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The changes of activity-travel participation across gender, life-cycle, and generations in Sweden over 30 years

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Abstract This study utilised the Swedish national travel survey covering a period of over 30 years. We investigated the long-term trends in activity-travel patterns of individuals in different life-cycle stages and generations using cohort analysis and a path model. The main findings are summarised as follows. The women, including mothers, in younger generations have become more active in out-of-home non-work activities and their trip chaining has become more complex, compared to their male counterparts. While men are still driving more than women, the gap is decreasing in the younger generations. The gender difference among teenagers in terms of out-of-home time use diminishes in younger generations. Teenagers of younger generations spend more of their leisure time inside their homes, possibly due to the rise of online activities and gaming and more time-consuming school trips, the latter attributed to changes in school choice policy. Older adults travel more, possibly due to better paratransit transport service, supported by better health services.

Keywords Activity-travel patterns · Life cycle stages · Long term changes · Time-use · Intra-household interaction

Introduction

In this study we use the national survey data to reveal the 30-year trend of activity-travel patterns changing over time for men and women in different life-cycle stages. Over these 30 years, there have been substantial changes in household structure, intra-household arrangements, and gender equality in Sweden. These changes are interrelated and have been potentially driven by some fundamental welfare policies. We do not attempt to explicitly investigate

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the possible causal effects of such policies on the travel behaviour. Instead we explore the trends over time and generations, and we qualitatively discuss possible causes of these trends (even if we cannot be conclusive on the causal effects).

Using a pseudo panel approach with several large cross-sectional datasets of the Swedish national travel survey (NTS) conducted between 1978 and 2011, this study systematically explores and quantifies travel behaviour and activity participation trends. Trends in activity-travel patterns have not previously been analysed over such a long period as 30 years. There have, however, been studies examining the impact of life-course or lifestyle on travel choices. We add to this literature in three dimensions: First, earlier studies only focused on travel behaviour indicators descriptively (e.g. Hjorthol et al. 2010; Kuhnimhof et al. 2011; Liu et al. 2014, 2015), whereas we model the interaction between a number of them. Second, earlier studies used a complex behaviour model (e.g. Susilo and Kitamura 2008; Susilo and Waygood 2012) but we add a distinction between different cohorts/generations and life-cycle stages (distinguished by age and household structure: with/without children and single/partnered living). Third, earlier studies explored the changes in detail via mobility biography among a small sample of respondents, such that the findings are difficult to generalise into a full population (e.g. Lanzendorf 2010; Jones et al. 2015), whereas we use large and representative samples.

Many of the earlier studies also point to the importance of accounting for the impact of life choices when exploring the travel behaviour (Zhang and van Acker 2017), while in this study the impacts of life choices such as marriage and having children are investigated. Moreover, studying trends in activity-travel patterns across gender and generation in Sweden is relevant for many other countries, since Sweden is among the most gender-equal nations in the world, and in the lead regarding many of the trends.

The study has some caveats, namely that each group (life-cycle stage) is treated independently and that it does not consider the dynamic effect over life-cycle stages (e.g. the travel behaviour in an individual's youth can influence the travel behaviour as they grow older). Moreover, the study does not explicitly model the effect of long-term choices such as residential relocation and owning the first car.

The outline of the next sections of this article is as follows. "Life-oriented travel behaviour research" section provides a literature review on how policies and instruments can affect individuals' travel and activity choices differently for individuals in different life-cycles and generations. "Data and classifications" section describes the national travel survey and the classification of life-cycles adopted in this study. In addition, we present a descriptive analysis of activity-travel patterns for men and women broken down to life-cycle stages and generations in Sweden. A path model structure is proposed in "Descriptive analysis: lifetime span distribution of travel indicators" section to systematically analyse, follow, and quantify the evolution of key factors driving those changes over time. "Controlling the differences over time: a model system to systematically examine the different paths of changes across different genders, life-cycle stages, and generations" section presents the model estimation and results. "Discussion and conclusions" section summarises the findings and also offers a brief reflection towards relevant policy implementation in Sweden in the last 30 years.

Life-oriented travel behaviour research

In this study we model travel behaviour differences among (a) generation and (b) life-cycle stages for men and women. We first refer to literature that models the effect of

life-cycle stages. We then refer to literature that models the difference in travel behaviour across generations.

Many studies have shown changes in travel behaviour being associated with key events and/or 'biographical processes' over a life course (e.g. Lanzendorf 2003, 2010; Axhausen et al. 2006; Beige and Axhausen 2012). These studies argue that travel behaviour is relatively habitual as long as an individual's daily needs and constraints are stable. However, an individual's behaviour may change due to the adaptation to new circumstances or learning processes (Scheiner and Holz-Rau 2013; Chatterjee et al. 2013). This includes the changes in the household's situation, employment, and residence locations (Lanzendorf 2010; Schoenduwe et al. 2015; Clark et al. 2016). For example, Zhang (2017) suggested that as people grow older, they become more careful about spending money, which may influence their decisions about owning private cars and buying public transport tickets. In the early stages of retirement, older people may choose to conduct more leisure and tourism trips. However, people in the later stages of retirement are more likely to focus primarily on their basic daily needs. Such changes over the life-cycle and generations will impact the activity-participation and travel behaviour studied in this paper.

To understand why travel behaviour changes over generations and life-cycle one needs also to understand the impacts of changes over time in one's values and opportunities. Because of the increase of wealth and creative, service-oriented and entrepreneurship economies, Hradil (1987) and Marshall et al. (2005) argued that social structure is not as stable as it once was. Individuals now behave not only according to their social classes, but also according to their personal lifestyles, based on their values and interests in life. Such changes may also influence travel behaviour and activity participation not only for the given individual, but also for the rest of the household, as Zhang et al. (2014) argued that households will continuously alter their lifestyles by collectively adjusting their behaviours in various domains in response to, or in anticipation of, mobilities within the household. Given that individuals' values, opportunities, and duties may change over time, travel behaviour and activity participation should be considered as constantly changing (Salomon and Ben-Akiva 1983; Scheiner and Holz-Rau 2007; Susilo and Kitamura 2008; Zhang 2017). The changing travel behaviour and activity participation on the one hand reflect the evolution of individuals' values, opportunities, and duties that shape their lifestyle, while their lifestyle on the other hand influences their life choices and life events as well as their travel behaviour.

Kitamura (2009), and later further elaborated by Van Acker et al. (2016), noted that lifestyle can be observed via activity and time use patterns, as well as values and behavioural orientation. However, it is sometimes impossible to separate changes in life-style, attitudes, preferences, values and travel behaviour since they are intrinsically correlated with each other (e.g., Kitamura et al. 1997; Stead and Marshall 2001; Steg 2005; Handy et al. 2005; Kitamura 2009; Van Acker et al. 2011; Elias and Shiftan 2012; Susilo et al. 2012). For instance, attachment towards car use may be influenced by changes in lifestyle, attitudes, preferences as well as more traditional economic factors and socio-economic variables. Some studies (e.g. Metz 2013; IMFO 2013; Goodwin and Van Dender 2013; Belgiawan et al. 2014), for example, argue that the recent decline in car use in developed countries is due to a shift in preference among younger people, a move from glorifying the use of the private car towards the use of more sustainable travel modes. At the same time, based on data from some selected western countries, Bastian and Börjesson (2015) and Bastian et al. (2016) have shown that such fluctuations in demand since the beginning of this century can also be explained by the fluctuations of GDP and

fuel prices that occurred in the last decade. Whilst the facts may actually complement each other, this highlights the importance of understanding the trends in a much longer perspective and in a more comprehensive way.

The relationships between life events/choices, lifestyle and travel behaviour are constantly changing over time and are therefore dependent on the generations. A particular generation is bound to a certain expectation and certain social norms (and subsequently welfare policies at a given point in time) which define the given generation's opportunity to participate in activity and travel. A study by Oppermann (1995) shows that as a result of growing up with much more relaxed social-norm constraints, younger generations gain different experiences from those of previous generations in travelling, and are likely to have different patterns in later life stages in terms of destination choices. Similar trends were found by Jones et al. (2015) when they compared walking and cycling lifetime behaviours between younger and older generations. With mobility biography, Beige and Axhausen (2008) show that the older generations are less likely to move house and do not have as much access to private cars as the younger generations. However, whilst individuals always tend to make choices based on their prior knowledge and norms of their generation [e.g. residential selection behaviour, as discussed by Chen and Lin (2011) and Yu et al. (2017), or travel patterns as discussed by e.g. Kuhnimhof et al. (2011), Beige and Axhausen (2012) and Schoenduwe et al. (2015)], such knowledge and behaviour are weakened and gradually changing (and remain) when individuals experience different opportunities and important milestones in their lives (Klöckner and Matthies 2004). Such changes are influenced not only by time-constants and time-varying preferences for the given choices (e.g. residential or mode choices) but also by the specific household biography, employment/education biography, and travel biography. These biographies include the history and the past changing patterns of the household and personal internal and external characteristics within the travellers' life domain (Zhang et al. 2014). Beige and Axhausen (2012) found strong interdependencies between the various turning points and long-term mobility decisions during the life course. Individuals will always try to compensate between the different dimensions of life. As spatial changes take place, the travel mode choice seems to be reconsidered and altered.

The constraints and opportunities for men and women in Sweden have differed substantially across generations, due to the development of welfare policies and social norms, and this must be taken into account when analysing the development of travel patterns over time. If not, differences between generation/life-cycle may be confused with temporal element changes. Various studies (e.g., Rosenbloom and Burns 1994; Chapple 2001; Kwan 1999; Hjorthol 2003; 2008; Uteng 2006, 2012) have provided comprehensive evidence on how men and women have different travel needs and constraints that shape their travel patterns differently over their life-cycle. In most countries, including Sweden, women are more likely to be the primary caregiver at home on a daily basis, compared to men. This leaves women with complex and intricate scheduling activities in both time and space (e.g., Little et al. 1988; Gordon et al. 1989; Kwan 1999; Susilo and Dijst 2009, 2010). Beige and Axhausen (2012) found that women seem to be more flexible, for instance, making considerable adjustments following the birth of children. Once children are born and live in a household, they have a stabilizing influence on the long-term mobility of this household. When children grow up, however, and leave their parents' house, both parents have more opportunities to work and to conduct leisure activities. Then, as people grow older they further adjust their life-styles.

Policies increasing independence of women and older people in Swedish society

There are many factors that may potentially contribute to the changes in travel behaviour in Sweden. These include the implementation of various policies that promote economic independence for women and older people. The first and largest reform in Swedish income tax was implemented in 1971, introducing individual income taxation. However, the system was not fully individualised until the early 1990s. The individual taxation in combination with the progressive tax system has made it more advantageous to have two lower incomes compared to one single higher income, and gave single women much better economic conditions. The expansion of public day-care also started in the 1970s. The family policies and work for gender equality in Sweden have facilitated extensive female employment and increased the fathers' responsibility for the children. They have made it possible for women and men to reconcile paid work while keeping the fertility relatively high (in 2015, the second highest in the EU, only France is higher) (Eurostat 2015). In the 1970s, the gender gap in employment started to reduce as a result of increasing employment for women but also a decline for men. In 1965, 55% of women and 90% of men were employed compared to 84% (women) and 87% (men) in 1990 (although more women were still employed part-time) (Edin and Richardson 2002). This change was partly driven by the changes in the labour market structure, favouring women, i.e., jobs in agriculture and industry, where primarily men worked, declined and the service sector, where most women worked, expanded (Löfström 2004). Almost all the new jobs of the 1970s and 1980s were created in the public sector, e.g. in the service sectors related to schools, healthcare, and childcare, where many women were employed. Presently, Sweden has the second highest female employment level in the EU (Eurostat 2015).

Another important government policy has been to promote independent travel among older people and travellers with special needs. In the early 1970s, the Swedish government introduced a free-fare special transport service (STS/färdtjänst in Swedish), which was operated similar to paratransit, for older people and travellers with special needs. The rationale behind this policy is to provide an inclusive transport system while supporting well-being in terms of the right to make choices, to act independently, and to preserve dignity and self-esteem, for older people and travellers with special needs in Sweden (Knutsson 1998).

All of these policies are expected to have profound effects on intra-household travel and activity arrangements. In particular, these policy developments could potentially affect women's travel patterns, leading to a different picture of gender equality in travel behaviour today compared with a few decades ago. Beside the changes in individual's constraints due to gender equality, there has been a surge in the use of smart-ICT devices, enabling individuals to connect and to "travel virtually" whenever and wherever they want (e.g. Mokhtarian and Salomon 1997; Mokhtarian et al. 2006; van Wee et al. 2013). In the last couple of decades, Sweden has become a society that tends to adopt new communication technology earlier than other developed countries (Vinnova 2015). For all the reasons mentioned above, Sweden is a particularly interesting country for studying the changes in men and women's travel behaviour and activity participation.

Data and classifications

Ideally, a longitudinal panel dataset of a large number of respondents over a long time period and a large area is needed for the detection of the effects of any change. Such combined datasets, however, are not available. The paper therefore employs a pseudo panel

approach which has been widely used in transportation research (e.g. Dargay 2002, 2007; Susilo and Kitamura 2008; Weis and Axhausen 2009; Jahanshahi et al. 2015). As explained by Weis and Axhausen (2009), a pseudo panel aggregated individuals from different cross-sectional surveys into groups with a consistent definition. The mean members of these groups are treated as individuals, who are followed over time, thus constructing an artificial panel dataset from a series of cross-section surveys.

In such longitudinal analysis, some researchers, such as Ganzeboom (1988), have argued that some 'stable' socio-demographic variables, such as gender, should be treated differently from changeable characteristics of stage of life (e.g., household composition, profession). Whilst, physically, gender status, from childhood to older age, is very stable over time, the values, opportunities, and constraints that come with the gender status, across eras and cohorts, have changed dramatically in the last few decades in Sweden. To observe the impacts of such dramatic changes, in this study, gender will be used as the basic classification variable for the comparison analysis. The long-observed time range covered by this dataset will help us to understand the underlying drivers of the observed gender gap in travel behaviour, valuations of travel options, and needs (Börjesson 2012; Scheiner and Holz-Rau 2013). This understanding will help us to better anticipate and/or accommodate the possible changes in travel patterns and activity participations that may happen in the future due to changes in family and transport related policies.

The Swedish national travel survey

The travel data information used in this paper comes from the Swedish national travel survey (NTS) datasets. The surveys were conducted in several time periods: 1978, 1984, 1994–1997, 1999–2001, 2005–2006, and 2011. The NTS data are travel diary data, in which a trip is defined as a certain errand having been achieved at the destination. Note that changing travel mode is not classified as an errand. A stratified random sampling method was applied based on age, gender, and municipality. The datasets covered all major municipalities in Sweden for all days of the week and for every week of the year. All trips undertaken within an observed day were recorded, including main travel mode, travel purpose, departure and arrival traffic zones, departure and arrival time, etc. (Algers 2000). The travel data collected in 1978 and 1984 only included the age, gender, and household structure of the respondent along with the trip information. In subsequent years, information such as car ownership, public transport usage, and internet accessibility was also collected (Susilo et al. 2015).

The profile of the dataset, providing the basic trend of activity-travel patterns between men and women, is presented in Table 1. Car share mode refers to the percentage of car trips (as driver or passenger) of all daily trips. Out-of-home activity duration refers to the total time that is spent on out-of-home activities on the given day. In-home activity was not included in the activity duration.

As shown in Table 1, in Sweden, on average, women have shorter total out-of-home activity durations and make fewer trips than men throughout all years. In 1978, the difference in out-of-home activity duration between men and women was, on average, 79 min. This difference decreased to around 20 min in 1999, and since then the difference of activity duration between men and women has fluctuated between 20 and 30 min. This potentially reflects women's increasing participation in the labour market. Similarly, the difference in the number of trips between men and women exhibits a similar declining trend. Men made significantly more trips than women in 1978 and

Table 1 Profile of sample and the trends of women, compared with men, over time

Survey year	Out-of-home activity duration (min)		Number of trips		Travel time (min)		Car share mode (%)		Number of observations (N)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
1978	339	260*	4.54	3.79*	98.7	79.8*	61.0	45.9*	3164	2944
1984	323	270*	4.43	3.83*	102.3	85.4*	59.4	45.2*	2847	2635
1994	321	283*	3.84	3.61*	83.7	74.5*	63.3	53.6*	3056	3088
1995	326	292*	3.68	3.58*	79.8	72.7*	62.1	54.0*	3820	3643
1996	330	289*	3.63	3.43*	75.5	70.9*	63.6	54.5*	2801	2812
1997	323	296*	3.51	3.42	76.8	70.5*	61.1	53.8*	2574	2582
1999	322	301*	3.56	3.54	85.0	77.3*	59.1	52.7*	2214	2281
2000	323	298*	3.59	3.39*	86.4	78.0*	61.1	53.1*	2204	2247
2001	329	294*	3.55	3.42	86.2	76.5*	60.5	52.3*	2285	2258
2005	327	302*	3.62	3.65	83.5	80.7	57.5	50.1*	3266	3272
2006	317	289*	3.57	3.60	87.8	85.2	56.5	48.7*	7705	7826
2011	301	280*	3.43	3.54*	90.4	88.5	57.2	50.1*	6417	6531

The statistics are weighted based on age and gender to represent the whole population in the given year

*The corresponding activity-travel parameter of women in the given year is significantly different from that of men at the 5% significance level

1984, men's trip frequency then decreased until the 1990s. Since 2000, the number of trips does not differ very much between men and women. These numbers echo the findings of previous studies (e.g., Susilo and Maat 2007; Kalter et al. 2011) showing the travel patterns of men and women becoming increasingly similar. Furthermore, in 2002 the Swedish government initiated a policy goal of a gender-equal transport system (Wittbom 2011), which may also have contributed to eliminating the gender gap in travel patterns. Women have a shorter travel time and lower share of car trips than men, but the gap was again much more substantial before the 1990 s, showing women's increasing use of cars (Kalter et al. 2011).

Defining life-cycle stages

To analyse systematically how men and women at different life-cycle stages from different generations composed and prioritised their activity-travel patterns differently, 17 life-cycle stages were defined, as shown in Table 2. The classification is based on the respondent's age and household type (single living or partnered living, and whether they have young/teenage children). As the dataset covers several time points in the period from 1978 to 2011, respondents of different generations at different life-cycle stages were sampled. Table 3 summarises the age range of each generation at each time point of the dataset. For early generations (e.g., 1930s and earlier), only their late life-cycle stages (e.g. "46–64 single with no child", "partnered elderly") were observed. For young generations, only their early life-cycle stages were observed.

Table 2 Life cycle groups used in the model

Group name	Description
Teenager	Aged between 12 and 17 years old
18–30 single	Aged between 18 and 30 years old, with no partners in the family
18–30 partnered	Aged between 18 and 30 years old, with at least one partner in the family
31–45 single with no child	Aged between 31 and 45 years old, with no partners and one child in the family
31–45 single with young child	Aged between 31 and 45 years old, with no partners but at least one young child, 0–6 years old, in the family
31–45 single with teenage child	Aged between 31 and 45 years old, with no partners but at least one teenage child, 7–18 years old, in the family
31–45 partnered with no child	Aged between 31 and 45 years old, with at least one partner but no child in the family
31–45 partnered with young child	Aged between 31 and 45 years old, with at least one partner and one young child, 0–6 years old, in the family
31–45 partnered with teenage child	Aged between 31 and 45 years old, with at least one partner and one teenage child, 7–18 years old, in the family
46–64 single with no child	Aged between 46 and 64 years old, with no partners and one child in the family
46–64 single with young child	Aged between 46 and 64 years old, with no partners but at least one young child, 0–6 years old, in the family
46–64 single with teenage child	Aged between 46 and 64 years old, with no partners but at least one teenage child, 7–18 years old, in the family
46–64 partnered with no child	Aged between 46 and 64 years old, with at least one partner but no child in the family
46–64 partnered with young child	Aged between 46 and 64 years old, with at least one partner and one young child, 0–6 years old, in the family
46–64 partnered with teenage child	Aged between 46 and 64 years old, with at least one partner and one teenage child, 7–18 years old, in the family
Single older adult	Aged 65 and over, with no partners in the family
Partnered older adult	Aged 65 and over, with at least one partner in the family

65 is the official retiring age for Swedish employees

Table 3 Age range for each generation at each time point of the dataset

Time points Generations	1978	1984	1994–1997	1999–2001	2005 and 2006	2011	All datasets
Earlier than 1930s	48–84	54–84	64–84	69–84	75–84	81–84	48–84
1930s	38–47	44–53	54–66	59–70	65–75	71–80	38–80
1940s	28–37	34–43	44–56	49–60	55–65	61–70	28–70
1950s	18–27	24–33	34–46	39–50	45–55	51–60	18–60
1960s	15–17	15–23	24–36	29–40	35–45	41–50	15–50
1970s	–	–	14–26	19–30	25–35	31–40	14–40
1980s	–	–	12–16	12–20	15–25	21–30	12–30
1990s	–	–	–	–	12–15	12–20	12–20

The age range of 1978 and 1984 datasets is 15–84, while the age range of data after 1994 is 6–84

Descriptive analysis: lifetime span distribution of travel indicators

Based on the given classification of life-cycle stages (as shown in Tables 2 and 3), Fig. 1 illustrates an example of how the number of trips per day by men in the 1960s varies in different life-cycle stages across their lifetime. As shown in Fig. 1, among men who come from the same generation (born in the 1960s), the trip frequency varied significantly over the different life-cycle stages. Single young men (18–30 years old), on average, made 0.3 fewer trips per day than teenagers (12–17 years old). The partnered young men made fewer trips than their single counterparts. When they were getting older, they made fewer trips, unless they had children. The presence of children, especially young children, increases the number of trips made by men, on average by 0.43 more than if they had no children.

These trends are unlikely to be the same for women and men of other generations. As mentioned earlier, in the literature review section, the presence of children, being single or partnered, or getting older, would have different meanings for women than for men (Hjorthol et al. 2010; Zhang 2017). Thus, women, at different life-cycle stages face different resources and constraints and may respond differently compared to men (Kwan 1999; Hjorthol 2003; Uteng 2012). This gender difference, which would be different across life-cycle stages, would also evolve over time. Women in younger generations may be more involved in the labour market, better educated, and more specialised, which would potentially affect their life-goals and life-style, and subsequently their activity-travel patterns, which would lead to different trends over time (Frändberg and Vilhelmson 2011; Elldér 2014). To explore these trends in men's and women's travel behaviour and activity

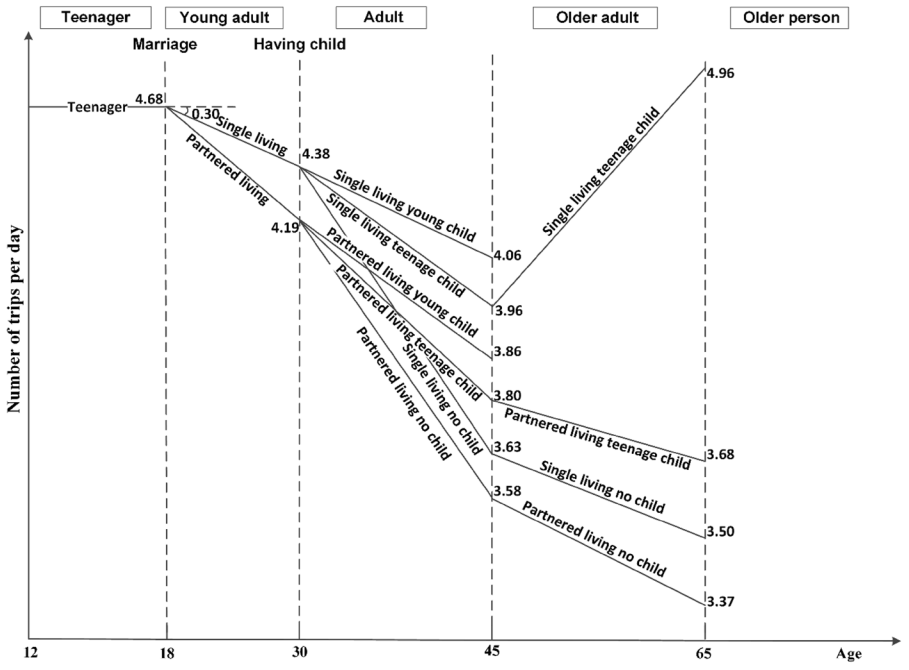

Fig. 1 An illustration of the variation of the number of trips per day of men who born in the 1960s across their life-cycles, throughout their lifetime

participation, in "The lifetime span distribution of out-of-home activity duration by gender, generation, and life-cycle stages", "The lifetime span distribution of the average number of trips per day by gender, generation, and life-cycle stages" and "The lifetime span distribution of car usage by gender, generation, and life-cycle stages" sections we will discuss how (1) the duration of out-of-home activity, (2) the number of trips per day, and (3) car usage, respectively, have been changing over different combinations of gender, life-cycle, and generation in Sweden within the last 30 years.

The lifetime span distribution of out-of-home activity duration by gender, generation, and life-cycle stages

Since it is not possible, due to limitations of the paper's length, to show every path combination of gender-generation-life-cycle stages, as shown in Figs. 1, 2 shows only the average values of men's and women's out-of-home durations (in minutes) of all observed generations at a given life-cycle stage. Out-of-home activity duration denotes the total amount of time a given individual spent on various out-of-home activities per day in minutes. For example, four generations of teenagers can be observed in the dataset, i.e., the teenagers of the 1960s, 1970s, 1980s, and 1990s generations. As shown in Fig. 2, teenage males of the 1960s generation have on average 379.8 min of out-of-home activity duration while teenage females of the 1960s generation have on average 350.1 min of out-of-home activity duration Women therefore have 29.7 min shorter out-of-home activity duration, which is significantly different at $\alpha = 1\%$ and 10% levels. Note that life-cycle stages for a given

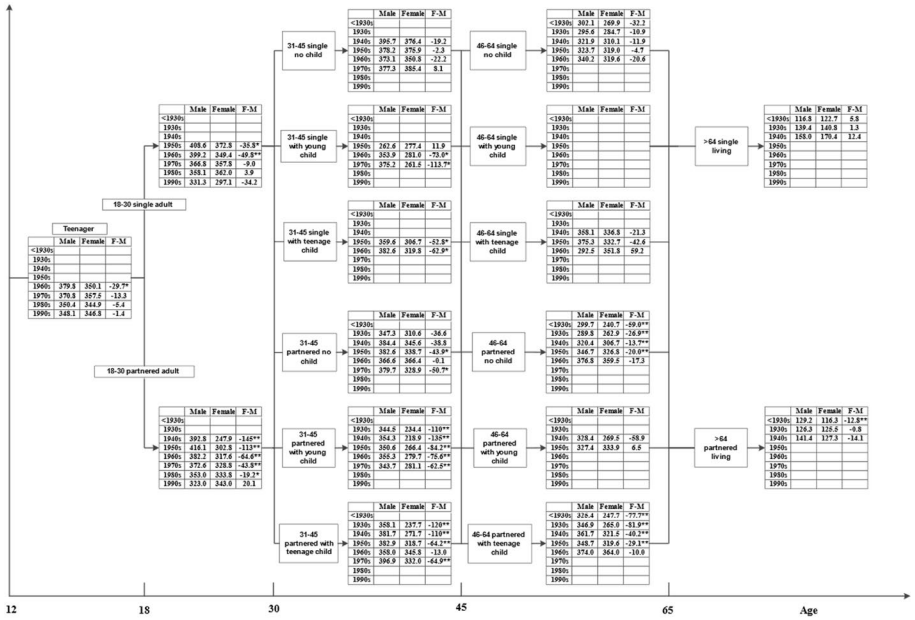

Fig. 2 Out-of-home activity duration per day across life-cycle groups and generations (**: the distribution of values for males and females is significantly different at the 1% level, *: the distribution of values for males and females is significantly different at the 10% level)

generation with fewer than 100 observations are not reported (e.g. life-cycle stage "46–64 single living with young child" among the 1950s generation has only 11 observations).

In terms of out-of-home activity duration, the average values in Fig. 2 show clearly that men and women evolved differently across different generations. In the teenage years (12–17 years old), the gender difference in terms of out-of-home time use diminishes in younger generations mainly due to a rapid decrease in the out-of-home activity duration for men over generations. It is plausible that factors such as technology developments, e.g. video games, have provided alternatives for in-home activities which may lead to a decrease in the out-of-home activity duration for teenagers. This trend is similar to the trend found by Susilo and Waygood (2012), who analysed the evolution of the activity-travel patterns of children in the Osaka metropolitan areas between 1980 and 2000. A similar trend is also found among young men (18–30 years old), with a more dramatic decrease for partnered young men. Partnered young women's out-of-home activity duration is increasing over generations while their male counterparts show a decreasing trend in out-of-home activity duration. These figures are evidence showing that the intra-household activity division across gender in Sweden has changed over generations, where in recent years women are more involved in social activities while men are taking more responsibility for in-home housework (Frändberg and Vilhelmson 2011; Susilo et al. 2015). However, this merging trend is not reflected in the trends among single young men and women; both show a decreasing trend of out-of-home activity duration, but more so for men. As in-home access to ICT and media in recent years has become more important in the daily life of most households in Sweden (Ellegård and Vilhelmson 2004), such decreasing trends are not surprising. No significant gender difference is found for singles (31–45 years old) without children.

The out-of-home activity duration difference becomes more apparent over generations for singles with young (0–6 years) and older children (7–18 years), where single fathers' out-of-home activity durations increase significantly over the generations, compared to their single mother counterparts. The gender difference among partnered/couple families with young and teenage children, however, diminishes over generations. This indicates a different evolution path between single and partnered parents over generations, and also echoes the success of gender equality in parenting between partnered/married parents in Sweden. This applies to both young and older parents between 31 and 64 years old.

For retirees (> 64 years old), no gender difference is observed in any generation except for the < 1930s generation, for singles and partnered. There is an increasing trend for out-of-home time use for both men and women retirees, which is in line with Zhang's (2017) findings in Japan.

The lifetime span distribution of the average number of trips per day by gender, generation, and life-cycle stages

Figure 3 presents the average number of trips travelled per day, by gender group, over generations and life-cycle stages. Overall, the trends of gender difference in terms of the average number of daily trips are similar to those in the out-of-home-activity duration (which was discussed in "The lifetime span distribution of out-of-home activity duration by gender, generation, and life-cycle stages" section), i.e., the difference in the number of daily trips made between gender groups diminishes over generations, where men of younger generations have many fewer trips than those of earlier generations, while women of younger generations have a similar number or slightly fewer trips compared to those of

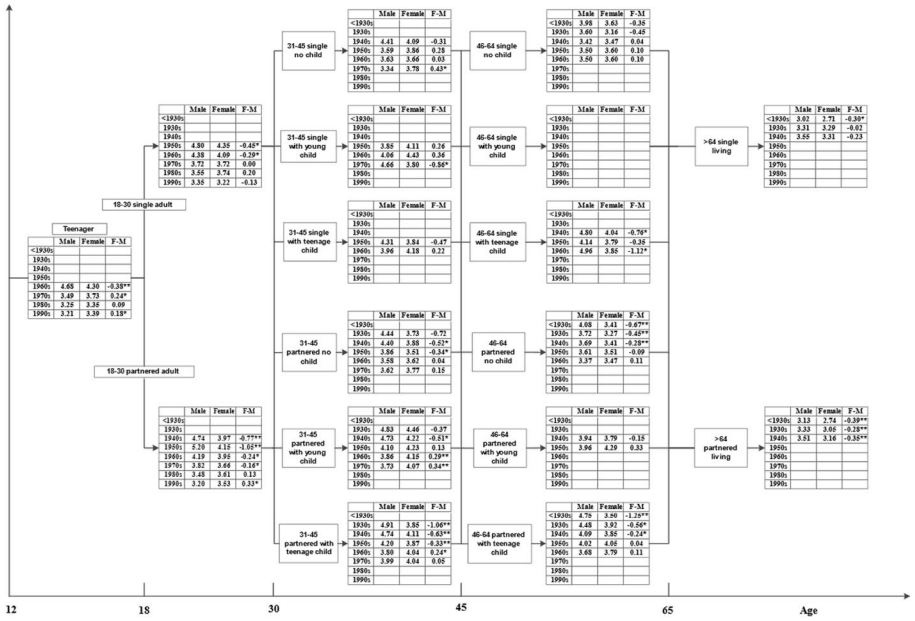

Fig. 3 Average number of trips per day across life-cycle groups and generations (**: the distribution of values for males and females are significantly different at the 1% level, *: the distribution of values for males and females are significantly different at the 10% level)

earlier generations. In particular, the largest changes appeared among partnered/married families with teenage children, which provides evidence of a clear intra-household activity division among older generations of those households (which is in line with Frändberg and Vilhelmson 2011; Susilo et al. 2015). Among older people, both for men and women, there is an increasing trend of the number of trips over generations; among older generations, men consistently make more trips than women. This is probably a combination of the implementation of a paratransit transport service and the increased health and wealth of older generations in Sweden.

The lifetime span distribution of car usage by gender, generation, and life-cycle stages

Figure 4 presents the gender differences in car usage (the share of car driving and car passenger trips on the given day) across generations and life-cycle stages. As can be seen in Fig. 4, female teenagers have a slightly higher car passenger trip share than their male counterparts, which is the case for all observed generations. This is in line with studies from other countries (e.g. van Vliet 1983; McMillan et al. 2006), where it was found that teenage girls were more likely to be car passengers and they walked more than teenage boys, as compared to taking public transport or travelling by bicycle. The reason underlying this behaviour, however, may not be similar to the reason in other countries. While in other countries (e.g. Waygood and Susilo 2011; Susilo and Liu 2016) parents' safety concerns are more likely to be the main reason, in Sweden it is relatively normal for teenagers to travel independently. Johansson et al. (2009) found that (teenagers') personal

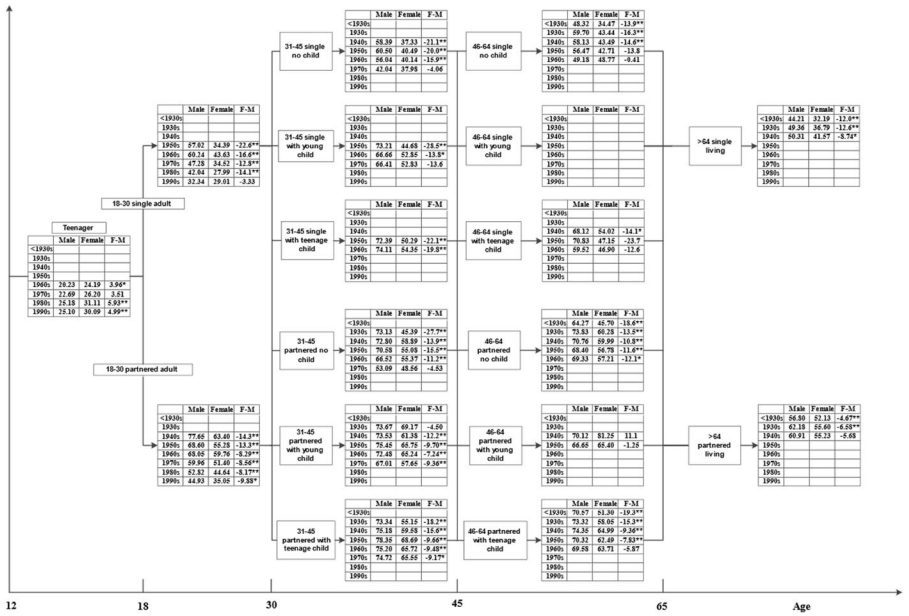

Fig. 4 Average daily car share across life-cycle groups and generations (**: the distribution of values for males and females are significantly different at the 1% level, *: the distribution of values for males and females are significantly different at 10% level)

fear, particularly of darkness, is the main reason for not walking/cycling among teenagers, which is significantly greater than their fear of traffic.

While the gender difference in car usage is diminishing over generations, especially among single young adults, as expected, women consistently had a lower car share than men. The life-cycle stages with the most prominent diminishing trend were couples and singles without children and older couples with teenage children. This is mainly due to the dramatic decrease in men's car usage over generations, while there is relatively stable car usage or even slightly increasing car usage among women. These trends could presumably be results of rapid urbanisation, improved public transport infrastructure, and higher labour participation among women over the last two decades in Sweden.

Controlling the differences over time: a model system to systematically examine the different paths of changes across different genders, life-cycle stages, and generations

The previous section has presented the trends of how the out-of-home activity duration, the number of trips per day, and car usage have been changing across different genders, life-cycles, and generations in Sweden in the last 30 years. To be able to systematically analyse, follow, and quantify the evolution of the key factors driving these changes over time, while at the same time also controlling internal and external factors that arose during the observed period, the following model system is proposed.

Model specification

A common procedure in previous studies to understand gender difference is to include a dummy variable (D_f) representing men or women in a model of an activity-travel indicator of interest (Y):

$$Y = f(D_f) \tag{1}$$

Then the estimated coefficient or marginal effect of this dummy variable (D_f) denotes the gender difference. However, as presented above, the gender difference would be different depending on the life-cycle stage (L) and generation (G) to which the given individual belongs. Then Eq. (1) can be rewritten as:

$$Y = f(D_f|L, G) \tag{2}$$

Equation (2) shows that the estimated coefficient or marginal effect of gender is unique for each life-cycle stage and each generation.

To estimate the marginal effects of gender, given different life-cycle stages and generation combinations, a model structure is proposed. The model structure follows the classic conceptual framework proposed by Golob (2000), as shown in Fig. 5a. The conceptual model links the activity duration, number of trips, trip chaining pattern, travel time, and car usage. Activity duration is determined first as the activity demand, and then followed by trip generation and the trip chaining pattern. Travel time is then determined given the number of trips and the number of trips per trip chain. The trip chaining behaviour provides a feedback loop from the number of trips to the activity duration. Travel time influences the activity time through the time budget concept. This approach is to model trip generation jointly with time use. The models can reveal how the generation of simple and complex trip chains is interrelated with the demand for out-of-home activities, and how the travel "time budget'' effects can affect activity demand and trip generation (Golob 2000; Susilo and Avineri 2014).

Thus, the proposed model structure used to capture the gender difference in activity-travel patterns follows the above-mentioned general conceptual framework. The model system is shown in Fig. 5b. The model system is based on 10 activity-travel pattern indicators (dependent variables):

D_n = daily out-of-home non-work activity duration (in minutes)
D_w = daily out-of-home work (school) activity duration (in minutes)
N_n = number of non-work trips on a given day
N_w = number of work trips on a given day
C_n = number of trips per non-work trip chain on a given day
C_w = number of trips per work trip chain on a given day
T_n = total non-work-related travel time on a given day (in minutes)
T_w = total work-related travel time on a given day (in minutes)
M_d = percentage of driving trips in all daily trips
M_p = percentage of car passenger trips in all daily trips

Following the conceptual model framework, the proposed model assumes the work (school) activity duration as given. Given the work activity duration, the non-work activity duration and the number of work trips were scheduled, as indicated by Fig. 5b. The number of non-work trips was determined given the non-work activity duration and the number of work trips. The number of trips per work and non-work trip chain were then determined given the

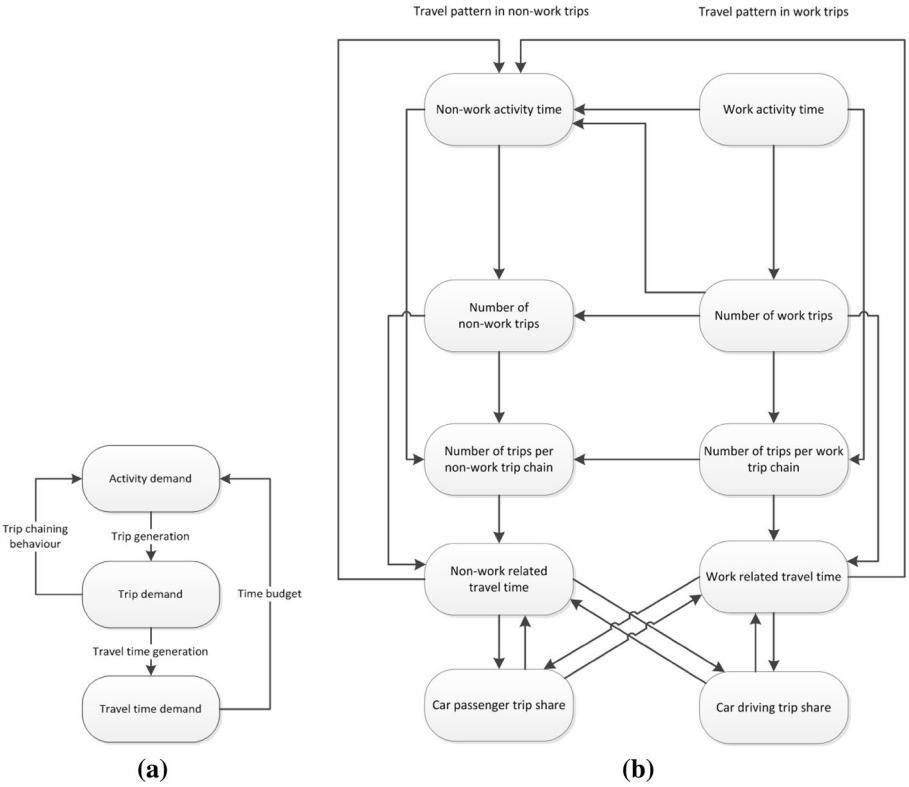

Fig. 5 Model structure used in this paper. **a** Conceptual model **b** proposed model structure

activity durations and trips. The number of work trips was assumed to influence the non-work activity duration. The work and non-work-related travel time were then a function of the number of work and non-work trips and the number of trips per work and the non-work trip chain, respectively, reflecting that travel was a derived demand of activity participation. The work and non-work-related travel time also influence the non-work activity duration to reflect the effect of the time budget. Finally, the proposed model expands the conceptual model by adding mode share parts. Both the work and non-work-related travel time were assumed to influence the car usage and car passenger share, and vice versa.

The model shown in Fig. 5b can be generally expressed in the following equations.

$$
\begin{cases}
D_n = \beta^1 f(D_w, T_n, T_w, N_w) + \gamma^1 D_f + \varepsilon_1 \\
D_w = \gamma^2 D_f + \varepsilon_2 \\
N_n = \beta^3 f(D_n, N_w) + \gamma^3 D_f + \varepsilon_3 \\
N_w = \beta^4 f(D_w) + \gamma^4 D_f + \varepsilon_4 \\
C_n = \beta^5 f(D_n, N_n, C_w) + \gamma^5 D_f + \varepsilon_5 \\
C_w = \beta^6 f(D_w, N_w) + \gamma^6 D_f + \varepsilon_6 \\
T_n = \beta^7 f(N_n, C_n, M_d, M_p) + \gamma^7 D_f + \varepsilon_7 \\
T_w = \beta^8 f(N_w, C_w, M_d, M_p) + \gamma^8 D_f + \varepsilon_8 \\
M_d = \beta^9 f(T_n, T_w) + \gamma^9 D_f + \varepsilon_9 \\
M_p = \beta^{10} f(T_n, T_w) + \gamma^{10} D_f + \varepsilon_{10}
\end{cases}
\tag{3}
$$

The SEM model in Eq. (3) in general can be expressed as

$$
y = By + \Gamma x + \zeta, \tag{4}
$$

where B is the matrix of coefficients (all βs) representing the direct effects of endogenous variables on other endogenous variables. Γ is the matrix of coefficients of endogenous variables (all γs), representing the direct effect of the exogenous variables. Then, y is the vector of endogenous variables, x is the vector of exogenous variables and ζ is the vector errors (all εs) in the equations with the standard assumption that ζ is uncorrelated with x. Note that each dependent variable in Eq. (3) is treated as a continuous variable under a multivariate normality assumption. However, several dependent variables are in fact count variables, e.g. the number of work trips on a given day, that do not satisfy the multivariate normality assumption. The SEM model with count and discrete endogenous variables is rarely used in practice due to the difficulties in model estimation, especially when the endogenous relationships are complex such as in this study. This limitation could possibly lead to over- or under-estimation of variable effects. However, the sign of the estimated variable effect, such as the gender dummy, still provides valuable implications for the gender difference in travel behaviour.

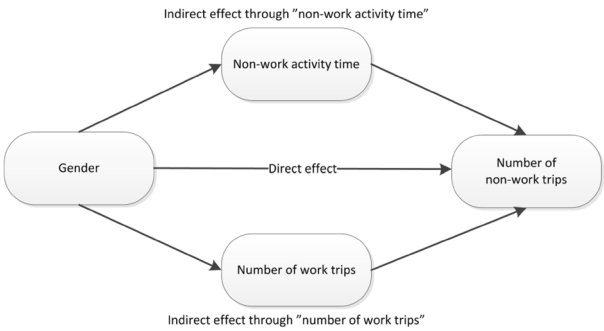

Fig. 6 Illustration of direct, indirect and total effect

The gender dummy is introduced as an exogenous variable of the model system. The model is treated as a path model or a structural equation model (SEM) with no latent variables. To derive the marginal effect of gender on each dependent variable, multi-group SEM is introduced. The whole dataset is first classified into different life-cycle stages (cohorts), and a multi-group SEM is then estimated on each life-cycle stage, where each generation in the given life-cycle stage is treated as a group. The estimated total effect and direct effect are presented. The total effect is the sum of the direct and the indirect effect, which denotes the marginal effects of being female compared to male on an activity-travel pattern indicator given the model structure. One example of the total effect of gender on the number of non-work trips is illustrated in Fig. 6, where the total effect is the sum of the direct effect of gender on the number of non-work trips and the indirect effects through non-work activity duration (the mediation variable) and the number of work trips (see Fig. 5). The estimated total effect of a given group (generation) and given life-cycle stage then denotes the gender difference of that specific generation and life-cycle stage.

It is important to mention that the model does not take into account other important exogenous variables such as land-use patterns, income and education, etc. This is due to the fact that the 1978 and 1984 datasets do not contain detailed information regarding income, education, car ownership and occupation. Therefore, the estimated gender effects in different generations/life-cycle stages may be influenced by the differences in the distributions of those exogenous variables. For example, the difference in the estimated gender effects for young partnered women in the 1950s generation and 1980s generation could be due to the difference in the distribution of education (higher percentage of educated women in the 1980s generation than in the 1950s generation, which affects their travel patterns differently). Therefore, the estimated direct and total effects should be interpreted as overall effects including the influences of exogenous variables that were not included in the analysis. Further speculations on the cause of gender effects (education, urbanization, income, etc.) need to be done with caution.

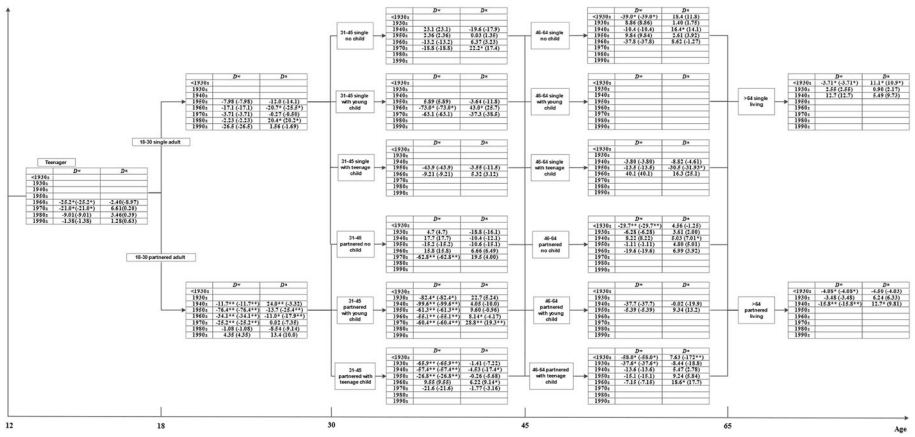

Fig. 7 Total and direct effect (in parenthesis) of gender on work/non-work activity duration (**: significant at the 1% level; *: significant at the 10% level)

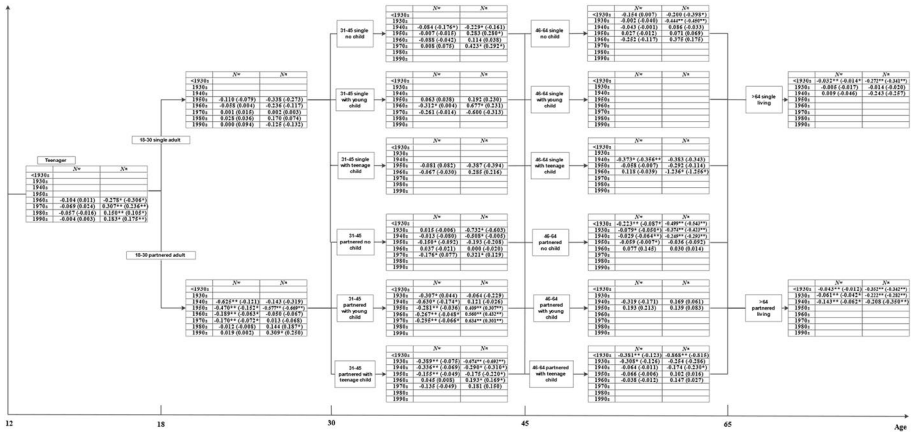

Fig. 8 Total and direct effect (in parenthesis) of gender on number of work/non-work trips

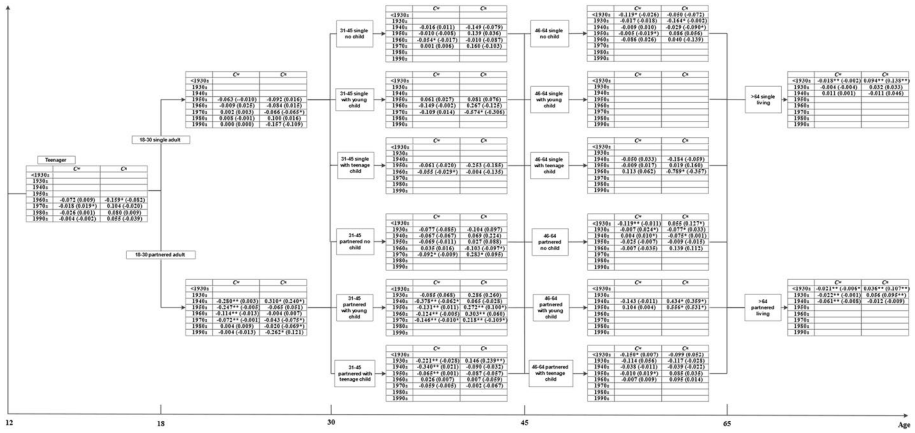

Fig. 9 Total and direct effect (in parenthesis) of gender on number of trips per work/non-work trip chain

Model estimation results

The models were estimated by AMOS 20.0 software using the generalised least squares method. The estimation result has a decent fit with the goodness of fit index: RMSA ranging from 0.036 to 0.197 and CMIN/DF ranging from 1.47 to 4.64. The total effect of gender on each dependent variable is presented in Figs. 7, 8, 9, 10, 11. The corresponding discussion follows.

Model results on activity duration

Figure 7 presents the estimated total effect and direct effect (in parenthesis) of gender on work and non-work activity duration for each life-cycle stage and generation. The gender difference exhibits large variations among life-cycle stages as well as among generations, which also indicates that the marginal effect of gender is not unique for different life-cycle

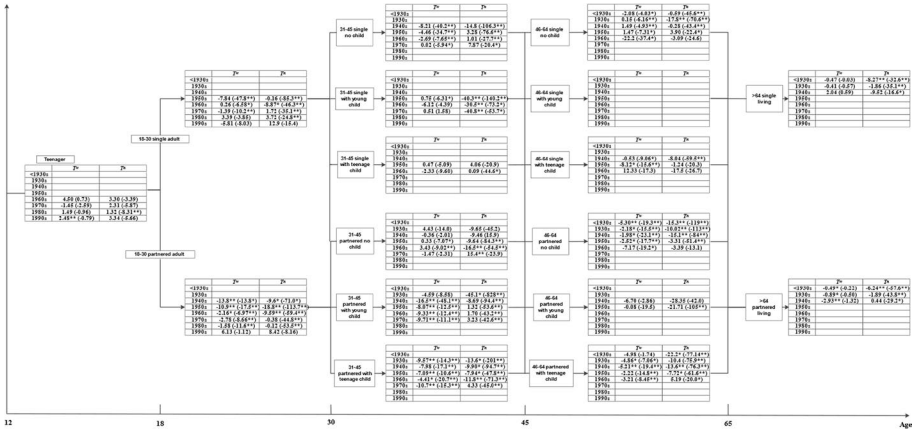

Fig. 10 Total and direct effect (in parenthesis) of gender on work/non-work related travel time

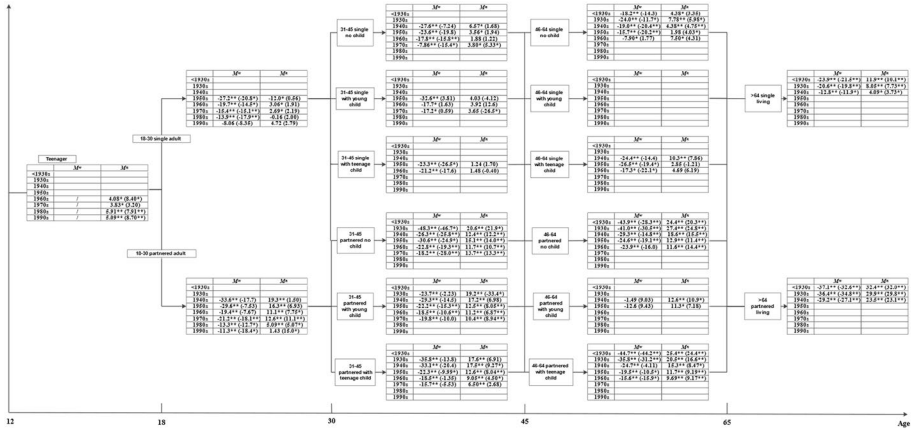

Fig. 11 Total and direct effect (in parenthesis) of gender on car driving and car passenger shares

stages and not stable over generations. Since there is no mediation variable towards work duration in the model, the direct effects on work activity duration are exactly the same as the total effects.

There is no clear gender difference in non-work activity duration between teenagers and the other generations. Female teenagers of the 1960s and 1970s generations have shorter school durations than their male counterparts, but the gender difference then diminishes in younger generations. Presumably this is an indirect impact of the government's early 1990s policy that provided children with an extensive right to choose their preferred school. This policy replaced a traditional system in which students were assigned to schools largely based on their place of residence. The introduction of school choice implies that children, in principle, can make decisions concerning daily travel-to-school distances in the same way that adults decide where to go to work (Andersson et al. 2012). Thus, while it was common for boys from older generations to spend more time at school, the younger generations have to spend more time travelling to and from school.

It can also be seen that the young partnered women of early generations have significantly shorter work durations than their male counterparts. The difference, however, becomes insignificant for younger generations. This demonstrates the success of the policy that facilitates partnered women's participation in the labour market which was implemented in the mid-1970s (Hjorthol et al. 2010; Frändberg and Vilhelmson 2011). However, single young adult women do not have significantly different work durations compared to single young adult men for all observed generations.

For couples, the trend in the gender difference in work duration differs between those with and without children. Consistent with the previous discussion, the earlier generations of partnered/married women have shorter work durations than their male counterparts; but this difference diminishes for younger generations. The gender difference has declined fastest among parents with children (teenage and younger), indicating that mothers have become more active in the labour market. The model estimation also shows that partnered/married women with young children are not only having shorter work durations but are also becoming more active in out-of-home non-work activities. The gender difference, however, further disappears when they reach 70 years old, presumably because after this milestone of age the physical ability differences between elderly men and women tend to be less (Zhang 2017). However, on average, single elderly women in Sweden are in better physical condition and more capable of engaging in daily activities such as shopping than single elderly men (Susilo et al. 2015). The direct effect on non-work activity duration is in most cases (when the total effect on work duration is negative) smaller than the corresponding total effect, indicating a positive indirect effect. This reflects the fact that women in their respective generation and life-cycle stage have shorter work durations.

Model results on number of trips

The estimated total and direct effects of gender on the number of work and non-work trips are shown in Fig. 8. As shown in the total effects on the number of non-school trips, female teenagers seem to have more non-school trips than male teenagers in all generations except the 1960s generation, implying that female teenagers are more engaged in outdoor activities. Meanwhile, the direct effects show the same trend indicating that a substantial part of the total effects are not from indirect effects (female teenagers have slightly longer non-work durations that indirectly lead to extra non-school trip generation). In the past, partnered/married young women had fewer non-work trips than their male counterparts while those of younger generations made more non-work trips than their male counterparts. The direct effect indicates that this trend is not merely a result of the mediation effects from the non-work activity duration and number of work trips. The trend might be driven by partnered/married young women reallocating their time from housework to more out-of-home social activities. Overall, the trend in the number of work trips corresponds to those in work durations, e.g. the gender difference in work trip frequency for partnered young adults diminishes over the generations. These trends again show that women are becoming more active in the labour market. Furthermore, partnered/married women with young children from younger generations also make more non-work trips than their male counterparts and a large part of the effects are direct effects. Although the total effects increase from 0.409 (1950s generation) to 0.634 (1970s generation), the direct effects remain around 0.3. This implies that the increase in non-work trip frequency is mainly due to partnered/married women with young children having longer non-work activity durations and fewer work trips. It is relatively easy and common for mothers and fathers to travel with buggies and

small children in Sweden due to the high standard specification of public transport modes (Susilo and Cats 2014).

Model results in trip chaining pattern

The estimated total and direct effects of gender on the number of trips per work and non-work trip chain are shown in Fig. 9. The model estimations show no significant difference between male and female teenagers' trip chaining complexity for all observed generations. Consistent with other variables, the early generations of partnered/married young women have fewer trips per work trip chain than their male counterparts, but this gender difference is becoming smaller among younger generations. The declining gender difference is mainly due to changes in gender effects in the number of trips and activity duration through indirect effects. Partnered/married adult women with young children have more complex non-work trip chains but simpler work trip chains than their male counterparts. This is in line with the findings of previous studies (e.g. Kwan 1999; Hanson 2010) that emphasise that women have more complex and intricate scheduling activities in both time and space than their male counterparts. When they become older, however, this gender difference disappears.

Model results on travel time

The estimated total and direct effects of gender on work/non-work related travel time are shown in Fig. 10. Most of the trends we find for travel time resemble those for activity duration and the number of trips. Teenagers show no significant gender difference in travel time in any generation. Partnered/married young women of earlier generations have shorter work and non-work related travel time than men, mainly due to indirect effects such as fewer work/non-work trips and simpler trip chaining patterns that lead to shorter travel time. Single women with children have shorter non-work travel time than their male counterparts, and the indirect effect here dominates, indicating that single women with children have shorter non-work travel time because of shorter trips rather than a lower trip frequency (indirect effect). Partnered/married elderly women have both shorter work and non-work travel time than their male counterparts, as they travel less. While elderly women who were born earlier than the 1930s have a shorter non-work travel time than their male counterparts, this is not the case for younger generations (1930s and 1940s generations), although women in all generations make shorter trips, which leads to a shorter travel time (direct effect).

Model results on car usage

The estimated total and direct effects of gender on car driving and car passenger sharing are shown in Fig. 11. Female teenagers are slightly more likely to be car passengers than male teenagers (3.83–5.91%), and this difference is slightly larger for younger generations. For adults and older people, the car driving share is consistently higher for men than for women in all life-cycle stages. However, the difference has reduced for younger generations. The drop in this gender difference over the generations (both in total effect and in direct effect) appears most substantially in the group of partnered/married families without children (a drop from 48% in the 1930s to 18% in the 1970s). Both single

and partnered/married young women have a significantly lower car driving share than their male counterparts, and this gender difference declines but does not disappear for young generations. The women of the 1980s and 1990s generations still have on average 10% less car driving share than men, although that number is 30% for the 1940s generation. These trends seem to show that although more women have started driving, the gender gap in terms of driving still remains.

Discussion and conclusions

Using several datasets from the Swedish national travel survey (NTS) covering a range of over 34 years, this paper explores the evolution of gender difference in work and non-work activity-travel patterns in different life-cycle stages, defined by age group and household structure. By jointly modelling the activity time use, number of trips, trip chaining pattern, travel time, and car usage, a comprehensive picture of gender difference over the generations is depicted.

Our results confirm that the behaviour is unique for each life-cycle stage and generation:

1. Women are becoming increasingly active in the labour market, with increased education level and specialisation. This change is consistent with the policy changes implemented in Sweden since the 1970s.
2. The women from younger generations, including those who have children, are becoming more active in out-of-home non-work activities and having more complex trip chaining, compared to their male counterparts. These trends are consistent with the change in the intra-household activity division between the genders in Sweden; in recent years, women have become more involved in social activities while men are taking increasing responsibility for in-home housework.
3. While men are still driving more than women, the gap is decreasing over time for all life-cycle stages, particularly in the group of partnered/married families without children (the gender difference in car driver percentage drops from 48% in the 1930s to 18% in the 1970s).
4. The gender difference among teenagers in terms of out-of-home time use diminishes in younger generations. The rise in the use of video games and changes of school choice policy may have contributed to teenagers of younger generations spending their leisure time more inside their home and spending more time making school trips, respectively.
5. Retirees are travelling more independently in later generations. The implementation of the special transport service (*färdtjänst*) might be one contributing factor for this.

It is also important to remember that the travel and activity participation behaviours and life-style changes we found were gained not only based on policy implementation, but also because of other general improvements in society, such as the level of education and improvements in the infrastructure. These changes did not just happen in a day, but are the results of long-term investment. In our model analyses, those factors were not explicitly taken into account due to the limitation of the datasets, especially in the datasets of 1978 and 1984. This remains a possible future direction for this study.

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