**Sector–Specific Agent Based Model Definition for the Mobility Sector**

-Deliverable 5.2-

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Introduction

The sector-specific Agent Based Model Definition for the Mobility Sector has been developed by the Delft University of Technology (TUDelft) team. It is the result of discussions between the TU Delft team and the UOXF.JQ team. The points of departure were the generic Agent-Based Model (which was submitted as Deliverable 3.3: “Demonstration of Agent Based Model: How servicizing policies affect absolute decoupling” and is available on the SPREE wiki¹), and the mobility sector case study definition provided in the Mobility Sector Report (Deliverable 5.1). In the discussions, the structure of the generic ABM on the one hand and the Mobility Sector case study details on the other hand have been considered in unison, resulting in a sector-specific Agent Based Model Definition for the Mobility Sector that is both relevant and workable.

As the generic model has been designed to enable the representation of Servicizing in various sectors, and in particular the Water, Mobility, Agri-food sectors, the sector-specific models are intended to require relatively small adaptations to the generic ABM. Likewise, the ABM definition for the Mobility Sector is similar to the generic ABM definition, but there are a few fundamental changes. The ABM definition for the Mobility Sector will be described using ontology terminology, and in the form of the adaptations made to the generic ABM definition. Therefore, the generic ABM definition is summarized first.

Generic ABM definition

Below, we summarize the agents and objects and agent/object interrelations in the generic ABM model definition. These have been defined in the Final Ontology (Deliverable 2.2: “Joint conceptual framework and formalization of concepts”). The

¹ http://www.wiki.spreeproject.com
Final Ontology can be found on the SPREE wiki. A more elaborate generic model description is provided in the master thesis of Kasper Kisjes².

In the generic ABM definition, Consumer and/or Consuming Business (CB) agents have a certain need, expressed in terms of a function. Functions can be provided in different ways: the Consumer/CB may buy a Product that (in)directly provides the function, or pay a Producing Business (PB) agent to deliver the function through a Service. A specific Product/Service corresponds with a specific Consumption Model (CM), which represents the process of consuming that Product/Service.

Producing Business (PB) agents make a similar choice when determining what Product and/or Service they will deliver, by adopting a certain Manufacturing Model (MM) (which represents the production process) and one or two Sales Models (SM) (which represent the product/service delivery process). Like a CM, a specific Sales Model corresponds with a specific Product/Service.

All Products and Services on the market have specific, predefined physical and non-physical properties. Products can be subdivided into Tools, which are bought per unit and can be used multiple times, and Consumables, which are bought in quantities and are used once (fully consumed in one go). Services are delivered through a Service Contract. Furthermore, Products and Services have a specific amount of resources used and wastes generated associated, which are defined by means of the Resource object. Products are bought from the World Market, while Products at end of life may be either sold to the World Market or dumped in the Physical Environment.

Skills and Infrastructures are both conceptualized as prerequisites of certain CMs, MMMs, and SMs, which means that agents should acquire a Skill or connect to an Infrastructure in order to adopt a CM/MM/SM.

Policy Instruments and Market Development Events are defined to consist of External Effects, which have a specific effect on a specific agent or object property, and can have certain activation and deactivation condition. The ontology elements and interrelations are illustrated in Figure 1.

Figure 1: Overview of generic model definition in terms of agents and objects and their interrelations (based on Kisjes (2014))
PBs choose once a while to perform a *strategic change*, which may involve changing their MM, SMs, and/or the MM production capacity. More frequently, they make a *tactical change*, which involves a modification of the offer prices and allocation of stock to each of the SMs (in case of two SMs). Consumers/CBs choose once a while to reconsider their CM (strategic change), and more frequently they may switch to an offer from another PB for the same Product/Service (tactical change).

The main mechanism of consumption behavior revolves around *Preferences* and *willingness to pay*. Different consuming agents may have different weights and thresholds for a single set of Preferences, and may have a different willingness to pay for 'preference fit' and also for 'loyalty'. As each Product/Service has a score for the same set of Preferences, the consuming agents can compare alternative offers, by calculating a total 'offer score' based on their weights, thresholds and willingness to pay. They will choose the offer with the highest score.

The main mechanism of production behavior is the *market research* performed by the PBs. The PBs calculate the expected profit for all alternative strategic options they have, by asking a subset of consuming agents at which price they would be willing to select the related offer, and how much they would consume in a given period. In addition, the PBs also consider their own willingness to 'sacrifice expected profit' for higher 'preference fit', in largely the same way as Consumers/CBs do.
Sector-Specific ABM Definition for the Mobility Sector

The system for the Mobility Sector case study has been defined by the UOXF.JQ team in the following way:

- **Topic:** Servicizing of passenger transportation
- **Market type:** Business to consumer (B2C)
- **System boundary:** A geographical area, on a medium to large city/metropolitan region scale, e.g., Bristol and London in the UK case
- **Servicizing shift:** The move from private car ownership towards servicized vehicle use, mainly concentrating on car sharing and bike sharing
- **Central need:** transport (for various purposes)
- **Functional unit of need:** kilometer of inner-city transport
- **Basic time unit:** week

This has led to the following sector-specific ABM definition for the Mobility Sector:

- The *production of cars/bikes* is not considered within the ABM; cars/bikes will be bought from the World Market.
- The case study will not include *Consumer Businesses*.
- Included *Products* are small cars, medium cars, large cars, electric vehicles, and bicycles. Included *Services* are the point-to-point car-sharing scheme, the back-to-base car-sharing scheme, and the bike-sharing scheme. Included *Consumption Models* are use of car only (different car types), use of private car + public transport, public transport + car sharing, bike sharing + car-sharing, and public transport.
- *Multiple transport modalities* are incorporated by defining CMs representing 'consumption bundles' that include the use of specific modalities, with specific proportions of usage (see below).
Different combinations of trip purposes may be incorporated by defining different Consumer groups with different Need volumes and different Preference weights (see below).

In Figure 2, important Sales Models and Consumption Models for the Mobility Sector ABM are illustrated.

Figure 2: Schematic of Sales Model and Consumption Model options in the Mobility Sector ABM
Given this definition for the Mobility Sector case study, the following can be said about the suitability of the generic ABM to represent this case:

- To incorporate into the ABM the aspect of combining different transport modalities for the same trip, Consumption Models can be included in the model that represent the use of e.g. both car sharing and public transport ('consumption bundles'). Such a Consumption Model would have different 'preference scores' than CMs representing 'pure' transport Products/Services that are provided by Producing Businesses. The preference scores for the consumption bundle CMs will be an average of the scores of the different modalities included in the bundles, proportional to their share of use. Incorporating multiple modalities in this way enables us to use the generic ABM, along with the assumption that Consumers use only one CM at the same time. The reason to include multiple modalities is that Consumers may not switch to a service as a single transportation option, whereas such services may be attractive in multi-modal transport.

  - The inclusion of different consumption bundles (multiple modalities) will lead to multiple Consumption Models having the same main input. In other words, one Product/Service may correspond to multiple CMs. This requires an extension of the decision-making by Producing Businesses, who, in their market research, must now ask Consumers what they are willing to pay for a Product/Service, considering all possible CMs (i.e. the Consumers should express their maximum willingness to pay).

  - The Consumption Models will continue to have one main input: the Product/Service the Consumers buy from the PBs. The consequence of this is that, if a CM ‘car sharing + bike sharing’ is defined, either car sharing or bike sharing is the main put. Transport products/services in the CM that are not a main input, are not modeled to be provided by
an active agent. Public transport is not provided by a PB; if there is a CM that consists of just public transport, a public transport Service will be created that is for sale in the World Market.

• The fact that consumers have a need for different kinds of mobility for different trip purposes can be reflected in the weights and the thresholds of the consuming agents. Weights can be averaged proportional to the need for different trip purposes, while thresholds can make sure that the chosen Product/Service is a suitable mobility solution for all trip purposes that a Consumer has. This does not require an adaptation to the generic ABM.

In sum, the following adaptations need to be made to the generic ABM, to create a useful sector-specific ABM for the Mobility case:

• An extension of the market research mechanism. The PBs should consider all the Consumption Models corresponding to a Product/Service, when considering to switch to the delivery of that Product/Service.