

More gray hair—but for whom? Scenario-based simulations of elderly activity travel patterns in 2020

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Abstract This paper reports the results of a scenario-based simulation study to explore mobility effects of an aging society in the Netherlands. Four accumulative behavioral scenario variants, embedded in an economic and demographic scenario are used to simulate possible future activity-travel patterns, using the Albatross system as the simulator. The variants account for likely differences in activity-travel behavior between elderly today and elderly in the future. Trends ongoing over the last decade in the Netherlands suggest that future elderly need to work longer, change their activity pattern with most growth occurring in the social/leisure activity category, will try to avoid morning peak hours by rescheduling their activities and may introduce more spatial diversity in terms of their residence location. Results show that these behavioral and spatial changes lead to a significant increase in travel demands as well as temporal, spatial and modal shifts in mobility patterns. We discuss possible policy implications of these predictions and evaluate the specific strength of activity-based models for studies of this kind.

Keywords Aging society · Economic change · Scenario analysis · Albatross · Activity-travel patterns

Introduction

As many other developed countries, The Netherlands is experiencing a rapid growth in its elderly population, and this trend is expected to continue. By 2030, about 25% of the Dutch

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will be over the age of 65. The growing number and proportion of older people will have significant impacts for different facets of society. The working population may be too small to support the elderly and there is a discussion about the increasing costs of medical care CPB (2000).

Pisarki (2003) has argued that an aging society will also cause major challenges for transportation planning. Although people tend to drive less as they get older, elderly drivers are more accident-prone and have an increased risk of injury, given a crash. For the Netherlands, it is predicted that the total number of seriously injured car drivers will increase from 11.8 to 18.43% in 2030 (Davidse 2000). Reduction of transportation resources in rural and suburban areas as a result of commercialisation of public transport may imply that the elderly as a vulnerable segment of the population may be hit the hardest (Stern 1993; Franklin and Niemeier 1998; Smith and Sylvestre 2001). Elderly may forego needed services leading to increased isolation and perhaps to social exclusion (e.g., Cvitkovich and Wister 2001; Harrison and Ragland 2003). Public transport may be infrequently used by the elderly as they grow older, often due to problems in boarding and disembarking from buses or to concerns about personal safety. Transport mode options such as walking or biking also tend to cease at some point in time. All these trends imply that the elderly may lose their independence and become socially excluded. On the other hand, the growth of the elderly population can also be viewed as an opportunity in the sense that the growing number of elderly may constitute an increasing market segment, should public transport companies be able to provide their transportation needs.

Little however is known about the impact on transportation of an aging society. Although several studies have examined current travel patterns of seniors in general (e.g. Tacken 1998; Alsnih and Hensher 2003; Siren and Hakamies-Blomqvist 2004, Newbold et al. 2005) or have examined their leisure activities (Föbker and Grotz 2003; Kemperman and Timmermans 2006), it is not readily evident that current observations can be extrapolated to the future. There are significant cohort effects. Whereas a substantial percentage of current seniors use public transport, the future generation has become less dependent on public transport as a larger percentage has a driver's license and owns a car. They tend to be more mobile with a tendency to make more and more varied trips, because of a different lifestyle, than previous elderly cohorts (Rosenbloom 2001; Waldorf 2003). Moreover, they are better-off in the sense that they are more healthy, more independent and have accumulated wealth. Further, many companies see the elderly as a target market and offer special discounts and programs. Hence, the combined effects of these trends may imply an increased mobility. Some of this may be long-distance (vacation travel, second house and temporarily moving to warmer countries), but some will also impact daily, regional travel, potentially leading to more congestion, congestion at other hours of the day, with negative externalities to the environment.

Despite the relevance for society, there is a paucity of research examining the effects of an aging society on future activity-travel patterns. To address this issue, the present paper reports a study based on a series of future-development variants that in addition to assumptions about economic growth reflects an aging society and elderly with a different behaviour. The study is rather unique in the sense that to the best of our knowledge, this is one of the first studies applying an activity-based model (Albatross). This implies that unlike previous research, the focus is not on isolated trips, but on comprehensive daily activity-travel patterns and time use. More specifically, the Albatross model system (Arentze and Timmermans 2000, 2004, 2005) was used to simulate future behaviour of different cohorts for a series of accumulative, behavioural variants. Previous versions of Albatross were based on activity diary data collected in different regions of the

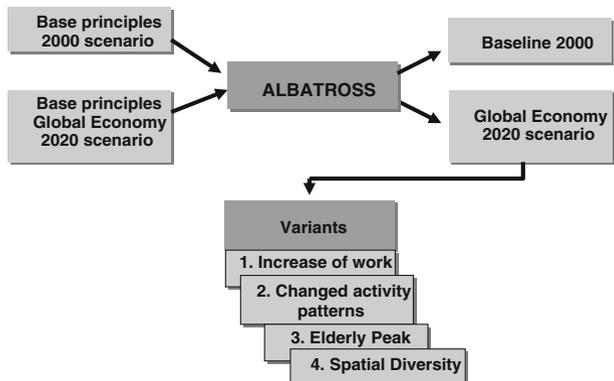
Netherlands. In the context of the present study, the decision rules, which constitute the basis of the model were re-induced, using the national MON data (the latest travel survey in the Netherlands, involving a sample of 29,221 households). A finer classification into age groups was implemented to distinguish subgroups within the group of elderly (i.e., 55–64, 65–74 and 75+ year). Furthermore, small adaptations in the classification of activities were needed, given the new dataset.

The remainder of the paper is organised as follows. First, we will discuss the nature of the scenarios that were used as the basis for the simulations. In addition to a demographic, economic and spatial prognosis for the year 2020, these include several scenarios or more precisely possible variants regarding behavioral aspects of elderly in that year. Next, we will explain how these variants were translated into input required for Albatross. This is followed by a discussion of the main results of the scenario-based simulations and possible policy implications. The paper is completed with a summary of main conclusions and a discussion of merits of the activity-based approach.

Scenarios

In the study, several scenarios were developed (see Fig. 1). First, there was a baseline scenario for 2000, describing the population, transportation system and land-use system for 2000. Next, several scenarios describing possible future roles of Europe in the world economy, exist for 2020 and 2040 (Janssen et al. 2007). The scenario’s differ in the way how Europe reacts to challenges in the public sector and with respect to international cooperation. This paper is based on the Global Economy scenario for 2020—a high growth scenario (see Input data for the Global Economy (GE) scenario for 2020). Finally, various accumulative behavioral variants for the elderly were formulated: Variant 2020-1: increase of labor participation; Variant 2020-2: change in activity patterns; Variant 2020-3: elderly peak and variant 2020-4: spatial diversity. The behavioral variants are plausible extrapolations of developments in the behavior of elderly that have occurred over the last decade in The Netherlands and are to be expected to take place in the near future in the Global Economy ‘ world’ (Jorritsma and Olde Kalter 2007). In this paper, we focus on these accumulative behavioral variants and report some main findings. Variants are accumulative in the sense that every next variant adds particular changes to a previous variant.

Fig. 1 Scenarios



Implementation of scenarios in Albatross

Albatross is a micro-simulation model which assumes that the household is the unit of decision-making. Therefore, before predictions can be generated, the population of households under study need to be synthesized. An Iterative Proportional Fitting procedure is used which assumes the following two data sources as input: (1) counts of individuals by zone and socio-economic group and (2) attribute data for a sample of households (Arentze et al. 2008). The zoning system used for this purpose divides the Netherlands into 1,308 zones (Note: for predictions Albatross uses a finer zoning system of 3,987 postcode areas). As source for the sample data, we use the same dataset as the one used for estimating the latest version of Albatross used in this study, namely the MON 2004 data (National Travel Survey data). This data set includes a total of 29,221 households. The database of Albatross further consists of employment data by postcode area and sector, travel times by mode across the road network, car parking data, opening hours by facility type, travel delay factors between zones by time-of-day, public-transport travel costs between zones, and per-kilometer travel costs by car. The base-line scenario for 2020 (Global Economy 2020) implies changes in all these components of the database. The behavioral scenario variants were implemented largely by implementing changes in choice probabilities predicted by the model before they enter Monte Carlo simulation, to simulate changes in activity scheduling behavior.

Input data for the Global Economy (GE) scenario for 2020

The Global Economy 2020 scenario is the result of a study conducted by several national planning agencies in The Netherlands. These include the Central Planning Bureau (CPB), the Environmental and Nature Planning Bureau (MNP) and the Spatial Planning Bureau (RPB) (Janssen et al. 2007). In this section we describe how scenario assumptions are implemented in data files and parameter settings for Albatross.

Population

Population developments assumed in the GE-2020 scenario are defined on the level of 1,308 zones in the Netherlands. The base scenario for 2020 assumes several developments to take place in the period from 2000 to 2020, including a population growth of 13%, an even stronger growth in the number of households by 26%, a relatively strong increase of the participation of women in the labor force by 29%, a shift from full-time to part-time work for males and an increase of older age groups by 60% (65–74 years) and 40% (75+ years).

Income

In terms of economic growth, the GE-2020 scenario assumes an average increase of 63% of household incomes in real terms compared to the 2000 baseline year. Household transition probabilities between income groups that would result from a general 63% real-income increase were calculated based on the assumptions: (1) incomes are distributed equally within income groups and (2) the income range of the lowest income group is bounded by a reasonable minimum (set as 5,000 Euro).

Car possession and car drivers

According to the GE-2020 scenario, the number of cars per 1,000 inhabitants will increase from 409 to 514. Transition probabilities between car-possession categories were calculated using the following assumptions: (i) transition probabilities are dependent on household composition: the probability of changing from one car to more than one car is zero in one-adult households and bigger than zero in two-adult households; (ii) in two-adults households, the probability of a state change from zero to one car is equal to the probability of a state change from one to two cars, and (iii) state changes that would involve an increase of the existing number of cars with more than one car do not occur. Changes in driving-license possession were implemented in direct relation to changes in car possession. That is, each time a car is added to a household, as a consequence of a transition, a driving license is added if needed, using the following rules: (i) if the household possesses one car after transition and there are no drivers in the household, then one person in the household will become a driver (arbitrarily the male person in case of a double household); (ii) if the household possesses two or more cars after transition and there is only a single driver in the household, then the non-driver becomes a driver.

Land-use data

Employment forecast data for GE 2020 are available on the level of 1,308 zones for agriculture, the service sector, retailing and the number of employees in total. Because Albatross uses a finer classification of sectors than the one used in the forecast, an interpolation projection method was used, assuming that employment in each sector and postcode area increases proportionally with the corresponding sector in the corresponding zone. On average, the total number of employees per postcode area increases with 15%. In service-related sectors the average number of employees per postcode area increases with 20 to 28% depending on the specific sector.

Travel-time data

Forecasts of travel-times by transport mode and time of day (morning-peak, afternoon-peak and off-peak hours) are available on the level of zone-by-zone relations. The GE scenario involves an investment package of in total 14.5 billion Euro in road infra-structure. As an effect of the corresponding expansion of road capacity, travel times between zones decrease, on average, compared to the baseline 2,000 scenario (see Janssen et al. 2007). To give an indication, the mean free-floating travel time across a full zone-by-zone matrix decreases from 102.3 to 76.8 min and the mean travel-time ratios between peak and off-peak travel decreases from 2.33 to 1.33 (morning peak) and from 2.41 to 1.37 (evening peak). For train, bus, tram and metro, the travel times virtually stay the same, whereas the ratios of access/egress time tend to decrease for the train, namely from 16.0 to 15.3.

Prices and variable travel costs

Price changes assumed in the GE-2020 scenario have an impact on variable costs of traveling by car and public transport modes. In real terms, fuel costs per kilometer traveled decrease due to increasing economy of cars, whereas public transport tariffs increase. Specifically, the following price indices were assumed (2000 is 100): car: 92.5; train

(morning peak before 9 am): 119; train (off peak after 9 am): 114; BTM: 108.4, and parking: 124.

Results of prediction

Albatross predicts for this scenario an increase of total travel passenger kilometers by 18.6% compared to the baseline. This increase is somewhat bigger than the increase of the population (+17.8%) suggesting that the average distance traveled per capita increases somewhat. The average number of trips a person makes on a day stays approximately constant. There is no significant increase in the ratio between number of trips and tours, indicating that the degree of trip-chaining stays the same as well. The distance traveled by car increases somewhat stronger (+21.8%) than the total travel distance (+18.6%), whereas distance traveled by slow modes (+13.4%) and public transport (+0.9%) increases much less. Thus, the model predicts a shift from public-transport to car-driver mode. The output of Albatross also reveal many changes on the level of choice facets of activity patterns underlying these mobility effects. Limited space does not allow us to discuss these here. In sum, the increase in car possession, increase in income level, improvement of travel time and an increase in labor participation all contribute to an increase in mobility. Because the mobility of the elderly is less than average, the aging of the population counteracts these mobility generation effects to a certain extent. In other words, mobility growth would be much stronger if the population would not age. Aging effects also explains why number of trips and trip-chaining on a per-capita basis do not increase with car-possession and income, as one might have expected. On average, elderly engage less often in out-of-home activities and less frequently make complex trip-chains. Thus, aging counteracts the effects of increases in car-possession and income on this level as well.

These predictions hold under the assumption that, after accounting for the economic, demographic and spatial changes assumed in the scenario, elderly of 2020 behave in the same way as elderly of today under same circumstances. To put it another way, the analysis so far assumes that behavioral rules, as incorporated in the Albatross scheduling model, apply in every respect to the future population. This strong assumption will be relaxed in the variants considered in the next section.

Input data for the behavioral scenario variants for 2020¹

The scenario variants considered in this section describe anticipated changes in behavior (in a broad sense) of the elderly in 2020 compared to the elderly in 2000 that are not captured by the demographic, economic and spatial (i.e., physical) changes assumed in the GE-2020 scenario. They are based on extrapolation of ongoing trends over the last decade in the Netherlands. Explaining the underpinnings of the variants is outside the scope of the present study; for this readers are referred to Jorritsma and Olde Kalter (2007). In this section, we describe how they are specified and implemented.

Variant 1: increase of work

This variant assumes, compared to the GE 2020 base scenario, increased labor participation of males and females in the age group of 55–64 years, as follows:

¹ Jorritsma and Olde Kalter 2007. *Vergrijzing en mobiliteit* (provisional title) to be published in October 2007.

- For males the percentage of part-time workers increases from 8.9 to 9.9% and the percentage of full-time workers increases from 40.8 to 45.3%;
- For females the percentage of part-time workers increases from 22.3 to 29.3% and the percentage of full-time workers increases from 13.5 to 16.5%.

Variant 2: change in activity pattern

Predictions for the GE-2020 scenario indicates that an increased labor participation of the elderly coincides with a decrease of shopping activities on a per-capita basis; the frequency of social and leisure activities stay approximately the same in this group. As said, these predictions do not take into account possible changes in behavior that are related to a change of cohort. Trend analyses suggest that elderly in 2020 may engage more often in out-of-home activities than the elderly of 2000. In specific, the present variant assumes that elderly who have no paid work and a relatively high income increasingly engage in out-of-home activities in particular for leisure and social purposes. To account for this trend, we assume increased probabilities of out-of-home activities for individuals who are 55 years of age or older, belong to the two highest quartile income groups and have no paid work. A distinction was made between 55–64, 65–74 and 75+ year age groups. Furthermore, probabilities were differentiated dependent on their activity schedule. The probability of a maintenance activity increases only if no work or other fixed activities occur in the schedule. The probability of a social/leisure activity increases in schedules that already include a social/leisure activity as well as those that currently do not have an activity in this category.

The variant was implemented by adapting activity selection probabilities in the activity scheduling phase. The implementation details of this variant can be summarized as follows: (i) if at the decision moment the schedule does not include an out-of-home activity, then the selection probability of both a maintenance activity and a social/leisure activity increases with 5.0% points (55–64 years), 4% points (65–74 years) or 2.5% points (75+ years); (ii) if at the decision moment the schedule does include an out-of-home activity, then the selection probability of a social/leisure activity increases with 15.0% points (55–64 and 65–74 years) or 10% points (75+ years).

Variant 3: the elderly peak

This variant assumes (in addition to variant 2) that, in order to avoid traveling during the morning peak hours, a certain fraction of flexible activities of elderly shift from the early-morning (before 10 am) towards the late-morning hours (10 am–noon) of the day. The change is assumed to take place in the 65+ age group who do not have paid work. Flexible activities include shopping-one-store, shopping multiple-stores, services, social activities, touring and leisure activities (other than touring). Activity schedules should remain internally consistent in the sense that activity and travel episodes involving the same individual should not overlap in time; neither should time gaps between out-of-home activity/travel episodes arise.

This variant was implemented by means of a manipulation of timing decisions in the activity-scheduling phase. The following rule is used for each flexible activity: if the person is 65+ years of age and has no work and the early episode (<10 am) was chosen for the activity, then change the timing to the earliest feasible next episode. An episode is feasible if the activity fits in the time slot given other activities scheduled and the duration

of the activity. In this way, it is made sure that flexible activities originally scheduled for the <10 am episode shift towards the earliest possible later episode of the day while the schedule remains consistent and all other activities that were already scheduled remain in their assigned time slot.

Variant 4: spatial diversity

This variant assumes (in addition to variant 3) a shift in residential location choice of elderly. A certain fraction of the 55–64 age group currently residing in high-density urban areas move to low-density areas, whereas a smaller fraction of the 65–74 age group moves in the opposite direction. For other age groups no changes are assumed. This variant was implemented by changing the total number of persons in the respective age groups in each zone, depending on the urban density of zones and, next, re-generating the synthetic population.

Results

To reduce computation times, a fraction of 10% of the national Dutch population was synthesized to generate predictions in each scenario variant. This means that 863,853 households (and 1,279,062 persons) were synthesized. This fraction is considered large enough to be able to identify even relatively small effects of the changes.

Variant 1: increase of work

As it appears, for the age group that undergoes the change (i.e., the 55–64 age group), the total distance traveled increases with 2.7% and the total distance traveled as car-driver increases with 2.1%. The number of trips and number of tours also show a slight increase of approximately 1.7%. The average trip length increases to a more important extent. In terms of the impacts on activity and travel choices, we see a significant increase in total number of activities of 1.7% in the 55–64 age group. This increase is far less, however, than the increase in number of work activities (+10.2%) and number of business activities (+7.9%), due to a simultaneous decrease of activities in other categories. The decreases are significant for service activities (–2.7%). The shift in activity participation explains the increase of average trip length, which we saw above. Since work trips are of above-average length, the substitution of non-work activities by work activities leads to an increase in average trip length. In terms of timing of activities, we see an increase in the share of activities starting before 10 am (+5.8% in the 55–64 age group). Probably this is a direct consequence of the substitution of non-work activities by work activities that this variant brings about. In the population at large there is no evidence of a change of degree in trip-chaining. The number of trips to large cities increases slightly (+1.2%). There is no evidence of a change in the distribution of tours across transport-modes. This means that the increase in car-driver kilometers is due to an increase of the average length of car-driver trips rather than an increase of frequency of these trips.

The results can be explained as follows. The total number of trips stays approximately the same, as a consequence of the fact that the increase of work activities, assumed in the variant, is compensated by a decrease of activities in other activity categories. This means that the increase in mobility that occurs is fully caused by an increase in average trip length

that follows from the substitution of non-work activities by work activities. The increase of the share of activities starting before 10 o'clock in the morning is another consequence of this substitution and means that the increase in car kilometers is bigger during peak hours.

Variant 2: change in activity pattern

This variant implied changes for each of the three older-age groups (55–64, 65–74 and 75+). The impacts tend to be largest for the 65–74 years group. The reason for that is, compared to the 75+ group, the assumed percentage increase of the activities is higher and, compared to the 55–64 group, the share of non-workers, and hence the subgroup to which the variant applies, is larger. The major changes are as follows.

The total number of out-of-home activities increases with 4.8, 10.5 and 5.6% for the 55–64, 65–74 and the 75+ groups, respectively. In absolute terms, this comes down to an increase of 541,680 out-of-home activities on average per day. In terms of activity duration, the extra activities lead to an increase of both short-duration and long-duration activities. Extra activities are not distributed equally across start-time categories. The number of early activities (before 10 am) does not increase at all, whereas the number of late activities (after 6 pm) increases above average because of rescheduling to make time for a work activity during the day. The other times of day receive approximately equal shares of the new activities. The number of activities conducted on single-stop tours grows less fast than the number of activities conducted on multiple-stop tours, indicating an increase of trip-chaining.

The total distance traveled increases with +4.4% (55–64 years), +11.6% (65–74 years) and +8.5% (75+ years). The average trip length stays approximately the same in the two younger elderly groups, but increases in the 75+ group (approximately, +1.0%). In each elderly group, the distance traveled as car driver increases approximately with the same rate compared to the distance traveled across all modes. The ratio between trips and tours increases in all three groups. However, the effect is largest in the 65–74 group suggesting that this group in particular makes more multiple-stop trips. As for mode choice, the car-passenger transport mode increases more than average in each elderly group. The shares of slow and public-transport modes stay approximately constant.

The results can be explained as follows. The increase in trip-chaining probably is an activity type effect: social and leisure activities, which show the largest growth, tend to be combined more often together with other activities on a same trip. The average trip length increases in the oldest age group because trips for social/leisure activities have an above average length in that group. The shift in transport mode towards an increase of car-passenger mode, most probably, is an activity-type effect as well: social and leisure activities are more often conducted jointly with other persons within or outside the own household, with as a consequence an increase in the proportion of joint traveling. An alternative explanation would be that it is an age effect: elderly more often choose a car-passenger mode for traveling. However, it appears that also *within* the elderly groups the shift in transport mode is strongly present, indicating that it is related to a selective increase of one particular activity category (namely social/leisure) rather than age. Since extra activities generated are not distributed equally across times of day, the variant probably does not lead to an increase of trips during the morning peak or to a substantial increase of trips in the afternoon peak. In the total population the increase of activities varies around an average of +2.5% on weekdays and Saturday, and +4.0% on Sundays. Probably, the variant does not have a strong day-of-the-week effect, because the assumed increase in activities is confined to people who have no work activity.

Variant 3: the elderly peak

As a direct effect of the variant, the number of activities in the earliest episode of the day (before 10 am) decreases with 50–60% in the age groups concerned (i.e., 65–74 and 75+ years). In absolute terms, this comes down to 308,310 activities per day shifting from the early morning episode to the late morning or early afternoon. In terms of the total population the number of activities starting in the early morning decreases with 5.7% and the number of activities starting in the late morning episode increases with 8.6%. The patterns also reveal secondary effects in the sense that activities in later episodes may also shift to (even) later moments. There are no changes in activity frequencies. In older age groups there is a slight decrease of days having a relatively large number of tours, whereas the number of tours including only one activity decreases. This may be caused by an increase of trip-chaining (the same number of activities are conducted on a fewer number of tours). The changes in timing do not seem to have any implications for transport mode choice. There is an increase in the use of car-passenger mode, but the difference is not significant. The changes do not have measurable impacts on mobility indicators. A slight but significant increase in ratio between trips and tours suggests a small increase of trip-chaining.

In sum, assuming elderly avoiding morning rush hours, this variant leads to a shift of activities from the early-morning to mainly the late-morning. As it appears, predicted secondary effects of this shift are limited. As tendencies, both the degree of trip-chaining and the use of car-passenger mode increase somewhat. These secondary effects are well interpretable as activity-scheduling effects. Moving to later moments of the day increases opportunities to combine activities in a single tour (trip-chaining) and to travel together (car passenger).

Variant 4: spatial diversity

Simulations suggest that in the age-group of 55–64, where most of the change occurs in this variant, the distance traveled by car increases with 1.6% and the distance traveled by slow modes decreases with 1.3%. However, in terms of total distance traveled across transport modes, there is no significant increase or decrease. There are no significant changes on these mobility indicators for the 65–74 age group except that the distance traveled decreases somewhat in favor of the use of slow and public-transport modes.

The impacts on underlying activity and travel choices can be summarized as follows. Although the total number of activities does not change significantly, we do see changes in activity-type choice. For the 55–64 age group a decrease in the number of shopping activities of 2.3% (one-store shopping) and 4.5% (multiple-store shopping). For the 65–74 age group the number of shopping activities stays approximately constant and the number of escorting activities ('bring/get') decreases with 6.3%. There are no significant changes in activity duration choice. In the 55–64 years group we see a small increase of activities starting before 10 am (+1.6%) and a small decrease of activities starting around noon and the early after noon. In the 65–74 years group there are no significant changes. The number of activities conducted in the own postcode area increases slightly (+0.7%). At the same time, the number of activities conducted outside the own municipality increases. The 55–64 age group shows an increase of choice of car-driver mode (+1.1%) at the expense of slow mode (–0.9%) and, particularly, public-transport mode (–7.0%). In the 65–74 years group, we only see a small decrease of car-driver tours (–1.5%).

In sum, a movement from urban to non-urban areas of part of the younger elderly group leads to: an increase of car possession, a decrease of number of shopping activities, an increase of car-driver mode, an increase of longer distance travel and an increase of traffic

in morning-peak hours. The increase of car-driver kilometers coincides with decreases in distance traveled by slow and public-transport modes. The decrease of shopping activities is compensated by an increase of other out-of-home activities. As a result, the total number of activities stays approximately constant. As there is no increase or decrease of trip-chaining, the number of trips stays the same as well. There is a small shift in destination choice. The increase of activities in the own postcode area may be explained by the fact that postcode areas in non-urban areas tend to be larger than postcode areas in urban areas. If we correct for this, we note that the average trip length increases, given that simultaneously more activities are conducted outside the municipality where the individual lives. The increase in activities starting in the early morning hours may reflect a characteristic of non-urban life or possibly reflect less congested traffic conditions on roads in non-urban areas during morning peak hours. The changes that are predicted for the 65–74 groups tend not to be significant, probably, because the variant assumes only a very small re-distribution for this group. The only significant change we see here is a decrease in the use of car-driver mode and increase of slow and public transport modes.

Overall effects and policy implications

Let us consider these results in the light of transport policy. What we see from the variants is a total growth of mobility in terms of passenger kilometers—especially the car (see Fig. 2)—travel time and trips with approximately 3% due to changing behaviour of the elderly people. So, the elderly of the future will contribute to a higher level of mobility.

The increased labour participation in the age group 55–64 years and the change in activity patterns are mainly responsible for this (see Fig. 3). The impact of the increased labor participation (variant 1) is a growth in car mobility during the morning peak hours (work related trips), which can lead to more traffic in already congested areas. The changed activity patterns in variant 2 together with the shift in starting times of activities from the morning peak to the late morning in variant 3, however, reduce the load on highways during the morning peak hours. All together there is a significant reduction of activities starting during the morning peak. A policy focused on reducing outdoor activities before 10 am (like pricing) can have an impact on congestion during the morning peak in 2020. On the other hand we see an increase of starting an activity between 4 and 6 pm, which affects the afternoon peak hour.

Besides an increase in car use (as car driver), we see an overall increase in public transport use (in passenger kilometers) across all the age groups, mainly due to the assumed increase of out of home activities in variant 2. Taking into account the changes in volumes and the share of public transport, which hardly changes over time, the impact is rather small. Nevertheless elderly people tend to use public transport more in the future than they do nowadays. Policymakers should be aware of that. Pricing measures aimed at elderly, like free of charge public transport, could attract potential users and expand the public transport market.

Another important aspect related to elderly and transport is traffic safety. The last decade we see in the Netherlands an overall decrease of the chance being involved in an (fatal) accident and it is expected this trend will continue in the future. On the other hand the proportion of elderly in the total population is growing and participation in outdoor activities is growing. Because of this and a higher vulnerability it is expected that the number of elderly being involved in an (fatal) accident will increase. Particularly the increase of the use of slow modes, like the bicycle and walking, will contribute to higher numbers of accidents among elderly. Therefore policy measures aimed at reducing the risk of being involved in an accident are needed.

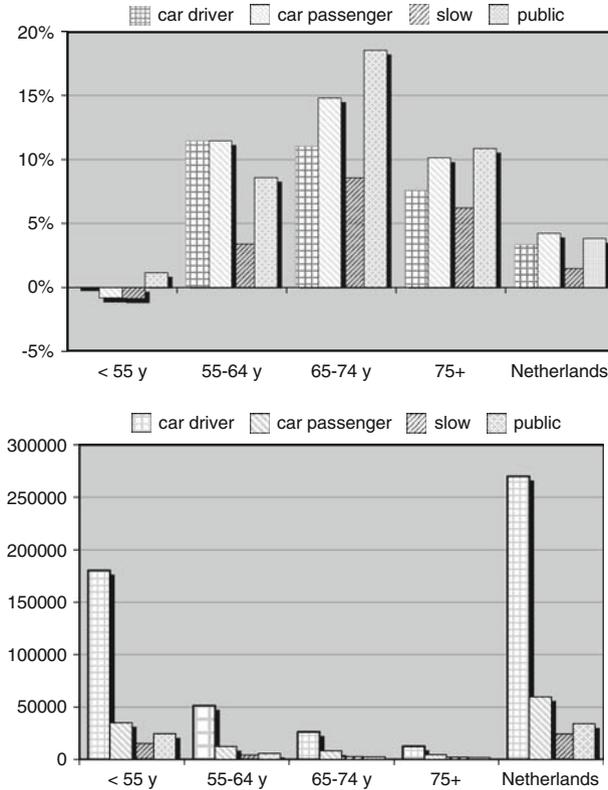
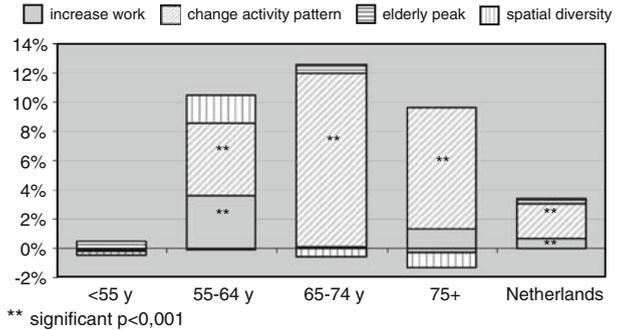


Fig. 2 Total change in passenger kilometers in relative terms (top) and absolute terms (bottom)

Fig. 3 Contribution of variants to change in passenger kilometers by age group



Conclusions and discussion

An aging society may offer a challenge for transportation planning. As we have argued in the introduction, there is a paucity of literature about that topic. Different trends may be observed and it is not clear which of these likely will dominate and what on balance the future activity—and travel patterns may look like. Moreover, results will vary as a function of general trends in the economy.

To explore this issue, this paper has reported the results of a scenario-based simulation study of future activity-travel patterns. An existing forecast of demographic, economic and spatial developments, called Global Economy, for the year of 2020 was taken as the baseline situation. Predictions for this baseline assume that elderly of 2020 will behave the same as the elderly of today under same circumstances. Based on ongoing trends of behavioral change in older-age groups over the last decade in the Netherlands, a number of scenario variants were formulated that accommodate likely differences in activity-travel behavior between the cohorts. In specific, it was assumed that the elderly of the future (1) need to work longer, (2) increasingly conduct out-of-home activities with most growth occurring in social/leisure activity category, (3) try to avoid morning peak hours by re-scheduling there flexible activities and (4) increasingly choose to live in lowly-urbanized areas (the ‘younger’ elderly) or in highly-urbanized areas (the ‘older’ elderly). Predictions indicate that these activity and residence-location changes have substantial effects on activity-travel patterns which add up to significant effects on the size of total travel demand and the temporal, spatial and modal distribution of this demand. We discussed the policy implications of these anticipated developments.

Activity-based models have only recently started to make the transition to practice and experiences with applications of these models are still very limited to date. Apart from the substantial findings, this study adds to this experience. The predictions showed clear activity scheduling effects implying that a behavioral change on one facet often entails changes on other facets of activity patterns as well. For example, in predictions we often see that increases of activities in one category are partly or fully compensated by decreases of activities in other categories with as a result that the number of trips displays a tendency to stay more constant than one would expect if these compensatory effects are not taken into account. As another example, in predictions of the model, shifts in the distribution of activities across activity categories tend to have effects on many other facets of activity patterns such as start times, locations, trip-chaining and transport-mode choice. Using a relatively fine classification of activities, Albatross is highly sensitive to secondary effects of such shifts. The results of scenario analyses showed many other examples of secondary responses, which would not be revealed by trip-based models. Finally, we note that the detailed information an activity-based model such as Albatross provides about activity patterns helps to built a comprehensive and coherent view of the behavioral changes underlying changes in mobility patterns which is a prerequisite for effective policy making.

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Author Biographies

Theo Arentze received a Ph.D. in Decision Support Systems for urban planning from the Eindhoven University of Technology. He is now an Associate Professor at the Urban Planning Group at the same university. His main fields of expertise and current research interests are activity-based modeling, discrete choice modeling, knowledge discovery and learning-based systems, and decision support systems with applications in urban and transport planning.

Harry Timmermans (1952) holds a Ph.D. degree in Geography/Urban and Regional Planning. He studied at the Catholic University of Nijmegen, The Netherlands. Since 1976 he is affiliated with the Faculty of Architecture, Building and Planning of the Eindhoven University of Technology, The Netherlands. First as an assistant professor of Quantitative and Urban Geography, later as an associate professor of Urban Planning Research. In 1986 he was appointed chaired professor of Urban Planning at the same institute. In 1992 he founded the European Institute of Retailing and Services Studies (EIRASS) in Eindhoven, the Netherlands (a sister-institute of the Canadian Institute of Retailing and Services Studies). His main research interests concern the study of human judgement and choice processes, mathematical modelling of urban systems and spatial interaction and choice patterns and the development of decision support and expert systems for application in urban planning. He has published several books and many articles in journals in the fields of Marketing, Urban Planning, Architecture and Urban Design, Geography, Environmental Psychology, Transportation Research, Urban and Regional Economics, Urban Sociology, Leisure Sciences and Computer Science.

Peter Jorritsma graduated in 1981 as a Traffic Engineer and in 1987 as MSc in Economic Geography at the University of Groningen. After a 2-year period as researcher at the Faculty of Spatial Sciences of the University of Groningen he started in 1989 a career at the Dutch Ministry of Transport, Public Planning and Water Management. Within the Ministry, Peter Jorritsma worked within different research departments. The focus of his research work was on (inter)national public transport issues, spatial planning in relation to

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Marie-José Olde Kalter graduated in 1997 as MSc in Traffic and Transport Engineering at the University of Twente. She started her career at Goudappel Coffeng BV, a traffic and transport consultant for public and private parties. Within Goudappel Coffeng, Marie-José was the first 3 years concerned with developing transport models to forecast the future use of infrastructure given different scenario's and policy measures. After this period she specialized in qualitative and quantitative research methods. In 2005 she continued her career at the Dutch Ministry of Transport, Strategic Modeling and Forecasting. Since 2006 is Marie-José working for the KiM Netherlands Institute for Transport Policy Analysis, a scientific research institute within the Ministry of Transport. She is mainly involved in qualitative and quantitative research related to travel behaviour.

Arnout Schoemakers graduated in 1998 as MSc in Environmental and Infrastructure Planning at the University of Groningen. He started his career at AGV, a traffic and transport consultant for public and private parties. Within AGV, Arnout was concerned with developing land-use and transportation models to forecast the future use of infrastructure and land-use given different scenario's and policy measures. In 2002 he continued his career at the Dutch Ministry of Transport, Strategic Modeling and Forecasting. At this Ministry Arnout was project manager of the new developed LUTI model TIGRIS XL and the activity based model ALBATROSS. Since 2008 Arnout is working at Oranjewoud, a stock-noted leading consultancy and engineering firm. He is mainly involved developing and using transport models, and in designing processes how to use these model systems in the Dutch planning system.