An Agent-based Model for Carpooling: Effect of Strict Timing Constraints on Carpooling Trips

Iftikhar Hussain,
Luk Knapen,
Bruno Kochan,
Tom Bellemans,
Davy Janssens,
Geert Wets

Abstract: *Although, in the carpooling process, effective negotiation requires that individuals (agents) effectively convey and interpret information to enable carpooling. However, the strict timing constraints in the schedule of the day have the opposite effect. Through negotiation, individuals can reach complex agreements in an iterative way. This paper presents the design of an agent-based model to analyze various effects of agent interaction and behavior adaptation of a set of candidate carpoolers that serves as a proof of concept. The proposed model extends the previous one by applying different cases for the constraining activities for their work trip start times. The start of the carpooling process depends on the individuals' objectives and intention to carpool. From the simulation's discussions, it is possible to portray the real picture of the potential carpoolers throughout their carpooling period. The Janus (multi-agent) platform is used for simulating the interactions of autonomous agents with their agenda.*

Keywords: Commuting, carpooling, negotiation, constraining activity, Agent technology.

1. Introduction

Carpooling is considered to be an effective alternative transportation mode that is eco-friendly and sustainable. It enables commuters to share travel expenses, save on fuel and parking costs, improve mobility options for non-drivers and it also reduces emission and traffic congestion. Change in some socio-economic characteristics (SEC) such as the increase in fuel price, in parking costs, or in the implementation of a new traffic policy, may prove to be an incentive to carpool. Strict timing constraints in the schedule of the day however, have the opposite effect. In order to commute by carpooling, individuals need to communicate, negotiate and coordinate, and in most cases adapt their daily schedule to enable cooperation. Through negotiation, agents (individuals) can reach complex agreements in an iterative way (Galland et *al.*, 2014, Bellemans et *al.*, 2012).
While traditional modeling tools cannot handle the complexity of communication and negotiation for carpooling, agent-based models (ABMs) are able to do so through modeling the interaction of autonomous agents. Currently many research areas including transportation behavior, need to analyze and model complex interactions between different autonomous entities (Kamar and Horvitz, 2009).
The aim of this research is to generalize the concept of communication, negotiation and coordination in a *multiple trip negotiation model* for the long-term carpooling (Hussain et *al.*, 2014). It considers the effect of different constraining activities (e.g. pick-drop and shopping) on the trip start times of the carpooling (to work) activity. The ability to carpool for commuting depends on schedule flexibility. The daily schedule for each individual is considered. Those consist of different activities, one of which must be (flexible) work activity. Our research also focuses on the setup of the simulation framework and the network of the carpooling candidates.
In the proposed model the agents are the individuals, who negotiate to reach an agreement to carpool. The carpooling related actions performed by agents are divided

into two main categories: exploration (communication and negotiation) and carpooling (coordination, negotiation during carpooling and effective driving). During the exploration the agent looks for other individuals to cooperate on commuting trips for a period of multiple months. The agents can explore their network by sending requests to carpool and sharing their schedule within a small group. While negotiating, agents can reach complex agreements depending on the matching mechanism, used to match with preferences, which are expressed by all negotiating partners. For the trip execution, carpoolers need to coordinate with each other for the long-term carpooling. Carpoolers may (re)negotiate timing and/or (re)schedule their agenda when someone joins or leaves the carpool. The Janus (Gaud et *al.*, 2008), agent based platform is used; it provides an efficient implementation of organizational-based and agent-based concepts.
This paper is organized as follows; first the related work on negotiation in carpooling is briefly described in section 2. Section 3 covers the long-term carpooling model. Section 4 explains the experimental setup and some results. Finally, conclusions and suggestions for future work are presented in section 5.

2. <u>Related Work</u>

According to the literature, agent-based models are also used in non-computing related scientific domains and can provide valuable information on society and the outcomes of social actions or phenomena. A detailed literature review (Horvitz et *al.*, 2005, Rady, 2011), focuses on technical development of the carpooling support systems, and empirical, interrelationships between willingness to carpool and socio-economic attributes of carpooling, is presented.
(Galland et *al*., 2014) presented a conceptual design of an ABM for the carpooling application, that is used for simulating the interactions of autonomous agents and to analyze the effect of change in factors of infrastructure, behavior and cost. This model used agents' profiles and social networks to initialize communication, and a utility function to trigger the negotiation process between agents. A simple negotiation mechanism is employed with constant preference values for the entire preferred time interval. However, despite of using a simple negotiation mechanism; the author conceptually sketched a methodology to formulate a behaviorally sound negotiation mechanism by defining the utility function.
(Hussain et *al*., 2014) proposed a single trip negotiation model for carpooling using a simple negotiation mechanism. The first implementation used home and work locations as well as preferred trip start times and carpool periods determined by uniformly sampling given sets. Authors determined the effective trip start time by taking the average of preferred trip start time of each individual for the carpool. The authors extended the single-trip negotiation mechanism into a multiple trip negotiation model (Hussain et *al*., 2015) by taking the possibility of flexible activity scheduling into account and limit the interaction between agents within small groups based on the origin and destination similarity.
(Ronald et *al*., 2009) presented an agent based model that focuses on the negotiation methodology. The proposed model includes a well-defined and structured interaction protocol integrating the transport and social layer. A utility function is presented on the basis of individual and combined attributes. The agents negotiate on the type, location and the start time of social activity.
(Hendrickson and Plank, 1984) studied the flexibility in trip departure times of the individuals focusing on fixed home-work trips. The authors developed a multinomial logit model to estimate the relation and significance of different attributes influencing choice of the transport mode and trip departure time. The authors proposed an equation to define the personal utility or preferences for a given set of departure times for the

work trip. It is worth noting that the authors gave a special consideration to trip departure time characteristics in case of a shared transportation mode.
(Knapen et *al.*, 2013) presents an automated, Global Car Pooling Matching Service (GCPMS), advisory service to match commuting trips for carpooling. The probability for successful negotiation is calculated by means of a learning mechanism. The matcher needs to deal with dynamically changing graph w.r.t. topology and edge weights.

3. Agent-based Carpooling Model

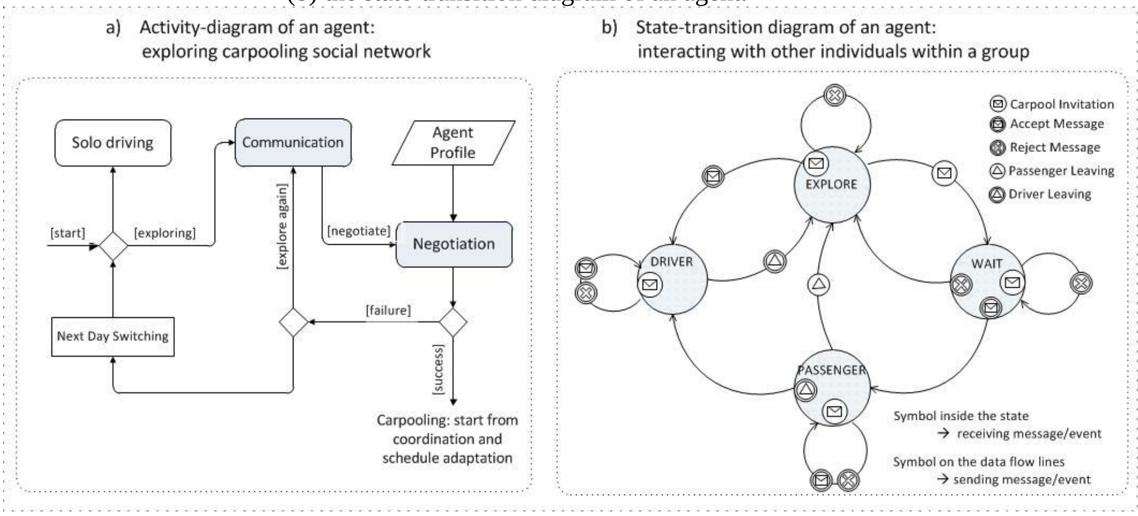
The agent-based negotiation model for the long term carpooling simulates the interactions of autonomous agents to enable communication to trigger the negotiation process. The negotiation process incorporates a personalized preference function for the trip start times with the participants' profile. The constraining (pick-drop and shopping) activities of the schedule on the carpooling trips are also considered during the negotiation process. The purpose is to introduce a negotiation mechanism that determines the extent to which people need to adapt their daily schedule to enable cooperation and accommodate for a carpooling activity. The agents can interact with each other autonomously to find matching partners in order to co-travel in several different consecutive carpools, each of which corresponds to a multi-day period.
In this paper, we focus on the set of constraining activities that affects the individual preference time to start the carpooling trips during the negotiation process. The negotiation mechanism for the individual preference trip departure time is employed with constant preference values for the entire preferred time interval. In order to make the negotiation mechanism, more accurate, a methodology is introduced to specify a personalized preference function by considering different cases of constraining activities for the individual's schedule. Apart from the preferred departure time function, the driver and vehicle selection is based on the inspection of the individual's profiles (car and driving-license ownership).
In this simulation model of carpooling, the commuting trips in daily schedules (home-to-work *HW* and work-to-home *WH*) is specifically detailed and discussed in the context of long term carpooling. The set of other activities including pick-drop, shopping etc. is also considered to evaluate the effect of their presence on the carpooling for commuting trips. The "negotiation mechanism" is used to adapt the trip start times of an individual. The commuting trips (*HW* and *WH*) in daily schedules are considered. Home and work locations, trip start times and their durations, activity duration and the SEC attributes, including vehicle and driving-license ownership are used as input.
For the experiments described in this paper, the operational activity-based model for the region of Flanders (Belgium) FEATHERS (Bellemans et *al.*, 2010) is used to generate a planned schedule for each member of the synthetic population. Mutually independent individuals using a transportation network free from unexpected congestion, are concerned. The initial daily plans are assumed to be optimal, i.e. generating maximal utility and hence to reflect the owner's preferences.
The network exploration and the carpooling process are described in more detail in the following subsections.

3.1. Exploration: Carpooling Social Network

Each agent looks for other individuals to cooperate while executing its periodic trips by exploring the carpooling social network. People decide to select carpool partners from the group of individuals who share respectively the home and work locations with them. It is assumed that people board and alight at home and at work locations only. The framework is based on traffic flows between traffic analysis zones (TAZ) as opposed to

specific street addresses. Autonomous agents iteratively try to find carpool partners during network exploration (Figure 1(a)).
The simulation launches each agent with its profile, according to data generated by the FEATHERS framework. Using the organizational-based concept, the agents are grouped based on their origin and destination locations to limit the communication requirements. Immediately after the agent creates or joins such groups, they can communicate, negotiate and coordinate with each other to determine effective trip start times (for both *HW* and *WH* trips).
The simulator contains at most one group for each pair *(A,B)* of TAZ. An agent joins the group for *(A,B)* if and only if (s)he lives in *A* and works in *B*.

Figure 1: (a) the activity diagram of an agent during network exploration.
(b) the state-transition diagram of an agent.



3.1.1. Communication Process

The agents belonging to the same group may communicate with each other by sending and receiving text messages. Through communication, the agents may negotiate on trip start times of *HW* and *WH*, on the vehicle to use and hence on the selection of the driver. If the agent decides to carpool, (s)he may start to explore the carpooling social network for partners, otherwise (s)he continues traveling solo by using his or her own car. This agent may continue to explore the carpooling social network throughout the simulation period (in case (s)he is unable to find a carpool partner).
The agent's behavior is modeled by a finite state machine (Figure 1 (b)). Each agent can send and/or receive messages to/from the other agents of the same group. Following messages are used: *Carpool invitation, Accept and Reject messages*.
An agent performs the following activities in different states.

a. In the **EXPLORE** state, each agent (*invitor*) may search for a partner (*invitee*) by sending a carpool invitation to a randomly chosen agent. For every simulated day, emission of invitations depends on the given $P_{Explore}$ parameter. Let $P_{Explore}$ is probability to start exploration by a non-carpooler at any given day. As soon as an invitation has been emitted, the invitor enters the WAIT state, waiting for the receiver's response. In the EXPLORE state, an agent can receive carpool invitations from other agents.
b. In the **WAIT** state, if the invitee's response is an *Accept* message then the invitor tries to join carpool as passenger and changes its state to PASSENGER. If the response is a *Reject* message, the inviting agent changes its state to *EXPLORE* again in order to try to find a partner. In the WAIT state, any incoming invitation is rejected.
c. In the **DRIVER** state the agent (driver) of a *Carpool*, can receive carpool

invitations and (s)he replies with either *Accept* or *Reject* message depending on the invitor's departure time requirements and on the remaining car capacity. If the carpool period for the driver expires, then the agent will leave the carpool and change its state to EXPLORE.

d. In the **PASSENGER** state the agent (passenger) continues sharing a carpool until the carpool period expires. While being a passenger, the agent handles carpool invitations in the same way as a driver.

Handling incoming invitations during the carpool lifetime, requires additional negotiation among the carpoolers and the new candidates to join the carpool.

3.1.2. Negotiation Process

The matching is applied in the negotiation where final decisions to carpool are taken. The agents negotiate on trip (*HW* and *WH*) departure times and also about who will become the driver. The driver and vehicle selection is based on the inspection of the individual's profiles. The schedule adaptation depends on the preferences among feasible schedules of the individuals. The negotiation will become successful only when the individuals' preferred trip start times for *HW* and *WH* trips are mutually compatible within the carpool.

Let:

a_i: represent an individual or agent, $a_i \in N$

TW: time window

$TW_{HWLower,a_i}$: the earliest departure time for *HW* trip of a_i (lower bound of TW)

$TW_{HWUpper,a_i}$: the latest departure time for *HW* trip of a_i

$TW_{WHLower,a_i}$: the earliest departure time for *WH* trip of a_i

$TW_{WHUpper,a_i}$: the latest departure time for *WH* trip of a_i

PST_{HWTrip,a_i}: preferred trip start time for HW trip of a_i

PST_{WHTrip,a_i}: preferred trip start time for WH trip of a_i

$TW_{HWLower,carpool}$: the earliest departure time for *HW* trip of the carpool

$TW_{HWUpper,carpool}$: the latest departure time for *HW* trip of the carpool

$TW_{WHLower,carpool}$: the earliest departure time for *WH* trip of the carpool

$TW_{WHUpper,carpool}$: the latest departure time for *WH* trip of the carpool

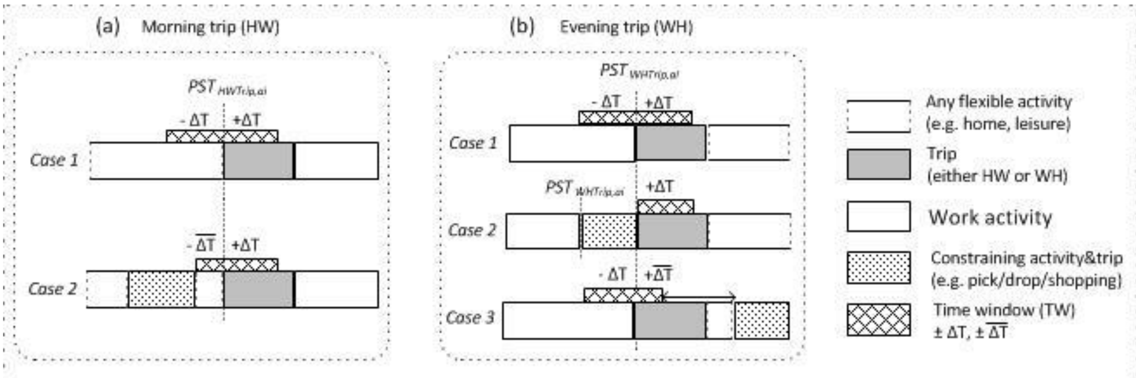
ca: constraining activity (i.e. pick-drop or shopping)

AFT_{ca,a_i}: finishing time of the ca for an a_i

AST_{ca,a_i}: the starting time of the ca for an a_i

$\pm\Delta T$ *and* $\pm\overline{\Delta T}$: symmetric deviation w.r.t. the preferred trip start time

Figure 2: The possible lower and upper bounds for the *HW* and *WH* trips of an agent.



Morning Trip (*HW*)

Case 1: Assume that a *ca* immediately precedes the *HW* trip. PST_{HWTrip,a_i} depends on the AFT_{ca,a_i} as: $\overline{\Delta T}$ = PST_{HWTrip,a_i} - AFT_{ca,a_i} where $\overline{\Delta T}$ is the tolerance period before the *HW* trip.

Case 2: In the simplest case (without constraining activity), the individual is assumed to accept a symmetric deviation $\pm\Delta T$ w.r.t. the preferred trip start time. In general, this is not necessarily true since preceding or succeeding activities can induce timing constraints.

The possible lower and upper bounds for the *HW* trip of an agent are given by the equation 1 (also see Figure 2 (a)).

$$\begin{aligned} TW_{HWLower,a_i} &= \begin{array}{ll} \text{If ca } \& \ \overline{\Delta T} < \Delta T \ (case{:}\,1){:} & PST_{HWTrip,a_i} - \overline{\Delta T} \\ otherwise \qquad (case{:}\,2){:} & PST_{HWTrip,a_i} - \Delta T \end{array} \\ TW_{HWUpper,a_i} &= \qquad\qquad (cases{:}\,1\ \&\ 2){:} \quad PST_{HWTrip,a_i} + \Delta T \end{aligned} \tag{1}$$

Evening Trip (*WH*)

Case 1: If the *ca* is conducted at the work location and immediately after the work activity then the *WH* trip will start after performing the *ca* activity. In this case PST_{WHTrip,a_i} will be the AFT_{ca,a_i}.

Case 2: Assume that *ca* immediately succeeds the *WH* trip at home or at any other location. Preferred start times PST_{WHTrip,a_i} depend on the AST_{ca,a_i} as follows. $\overline{\Delta T}$ = AST_{ca,a_i} - ($PST_{HWTrip,a_i} + trip_{duration}$) where $\overline{\Delta T}$ is the tolerance period after the *WH* trip.

Case 3: Without constraining activity case, also assumed to accept a symmetric deviation $\pm\Delta T$ w.r.t. the preferred trip start time for the *WH* trip.

The possible lower and upper bounds for the *WH* trips of an agent are given by the equation 2 (also see Figure 2 (b)).

$$\begin{aligned} TW_{WHLower,a_i} &= \begin{array}{lll} if\ \ ca & (case{:}\,2){:} & AFT_{ca,a_i} \\ otherwise & (case{:}\,1\ \&\ 3){:} & PST_{WHTrip,a_i} - \Delta T \end{array} \\ TW_{WHUpper,a_i} &= \begin{array}{lll} if\ \ ca & (case{:}\,1){:} & AFT_{ca,a_i} + \Delta T \\ if\ \ ca & (case{:}\,2){:} & PST_{WHTrip,a_i} + \overline{\Delta T} \\ otherwise & (case{:}\,3){:} & PST_{WHTrip,a_i} + \Delta T \end{array} \end{aligned} \tag{2}$$

Negotiation on Trip Start Times of *HW* and *WH*

The negotiation outcome is assumed to be associated to the intersection's length of the time intervals of the individuals (see Figure 3). The following equations show the lower and upper bounds for the *HW* and *WH* trips of the carpool; the indices used for the *max()* function range over the set of candidate participants).

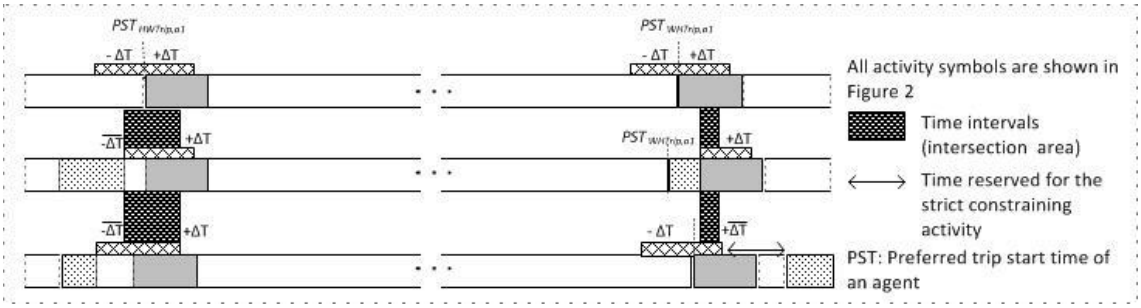
$$\begin{aligned} TW_{HWLower,carpool} &= \max_{j=1\ldots N}(TW_{HWLower,j}) \\ TW_{HWUpper,carpool} &= \min_{j=1\ldots N}(TW_{HWUpper,j}) \\ &\text{AND} \\ TW_{WHLower,carpool} &= \max_{j=1\ldots N}(TW_{WHLower,j}) \\ TW_{WHUpper,carpool} &= \min_{j=1\ldots N}(TW_{WHUpper,j}) \end{aligned} \tag{3}$$

The available time intervals for the carpool are given by the equations;

$$\text{Time Interval width} = \begin{array}{ll} \min_{j=1\ldots N}(TW_{HWUpper,j}) - \max_{j=1\ldots N}(TW_{HWLower,j}) & for\ HW\ trip \\ \min_{j=1\ldots N}(TW_{WHUpper,j}) - \max_{j=1\ldots N}(TW_{WHLower,j}) & for\ WH\ trip \end{array} \tag{4}$$

An individual decides to join the carpool if and only if the preferred trip start times for both the trips (*HW* and *WH*) within the appropriate intervals.

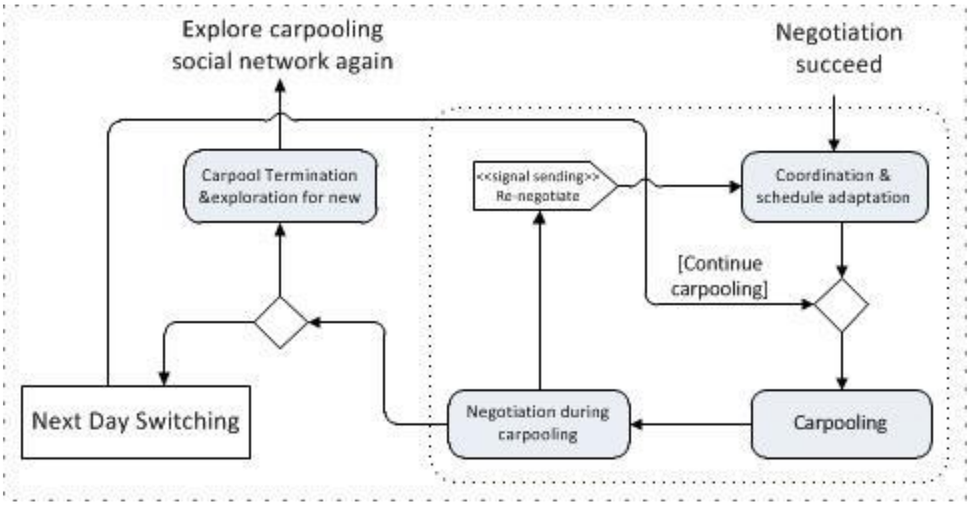
Figure 3: Negotiation between the agents of the carpool on trip (HW and WH) departure times.



3.2. Carpooling

The individuals' schedule of a working day remains the same for all the working days. If the negotiation becomes successful, the agents may coordinate and adapt their schedule, otherwise they may continue to explore for carpool partners. The activities performed during carpooling are described in more detail (see Figure 4).

Figure 4: activity-diagram of an agent during carpooling.



3.2.1. Coordination and Schedule Adaptation

The negotiation becomes successful when the negotiators adapt their daily schedule to enable cooperation. In general, during this step, the carpoolers agree on pickup times, pick-up and drop-off order, trip start times (for *HW* and *WH*) of the carpool taking into account the constraints imposed by their agenda. At negotiation time, each individual specifies the period (number of days) during which to carpool for the periodic trip.

After the successful negotiation, the invited agent who is able to drive will become driver of the carpool and starts playing his role as driver. Then, (s)he replies to the invitor (candidate passenger) with an accept message in order to allow the invitor the carpool and start playing role as passenger.

When the driver decides to leave the carpool, (s)he will assign the driving responsibilities to the senior passenger owning a car and driver license (if the carpool size is not less than two persons). When someone leaves the carpool, the remaining agents reschedule the trip start times.

3.2.2. Trip Execution (Effective Driving)

The carpooling activity corresponds to the execution of the *HW* and *WH* trips over multiple days (Figure 4). The model assumes that travel times are insensitive to the level of carpooling (i.e. carpooling does not significantly decrease congestion). Travel times between locations have been computed a priori and are assumed to be time independent. This is to be refined by making the negotiation aware of time dependent travel time.

3.2.3. Negotiation During Carpooling

During the carpooling trips, the carpoolers need to communicate and negotiate with each other when someone wants to join or decides to leave the carpool. The agent (either driver or passenger) can receive carpool *invitations* and reply with either *accept* or *reject* messages on the basis of the invitor's profile and the car capacity. New start times for *HW* and *WH* trips need to be negotiated before a new candidate can be accepted.

When someone (either driver or passenger) leaves the carpool, the remaining carpoolers re-negotiate and may adapt their carpool trip start times for both the trips. When changes in the carpool happen the agents may reschedule the carpool and continue carpooling.

3.2.4. Carpool Termination

Drivers and passengers leave the carpool at the end of the agreed participation period. In case the driver leaves the carpool and if after re-negotiation the remaining group size exceeds one, then (s)he will hand over the driver responsibility to the senior passenger (having vehicle and driving-license) of the same carpool. An individual who once left carpool, can become part of the same or any other active carpool later. The individual can also create a new carpool with the individuals of his or her interest. A carpool is destroyed if only one individual is left or if no persons with a car and a driving license are available. If an agent leaves the carpool, (s)he immediately starts to explore the carpooling social network to find new carpool partners.

4. Simulation Experiment and Discussion

The proposed model was run for data created by the FEATHERS activity-based model for the Flanders region.

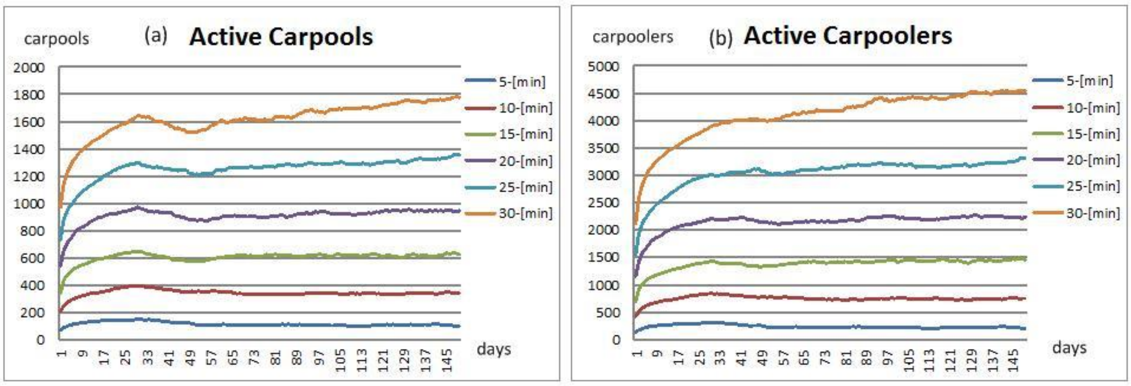
For the experiment;

No. of individuals	30,000 from a set of selected zones
Network exploration	An exploring individual is allowed to contact 5 other people at most during every simulated day
$P_{Explore}$	If 100% then (s)he must send carpooling requests. Otherwise, (s)he can decide not to emit any request.
Carpool period	A carpooler determines the number of working days to carpool by selecting a number randomly from 30 to 60.
Carpool size	Four people at most can share a car (driver included)
Simulation period	150 working days
Time window	Without constraining activities: 5[min], 10[min], 15[min], 20[min], 25[min] and 30[min] With constraining activities: $\pm\Delta T$ = 30 min.
Constraining activities	About 12% people have constraining (either pick-drop or/and shopping) activities
No. of explorations	At most 5 in a day

Table1: The parameters set for the simulation experiments

Figures 5(a) and 5(b) shows the results for a simulation where the trip timing was not constrained by any other activity (e.g. pick-drop, shopping). Individuals could adapt the trip start time with a specific window. Time windows of 5[min], 10[min], 15[min], 20[min], 25[min] and 30[min] were used. The line graph (see Figure 5(a)) shows the evolution of the number of active carpools over 150 working days. The horizontal axis shows the working days and the vertical axis represents the number of active carpools for each day. It is observed that on average, a larger time tolerance window allows for more carpooling. During the first 30 days the number of groups monotonically increases since the shortest possible carpooling period lasts for 30 days. After 30 days, the curves show a decrease because new carpoolers seem to join existing groups rather than create new ones. It seems to be easier to join an existing carpool than to create a new one: the number of carpools decreases but the number of participants does not decrease in that period. A gradual increase of the number of carpool groups occurs again after 45 days because the possibility to join existing carpool becomes less due to the limited car capacity (car saturation effect).

Figure 5: The number of active carpools (a) and carpoolers (b) for different time windows and without constraining activities.



The graph in Figure 5(b) shows the number of active carpoolers throughout the simulation period. For each time window, the number of active carpoolers rapidly increases at the start of the simulation up to about 30 days. After 30 days, the increase rate is lower up to the end of the simulation. The share of carpooling individuals seems to have converged after 100 simulated working days except for the 30[min] case.

Figure 6: The number of active carpools (a) and carpoolers (b) for the time window of 30 min. and with constraining activities.

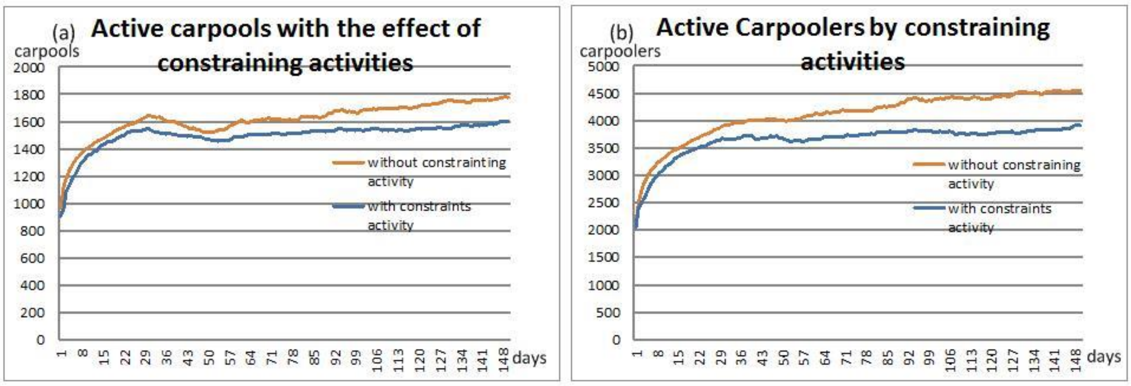
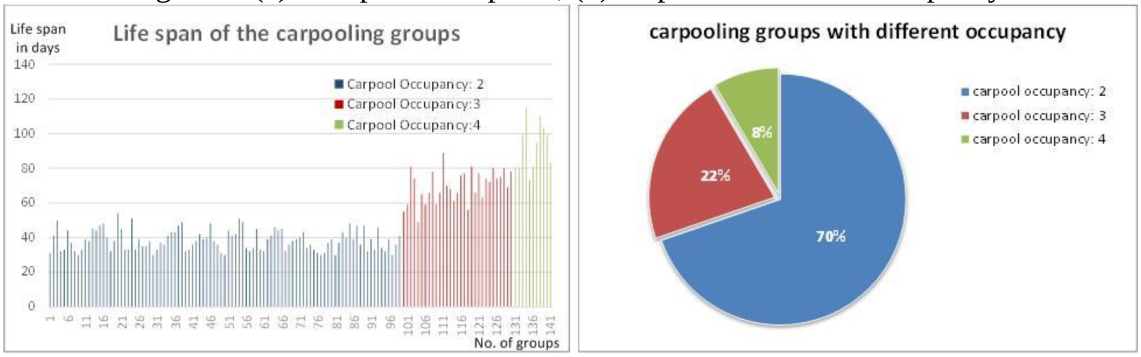


Figure 6 (a and b) show the effect of constraining activities on the trip (*HW* and *WH*) start times. All individuals used a 30[min] time window for the trip start times. In the FEATHERS schedules 5% of the individuals have a pick/drop activity immediately preceding the commuting trips (HW and/or WH). Furthermore, 7% of the individuals are constrained in a similar way by a shopping activity. The graph shows that the constraining activities reduce the probability for negotiation success.

Figure 7: (a) life span of carpools, (b) carpools with their occupancy.



In Figure 7 (a), the bar chart shows the life span of the carpools according to the carpool occupancy. The data of 1000 individuals is used as input. In total 142 carpools were created: 12 of them have an occupancy of 4 agents in each carpool, 31 carpools have an occupancy of 3 agents and the remaining 99 carpools contain 2 agents each. This shows that the life span grows with the. The average life span of carpools with 2, 3 and 4 person are 38.5, 69.8 and 91.3 days respectively. The pie chart in Figure 7(b) represents the percentages of carpools with different occupancies (2, 3 and 4 persons). According to results: 70%, 22% and 8% with the occupancy of 2, 3 and 4 persons of the carpools were created.

5. Conclusion and Future Work

Modeling the interaction between individual agents becomes progressively important in recent research. An agent-based framework using the Janus organization concept has been setup to evaluate the evolution of a carpooling society under several conditions. The model aims to analyze various effects of agent interaction and behavior adaptation. This paper covers the concept of communication, negotiation and coordination for the long term carpooling of a multiple trip model and takes the possibility of flexible activity scheduling into account. The experiments also try to limit the amount of communication between agents by restricting communication to groups based on the home and work locations. The agents negotiate on trip (HW and WH) departure times and on the driver assignment. The data used for implementation have been created by the FEATHERS activity-based model for the Flanders region. The simulation model on the Janus platform provides a solution to the complex problems of mutual adaptation.
Future research will focus on the effect of schedule adaptation and enhancing the mechanisms for communication and negotiation between agents.

Bibliography

Galland S., Knapen L., Yasar A., Gaud N., Janssens D., Lamotte O., Koukam A. and Wets G., *Multi-agent simulation of individual mobility behavior in carpooling*, **Tranportation Research Part C**, 45, pp. 83 – 98, 2014
Bellemans T., Bothe S., Cho S., Giannotti F., Janssens D., Knapen L., koerner C., May M., Nanni M., Pedreschi D., Stange H., Trasarti R., Yasar A. and Wets G., *An Agent-*

Based model to evaluate carpooling at large manufacturing plants, **Procedia Computer Science**, 2012

Kamar E. and Horvitz E., *Collaboration and shared plans in the open world: Studies of ridesharing*, **The 21st International Joint Conference on Artificial Intelligence**, 2009

Hussain I., Knapen L., Bellemans T., Janssens D. and Wets G., *An agent-based negotiation model for carpooling: A case study for Flanders (Belgium)*, **94th Transportation Research Board**, 2015

Cossentino M., Gaud N., Hilaire V., Galland S. and Koukam A., *ASPECS: an agent-oriented software process for engineering complex systems - how to design agent societies under a holonic perspective*, **Autonomous Agents and Multi-Agent Systems**, 20, pp. 260–304, 2010

Gaud N., Galland S., Hilaire V. and Koukam A., *An organizational platform for holonic and multiagent systems*, **7th International Conference on Autonomous agents & Multiagent Systems, Portugal**, 111–126, 2008

Horvitz E., Apacible J., Sarin R. and Liao L., *Prediction, expectation, and surprise: Methods, designs, and study of a deployed traffic forecasting service*, **UAI, AUAI Press**, pp. 275–283, 2005

Rady H.A., *Multi-Agent System for Negotiation in a Collaborative Supply Chain Management*, **International Journal of Video & Image Processing and Network Security**, 11(5), 2011

Hussain I., Knapen L., Galland S., Janssens D., Bellemans T., Yasar A. and Wets G., *Organizational and agent-based automated negotiation model for carpooling*, **EUSPN'14**, 2014

Ronald N., Arentze T. and Timmermans H., *An agent-based framework for modelling social influence on travel behaviour*, **Proceedings of the 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation**, 2009

Hendrickson C. and Plank E., *The Flexibility of Departure Times for Work Trips*, **Transportation Research Part A**, 18(1), pp. 25-36, 1984

Knapen L., Yasar A., Cho S., Keren D., Abu Dbai A., Bellemans T., Janssens D., Wets G., Schuster A., Sharfman I., and Bhaduri K., *Exploiting Graph-theoretic Tools for Matching in Carpooling Applications*, **Journal of Ambient Intelligence and Humanized Computing**, 17p, 2013

Bellemans T., Kochan B., Janssens D., Wets G., Arentze T. and Timmermans H., *Implementation framework and development trajectory of feathers activity-based simulation platform, Transport. Research Record: J.*, pp. 111–119, 2010

Ettema D. and Timmermans H., *Modeling departure time choice in the context of activity scheduling behavior*, **Transportation Research Record**, 1831(1), pp. 39–46, 2003

Hussain I., Knapen L., Galland S., Yasar A., Bellemans T., Janssens D. and Wets G., *Agent-based Simulation Model for Long-term Carpooling: Effect of Activity Planning Constraints*, **The 6th International Conference on Ambient Systems, Networks and Technologies**, 2015a

Hussain I., Knapen L., Bellemans T., Janssens D. and Wets G., *Agent-based Negotiation Model for Long-term Carpooling: A Flexible Mechanism for Trip Departure Times*, **21st International Conference on Urban Transport and the Environment**, 2015b