Supply Chain Demonstrator Based on Federated Models and HLA Application

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Summary

Supply chains are complex systems that are difficult to be understood from the viewpoint of the single enterprise. This often leads to local optimizations that form an optimum for one company or a short section of a supply network. Such local optimizations endanger the competitiveness of the whole supply chain, as today not the single enterprise, but the production network (sometimes named Virtual Enterprise) has to be the competitive entity. Simulation could help to understand the full network and to study and improve the network as a whole. However, the development of such networks is complicated, as it models several distributed entities and might also be forced to introduce the human-in-the-loop or to include IT control systems in the simulation run. The authors propose a supply chain demonstrator, that can run distributed, combine several (local) simulation models into one federation and also include non-simulation federates like human user interfaces or additional IT systems.

1 Introduction

Supply chains are characterized by complexity, randomness, dynamics and missing transparency. These properties induce a supply chain behaviour and system effects which are hardly understandable. Therefore, it is not amazing that the management of supply chains is a very difficult task. But, these tasks are more and more put into the strategic focus, as supply chains are considered to be an important part of the value chain and the global competition is changing from competition among single enterprises to competition among complete supply chains.

Therefore, all supply chain partners need to fully understand the mechanisms of the supply chain and how their own decisions affect the other partners along the complete chain. This paper presents an approach which uses different federated models to demonstrate the effects in a supply chain. Hence the Supply Chain Demonstrator (SCD) based on federated models intents to visualize the situation of a supply chain without any methodological management and IT support and the resulting potentials. Furthermore, it should demonstrate how specific management mechanisms affect the supply chain, and how each partner can profit from these positive effects. Finally, the Demonstrator is needed to analyse and illustrate the effects of IT tools that support supply chain execution and management.

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A supply chain consists of various partners. By the use of methods and techniques of distributed modelling and simulation for the Supply Chain Demonstrator, these participants can be easily embedded into one common scenario.

2 Requirements on a Supply Chain Demonstrator

The various partners of a logistical supply network usually follow their own economical aims, independently, and have their own view on the supply chain. However, a supply network is a system that is characterized by complexity, randomness, dynamics and limited transparency. The complexity has its roots in the high number of partners, the number of links and relations among them as well as the response time (delay). The supply chain as a whole system seems to be not transparent form the point of view of an individual enterprise, because of the inability of this company to collect all relevant information in the required quantity and quality (accuracy). Furthermore, sometimes enterprises are suspicious that delivered information can be used to increase the economic pressure on them (e.g. information relating to free capacity can be used during prize negotiations). If there is no trust in the supply chain, partners might intend to be less transparent. Finally, randomness and dynamics are increased by the huge number of orders and other exchanged information as well as by influences from the enterprise's environment (competitors, government etc.). All these properties are the reasons for specific problems of the supply chains like the well-known bullwhip effect [Sou00] [Ste00] (figure 1). This is a supply chain phenomenon revealed by a distortion of the demand orders – like fluctuation in demand amplification and/or rogue seasonality – as it is transmitted upstream, from retailers to suppliers. The fluctuation in demand amplification causes a growth of the costs and a decrease of the service through higher stock levels, a greater fluctuation of quantities and a raise of the complexity of scheduling.

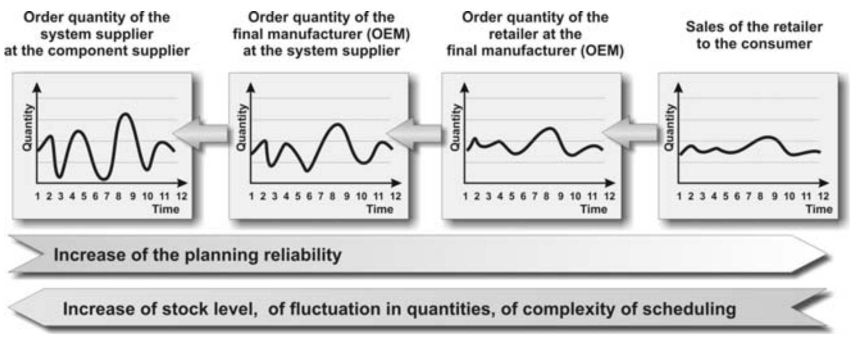

Figure 1: The bullwhip effect in supply chains and its consequences

However, during the currently conducted European project SPIDER-WIN (IST 507 601 <http://www.spider-win.de/>) the experience was made that it is a difficult task to illustrate and measure all these effects. The project aims to develop new methods and tools to achieve an efficient, simple and context-aware co-operation of small and medium sized enterprises (SME) in supply chains taking into account their low-level IT support as well as the typical availability and quality of resource data in very small enterprises [Rab06].

Specific methodologies for the data analysis and propagation as well as for event predication along the complete supply chain were researched and designed. However, during the field study, the development phase and method evaluation the consortium has realized that an easily usable instrument is missing to visualize and evaluate the dynamics and relations among the individual local decisions and behaviour of each enterprise (cause) and their effects to the other partners along the complete chain as well as to the supply chain as whole.

Therefore the SCD needs to demonstrate different levels of impact on a supply chain, especially, for the multi-tier and multi-participant characteristics of a supply chain as well as its distributed environment.

As a first level the Supply Chain Demonstrator intents to visualize the situation of a supply chain without any methodological management and IT support, where the information exchange between the partners occurs only bilateral ("uncontrolled" supply chain). Furthermore, it demonstrates the challenges of this situation as well as the resulting potentials. The Supply Chain Demonstrator ensures that all supply chain partners fully understand the mechanisms of the supply chains and how their own decisions affect the other partners along the complete supply chain. Items that can be demonstrated are the missing transparency and the resulting communication and coordination lack, the complexity and the possible exaggerated reaction in stocking orders by some supply chain partners, and dynamic effects based on unsatisfying attention to inventories.

The second purpose of the Supply Chain Demonstrator is to explain management mechanisms and methods for an enhancement of the supply chain coordination that support a common supply chain management and execution ("coordinated" supply chain). Hereby, changes can be shown that occur in the daily workflow of each supply chain partner, and it can be demonstrated how these changes affect the supply chain. Furthermore, each partner can see its benefits from the new mechanisms and methods.

The third area of interest of the SCD is the ability to integrate IT tools for supply chain management and execution into the demonstration scenario ("supported" supply chain). The participants can learn how the base functionalities of these tools work and how they influence the supply chain. Especially the second and third area have been realized to be a very important feature for the demonstration of a new Supply Chain Management Model with the corresponding methods and platform in the SPIDER-WIN project [Rab05] [Rab06].

Summarizing, the Supply Chain Demonstrator aims

1. to visualize the situation of a supply chain without any supply chain management, where the information exchange appears only bilateral (uncontrolled supply chain), and the potentials and challenges resulting on this situation,
2. to demonstrate how specific management mechanisms or new methods favourably affect the supply chain (coordinated supply chain), and how each partner can participate on these positive effects, as well as
3. to check and demonstrate the mode of action of IT tools that support the supply chain execution and management (supported supply chain).

The Supply Chain Demonstrator is addressed especially to small and medium sized enterprises in order to convince them that a well-balanced supply chain support by specific management and execution mechanisms has significant benefits. For example, the

Demonstrator can be embedded into training or coaching seminars or other events like exhibitions, fairs etc.. A further application domain might be the education area, e.g. during the study of MBAs or industrial engineers at universities and colleges. Finally, the demonstrator approach can also be used by software providers for marketing or coaching issues to visualize the benefits of their SC tools.
Based on the experiences from the SPIDER-WIN and other projects the Fraunhofer IPK therefore proposes to develop a Supply Chain Demonstrator (SCD) with following properties:

1. an environment for simulation of the dynamical behaviour of a supply chain
2. with an interactive multi-actor environment (embedding different persons in various roles within a supply chain)
3. reconfigurable supply chain and environment to simulate flexible scopes (various scenarios in different situations)
4. easy embedding of supply chain supporting instruments like new methods or tools
5. monitoring of the dynamic effects in the supply chain
6. self-generated and self-explaining evaluation (including detailed explanation)
7. easily usable software platform (low hardware and software requirements, easy handling)

Different authors provide also ideas and approaches for simulation based supply chain training. For example, the Delft University of Technology provides an object-oriented approach for a supply chain library [Ver05]. The concept is a very interesting approach especially to create a new supply chain scenario based on standard elements. The implementation was performed in Java using the simulation tool ARENA. For these environment a so-called 'Distributor Game' as an interactive gaming mode was developed, which places students in the role of the logistics manager of a distribution centre [Hou05]. The approaches are extendable. However, it seems that the embedding of business strategies for example in form of new supply chain management methods are still missing.
Adams et al. follow another approach with the combination of a simulation environment with a spreadsheet in order to enhance the hands-on approach of teaching supply chain management [Ada05]. Here, the game concept is very interesting, but the extendibility is missing.

3 Architecture of a Supply Chain Demonstrator

3.1 General Elements and Logical Structure

Models in a general sense are required for different activities supporting enterprise targets. Simple graphical representations derive transparency of the enterprise and the supply chain structure form the essential basis for the diagnostic and optimisation of enterprise processes (e.g. business process models) [Mer99]. Complex models which represent the network structure enable static and dynamic evaluation of the as-is and the to-be scenarios (e.g. in form of a simulation model). At the end, models can support the implementation of new workflows. In the past such models have been mainly oriented to the internal process of an organisation, sometimes representing several subsidiaries of the organisation. In the last years, applications across independent organisations like supply chains have been considered, also [Rab03a]. In parallel to all modelling and analysis steps, the model itself forms a knowledge base. The Supply Chain Demonstrator should be such a knowledge base for education, consulting and training.

As pointed out above, the Demonstrator aims to support the explanation of the dynamic effects in unsupported as well as supported supply chains. In this context, the Supply Chain Demonstrator is a kind of an interactive "game" in form of a simulation environment for the demonstration of the dynamical behaviour and effects within supply chains. Thereby persons can each "play" different roles (e.g. enterprises on different tiers) within an exemplary supply chain. During the run of the simulation the players interact actively within the supply chain environment and fulfil different tasks depending on the specific scenario. For example, the participants can order products from a supplier based on demand forecasts from the customers. In a first scenario they have to fulfil this task with the limited information of a bilateral information exchange. In a second scenario they are allowed to communicate along the supply chain in order to coordinate the ordering and furthermore they get support by specific management methods.

The comparison of the results of both scenarios can help to demonstrate the win-win-situation for the different supply chain members by the implementation of supply chain management strategies as well as the benefits for the whole supply chain. For this purpose the SCD has to provide the calculation of the effort and return as target values for each supply chain partner as well as for the complete supply chain. This has to be done first for the "uncontrolled" supply chain and afterwards in the situation of the supply chain under the use of methods (and tools) for supply chain planning and execution.

In order to fulfil the aims, the Supply Chain Demonstrator should consist at least of 3 logical components or areas (figure 2):

1. several workplaces where each participant of the demonstration can "play" a different role within the supply chain (independent decisions but in interaction with the supply chain),
2. a component for the customization of the supply chain and the demonstration scenario, for monitoring the supply chain as well as for the evaluation and visualization of the results,
3. an interface for the integration of IT-oriented supply chain support tools (optional)

The Supply Chain Demonstrator always has to represent at least three tiers of a supply chain in order to demonstrate overall effects within the supply chain. Therefore, at least three federated models are required, which each represent one tier. However, a supply chain scenario in the Demonstrator can be enhanced by additional real or emulated participants. The virtual model(s) can be implemented as (distributed) self-running simulation model(s). The other models have to be designed with an end-user interface that the human participants of the scenario use to interact with each other in the supply chain during the runtime of the scenario. In addition to the logical components, the workflow for the Supply Chain Demonstrator needs to be defined.

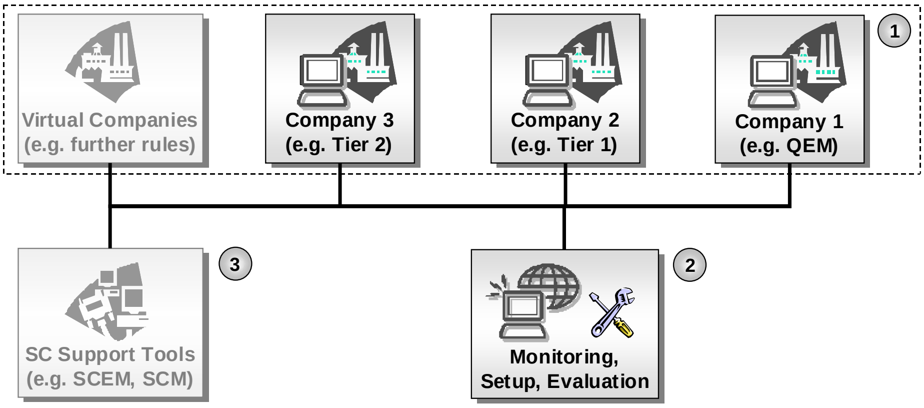

Figure 2: Necessary logical components of a Supply Chain Demonstrator

The complete case study should have a maximum length of no more than 1½ hours and include three scenarios which each show a specific coordination variant of the supply chain (uncontrolled, coordinated, IT supported supply chain). Depending on the specific target of the demonstration, further scenarios can be integrated. The configuration of the content and the workflow for each scenario can be controlled by a central customization environment. With the support of a monitoring component the scenario results can be examined and prepared for the evaluation. Actions can be easily visualized and explained, and their consequences within the supply chain demonstrated to all participants.

3.2 Possible Technological Realisation with Federated Modelling and Simulation

The Supply Chain Demonstrator could be designed as a single simulation solution using off-the-shelf simulation programs. However, especially the multi-tier and multi-participant characteristics of a supply chain as well as its distributed environment suggest the use of technologies which can manage, analyse and simulate distributed information. Such technologies are the distributed, federated modelling and simulation. They enable to embed all relevant real participants (e.g. manager, executor on the various tiers) of a supply chain consistently into one singular education or training environment.

"Distributed simulation" means that two or more (logical or physical) separated simulation models, which might be run in different off-the-shelf simulation packages, interact with each other during the simulation execution in a single simulation scenario.

This implies a high degree and effort in interoperability during the complete working process, starting from the collaborative collection of relevant information with enterprise models, over the design and configuration of distributed simulation scenarios and their related experiments, up to the enactment of the result in distributed processes. It requires a high interoperability and synchronisation support for the information exchange and simulation execution in a federated environment. Moreover, on top of the interoperability mechanism a high performance is necessary because of an extremely high amount of message and data exchange.

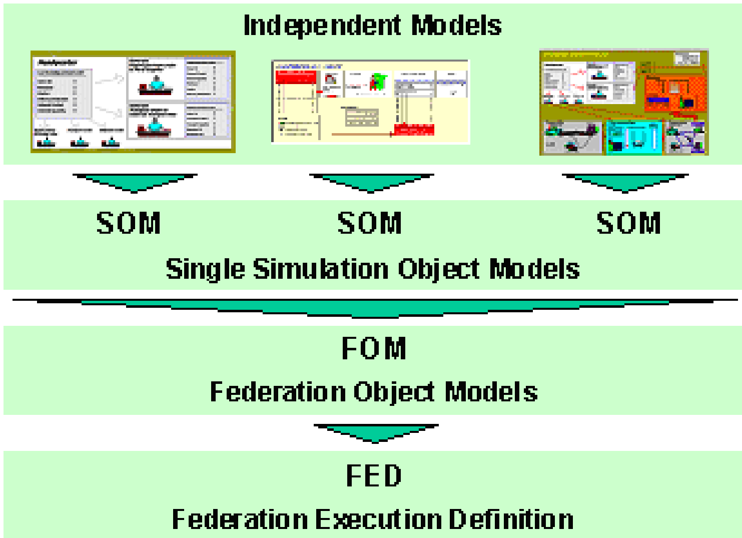

Figure 3: Concept to achieve interoperable models in HLA [IEE00]

Several basic methods, techniques and tools are available for the design and implementation of distributed simulation. For example, there is the "High Level Architecture" (HLA) approach of the US Department of Defence (DoD), which is an IEEE and OMG standard. The HLA defines federates as members of federations. A federate is one actor – e.g. one company – in a cross-organisational scenario. A federation could be the composition of all companies of a cross organisational scenario. The HLA does not say how to exchange the data among the federates and it does not define the data of the federation. However, the HLA defines the interface that needs to be provided to the simulation by a "Run Time Infrastructure" (RTI) as well as the logic for the RTI and the format for documenting user data. Since 2002 the development of the RTI is commercialized.
An adoption of this standard to industrial processes was developed within the MISSION project (IMS-FP5 29 656 (http://www.ims-mission.de/) and further improved by Fraunhofer IPK [Rab03b]. This approach covers a configuration of the runtime infrastructure with object and attributes names and the configuration of the system composition by 'configuration files' for each system. The files are generated from a modelling approach (figure 4).
The models can be located within different enterprises and executed within different off-the-shelf simulation packages. Therefore, two levels of interoperability are required. Firstly the off-the-shelf simulation packages have to provide mechanisms to be interoperable, and secondly the models executed within the tools have to be synchronised and also interoperable. The connection of different models requires a synchronisation of models which is independent from the technical realisation of the connection. This synchronisation enables the models to run in one whole scenario. This requires adding interface elements within the models and the definition of objects which have to be exchanged. Moreover, the overall monitoring needs additional information from the simulation models to measure a global view of the operating features. It collects and calculates

statistical data generated by the simulation models. After the overall scenario model is created, the files (exchange data model) for the HLA (SOM, FOM, FED) have to be generated. At the same time the configuration files for each model within an off-the-shelf simulation package are generated.

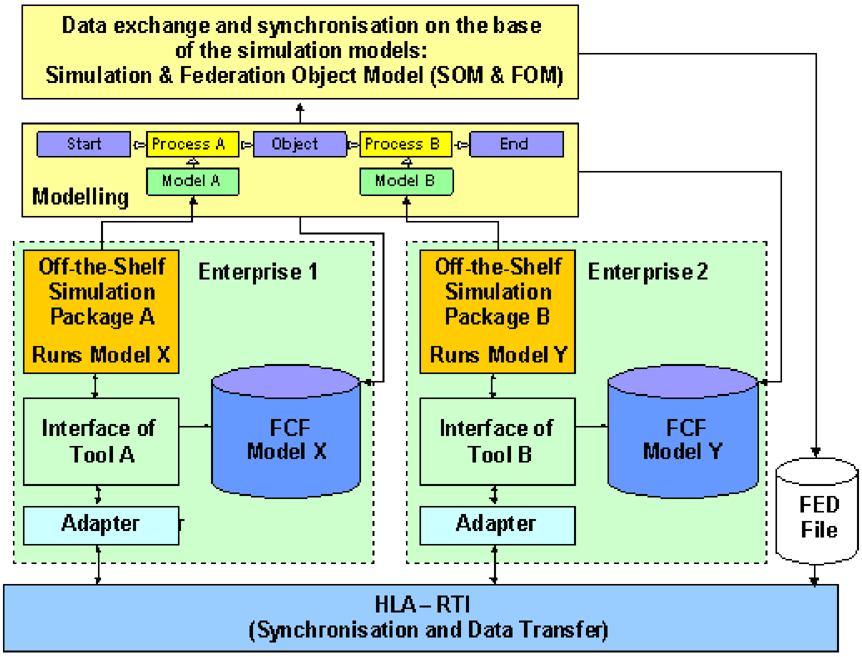

Figure 4: Holistic concept from the modelling approaches to the execution across different models located within different enterprises [Rab04]

Optional tools could be proposed to simplify the creation of scenarios, the reuse of models, the expandability of the monitoring and the influence in the scenario of the user at runtime, such as:

- configurable visualisation and monitoring components
- A Simulation Manager to ease the set-up of the scenarios
- Scenario management to administrate the scenarios and the related result figures

These components have to be developed for an efficient creation and use of the Supply Chain Demonstrator.

3.3 Description of a Potential Industrial Case

In order to make the use of the approach concrete, an industrial case is under preparation. Three models (part production, assembly, test) can be run and controlled separately. The simulation of the supply chain includes the different interfaces that are required for the combination of these models. Each model is provided by an independent service provider (separate companies). The objectives of the scenario are:

- Identify inconsistencies among the interfaces of the three models
- Evaluate the whole supply chain instead of only checking separate models
- Realize an environment to integrate supplier simulation models
- Evaluate different supply chain scenarios
- Detect the influence of changes and interferences within the supply chain

The required tasks cover the connection of simulation models and user interfaces, the monitoring of the whole scenario and the definition of different scenarios.

4 Conclusion

A well defined Supply Chain Demonstrator can help to explain the specific effects within a supply chain and how they can be handled by the use of supply chain management strategies and methods as well as IT support. For this reason, the Supply Chain Demonstrator is basically addressed to SMEs which act in supply chains as well as for the education in universities.

Because of the distributed structure of a supply chain, it is obvious to use technologies of distributed modelling and simulation for implementing and running the Supply Chain Demonstrator.

In addition, the concept of the Supply Chain Demonstrator can also be enhanced in the future to check the applicability of new supply chain support mechanisms, methods or supply chain support IT tools, like the methods and the platform which are currently under development in the SPIDER-WIN project.

References

[Ada05] Adams, J.; Flatto, J.; Gardner, L. (2005) *Combining hands-on, spreadsheet and discrete event simulation to teach supply chain management.* In: Kuhl, M. E.; Steiger, N. M.; Armstrong, F. B.; Joines, J. A. (Editors) *Proceedings of the 2005 Winter Simulation Conference*, pp. 2329-2337

[Hou05] van Houten, S-P; Verbraeck, A.; Boyson, S.; Corsi, T. (2005) *Training for today`s supply chains: An introduction to the distributor game.* In: Kuhl, M. E.; Steiger, N. M.; Armstrong, F. B.; Joines, J. A. (Editors) *Proceedings of the 2005 Winter Simulation Conference*, pp. 2338-2345

[IEE00] IEEE (2000) IEEE 1516-2000 *Standard for Modelling and Simulation (M&S) High Level Architecture (HLA)* New York: Institute of Electrical and Electronics Engineers, Inc.

[Mer99] Mertins, K.; Jochem, R. (1999) *Quality-Oriented Design of Business Processes*. Boston, Dordrecht, London: Kluwer Academic Publishers.

[Rab03a] Rabe, M. (2003) *Simulation of Supply Chains*. Int. J. of Automotive Technology and Management 3 (2003) 3/4, pp. 368-382

[Rab03b] Rabe, M.; Jäkel, F.-W.; Dassisti, M.; Erriquez, M. (2003) *Generic Adaptor for Distributed Simulatio*n. In: Schulze, Th.; Schlechtweg, S.; Hinz, V. (Eds.): Proceedings Simulation und Visualisierung, Magdeburg 2003, pp. 205-216

[Rab04] Rabe, M.; Jaekel, F.-W. (2004) *Distributed Simulation and Supply Chains*. In: Dimitrov, D.; Preez, N. D.; Wijck, W. van (Hrsg.) *International Conference on Competitive Manufacturing 4-6 Febraury 2004 (COMA'04), Proceedings*. Stellenbosch, South Africa, University of Stellenbosch, pp. 437-442

[Rab05] Rabe, M., Mussini, B.; Gocev, P.; Weinaug, H. (2005) *Requirements and potentials of new supply chain business processes in SME networks*. In: Cunningham, P.; Cunningham, M. (Editor) *Innovation and the Knowledge Economy – Issues, Applications, Case Studies*. Paper eChallenges 2005, Ljubljana. pp. 1645-1652

[Rab06] Rabe, M., Gocev,, P., Weinaug, H. (2006) *ASP supported execution of multi-tier manufacturing supply chains*, Paper submitted for ILS'06 conference in Lyon, May 2006

[Sou00] de Souza, R.; Zice, S.; Chaoyang, L. (2000) *Supply chain dynamics and optimization*. Integrated Manufacturing Systems, 11 (2000) 5, pp. 348-364

[Ste00] Sterman, John D. (2000) *Business Dynamics: System Thinking and Modelling for a Complex World*. Boston: McGraw-Hill Companies Inc.

[Ver05] Verbraeck, A.; van Houten, S-P. (2005) *From simulation to gaming: An object-oriented supply chain training library*. In: Kuhl, M. E.; Steiger, N. M.; Armstrong, F. B.; Joines, J. A. (Editors) *Proceedings of the 2005 Winter Simulation Conference*, pp.2346-2354