Dijkstra, J., H.J.P. Timmermans, and B. de Vries, 2004, Data Requirements for the Amanda Model System, In: Van Leeuwen, J.P. and H.J.P. Timmermans (eds.) *Developments in Design & Decision Support Systems in Architecture and Urban Planning*, Eindhoven: Eindhoven University of Technology, ISBN 90-6814-155-4, p. 127-139.

# Data Requirements for the Amanda Model System

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Keywords: Multi-Agent Systems, Activity Modelling, Pedestrian Behaviour

Abstract: The Amanda model system uses a multi-agent approach in an attempt to simulate pedestrian dynamic destination and route choice. Data collecting efforts are needed to calibrate the model. This paper discusses these data requirements.

## 1. INTRODUCTION

In 1990s, several models of pedestrian movement and pedestrian flows have been developed. Noticeable is the success of cellular automata models in various disciplines, including transportation (e.g., Blue and Adler, 1999, 2001; Kukla, Kerridge, *et al*., 2001; Schelhorn, O'Sullivan, *et al*., 1999). Most models are concerned with pedestrian movement in hazardous situations, such as evacuation and escape situations (e.g., Helbing, Farkas, et al., 2000; Hoogendoorn, Bovy, et al., 2001; Meyer-König, Klüpfel, *et al*., 2001). After the 11 September 2001 disaster, great importance has been attached to these models because the prediction of such behaviour is of great public interest.

In line with this tradition, several years ago we started a research project that has received the acronym Amanda, which stands for A Multi-Agent model for Network Decision Analyses. The acronym indicates that in principle the model framework can be used for all kinds of agents who have to make decisions in a network: pedestrian movement is just one example. The purpose of this research project is to develop a multi-agent system for network decision analyses (Dijkstra and Timmermans, 2002). The term network decision analysis is used to encompass all design and decision problems that involve predicting how individuals make choices when moving along a network such as streets and corridors in a building.

Previous models of pedestrian behaviour have focused primarily on movement rules, lane forming and crowd dynamics. We want to extend these models with destination and route choice, and activity scheduling. To that effect, we started with the basics of approaches that have focused on destination and route choice (e.g., Borgers and Timmermans, 1986a, 1986b). In these approaches, it was not so much the actual detailed movement itself, but rather the outcomes of such movements in terms of destination and route choice that was the purpose of the modelling process.

We assume that in turn destination and route choice decisions are influenced by such as motivation, activity scheduling, store awareness, signalling intensity of stores, and store characteristics. The domain of our model is pedestrian behaviour in a shopping environment and the choice mechanisms that are involved including where to stop, in what order, and which route to take. The conceptual framework underlying the model has been reported elsewhere (Dijkstra, *et al*, 2002). In this paper, we will discuss the data that are required to estimate the model, and suggest alternative ways of how such data can be collected.

The paper is organised as follows. First in section 2, we will discuss the Amanda model system. Then, in section 3, we will describe the data requirements. Section 4 will discuss the data collection. We will finish with a brief discussion.

## 2. THE AMANDA MODEL SYSTEM

In this section, we will describe the major features of the Amanda model system, without going in too much detail. Successively, the environment, the simulation of individual (pedestrian) behaviour, the agent model description and the pedestrian model will be discussed.

### 2.1 Environment

In the Amanda model system, we populate an environment with agents representing pedestrians. This environment consists of a street network and a set of establishments. Polygons are used to indicate borders, and functional areas like walkways. Discretisation of these polygons generates a grid of cells, which is called a cellular automata grid. Therefore, a cellular automata grid together with the polygons represents the environment. Each cell in the cellular automata grid can be considered as an information container object. It has information about which agents and polygons occupy it. Also, it contains information about other features such as appearance characteristics of establishments that are observable from that cell.

## 2.2 Simulation of individual behaviour

Two aspects are relevant for understanding the simulation of individual behavior: *steering* including path determination, and *action selection* including strategy, goal formulation and planning.

### 2.2.1 Steering

Agents use the cellular automata grid for path finding. In this respect, the grid is viewed as a graph on which the path is constructed. Steering is responsible for determining an agent's path. A steering system controls and implements agent movement, paying attention to multiple goals such as implementing an activity agenda, time constraints and obstacle avoidance. A basic gradient is used for steering, while reactive procedures take local information about the environment into account. Steering reacts to continuous changes in the environment. With respect to navigation, an agent may decide for a faster or slower lane, window-shopping is done at the outer lanes; there is tendency to keep right (left), etc. Speed may be influenced by socio-economic variables (gender, age, etc.), physical features such as obstacles, passages, crossings, and width of the corridor or street. All these facets influence agent movement and are part of the simulation process.

### 2.2.2 Action selection

We assume that pedestrian movement is embedded in the larger problem of activity scheduling (Tan, *et al*., 2000). It is assumed that individuals made decisions regarding their activity agenda, destination and route choice when moving over the network. We assume that the completion of an activity results in adjustments, if necessary, of a pedestrian's activity agenda. In other words, action selection is viewed as scheduling and rescheduling activities. Such scheduling decisions involve decisions about which activities to conduct, where, in what order, when and for how long. Pedestrians can perform the activities in a set of stores or establishments. Action selection may depend on personal characteristics, motivation, goals, time pressure/available time budget and familiarity with environment respectively stores and establishments. In addition, store and establishment characteristics, duration, and awareness also influence the scheduling of a pedestrian's activity agenda.

## 2.3 Agent model description

To better communicate our interpretation of agent architecture, we use UML (Unified Modelling Language) diagrams to guide an implementation design. Figure 1 represents a global description of a pedestrian agent.

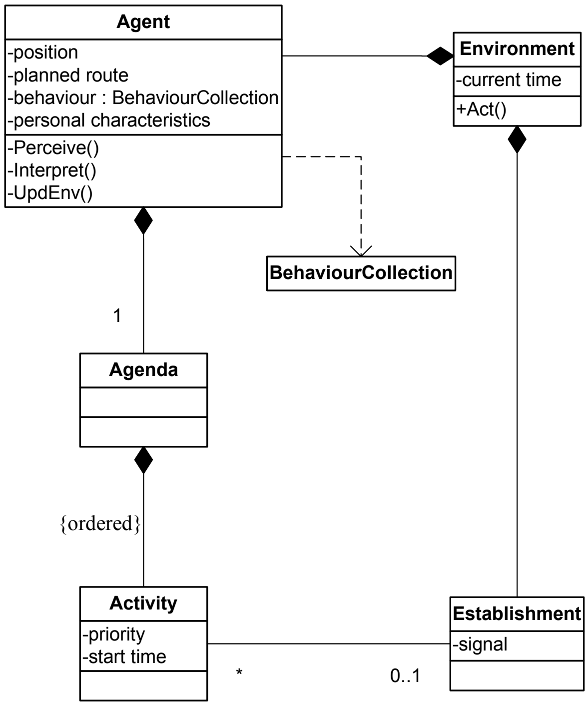


*Figure 1.* UML diagram of a pedestrian agent

Regarding the diagram in this figure, one can observe that the *Environment* contains agents representing pedestrians. Each agent has an *Agenda* that contains an ordered list of *Activities*. Activities can be performed at *Establishments*, which are located in the *Environment*. The declaration of *behaviour* represents the set of possible attitudes, perceptual nature, tendency of impulsive behaviour and motivational state that is called *BehaviourCollection* in the diagram.

By declaring the methods *perceive, interpret* and *updEnv* private, the agent has its own control of the methods. The function *perceive* represents the perception process of the agent. It maps the environment to a set of perceptors. The function *interpret* represents the decision making process of the agent and has a more complex form because an agent has an internal state, which includes the built-in knowledge. This function maps a set of perceptors, the current internal state and the current activity agenda into a list of one or more actions, for instance the activity to visit a store implies a movement into that store. The internal state and the activity agenda will be updated. The function *updEnv* represents the reaction of the environment to the agents' actions. A new state of the environment is realized. The visible action of the agents is movement, which realizes a new agent's position on the cellular automata grid.

Agent behaviour can be distinguished into a hierarchy of three layers: *action selection, steering* and *locomotion* (Reynolds, 1999). Figure 2 shows this division in several layers. The interpretation of an agent's perceptor leads to action selection and as a consequence to path determination. Tstate of the environment is updated as a function of agent movement.

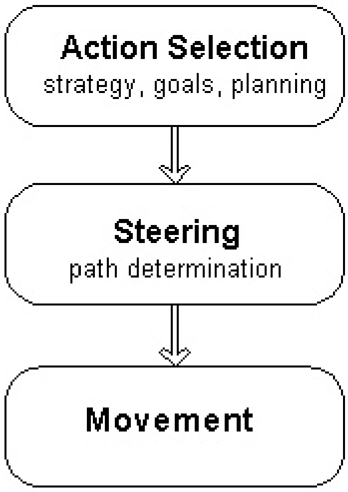


*Figure 2.* A hierarchy of pedestrian motion behaviours

## 2.4 Pedestrian model

The pedestrian model is model for illustrating the Amanda model system. We consider a shopping environment populated with agents representing pedestrians. Each agent *i* is supposed to carry out a set of activities $A_i$. That is, agents are supposed to purchase a set of goods, become involved in window-shopping, and possibly conduct other activities such as having a lunch, etc. Thus, agents make a trip in the shopping environment, each with their own activity agenda. We assume that the activity agenda is time-dependent and that activities have their priorities. We assume that the completion of an activity is a key decision point, where agents will adjust, if necessary, their activity schedule and anticipated time allocation to the activities not yet completed. In order to implement the activity schedule, the agents need to successfully visit a set of stores and move across the network. Agents need to decide which stores to choose, in what order, and which route to take, subject to time and institutional constraints. We assume that agents are in different motivational states. They may at every point during the trip have general interests in conducting particular activities, without having decided on the specific store to visit, but they may also be in a more goal-directed motivational state in which case they have already decided which store to visit.

When moving over the network, we assume that agents have *perceptual* fields. Perceptual fields, which guide which stores an agent will perceive, may vary according to the agent's awareness threshold, which in turn may depend on his motivational state, age, etc., and the *signalling intensity* of the store or establishment, which is assumed a function of distance, appealing architecture, and whether or not the view is interrupted by other agents (Dijkstra, *et al*., 2002).

## 3. DATA REQUIREMENTS

As mentioned in the introduction, we want to apply the pedestrian model to the city centre of Eindhoven as an illustration. Data collecting efforts are needed to calibrate the Amanda model system for this illustration. Three main types of data are required to implement the model. First, data collection efforts are needed for calibrating steering behaviour. Secondly, activity diary data are required to simulate activity agendas. Thirdly, data are required to estimate awareness thresholds of agents, signalling intensities of stores, propensity of window shopping and subsequent store visits, and successful completion of activities. In particular, operationalisation of the models requires:

1. *Data collection about steering behaviour, which* concerns movement patterns and includes:
    a. Speed as a function of pedestrians' personal characteristics: desired speed which corresponds to comfortable walking speed
    b. Proportion left-right in shopping streets

c. Proportion overtaking left – overtaking right
d. Moving behaviour: tendency to keep right (left)
e. Moving tendency: tendency of increasing speed at inner lanes
f. Moving behaviour: window-shopping at outer lanes
g. Moving behaviour from pedestrian to a store or establishment: reducing speed and under which angle
h. Moving behaviour at cross-sections
i. Moving behaviour control: longitudinal acceleration at side-stepping
j. Anticipatory behaviour in relation to b. until e. and at obstacles, collisions, congestions, incoming pedestrians
k. Avoidance behaviour: keep a certain distance to other pedestrians and borders (of streets, walls, and obstacles)

These data can be acquired from the literature (e.g. Fruin, 1972; Løvås, 1994), and by counting, and camera observations. This is not to say that the collection of such data does not cause any problems, but a discussion of these is beyond the scope of this paper, given the limitations in length.

2. *Data collection for activity agenda modelling*. In order to generate activity schedules, data are required about the activities that pedestrians conduct in what order, where, etc. To conduct the simulation, activity agendas can be sampled from such observations. Alternatively, to generalize observed schedule, a separately activity scheduling model could be developed. Regardless of the specific approach, a representative sample of pedestrians who have completed their visit to the city centre should be interviewed and be asked about the nature of their completed activity patterns: which activities for successively conducted, where, when, for how long, whether the activities were planned or not, and the route that was taken. Again, due to constraints, we will not discuss this in any detail.

3. *Data collection about the specific pedestrian behaviour*. The underlying equations for the behavioural principles are described in Dijkstra, *et al*. (2002). To estimate the parameters of these equations, a survey needs to be administered. This survey involves collecting data about pedestrian's perception of stores and signalling intensity of stores as well as visits to stores and the completion of activities. In the Amanda model simulation that means that the movement of the

agents over the network is assumed to be influenced by their perceptual fields, which in turn is influenced by the agent's awareness threshold, and the signalling intensity of the store. When stores are signalled and become included in an agent perceptual field, the agent has to decide whether or not to act and visit the store (activation). In this paper, we focus on this data collection effort.

# 4. DATA COLLECTION

## 4.1 Awareness and signalling intensity

To estimate the parameters of this equation, we need data on the probability that a store belongs to an agent's perceptual field, and data on signalling intensity and awareness threshold level. A perceptual field implies that an agent will view a store at which he/she can purchase the good of interest. The problem of measuring this field is that one cannot ask respondents to think aloud when walking through a city centre because they very question will lead them to become conscious about their environment. Hence, we suggest asking respondents listing the store they perceived immediately after crossing some point on the network. The basic equation is:

$$p_{j \in F_i^t} = \frac{\exp\left(\vartheta_j^t - \theta_i^t\right)}{1 + \exp\left(\vartheta_j^t - \theta_i^t\right)}$$

where,

$\vartheta_j^t$ is the signalling intensity of store $j$ at time $t$ during visit $v$;
$\theta_i^t$ is the awareness threshold of agent $i$ at time $t$ during visit $v$;

This equation shows that we assume that the probability that a store belong to an agent's perceptual field increases if the signaling intensity of the stores increases and decreases if the awareness threshold of an agent is higher. This is also depicted in Figure 3.

Note that signalling intensity and awareness threshold both are parameters and hence should be inferred from data about perceptual fields. The question specified above provides us with this information and hence we can estimate the two parameters. In principle, the parameters can be estimated for all stores and each agent, provided sufficient data point have been collected. However, to generalize, it is better to use some classification of stores and perhaps some segmentation of agents as well. The estimated parameters can apply to this level of aggregation. In turn, both parameters can be estimated as a function of additional parameters. For example, signalling intensity may depend on the size of the story, its architecture, use of colours, window display, etc. Empirical analyses will indicate which of these factors is most discriminating. Likewise, awareness threshold can be further explained in terms of a set of socio-demographic variables, trip purpose, urgency, etc.

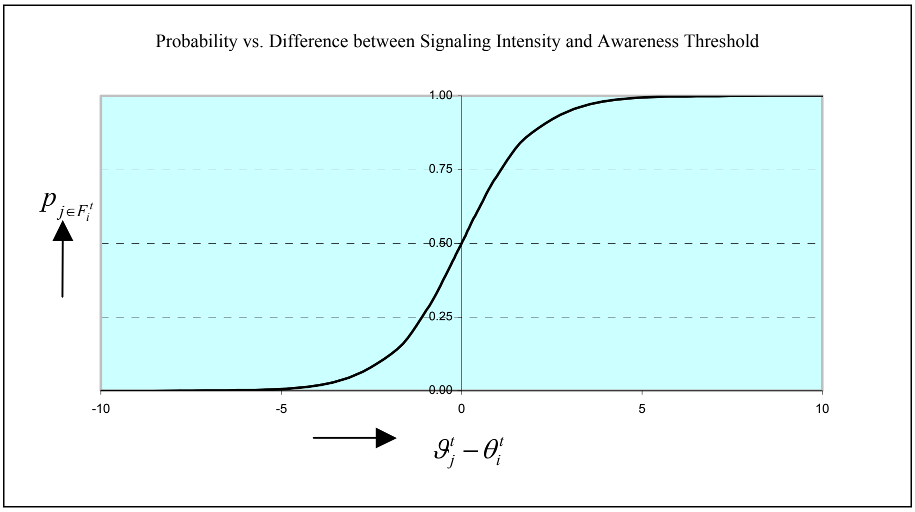


*Figure 3.* $p_{j \in F_i^t}$ vs. ($\vartheta_j^t - \theta_i^t$).

To estimate such relationships, we also need to collect data on *personal characteristics* (A), and the *evaluation of store attributes* (B), if one would like to base the model on subjective measurements, or *physical attributes* otherwise. The personal characteristics refer to:

- Gender, age, companionship, ability
- Motivation
- Familiarity with the city centre
- Frequency of visits

Table 1 provides an example of how respondents could be asked about their evaluation of store attributes. A rating scale could be use to express their evaluations.

*Table 1.* Attraction of stores

| Name of Store | As a result of what? | | | | | |
|---|---|---|---|---|---|---|
| | **Window-shop** | **Architecture** | **Advertisement** | **Presentation** | **Size** | **Other** |
| | | | | | | |
| .......... | .......... | .......... | .......... | .......... | .......... | .......... |

## 4.2 Activation of a store visit and probability of completing an activity

When stores are signalled and become included in an agent's perceptual field, the agent has to decide whether or not to act and visit the store. This is called the *activation* of the agent. We assumed that activation is defined and depends among others on agent's personal characteristics, motivation, familiarity with a store, suitability to conduct a visit, and the agent's consideration set. A consideration set is a set of stores that an agent considers in performing a particular activity. If an agent is not familiar with a store, the activation of the agent towards this store will be lower. Similarly, activation will be equal to zero if the store is not suited to conduct any of the activities that are still scheduled to be completed.

If an agent becomes activated, it will gradually move to the store. The simulation then decides on the duration of window-shopping, if any, the probability and duration of an actual visit to the store, the probability of successfully completing the activity at the store, and the amount of money spent. We assume that the probability of a successful completion is a function of availability and predictability of the product, the urgency of completing the activity, the familiarity of the store to the agent, the duration of the visit, and the attractiveness of the store. Thus, first we need data on the propensity to become activated. This can be collected by observing pedestrian behaviour, for example using cameras. Counts are then the required input. As illustrated in Table 2, data should be available about the percentage of pedestrian moving towards the stores, the percentage of window shoppers and the percentage of pedestrian actually entering the store. Because collecting such data for every store, preferably on numerous occasions would be too demanding, unless fixed cameras could be used, a classification of stores and a sampling of stores would be required.

*Table 2.* Measurement of activation

| | **Show-window & go inside** | **Show-window & pass by** | **Pass by** | **Go inside** |
|---|---|---|---|---|
| Shop 1 | | | | |
| ……. | | | | |
| Shop n | | | | |

For collecting data we assumed an underlying conceptual model for visiting a store (Figure 4).


*Figure 4.* Influence of personal and store characteristics on store visiting.

We proposed a survey for collecting data of agent's *personal characteristics* and *store characteristics*. The personal characteristics refers to:

- Gender, age, companionship, ability
- Motivation of visiting city centre
- Familiarity with the city centre
- Frequency of visits city centre
- Familiarity with the store
- Frequency of visits of the store
- Planned activity
- Attractiveness of the store
- Motivation of visiting the store
- Completed activity
- Urgency of the activity
- Duration
- Time spent to the city centre
- Remaining time of visiting city centre

Respondents are invited to report their satisfaction levels with store attributes. This is similar to the previous type of questions, except that the focus here is on product and service attributes, whereas the previous question focused on attributes influencing perception. In other words, the focus here is on the utility that agents derive from visiting a store. We assume that agents have an ideal attribute profile and that the utility that derives from visiting a store is a function of the difference between their ideal and the actual profile.

For completing an activity successfully, we assume the underlying conceptual model shown in Figure 5. Data collection then implies that shoppers should ideally be interviewed before they enter the store for their expectations and ideal profile and immediately after they leave a store for their experiences and information about availability and the like.

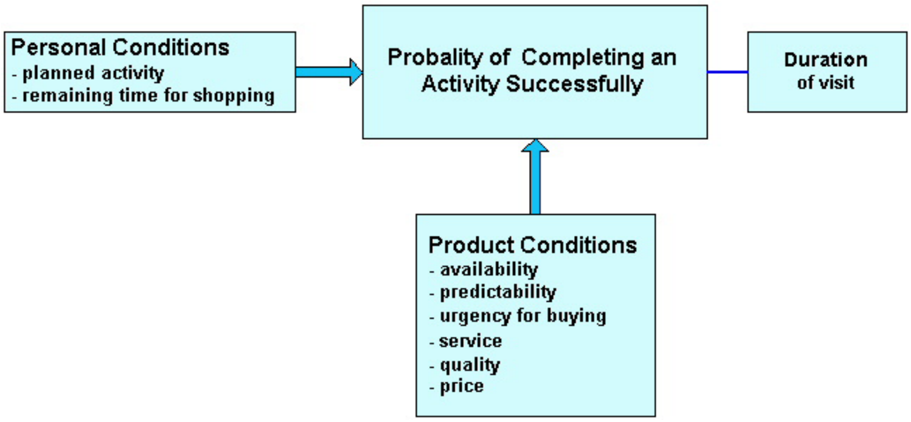


*Figure 5.* Influence of product conditions and additional personal conditions on the probability of completing an activity successfully, and the duration of visit

## 5. DISCUSSION

In this paper we presented an approach for collecting data with respect to pedestrian behaviour, in particular pedestrians who visit a city centre. The discussion suggested the wide variety of data that is required to estimate an agent based model of pedestrian movement. Hence, it is not surprising that most existing models have not been calibrated, but have mainly been used to demonstrate some principles and properties.

At this moment, the data for the Amanda model are being collected. We intend to report empirical results and experiences with the suggested data collection method in the near future.

## AKNOWLEDGEMENTS

The authors thank Joran Jessurun for his contribution to the agent model description and comments to the Amanda model system.

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