

# HOW TO SOLVE THE PUZZLE? SIMULATION SUPPORT FOR COMPONENT-BASED PROCESS DESIGN IN LOGISTICS

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## KEYWORDS

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## ABSTRACT

Logistics process design is one of the major challenges in logistics planning and known as being a complex and complicated problem, since it is subject to a large number of many and diverse influences. The approach of a component-based logistics process design should help to reduce complexity of the design problem and its solution, but especially to overcome the traditional thinking in terms of technical systems instead of focusing on what kind of functionality is really needed to be implemented only. The paper delivers the basic idea of this concept and discusses how simulation and visualization can support this method even though available tools and packages are based on representations of technical components only.

## THE PROBLEM

Logistics planning aims at the planning of logistics processes and systems in general and at both levels, the strategic one and the operational one. In the context of this paper the term logistics planning is strongly related to the strategic design of logistics processes and systems in preparation of investments for building or modifying logistics services. Within this context it must not be understood as operational planning of logistics processes for running them efficiently and effectively. Furthermore, special attention is paid to the design of materials flows instead of the flows of information, money or energy. With this, logistics shouldn't be reduced to materials flow design, management and control only, but this special aspect of logistics is used as an example to figure out main ideas, discuss basic problems and present approaches that seem to be applicable to logistics in its entirety.

The planning of materials flows can be defined as process of purposeful design and needs-related development of materials flow solutions in their entire complexity of materials flow system and the operational processes carried out by it (Neumann 2001). This

complicated structure of potential solutions causes a high degree of complexity not only to the problems to be solved but also to the planning processes for solving those problems. As shown in figure 1 the latter can be characterised as a phased process of loops, as a process developing variants and versions concerning both the materials flow process and the materials flow system. There are analysing steps and creative, evaluating steps for synthesis by turns with partially changing cognitive problems and views. As a rule searching for appropriate and suitable components for solving the problem comes first. After that the defined components must be made consistent with each other to realise the overall functionality as given in the problem specification.

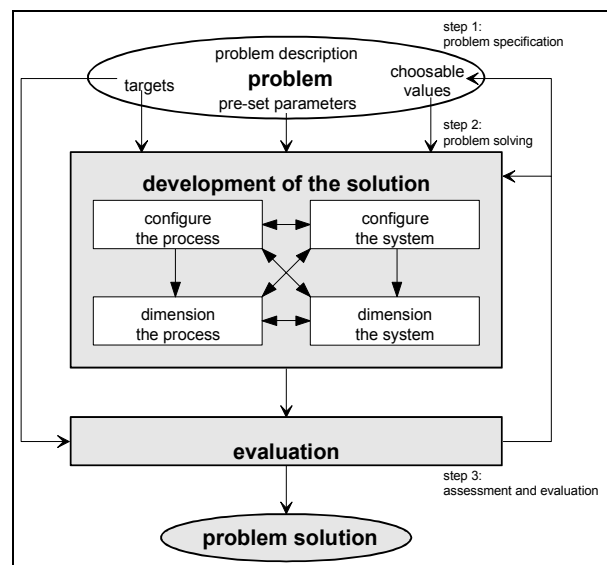


Figure 1: Complex problem solving for planning materials flows

Despite of this holistic approach to materials flow planning in principle, often and in particular planning processes system design dominates the planning process, although process design defines required system functionality any system design should be based upon. As a result materials flow systems use to offer much more functionality than it is needed to fulfil object transformation as required. This too much of system functionality afterwards needs to be reduced by

sophisticated control algorithms requiring a certain amount of control technology and equipment. In the end this leads to a high degree of system complexity and increased implementation costs. Furthermore, this kind of thinking in systems instead of processes reduces very much the chances for real creativity and visionary solutions. To overcome this, a component-based process design is proposed to reduce problem complexity and efforts in the planning process, but also to enable smart materials flow processes and cost-effective materials flow systems behind them.

### THE CONCEPT

The idea of re-usable components for creating new complex solutions in materials flow planning is already well known: CAD packages usually contain catalogues with standard parts such as screws or even more complex technical components. High level simulators defined by Law and Kelton (2000) as “a computer package that allows one to simulate a system contained in a specific class of systems with little or no programming” enable model building from pre-defined sets of components. “The particular system of interest (in the domain of the package) is typically selected for simulation by the use of menus and graphics, without need for programming.” For modelling logistics processes components representing materials flow or information flow operations are used to build up process chains along which objects, i.e. goods or information, are purposefully transformed from a given initial state into the desired final state. The traditional methodology for structuring materials flow processes as described and used in literature (Bolz and Hagemann 1958, Woodley 1964, VDI 3300, VDI 3596) is based upon four categories of processes:

- Operation
- Transportation
- Delay
- Storage

Each of these transformation processes can be characterized by the changes an object experiences with regard to its appearance in space and time. Quantitative characteristics resulting from this are type or sort, quantity, location and time. But this set of characteristics allows to represent selected aspects of object transformation only. For solving problems in logistics process design an extended set of characteristics is required also representing aspects like state of information or quality (Ziems and Neumann 1999). From this, a variety of building blocks for processes, i.e. operations, can be derived (see figure 2):

- Operations modifying an objects appearance according to space, time or structure
- Operations modifying an objects relationship with neighbour objects within the same flow
- Operations effecting several flows

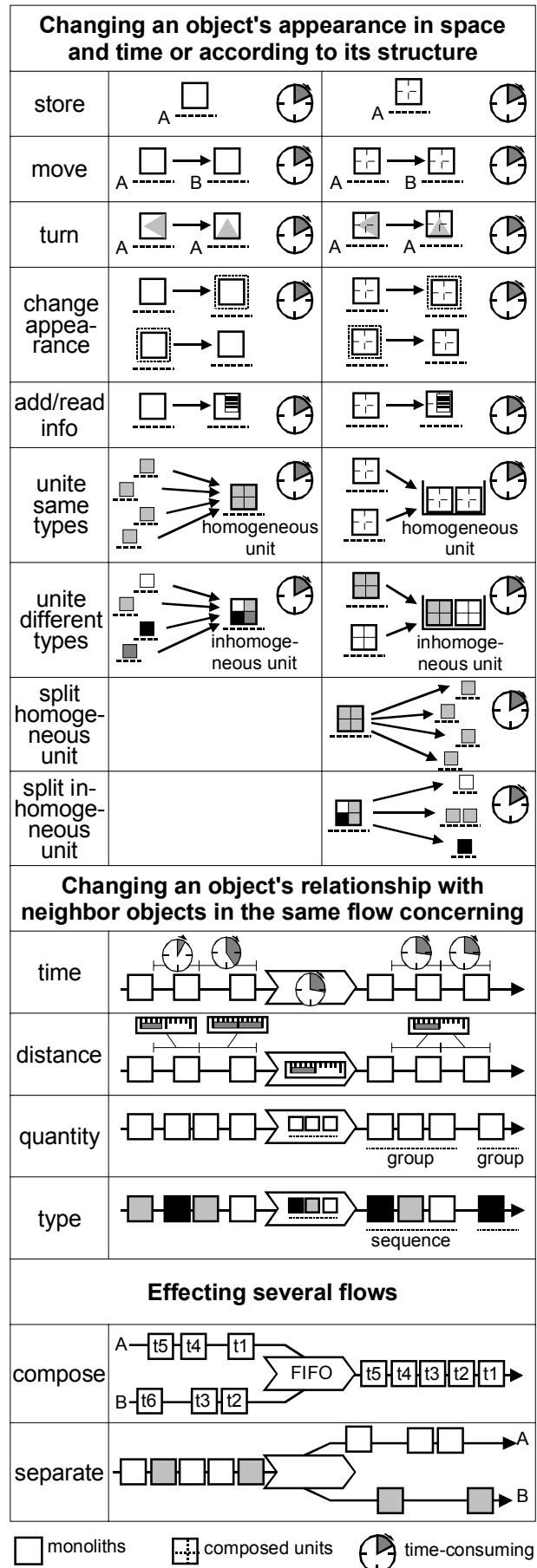


Figure 2: Elementary materials flow operations

These classes of operations are of fundamental nature; by use of them changes with individual goods and units as well as one or more materials flows can be described as transformations of objects and process chains in state models. For defining those elementary operations similarities (and differences) relevant to the design of logistics processes are used to structure the wide variety of phenomenon and to model them along the same lines.

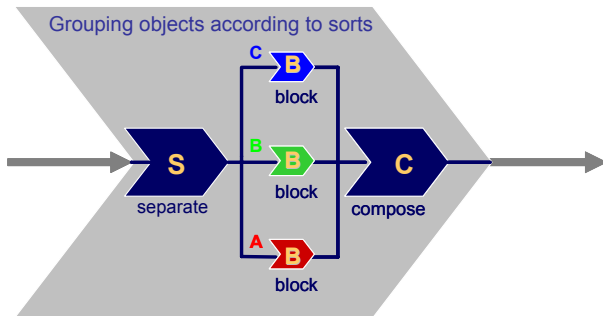
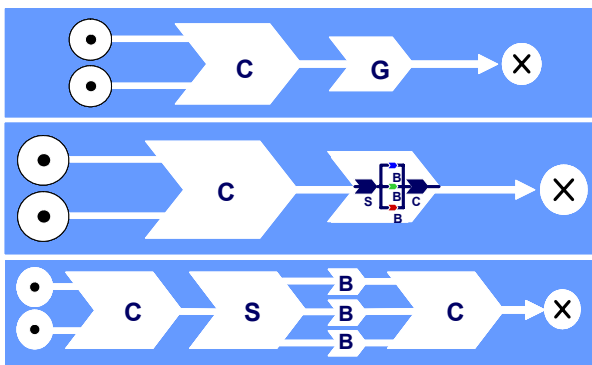


Figure 3: Model building using elementary operations

Elementary operations are the smallest pieces in the puzzle of a logistics process. The entire process can be configured sequencing them alongside the timeline. But, especially in the case of a complex process, it is also possible and might be useful to identify a kind of standard sub-processes of a certain level of complexity (e. g. grouping objects according to sorts) and to model them in detail using elementary operations (see figure 3), but to represent them in the overall process chain by just one component (see figure 4). As a result equivalent models of varying levels of detail of the same object transformation can be built to meet the particular needs of a certain step in the design or analysis process.



C: composing flows G: grouping objects S: separating flows B: blocking objects

Figure 4: Varying levels of detail in the process chain model

## THE METHOD

The approach for component-based process design in logistics is based upon the concept as described in the previous section. In a kind of top-down design a process of complex nature is configured and further specified (see figure 4). In the beginning, building blocks of more complex nature are used to create a first principle

version of the process eventually taking basic variations into consideration. In a second step components representing sub-processes are specified using elementary operations which finally replace the complex component of the first approach. As a result the process chain consisting of elementary operations only represents the minimum functionality required of a system to transform objects as needed. According to this early stage of a planning process the functional specification of the materials flow system is based upon technological and eventually geometric requirements of object transformation only, whereas performance requirements requesting for additional operations such as storing or buffering have not been included yet. To decide about additional functionality eventually to be provided by the system, the process chain as developed so far needs to be analysed using further methods like simulation or visualisation which requires further models of specific types. This way up to four different kinds of process models are built and used in the course of the materials flow design process. For a small illustrating example figure 5 shows these different models:

The *process chain model* (see figure 5b) describes in a standardized way an object's life cycle as sequence of operations in the course of which object characteristics are purposefully changed. A superposition of process chains of different objects forms an abstract model of a company's logistics processes which is used for documentation, visualization, analyzing or planning purposes.

The *principle animation model* (see figure 5c) transfers these static process elements into dynamic operations. These operations are of elementary nature, i.e. they aim at transforming the object with respect to one particular characteristic only. Due to the fact that all of these operations are time-consuming ones an object's time characteristic is changed as a side effect, too. The animation model finally consists of a sequence of small animations each of them representing one operation to transform an object from an initial state starting from the one given with the source into a final state required by the sink. Obviously, the state an object reaches through an operation is also its initial state for the following operation. This equivalence allows to check the sequencing of operations for logical correctness with regard to object transformation. The purpose of using a principle animation model for this is to give visualized support in evaluating the process chain. Consequently there is no possibility for defining or modifying any parameters and this model is to be seen as a qualitative representation of the process chain.

The *simulation model* (see figure 5d) forms the dynamic representation of the process chain modelling not just principal functionality but quantitative parameters as well. With this it allows to investigate flows on the

basis of types of objects and quantities and to analyze flows according to process performance measures like throughput, intensity, or average arrival time and distribution. As a result not only the process' way of working can be proven correct, but also the need for additional buffering or storing functionality and their capacities can be derived.

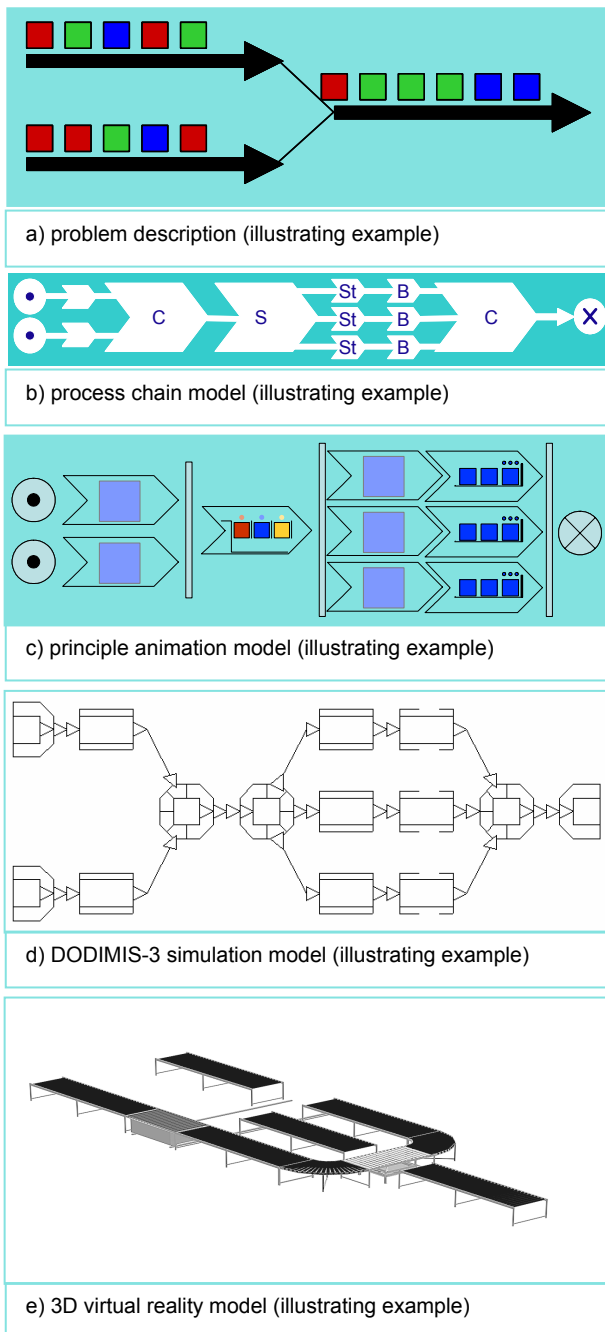


Figure 5: Evolution of the process description

The *3D virtual reality model* (see figure 5e) transfers the outcome of the simulation model, i.e. the trace file, into a dynamic three-dimensional representation of the process chain. The objective of this step is to ensure and validate that the materials flow links sources and sinks correctly also from the geometric point of view. Amongst others this might lead to the introduction of

additional moving, lifting or handling operations which have not been included yet. Furthermore this model also allows producing a nice looking, attractive visualization of the process which can be used for presentation purposes as well.

Although there are four different models to be developed in the course of the design process, the process chain model always forms the basic representation of the materials flow process as developed so far. Since the development and use of the other three models might lead to modifications of the process, the process chain model needs to be adapted and changed respectively after each modification step. In this way, also a correct documentation of the process (as the outcome of the design process) is produced, although focus of the design step, way of modelling and tools used for model building and experimentation do change.

### PROTOTYPE IMPLEMENTATION

For implementing the method of component-based logistics process design, tools from different categories need to be used and available. Currently, there is no automatic crossover from one model to another one. The person designing the process and developing the respective models is changing focus and way of model building as required, but clearly having in mind that there is precisely one process chain, animation and visualisation component for each of the elementary operations. Only for translating elementary operations into an executable simulation model there are alternatives in modelling (see figure 6). This is caused by the simulation package used, DOSIMIS-3, which is specialized to answer questions related to functionality and performance measures of logistics systems and processes and widely deployed in industry as well as logistics education and training in German-speaking countries. (Further information on DOSIMIS-3 in German or English languages can be found on the provider's website [www.sdz.de](http://www.sdz.de).)

operation	process chain	animation	DOSIMIS-3	visualization
moving	T transporting		SST FST UTM	
storing	St storing		LAG SST LFP	
uniting	C collecting		MON	
adding information	L labelling		AST MON	

Figure 6: Mapping list of elementary operations

In typical simulation projects DOSIMIS-3 is mainly used for analysing materials flow systems and their functionality instead of abstractly representing materials flow operations and processes without taking care of

any possible technological implementation. Because of this some of the elementary operations are principally represented within alternative simulation components which gives the modelling person some degree of freedom in designing the simulation model. To not reduce this kind of flexibility too much but at the same time enable automatic generation of the 3D model and its dynamical visualisation through interpreting the DOSIMIS-3 trace file (see also Bernhard and Jessen 2005), a mapping list describes which simulation component is applicable to represent which elementary operation.

Finally, it is necessary to point out that all models represent just the process, but not at all any underlying technical equipment that would make this process become possible. Even the 3D virtual reality model uses principle concepts to show the process in the real layout. If any object movement, for example, is realized in a continuous way by use of any type of conveyor or in a discontinuous way through a vehicle or truck, this is not defined yet. System design would be the next step in the developmental process, although a kind of interrelated design of materials flow process and materials flow system are highly recommended. The proposed method can provide extensive support to such kind of a procedure by guiding through a systematic and structured design process as well as by enabling and encouraging continuous documentation of the results achieved.

Prototype implementation of the method as described aimed at providing a mixture of online and offline services to potential users via the web (Neumann 2003). For this, a web-based learning, information and communication enabling wide-scale and multimedia education in logistics was used as the framework for providing access to the variety of tools and services, but also to knowledge needed for component-based logistics process design. LogEduGate ([www.logedugate.de](http://www.logedugate.de)) is a new kind of a logistics e-learning environment that is tailor-made for the specific needs of this complicated, complex, interdisciplinary field of knowledge. This logistics education gate interlinks a large number of knowledge units covering different aspects of logistics from engineering and business points of view at the same time and especially provides functionality to strengthen competencies in problem solving, decision making, organizing, designing etc. At the moment LogEduGate is developed to support university students in logistics in both modes, face-to-face and distance learning, but at a later stage it wants to meet training needs of logistics professionals, too.

For being integrated into the LogEduGate platform, no major changes to DOSIMIS-3 which runs on PC requiring Windows 95 or higher operating system where required. DOSIMIS-3 is available for download

to all registered users of a particular LogEduGate course. After installing the package on the own computer and without any further add-ons, the simulator automatically comes up with its demo version enabling to build and run small simulation models which do not consist of more than 15 elements. For dealing with more complex problems and building larger models an additional, personalized simulation ID is required that is centrally created and provided on demand. This ID is valid for a certain period of time according to the time scale of the simulation project. During this period the complete functionality of the package is available, whereas after the expiry date has passed by the software automatically returns to demo mode again. In this way, the user needs to be online for downloading the package, requesting for and receiving the simulation ID and submitting the model and trace files for automatic generation of the visualization model only. All time-consuming activities, like model building, validation, running experiments, watching animation or monitoring and analyzing results take place in the offline mode (figure 7). With this, the simulator works and can be used exactly in the same way as it would happen in an industry setting. There is no loss of speed and performance; online costs are reduced to a minimum once the package has been downloaded.

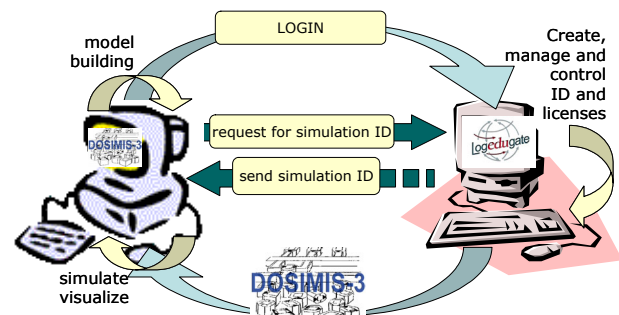


Figure 7: Embedding DOSIMIS-3 into LogEduGate

Further tools used for dynamical representation of the designed process are an animation toolkit and a visualization model generator (see Bernhard and Jessen 2005). Both tools were specially developed to meet the needs of this particular concept and method.

## CONCLUSIONS

As experience from integrating the method of component-based logistics process design into logistics courses at university level have shown this new way of thinking in processes instead of systems needs to be trained intensively, whereas the changes between models and tools did not cause major problems. The challenge consists in overcoming the traditional way of thinking in systems, system components or existing technical solutions at early stages of the design process. Thinking in terms of operations and processes only helps to define what kind of functionality is really needed and allows to play with basic principles instead of combining existing technical components only. With

this truly innovative technical solutions become possible. At the same time this is also the chance this new concept and method offers for reducing functional complexity of today's materials flow and logistics systems and with this the amount of investments into technical solutions as well. Of course the process chain model is not the end of the design process in logistics, but forms an excellent starting point for technical specification of functionality and designing an appropriate materials flow or logistics system afterwards. Here, the models developed in the steps of process design provide serious input. Especially simulation and visualization models and techniques are of tremendous relevance for this kind of a continuous developmental process. They are applicable even at early stages with poor knowledge on how the final solution might eventually look like. And they can be modified and adapted to the progress in a creative problem solving process representing the process first, but then being more and more changed into a representation of the specific system.

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**GABY NEUMANN** received a Diploma in Materials Handling Technology from the Otto-von-Guericke-University of Technology in Magdeburg and a PhD in Logistics from the University of Magdeburg. Since 2003 she has been Junior Professor in Logistics Knowledge Management there. Since 1991 she has been also working as part-time consultant in logistics simulation. Her current activities and research interests are mainly linked to fields like problem solving and knowledge management in logistics, logistics simulation and planning, and technology-based logistics learning, didactics of teaching logistics as well as logistics competence profiling and assessment. She is author/co-author of two books, one educational multimedia module on warehousing and a series of e-learning modules in logistics as well as of 30 journal publications and 66 papers and presentations at national and international conferences. She co-ordinates the European logistics educators network for providing new technologies for logistics education inside the European Logistics Association (ELA-LogNet) and has been or is being involved in a couple of respective projects.