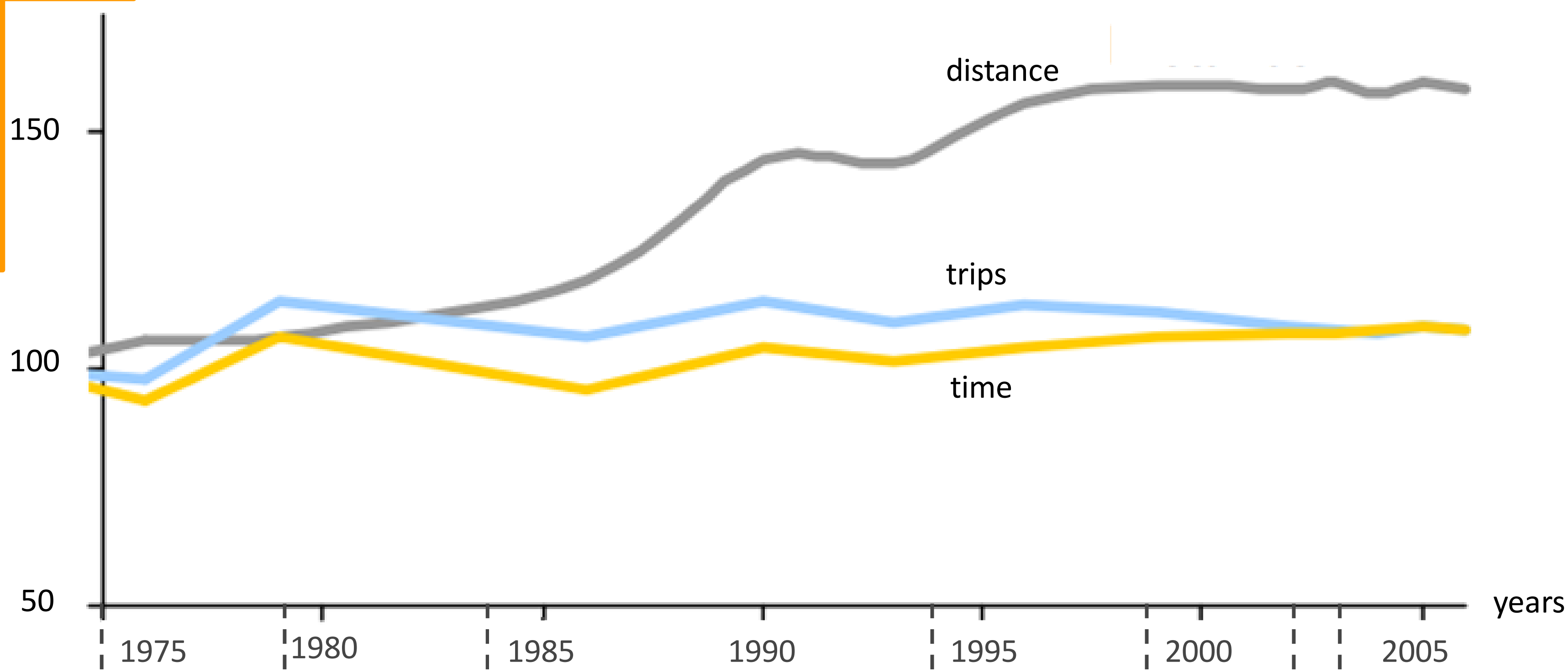
1 The application of duration model to the TTB **failed to consider transport as a derived demand**.

The interaction between **travel times and activity need to be included**. The c**ompetition between activities for the time resource can be modelled** through the competing risk model framework.

Duration models may offer an appropriate framework to reach the integration of derived demand concept into the allocation of time modelling.

2 In travel demand modelling **predictions of expenditures of travel could be based on the weak hypothesis** of regularities.

Both **travel time and money budgets could act as constraints in the model** thus reducing the problem of allocation of resources to transportation to the simple problem of distribution of time and money resources between different modes. (exhibited in UMOT by Yacov Zahavi)



Transport related decisions

1975 1st section of Piccadilly Line extension to Heathrow opens.

1979 First section of Jubilee Line opens to traffic (Stanmore-Charing X)

1984 London Regional Transport Act receives Royal Assent

1985 London Regional Transport vesting day 16 July. Local Government Act [dissolving GLC] receives Royal Assent

1994 Croydon Tramlink Act receives Royal Assent

1999 First section of Jubilee Line extension opens (Stratford-N.Greenwich) 11 November Greater London Authority Act receives Royal Assent

2000 Trams enter service in Croydon/Wimbledon/Beckenham areas. Greater London Authority and Transport for London start work

2002 LRT Board approves PPPs. Dec. PPP contract signed with Tube Lines

2003 Two PPP contracts signed with Metrolink

London Underground Ltd transfers to TfL. London Regional Transport wound up

Source : An analysis of urban transport ,November 2009, Cabinet office- strategy unit – Britain. Source Historical chronology : London Transport – a brief history – Sim Harris.

THANK YOU.