CONFIGURABLE LOGISTICS PLATFORM TO HANDLE SUPPLY TURBULENCES – A CASE STUDY IN A FOCAL SUPPLY NETWORK

József VÁNCZA, Péter EGRI

Computer and Automation Research Institute, Hungarian Academy of Sciences
Kende u. 13-17, Budapest, 1111
HUNGARY
E-mail: {vancza,egri}@sztaki.hu

Hans-Hermann WIENDAHL

Institute of Industrial Manufacturing and Management (IFF), University Stuttgart
Nobelstrasse 12, 70569 Stuttgart
GERMANY
E-mail: hhw@iff.uni-stuttgart.de

Abstract:

The paper exposes the coordination problem of focal supply networks that typically serve markets of customized mass products. For assessing and analyzing critical issues, a qualitative approach based on so-called turbulence patterns is proposed. We give the design principles and present in short the operation of a logistics platform that is aimed to provide means for handling objective turbulence factors and to eliminate the causes of subjective turbulences.

Keywords:

Supply network management, turbulence, production planning and control, coordination

1. INTRODUCTION

The ultimate goal of manufacturing is the "general transformation of all resources to meet human needs" [1]. In this transformation process, the question all manufacturers have to answer time and again can be put simply as how to produce what and when is needed, not more, nor less, not earlier, nor later, just in the required quality. Giving appropriate answers is hard because market demand is uncertain and distributed, while production processes are complex involving geographically dispersed producers of raw materials, components and end-products. Further on, customers have a tendency to wait for meeting their needs for less and less time: typically, acceptable order lead times are much shorter than actual production lead times. Decisions are to be made under the pressure of time, relying also on uncertain and incomplete information.

The markets are served not by individual companies but by *production networks* that consist of autonomous companies. The parties typically take part in several network relations at the same time. Hence, the common goal of exploiting market opportunities can hardly be made explicit.

Taking high service level as their main priority, manufacturers can hedge against demand uncertainty only by maintaining time, capacity and/or material buffers. This however, incurs extra equipment, labor, inventory and organizational costs, as well as – especially under dynamic market conditions – the risk of producing obsolete components and/or products. Partners within a production network are legally independent entities, with their own resources, performance objectives and internal decision mechanisms. They have to find their own *trade-offs* between service level and cost that are acceptable both for their markets and other partners. Such a solution can only emerge from the interaction of local and asynchronous decisions. Hence:

- There is an inevitable need to design organisations to perceive actual market demand and respond by sustaining coordination and cooperation among network members.
- Essential *planning problems* must be solved, since manufacturers would like to exercise control over some future events based on information what they either know for certain (about products, production technologies, resource capabilities, fixed orders, sales histories) or only anticipate (market demand, resource and material availability).
- *Execution* of production schedules should be supported by real-time control that is able to adapt plans to changing conditions in a way, with minimal ramification of changes.

In the sequel we shortly present an academy-industry project that handles the above issues in a holistic way and attempts to make advance on all the three fields. Next, we focus of the network level coordination problem and by taking the approach of so-called *turbulence patterns*, we classify and characterize basic problematic situations at the logistic level of the network. We give typical examples of problems due to combinations of fluctuations, short-periodic changes of boundary conditions, heterogeneous variations, as well as of unexpected deviations. Finally, for solving the network coordination problem, we suggest a generic, configurable *logistics platform* that links the planning and control functions of the manufacturer and its suppliers.

2. TOWARDS REAL-TIME COOPERATIVE ENTERPRISES

2.1. The VITAL project

The most “vital” features of enterprises is their ability to plan their activities even in the face of uncertain future, to control the execution of their plans by responding to changes and unexpected disturbances, as well as to coordinate their activities with those of other partners. The goal of the VITAL project is to research and develop new methods for the real-time management of complex technical and economic systems that work in changing, uncertain environments [8,10]. The application is a supply network producing customized mass products provides the actual problems to be solved. Market demand is met by a *focal manufacturer* who is supplied by other network members with components, including sub-assemblies and packaging material. Some of the suppliers (e.g. packaging material providers) serve several manufactures acting on different markets. The network produces consumer goods in a *customized mass production* scheme: it offers large diversity of products that are manufactured by relatively cheap mass production technology. The main technical areas of the project are production planning and scheduling, real-time production control handling changes and disturbances and management of a distributed, cooperative supply network.

The reasons for the above sharing of work are, on one hand, that the high-level resource-management and scheduling of enterprises can give the basis for the reliable, near to optimal management of supply chains and production networks. On the other hand, plans and schedules should be executed even in face of changes and disturbances in the shop floors or production lines.

2.2. The VITAL supply net coordination problem

The focal manufacturer produces a large number of components at the same time. Since order lead times are typically shorter than production lead times, production is based mostly on *forecasts*. Part of the forecast information must be shared with the suppliers in order to decrease the well-known bullwhip effect [6], hence long-term relations and trust are prerequisites for managing the network. As a consequence, it can be considered stable: there are tight relations between the nodes (e.g., key supplier and customer partnering, dedicated warehouses, etc.), and there are few and rare newcomers. *Inventories* are inevitable to provide service at the required level and to enable local resource optimization, but the partners in the network cannot store too much products or components because the *inventory holding costs* are high, some components are *perishable*, and some products or components may shortly became *obsolete*.

All in all, the network-level problem is stated as follows: the common goal of each network partner is to *provide high service* level towards the customers of end-products, while, at the same time, *keeping expected production and logistics costs at a minimum*. These requirements are conflicting:

- Only inventory guarantees high service level (components, packaging materials, end-products).
- In mass production technology, low costs can be achieved only with larger lot sizes, which involve, again, higher product and component inventories as well as increased work-in-process.
- Markets of customized mass products are volatile. If the demand unexpectedly ceases for a product, then accumulated inventories become obsolete and cause significant losses.
- Further challenge is that all network partners are autonomous, and those in the supplier's role take typically part in other network relations as well.

The autonomy of each partner complicates the supply net coordination: each partner aims for an individual planning and control approach which fit his specific market, production and supplier requirements. But all partners have to be synchronized with the same planning and control logic to guarantee the achieved logistical performance of the supply net. Though there exists a number of enterprise resource planning (ERP) and supply chain management (SCM) systems that provide technology for information storing, retrieval and sharing within and between the nodes of a production network, these systems are mainly transactional: they do not really support coordinated decision making [5,7,9].

3. TURBULENCE HANDLING

To be able to strike a balance between the individual local requirements and the global network standards, it must be possible to quickly and efficiently compare the individual requirements of each partner. Important factors of supply chain management design are those which potentially cause turbulence (i.e. dynamics) and consequently lead to schedule deviations. Experience shows that it is difficult to describe these requirements in a comparable way. During the project we use a method to capture the qualitative requirements based on expert interviews, see also [12,13,14].

Turbulence provides an appropriate metaphor for dynamics in production. So the basic idea is to transfer the conclusion of physics according turbulence to production. This leads to the following definition: Turbulence exists if actual values deviate significantly from mean-based planning values [11]. The tolerance denotes the permissible deviation between planned and actual values. This forms the theoretical fundament to analyze the logistical requirements [12,13,14].

3.1. Turbulence cases in the network

To handle turbulence, one must understand the following distinction:

- *Objective turbulence* has its roots in uncertainties of market demand, manufacturing and supply. For instance, the customer of end products changes the design of packaging, but does not give the exact amount to be delivered still with the old design.
- *Subjective turbulence* has its roots in fear of exaggerated uncertainty. E.g., supply planners at the manufacturer, being afraid of eventual material shortage, order more components than needed. This may result in extra resource requirements at the suppliers (extra shifts, re-planning of production), as well as involve the risk of obsolete inventory. Hence, a wish to "remain on the safe side" may cause further turbulence and involve higher costs.

Using the categorization of logistics requirements on turbulent markets (see also [14]), we can give the following characterization of our network at hand:

- *Variations*: the network produces a mix of thousands of products. The ratio of the customized items is considerable in terms of their share in the product mix, but smaller in terms of volume (i.e., it follows the so-called Pareto principle). The life cycle of the products varies also on a wide spectrum, with customized products having definitely shorter cycles.
- *Fluctuations*: Various combinations of seasonal and heterogeneous demand are the main characteristics of the market. In any case, this "complexity" of the market is accepted by the network.

- *Frequencies*: Changes of customized products – typically of the design of packaging – can happen in certain product categories in an abrupt way.
- *Deviations*: Another aspect of market “complexity” is the unexpected an unforeseeable deviation of demand from the levels anticipated earlier. This deviation in forecasts ramifies and initiates further deviations: the master plan at the focal manufacturer has to be changed, what is followed by re-generating production plans and production schedules. From the angle of suppliers, all these changes imply unreliable medium-term and short-term demand forecasts.

Note that the turbulences may appear in a combination. For a typical example, see **Figure 1** below that shows two series of seasonal forecasts generated for the same product at different times.

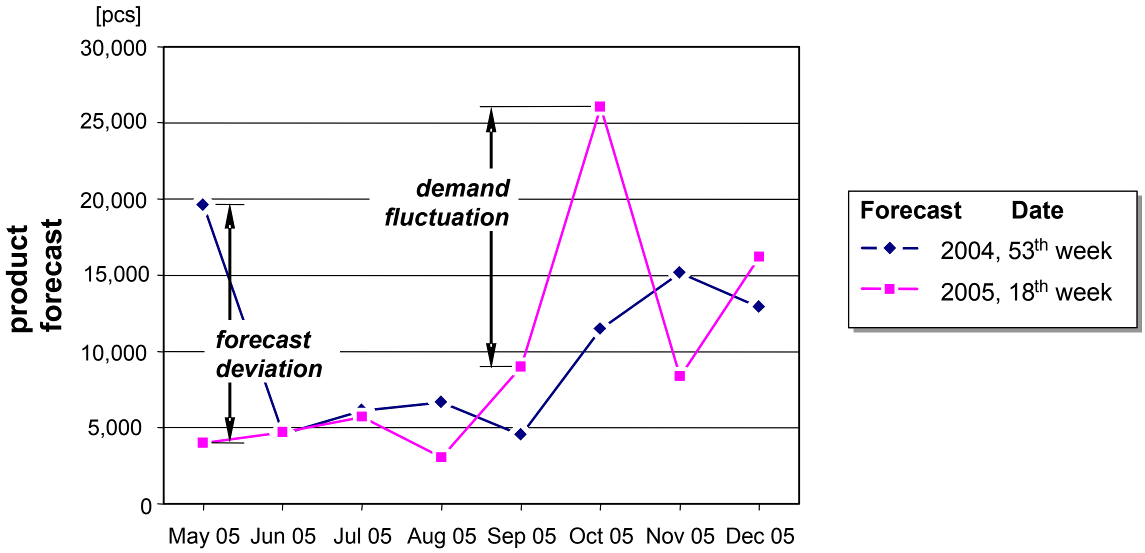

Figure 1 Example for seasonal demand fluctuations and forecast deviations.

3.2. Turbulence analysis

Production planning and control has to provide appropriate methods for handling turbulences (for other methods, see [14]). Hence, the first issue is to distinguish which factors belong to the scope of planning and control, respectively. Secondly, at various companies the sources of turbulences appear in different combinations and with various influences. The combination and influence of main turbulence factors can be captured in a *turbulence pattern*. As an example, a pattern based on the subjective evaluation of experts at one of the network partners is presented on **Figure 2**.

The interpretation of the actual pattern helps to clarify the main sources and interactions of turbulences. In this example, the experts judge the turbulence germs in planning higher than in control. From the planning point of view three germs have a big impact on turbulence:

- *Demand fluctuations*: There is a serious seasonal fluctuation: there are peak seasons when much more products are needed (see also Figure 1). In fact, in certain periods demand may even exceed the capacities. Even if the focal manufacturer levels its load by appropriate advance planning, the supply of packaging materials must follow the actual demand in the peak seasons.
- *Product life cycles*: The manufacturer's own products have long, stable life cycles. However, the design of so-called private labels may change more frequently. In case of promotion campaigns extra packaging materials are also needed on a short notice.
- *Batch creation*: Even if the products are customized, batch production is a must at each partner to exploit economies of scale and to reduce setup costs. In the production of packaging materials, batch cycles can be created both for colours and cutting tools. In these batches, several kinds of orders – even of different customers – can be combined. This complicates the required planning algorithm for lot sizing.

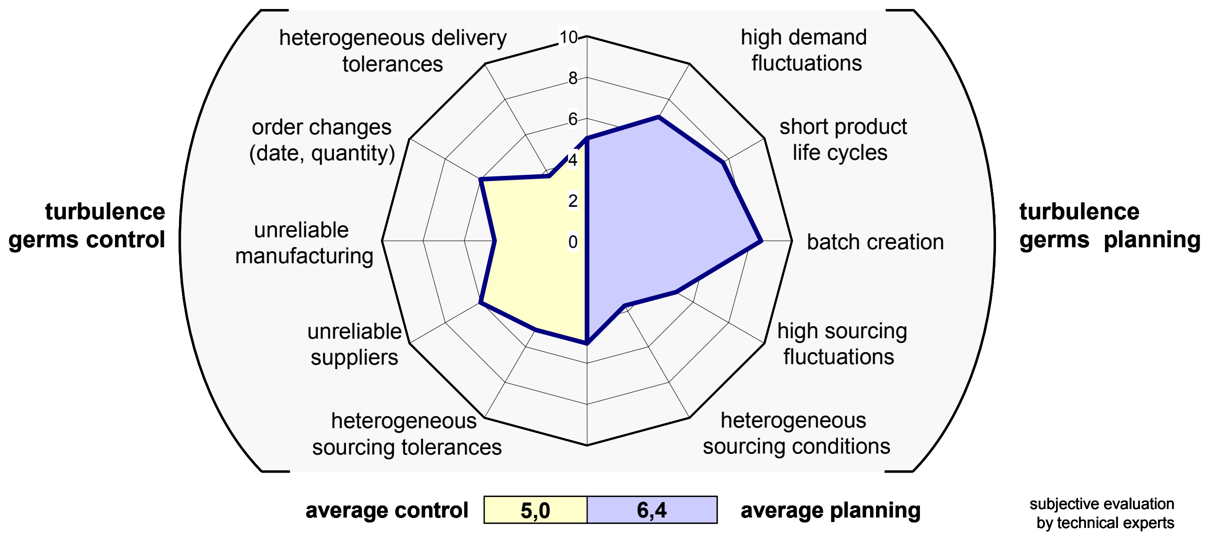

Figure 2 Turbulence pattern of a supplier.

The following germs trigger turbulence after order release (control point of view):

- *Order changes*: Sometimes a partner changes his order quantity or the desired delivery date. Note that this is not always due to changes of the actual market demand: since planners are measured also by resource utilization they fill in the capacities and move forward some demand in time. This creates preventable effort for re-planning.
- *Unreliable suppliers*: Under some extreme conditions (like weather, flood) the basic material supply of the packaging material providers may get stuck. Note that inventory control has only limited means for handling situations of such kind of material shortage: design (using standard materials) and organization of the supply network (lateral cooperation between suppliers) provide a much wider array of opportunities.

All in all, the turbulence germs with the biggest impact form the requirements to the solution. Note that our work is confined to production planning and control, and does not cover the aspects of product, product mix or supply network design.

4. THE LOGISTICS PLATFORM

Our ultimate goal was to design a coordination method and to develop an appropriate system that supports the partners in the supply network in

- providing extremely high (98-99%) service level towards the customers, while
- keeping their overall, network-wide costs at a minimum (see section 2.2).

We call this system that links and coordinates the planning functions of the focal manufacturer and its suppliers a *logistics platform* [2]. This platform extends the capacity of the *overall network* to cope with turbulences in different market channels. Since the market demand is transmitted to the network through the focal manufacturer, the platform is managed mainly centrally, at the focal manufacturer. However, at the same time, it has to cover the perspectives of the suppliers, too.

Taking the angle of turbulences, the logistics platform has to provide means for handling objective turbulence factors and to eliminate, as far as possible, the root causes of subjective turbulence.

4.1. Design principles and requirements

Planning functions (demand and master planning, production planning and scheduling, supply planning, etc.) and their interactions and information resources can be described on different horizons and aggregation levels [5]. We focused on planning functions that determine the future activities of the various network partners. The main recommendations are recapitulated below.

4.1.1. Vertical planning and scheduling integration

Production planning and scheduling (PPS) match future production loads and capacities by determining the flow of materials and the use of finite resources, over different horizons and levels of detail. So planning and scheduling problems have their own, specific timescale, resource and activity model granularity as well as optimization criteria:

- Planning guarantees on the long term the observance of high level capacity constraints. This set the goals as well as the resource and temporal constraints for scheduling.
- Scheduling unfolds a production plan into executable schedules; i.e. to detailed resource assignments and operation sequences. No scheduling strategy can patch an inadequate plan, but an inappropriate scheduling waste resources and inhibit the fulfilment of a good plan.

Hence, planning and scheduling problems are solved in a superior-inferior hierarchy. At each node of the network, local planning and scheduling have to be treated in an integrated manner, by taking care of the strong and mutual dependency of the two levels.

4.1.2. Horizontal information sharing between the partners

Production plans and schedules of the focal manufacturer determine the behavior of the whole supply network. They give the heartbeat of the complete system: the production plan of the manufacturer is, from another angle, the *demand forecast* for the suppliers. If the plans are realistic – i.e. they can be refined into executable schedules – then one of the main uncertainty factors can be removed from the forecasts towards the suppliers. Further on, the manufacturer needs the materials and components just in times when they are assembled into the final products. Reliable production schedules even with a short horizon can *pull the supply*, thus relieving the manufacturer from the burden of keeping and controlling inventories.

The second aspect of information sharing is inventory: we suggest establishing such a one-point inventory system between companies whose management can be based on coordination, truthful information sharing and optimization. This is the point where local and autonomous planning and scheduling decisions can be coupled.

Thirdly, for coordinating the supply channels between the manufacturer and the suppliers, truthful sharing of cost (production, setup, inventory) and demand (forecast, market uncertainty) related information is required. All this is possible only either in a cooperative setting, or when cooperation (like sharing undistorted information) is in the interest of the partners.

4.1.3. Regular actualization of plans and schedules

Controlling the future by planning is possible only if one has accurate status information about past and present affairs. Hence, the initial state of planning must be matched to the reality time and again. This means planning on a *rolling horizon*. However, the length and the resolution of the horizon, as well as the frequency of updates should comply with the detail of aggregation. Accordingly, at each node of the network we suggested the coordination of monthly (capacity planning), weekly (master and production planning) and daily (production scheduling) planning cycles, with shorter and shorter horizons, but finer and finer resolution.

Handling certain turbulence germs – like order changes – by *ad hoc* re-planning can easily result in system nervousness. To avoid this, conservative plan/schedule modification methods are needed that guarantee the execution of operations at least on the short term as planned. Note that this is one of the main goals (real-time production control handling changes and disturbance, see Sect. 2.1) of the VITAL project.

Finally, there is also a potential for the application of embedded and ambient information and communication technology so as to enhance the visibility of logistic and production processes by implementing active, intelligent identifiers and integrating information and material flows.

4.1.4. Open and configurable software design

Local planning at the nodes of the network is done in many different ways and partners along various supply channels have specific relationships. Consequently, there is no “one-size-fits-all” solution for coordinating the network: rather, we need a portfolio of coordination mechanisms. So, the logistics platform should be open and configurable. Further on, this system design is essential if we want to generalize the platform and make it applicable in other supply networks [3,9].

4.2. The solution approach

Following the above principles, we designed the logistics platform for coordinating the partner's decisions along the supply channels. The platform consists of two levels:

1. On the *planning platform*, the supplier builds up and maintains the one-point inventory. So as to be able to do that, the supplier receives information from the manufacturer concerning demand forecasts and the chances of product run-outs. The component demand is generated from the master production plan of the manufacturer that determines its planned output for a longer horizon. On this platform, decisions are made in a weekly cycle.
2. On *the scheduling platform*, the supplier meets the exact, short-term component demand of the manufacturer. This demand is generated from the actual production schedule of the manufacturer in form of call-offs and is satisfied by direct, just-in-time delivery from the inventory. On this platform, decisions are made on a daily basis, with a horizon of 1 to 2 weeks. With this short look-ahead, demand uncertainty is hedged by appropriate inventory policies.

This framework detaches the two main conflicting objectives and makes both of them manageable: cost-efficient production is the main concern at the medium-term planning platform, while service level is tackled at the short-term scheduling platform.

4.3. Methods for channel coordination

For supporting inventory planning that links the planning and scheduling functions of autonomous partners along a supply channel, we developed a portfolio of novel *lot sizing methods* that take into account all logistics costs as well as uncertainty of demand [4,10]. Hence, decisions that coordinate a channel can be made on the basis of information coming partly from the manufacturer (demand and its uncertainty) and partly from the supplier (setup, production and inventory holding costs). The various methods have been developed for different situations: typically, when plans should be made for the whole horizon, or when it is enough to plan for the close future, or alternatively, when a product is approaching the end of its life-cycle, but the partners do not know when product run-out will happen exactly.

All in all, the methods handle two, fundamentally different situations:

1. run-out of a product can occur with a certain possibility, but no further details are known, and
2. the fact of the run-out and its date are known, but the amount of demand is still uncertain.

For the case of the unknown run-out date (case 1), we introduced two similar heuristic policies as well as an extended version of the so-called Wagner-Whitin (WW) method. These methods depart from long-term demand forecast and the probability of run-out, as well as from the cost factors of production, setup and inventory holding and determine the optimal lot size. The heuristic methods disregard the less trusted remote forecasts and minimize average costs (per item, per time). The modified WW plans the whole horizon by minimizing the total cost. It can also approximate the number of setups on a longer horizon in advance. Detailed descriptions of these multi-period methods, together with test results can be found in [4] and [10].

Finally, a recently developed model – a version of the so-called *newsvendor* method – handles the case when the product will run-out (e.g., the customer changed the design of packaging), but the exact time and/or amount of demand is not known in advance.

5. CONCLUSIONS

In this paper we discussed conflicting performance requirements of customized mass production and suggested a logistics platform as a basis for sharing information and coordinating decisions between a focal manufacturer and its suppliers. In this work, we started to apply the recently introduced method of turbulence patterns. According to our experience, this approach helps to identify and distinguish various sources of turbulence and to make explicit their relationships.

Beyond analysis, turbulence patterns can be used for synthesis, too. Within the scope of production planning and control, we are going to extend the portfolio of the actual planning methods to handle turbulence germs closest to their source (in order to stop their ramification throughout the network) and to eliminate the causes of subjective turbulences as far as possible. Subjective turbulences are rooted in a fear of uncertainty what can be resolved by information sharing, coordination and cooperation. Hence, we anticipate this research direction will lead to the development of novel cooperative planning methods as well as to the design of cooperative supply networks.

ACKNOWLEDGEMENTS

The paper is based on a joint research effort which was funded on the Hungarian side by the VITAL NKFP grant No. 2/010/2004 and OTKA grant No. T046509, and on the German side by the German Research Foundation DFG (WI 2670/1). The authors would like to thank their supporters.

REFERENCES

[1] Manu*futur*e, 2004: A Vision for 2020, Assuring the Future of Manufacturing in Europe, Report of the High-Level Group, EC, November: 1-20.
[2] Aldin, N., Stahre, F., 2003: Electronic commerce, marketing channels and logistics platforms – a wholesaler perspective. European Journal of Operational Research, 144:270-279.
[3] Desai, N., Mallya, A. U. , Chopra, A. K., Singh, M. P., 2005: Interaction protocols as design abstractions for business processes. IEEE Transactions on Software Engineering (TSE) December 2005.
[4] Egri P., Váncza J., 2006: A logistics framework for coordinating supply chains on unstable markets. Proceedings of 3rd Conference on Digital Enterprise Technology (DET'06), in print.
[5] Fleischmann, B., Meyr, H., 2003: Planning hierarchy, modeling and advanced planning systems. In de Kok, A. G., Graves, S. C. (eds): Supply Chain Management: Design, Coordination and Cooperation. Handbooks in Op. Res. and Man. Sci., 11:457-523.
[6] Forrester, J. W., 1958: Industrial dynamics: A major breakthrough for decision makers, Harvard Business Review, 7/8:37-68
[7] Holsapple, C.W., Sena, M.P., 2005: ERP plans and decision-support benefits. Decision Support Systems, 38:575-590.
[8] Monostori, L.; Váncza, J.; Kis, T.; Kádár, B.; Viharos, Zs.J., 2006: Real-time, cooperative enterprises: requirements and solution approaches, Preprints of the 12th IFAC Symposium on Information Control Problems in Manufacturing, INCOM-2006, May 17-19, 2006, Saint Etienne, France, I:591-596.
[9] Stadtler, H., 2005: Supply chain management and advanced planning -- basics, overview and challenges. European Journal of Operational Research, 163:575-588.
[10] Váncza J., Egri P., 2006: Coordinating supply networks in customized mass production – A contract-based approach. Annals of the CIRP, 55/1, in print.
[11] Wiendahl, H.-H., Roth, N., Westkämper, E., 2002: Logistical positioning in a turbulent environment, Annals of the CIRP, 51/1:383-386.
[12] Wiendahl, H.-H., 2006: Auftragsmanagement im turbulent Umfeld, Teil 1 –- Anforderungen. wt Werkstattstechnik online 96/4:183-189.
[13] Wiendahl, H.-H., 2006: Auftragsmanagement im turbulent Umfeld, Teil 2 – Lösungsansätze. wt Werkstattstechnik online 96/5:325-330.
[14] Wiendahl, H.-H., 2006: Designing order management for supply networks with the turbulence pattern – A qualitative approach, Proc. of MITIP 2006 (this volume).