CONCEPTUAL PROCEDURE FOR GROUPING LOGISTICS OBJECTS FOR MESOSCOPIC MODELING AND SIMULATION

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ABSTRACT

The field of logistics is confronted with an increasing complexity. This mainly results from the immense amount of goods which are part of logistics systems and processes. To address that the description of logistics systems and processes is to be conducted from an object oriented point of view by including object characteristics and their relations among each other. Therefore, in context of mesoscopic modeling and simulation, this paper presents a procedure which supports the conceptual modeling phase of the mesoscopic simulation approach in grouping and aggregation of logistics objects, i.e. goods and products, in an effective and credible way. This is considered as a method of simplification and will contribute to better model credibility and simulation efficiency as well as reducing model complexity.

Keywords: grouping, aggregation, logistics objects, mesoscopic modeling and simulation, logistics systems, complexity

1. INTRODUCTION

The field of logistics is confronted with an increasing complexity. Due to globalization production and logistics networks are becoming more international and the number of involved parties is increasing (Simchi-Levi 2008, p. 312). A rising variant diversity of products, a growing amount of globally sourced goods as well as an increasing availability of information due to new identification technologies contribute to that. Besides rising customer demands, decreasing length of product life cycles or increasing costs pressure, the complexity and heterogeneity of networks mainly result from the immense amount of goods which are part of logistics systems and processes (Bretzke 2010, pp. 1–4; Schenk et al. 2006). This trend has an impact on the sensitivity to disturbances of logistics networks, as well. According to this, tools of modeling and simulation provide suitable methods to analyze logistics systems as well as to support a fast adaptation process to changes and disturbances.

Here, the mesoscopic modeling and simulation approach seems to be very promising due to its trade off between simulation time and accuracy as well as providing the opportunity of incorporating logical groups of objects.

To address the rising diversity among the goods, which is a driving factor for complexity, the description of logistics systems and processes is to be conducted from an object oriented point of view by including object characteristics and their relations among each other. This comprises the application of appropriate concepts for incorporating that aspect and for grouping objects as well as defining standard processes to provide efficient solutions.

In this paper we consider logistics objects to be "physical goods such as raw materials, preliminary products, unfinished and finished goods, packages, parcels and containers or waste and discarded goods. Also, animals and even people can be logistics objects, which need special care and service" (Gudehus and Kotzab 2009, p. 3). But besides these physical objects also information are to be considered as logistics objects, often referred to abstract objects (Arnold et al., p. 3; Schenk 2007).

The objective of this paper is to present a procedure which supports the conceptual modeling phase of the mesoscopic simulation approach in grouping logistics objects in an effective and credible way. This will contribute to better model credibility and simulation efficiency as well as reducing model complexity.

2. MESOSCOPIC MODELING AND SIMULATION OF LOGISTICS FLOW SYSTEMS

Three classes of simulation models exist, namely continuous, mesoscopic and discrete. Continuous models are based on differential equations and most frequently applied as system dynamics models to reproduce manufacturing and logistics processes (Banks 2005). Discrete event simulation models provide a high level of detail in modeling logistics systems, but can be very complicated and slow, i.e. when it comes to modeling and simulating complex and diverse system structures or incorporating different scenarios (Sterman 2000). In order to overcome the disadvantages of these traditional simulation approaches Reggelin and Tolujew developed the mesoscopic modeling and simulation approach which will be shortly described in this section. For further reading we recommend (Reggelin 2011; Tolujew, Reggelin, and Kaiser 2010; Schenk et al. 2010; Schenk, Tolujew, and Reggelin 2009b). The developed mesoscopic modeling and simulation approach has the following characteristics:

- Less modeling and simulation effort than in discrete event models,
- Higher level of detail than in continuous simulation models,
- Straightforward development of models.

The mesoscopic modeling and simulation approach is situated between continuous and discrete event approaches in terms of level of modeling detail and required modeling and simulation effort (see Fig. 1). It supports quick and effective execution of analysis and planning tasks related to manufacturing and logistics networks.

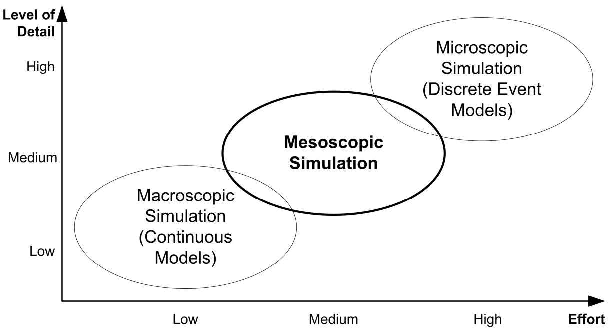

Figure 1: Classification of the mesoscopic simulation approach

This mesoscopic approach is consistent with the principles of the discrete rate simulation paradigm implemented in the simulation software ExtendSim (Krahl 2009; Damiron and Nastasi 2008). Piecewise constant flow rates and the resulting linear cumulative flows support event scheduling and boost computational performance.

Even when the term mesoscopic is not explicitly applied, a mesoscopic view often already exists from the start of flow system modeling and simulation. Many practical analysis and planning problems like capacity planning, dimensioning or throughput analysis describe performance requirements, resources and performance results in an aggregated form that corresponds to a mesoscopic view (cp. Schenk, Tolujew, and Reggelin 2008a). Mesoscopic models are particularly suited for the analysis of large-scale logistics networks and processes with a homogenous flow of a large number of objects. In most cases, the disproportionate amount of computation required would make item-based discrete event simulation overly complex for these applications.
The principles of mesoscopic simulation of logistics processes were derived from several mesoscopic models (Schenk, Tolujew, and Reggelin 2008a; Schenk, Tolujew, and Reggelin 2009a; Schenk, Tolujew, and Reggelin 2008b; Savrasov and Tolujew 2008; Tolujew and Alcalá 2004; Hanisch et al. 2003).

3. CONCEPTUAL MODELING PHASE

The conceptual modeling phase of a simulation study is one of the most important parts (Robinson 2008). In context that good conceptual modeling can significantly contribute to a successful outcome of a simulation study, it still is a difficult and hard to understand stage in the modeling process (Law 1991). Guidelines for the modeling process can be found in (Law 2007; Pidd 1999; Uthmann and Becker 1999).

For conducting a successful simulation study the Seven-Step approach by Law can be applied for mesoscopic simulation (Law 2009). In the conceptual modeling phase step 2 is an important part for determining the level of detail as well as the system and process structure of the model (see Fig. 2). Here, for mesoscopic modeling and simulation an essential and inherent part is the grouping or aggregation of logistics objects.

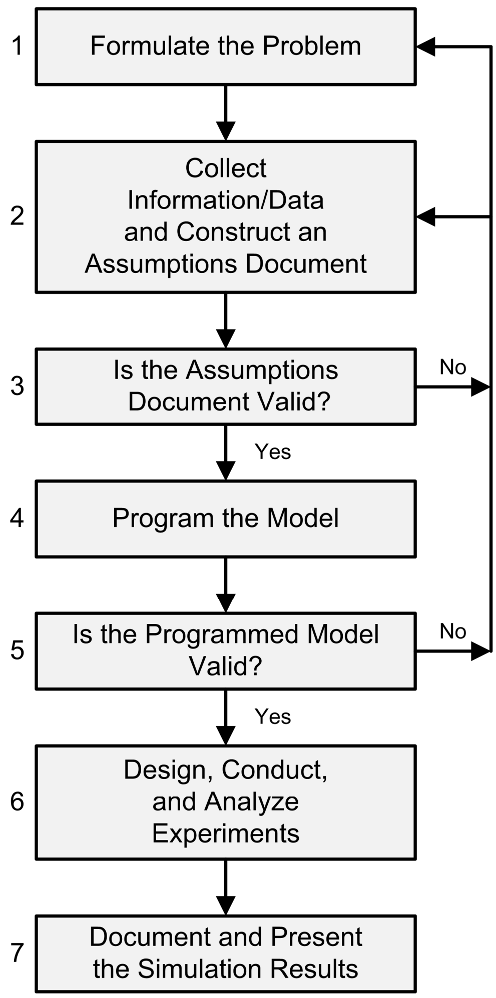

Figure 2: A Seven-Step Approach for Conducting a Successful Simulation Study (Law 2009)

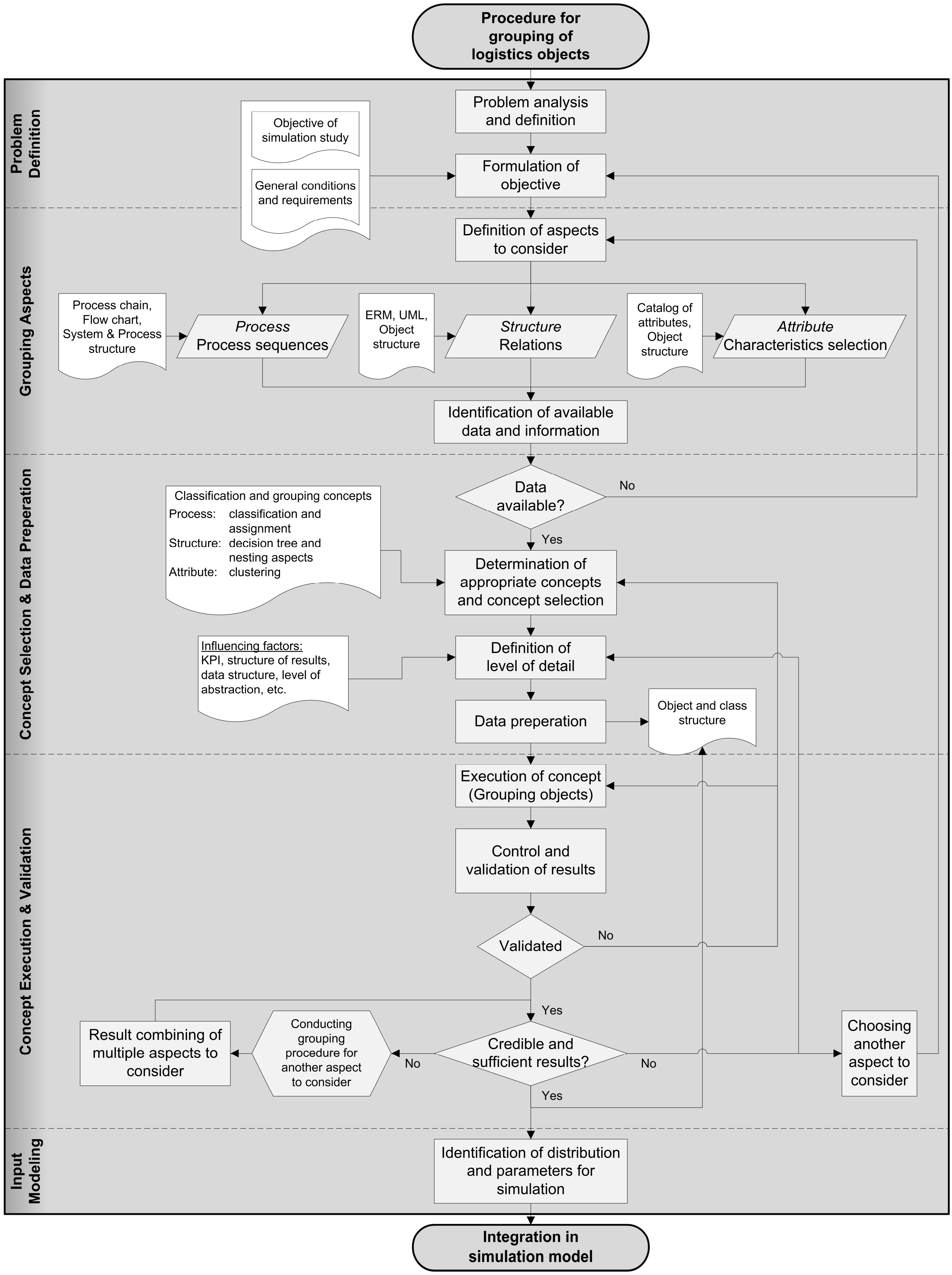

Figure 3: Procedure for grouping of logistics objects

But there is a lack in supporting the composition and decomposition of logical groups of logistics objects. However, this is of significant importance to approach the increasing complexity of logistics systems and processes efficiently. Zeigler et al. also suggest as one method of simplification for simulation modeling to group components of the model (Zeigler, Praehofer, and Kim 2007).

In (Law 2009; Brooks and Tobias 1996; Zeigler, Praehofer, and Kim 2007) guidelines for determining the level of detail of a simulation model can be found. They are also related to the aspect of simplification by grouping objects and elements of the simulation model. However, these guidelines do not provide a clear procedure in how to approach the grouping of objects.

4. CONCEPTUAL PROCEDURE FOR GROUPING OF LOGISTICS OBJECTS

Therefore, to support this step of the conceptual modeling phase a procedure was developed which addresses the effective and credible grouping (aggregation) of logistics objects in context of mesoscopic modeling and simulation (see Fig. 3).

The procedure is based on grouping the considered logistics objects (i.e. products that are processed through logistics systems and processes) according to three aspects that basically determine the relations among objects. This implies the consideration on a process basis, structure basis and/or attribute basis. For conducting the grouping procedure on an attribute basis an attribute catalog will support the process of identifying relevant characteristics of the considered logistics objects. Here, (Koch 2010) presents a first overview of characteristics related to object analyses in the field of logistics. For the aspects of process and structure modeling concepts like Process Chain, Flow Chart or Entity Relationship Model and Unified Modeling Language as well as a system, process and object structure can be used for illustrating and determining the relations (Koch, Tolujew, and Schenk 2012).

The fundamental steps of the procedure are:

- Problem definition
- Grouping aspects
- Concept selection & data preparation
- Concept execution & validation
- Input modeling

The problem definition is based on the problem task and objective of the related simulation study. These aspects have an impact on formulating the objective of the grouping procedure.

The second fundamental step is about defining and choosing the aspect (process, structure or attribute) to be considered for the following steps of the procedure.

After identifying and collecting available data an appropriate grouping concept has to be chosen. Here, methods of multivariate data analysis, in particular classification schemes and clustering methods are to be applied. For the three grouping aspects we propose different grouping concepts (see Fig. 3). Before executing these methods, the respective and wanted level of detail has to be defined. This is one of the most difficult steps of the procedure. A collection of influencing factors for determining the level of detail is presented to support the decision making process. If the results according to the level of detail will not be satisfying the procedure should be repeated.

After preparing the data for the chosen concepts, which will contribute to forming an object structure (see Fig. 4), the grouping method can be applied. In the following step the validation and control of the results according to credibility and sufficiency is conducted. If this is not satisfactory the procedure should be repeated. This even provides the opportunity to combine the results of multiple aspects that were considered.

As a last step there is the process of input modeling for the simulation model which refers to identifying the distributions and parameters of the identified groups out of the data of the considered logistics objects. As a consequence the groups or classes respectively can be then implemented in the simulation model.

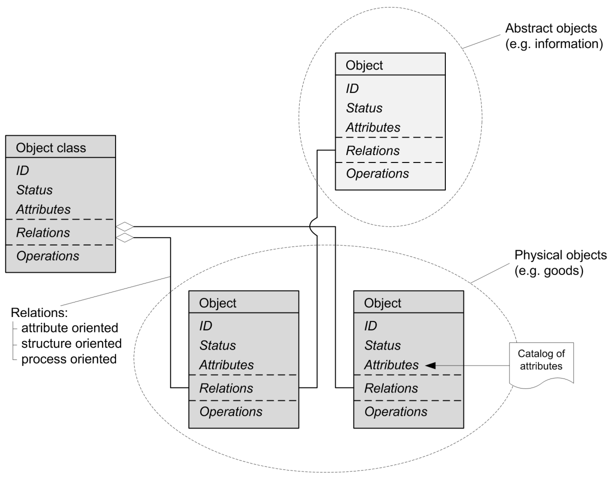

Figure 4: Object and class structure

The complete procedure should be seen as iterative until the wanted and needed results, i.e. groups of logistics objects in an appropriate level of detail, are obtained.

For the mesoscopic simulation approach the identified groups or classes respectively can be implemented as product types in the simulation model. This will reduce model complexity.

5. APPLICATION

The application example is from the field of biomass logistics. Biomass logistics is a relatively young research area which is confronted with challenging planning and problem tasks. This is for example due to the heterogeneity of biomass and the different parties involved in the biomass logistics chain. For further reading we recommend (Trojahn 2011). In order to cope with the identified challenges a grouping of biomass objects and the application of the mesoscopic modeling and simulation approach for logistics flow systems is applied.

Biomass is characterized by a high level of diversity and heterogeneity. In (Reggelin, Trojahn, and Koch 2011) an exemplary overview of characteristics that are relevant to biomass is shown. This provides support for conducting a grouping based on a selection of relevant attributes and characteristics.

In this example we consider a biomass logistics chain consisting of six sequential process steps: consolidation, gasification, power generation (fuel cell) and the related transportation steps as illustrated in Figure 5. The system structure is characterized by three sources of different biomass, i.e. wood, hay and straw, two consolidation points, one gasification facility, one power generation facility as well as two customers.

scenario, which refers to a more diverse and heterogeneous structure of biomass types, clustering methods will provide a high level of support.

At first the different objects or the diverse supply of the biomass types were grouped together according to their general same type or kind of biomass and the related process steps (based on the same source and process sequence). This results in the groups of *Wood*, *Hay* and *Straw*. They also form the input product types of the supply chain. The same procedure was also applied for the product types of *Biogenic Gas* and *Power*. In grouping objects of the same type or kind respectively together a transparent and credible result is attained and presented.

Second, the structure of the system and the processes of the considered biomass supply chain allow

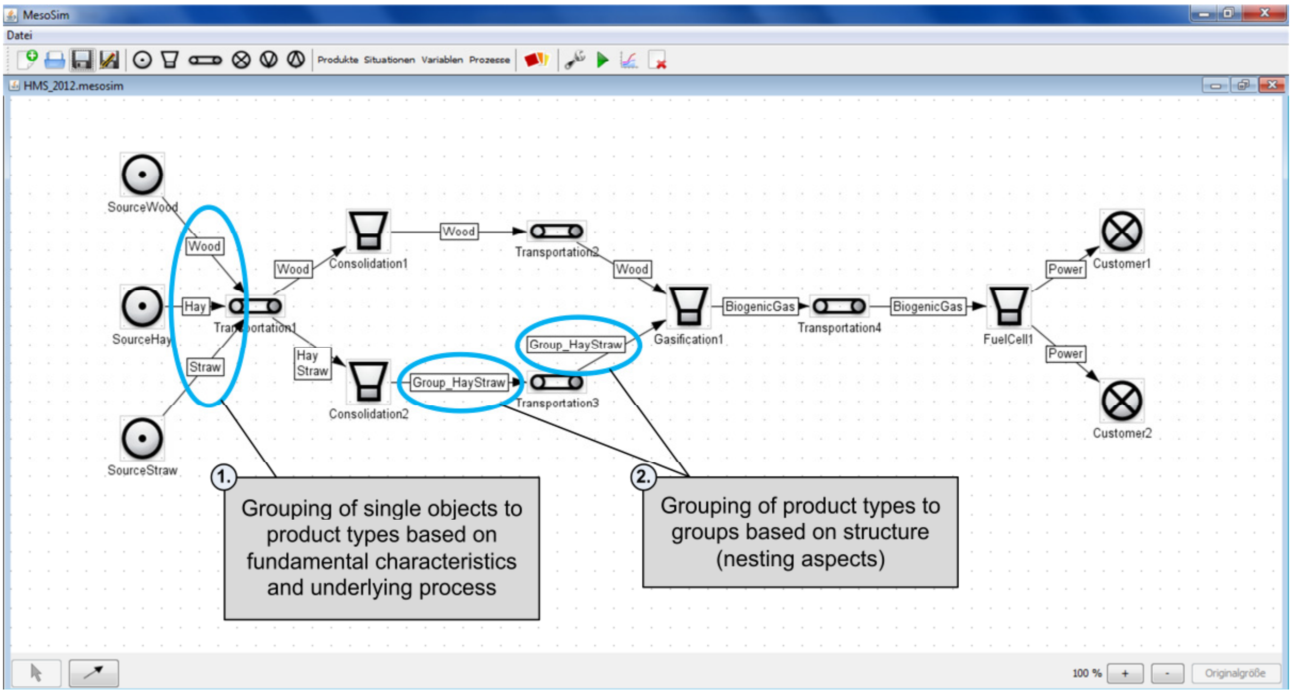

Figure 5: A mesoscopic model of a biomass logistics chain with MesoSim

The mesoscopic simulation model of the considered biomass logistics chain shown in Figure 5 was created with the simulation software MesoSim. This tool was developed by Reggelin and Tolujew (Reggelin 2011) in order to facilitate an easy and direct implementation and computation of mesoscopic simulation models.

For grouping the biomass logistics objects as a significant part of the conceptual modeling phase the proposed grouping procedure is applied. In the following the key aspects of the presented grouping procedure are explained. For demonstration purposes an example of only three different types of biomass was chosen.

For grouping the different biomass logistics objects the aspects of process and structure were chosen (see Fig. 5), due to the fact that information about attributes were limited and conducting a clustering process would not add significant benefit because of the simplicity of the example. However, in case of a more complex

a further grouping of the product types related to nesting aspects. In using the same transportation means the product types *Hay* and *Straw* can be grouped together in sections forming the product type *Group_HayStraw*. This means a reduction of product types for this part of the supply chain that need to be considered during the simulation run.

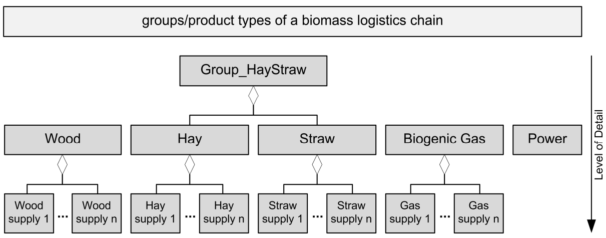

Figure 6: Grouping hierarchy of an exemplary biomass logistics chain

Figure 6 shows again the grouping hierarchy of the application example. This simple object and class structure allows the implementation of different aggregation levels into the simulation model which has a direct impact on defining the level of detail for the simulation model according to the object level. Hereby it is important to choose an amount of product types or a level of detail respectively that is appropriate in context of the problem definition. A higher level of detail will contribute to a higher simulation effort.

In grouping the logistics objects together with the help of the proposed procedure the amount of entities that need to be considered for computations in the simulation run can be reduced. This has a positive effect on the simulation effort without neglecting aspects of transparency and credibility that impact model accuracy and validity.

6. CONCLUSION

The paper describes the challenges that are incorporated with the increasing complexity of logistics systems and processes. This complexity is mainly caused by the increasing diversity and heterogeneity of the logistics objects, i.e. the goods processed through the logistics system. Therefore methods for simplification are needed. Zeigler et al. also suggest as one method of simplification for simulation modeling to group components of the model (Zeigler, Praehofer, and Kim 2007).

Here, the mesoscopic modeling and simulation approach requires support in grouping logistics objects for simplification purpose in an effective and representative way, because there is a lack in supporting the composition and decomposition of logical groups of logistics objects. However, this is of significant importance to approach the increasing complexity of logistics systems and processes efficiently.

Therefore, the paper presents such a procedure for grouping logistics objects in an efficient way supporting the determination of the right and appropriate level of detail for the simulation model and the considered problem task and logistics system. The benefits and effects of the presented grouping procedure as well as its relevance to the field of logistics were demonstrated by an application example in the field of biomass logistics.

The described procedure shall form a part of the conceptual modeling process according to the mesoscopic simulation approach supporting the modeler in the decision making process and contributing to a transparent, effective and qualitative conceptual modeling phase.

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