Event Management for Uncertainties in Collaborative Production Scheduling and Transportation Planning: A Review

Bernd Scholz-Reiter, Yi Tan, Nagham El-Berishy and José B. S. Santos Jr.

Abstract This paper presents a review of using event management to deal with the uncertainties in production scheduling and transportation planning processes at the operational level. Moreover, it argues the importance of considering uncertainties and the application of event management in a collaborative production and transportation planning process at the operational level.

Introduction

Supply chain management (SCM) requires a precise coordination of flows of raw materials, finished goods, information and financial resources. With the fast development of information technology and the global market, collaboration between different functional units in a supply chain (SC) has become one of the key success factors for companies involved in SCs.

B. Scholz-Reiter · Y. Tan (✉) · N. El-Berishy
Planning and Control of Production Systems (PSPS), University of Bremen, Bremen, Germany
e-mail: tan@biba.uni-bremen.de

B. Scholz-Reiter
e-mail: bsr@biba.uni-bremen.de

N. El-Berishy
e-mail: elb@biba.uni-bremen.de

J. B. S. Santos Jr.
Learning Lab in Logistics and Transport, Civil Engineering Architecture and Urban Design School at the University of Campinas,
Campinas, São Paulo, Brazil
e-mail: jbened@fec.unicamp.br

H.-J. Kreowski et al. (eds.), *Dynamics in Logistics*, Lecture Notes in Logistics,
DOI: 10.1007/978-3-642-35966-8_16,

However, to achieve this collaboration companies are facing new challenges. On the one hand, this collaboration requires companies to respond to changes of customer needs quickly. On the other hand, due to shorter product life cycles as well as an increased number of product variants and the increasing dependence of supply chain functional units, the entire supply chain has become more dynamic than ever before (Stank et al. 2011).

In this dynamic environment, uncertainties of the SC activities, represented by the gap between the planned and the actual system status, occur frequently and therefore must be considered in the SC planning processes. This gap shows a new challenge for the management of complex and dynamics SC processes. The entire organizations and the SC partners are more susceptible to unexpected events or situations not covered in the SC planning stages (Christopher et al. 2011). Processes, such as the coordination between transportation planning stages for dealing with long lead times, the ability to quick response to relevant changes in demand or supply, the synchronization between production scheduling and transportation planning, the outsourcing of products and services, the reduction of inventory levels through just in time (JIT), the collaboration with suppliers, etc., emphasize this important management issue.

This paper focus on two SC processes: production and transportation. The aim of this paper is to review the state of the art of using event management to deal with the uncertainties in these two processes. Indeed, this work argues the importance of considering the uncertainties in a collaborative production and transportation planning at the operational level. The paper is organized as followed: section Supply Chain Event Management and Supply Chain Risk Management presents an overview of Supply Chain Event Management (SCEM) and Supply Chain Risk Management (SCRM). Section Event Management for Uncertainties in Production Scheduling shows a review of the literature regarding event management and rescheduling techniques in the production environment to deal with uncertainties. Section Event Management for Uncertainties in Transportation Planning summarizes the important issues and methods in transportation planning linked with uncertainties. Section Event Management in Collaborative Production and Transportation Planning discusses the collaborative production and transportation planning considering uncertainties. The paper closes with a conclusion and description of future research.

Supply Chain Event Management and Supply Chain Risk Management

In order to properly react to these unexpected deviations, a high degree of transparency and visibility in the supply chain processes are necessary. The concept of Supply Chain Event Management covers the visibility and transparency requirements focusing on two main goals. First, identifying possible unexpected deviations and reducing their impacts, to assure the customer satisfaction and the operation efficiency; second, creating the supply chain visibility (Otto 2003).

In order to fulfill these goals SCEM identifies deviations in SC processes between the planned and the actual status. Afterwards, it starts actions to minimize the gaps for the whole SC, according to some predefined rules. The main role of applying the SCEM is to eliminate or to reduce the delay time between the moments when an unexpected event occurs and when the decision maker addresses and solves the problem caused by this event.

Supply Chain Risk Management consists of the identification and evaluation of risks as well as the consequent losses. In addition, this approach mitigates these losses and ensures the supply chain outcomes through the implementation of coordinated strategies among the SC partners (Manuj and Mentzer 2008).

In general, the SCRM considers four steps: risks identification, analysis, evaluation and monitoring. In the first step all risks for the supply chain are determined. At the analysis phase, a deep understanding of the risk's identification must be done. The purpose of the evaluation step is to define the most appropriate management response for each risk or combination of risks. Finally, a monitoring and control procedure has to be implemented to manage the risks (Ritchie and Brindley 2007a, b; Khan and Burnes 2007). This step encompasses the major part of the SCEM process. This fact shows the strongest link between SCEM and SCRM.

Basically, potential sources of risks can be identified in accordance with: environmental characteristics, industrial characteristics, network configuration, network partners, organization's strategy, problem specific variables, and decision making. The risks associated with SC management are classified as: risks related to the operation (variability in demand, disruption in the supply process, etc.,); risks related to natural disasters (hurricanes, tsunamis, earthquakes, etc..); and, risks caused by direct action of human (war, financial bubbles, etc.,) (Tang 2006). This paper focuses on the operation risks. Table 1 presents the most relevant uncertainties at the operational level focusing on these two SC processes.

The risk-taking decisions influence the selection of risk management strategy for operations in a supply network. For example, the postponement[1] strategy in a manufacturing environment could increase the product development costs and the investments to the higher flexibility needed for the assembly lines.

However, planning process needs to react for these exceptions to give a solution for the system's current status. In an effort to extend the SCEM research, this paper proposes an approach considering the uncertainties in the integrated production and transportation planning systems at the operational level simultaneously.

[1] The decision to delay some manufacturing activities like assembly, labeling or packaging.

Event Management for Uncertainties in Production Scheduling

In order to deal with unexpected events occurring during a production process (see the rescheduling triggers for production planning listed in Table 1), rescheduling has been investigated in the last decade. Rescheduling focuses on the operational level of the production planning.

When unexpected events take place and invalidate the planned production schedule, rescheduling is applied. It updates the current production schedule or generates a completely new schedule according to the current state of the production system. Rescheduling as a reaction to events enhances the reliability, robustness and performance of a production planning and control system. Thus maintains the desired manufacturing objectives, such as on-time completion of customer orders, factory throughput or production cycle time.

Compared with the conventional scheduling, rescheduling has to fulfill two new requirements:

- *Efficiency*: In contrast to the offline scheduling approaches that run a long time (from several hours to several days) to generate a near optimal schedule prior to a production process starts, rescheduling is applied during a production process. Hence, the production has to stop and wait for the new schedule. Any delay of the production process caused by the computational time of the rescheduling approach lengthens flow time of the production process and affects the delivery dates of the customer orders. Therefore, rescheduling is time critical and typically has to be a real-time application.
- *Flexibility*: The initial state of a rescheduling problem is normally more complex than that of a scheduling problem. Rescheduling has to take more aspects of the production systems state into account, e.g., release times of machines.

Furthermore, a necessary information system (sensors, communication networks, hardware and software) for monitoring unexpected events as well as the manufacturing system state (jobs and machines) is a precondition to apply the rescheduling.

Vieira et al. (2003) summarizes works in production rescheduling and presents a framework (see Table 2) for understanding and classifying rescheduling research. The framework includes rescheduling environments, strategies, policies, and methods. "The rescheduling environment identifies the set of jobs that need to be scheduled. A rescheduling strategy describes whether or not production schedules are generated. A rescheduling policy specifies when rescheduling should occur. Rescheduling methods describe how schedules are generated and updated".

For event management in production we focus on the predictive-reactive rescheduling strategy and its event-driven rescheduling policy, in which an initial schedule is generated before a production process start and this schedule will be updated if an event occurs during the production process. For this strategy and policy Vieira et al. (2003) introduces three categories of rescheduling methods to

Table 1 Uncertainties related with production and transportation planning processes at the operational level

Type of uncertainty	Triggers related with production planning	Triggers related with transportation planning
Supply	Raw material delay	Single sourcing under JIT strategies
	Quality problem	Lack of carrier flexibility (time, fleet options and capacity)
Production	Machines breakdown	Lack of integration with production
	Job cancelled (dropped/destroyed)	Production system delay
	Urgent order (rush or "hot") arrival	Production order cancelled
	Over/under estimated processing time	
	Job goes on hold	
	Number of jobs exceed threshold	
	Schedule not followed by personal	
	Unexpected maintenance	
	Rework or quality problems	
Transportation	Transportation system delay	Shipment time variability
		Loss or damage of materials in the shipping operation
		Fleet breakdown or lack of drivers
		Unexpected repairs for preferred transport routes
Information	Poor stock auditing and poor quality control system	Poor stock auditing and poor quality control system
	Database inaccuracy	Database inaccuracy
Demand	Urgent (rush or "hot") job arrival	Customer order cancelled (dropped/destroyed)
People management	Personnel delay	Lack of drivers

Table 2 Rescheduling framework of Vieira et al. (2003)

Rescheduling environments				
Static (finite set of jobs)		Dynamic (infinite set of jobs)		
Deterministic (all information given)	Stochastic (some information uncertain)	No arrival variability (cyclic production)	Arrival variability (flow shop)	Process flow variability (job shop)
Rescheduling strategies				
Dynamic (no schedule)		Predictive-reactive (generate and update)		
Dispatching rules	Control-theoretic	Rescheduling policies		
		Periodic	Event-driven	Hybrid
Rescheduling methods				
Schedule generation		Schedule repair		
Nominal schedules	Robust schedules	Right-shift rescheduling	Partial rescheduling	Complete regeneration

repair the initial schedule. They are right-shift rescheduling, partial rescheduling and complete regeneration.

Pfund et al. (2006) processed a survey in 14 semiconductor companies and shows that the state of the practice for rescheduling is to use dispatching rules. The framework of Vieira et al. (2003) defines dispatching rules as a dynamic rescheduling strategy without generating a new schedule. Nevertheless, with light extensions [e.g., by means of the active schedule generator of Giffler and Tompson (1960)[2]] dispatching rules can also generate schedules and be applied as the predictive-reactive rescheduling strategy. Dispatching rules can repair the current schedule partially or generate a new schedule completely.

In the practice, dispatching rules are simple to be implemented and applied in production processes. In addition, they fulfill the efficiency and flexibility requirements of rescheduling. Priore et al. (2001) as well as Chen and Yih (1996) indicate that the performance of dispatching rules depends on the state of the manufacturing system at each moment, and no single rule exists that is better than the rest in all the possible system states.

Tan and Aufenanger (2011) show a trend and the potential of using artificial intelligence in the event management for uncertainties in the production scheduling. They introduce a machine learning process to acquire the knowledge about the relationship between system states and dispatching rules. With this acquired knowledge they develop a knowledge-based rescheduling approach, which can dynamically select the most appropriate dispatching rule depending on the current production system state.

Figure 1 illustrates the learning process and the rescheduling approach of Tan and Aufenanger (2011). The approach consists of offline and online two phases. In the offline learning phase it uses scheduling approaches to generate schedules for the previous scheduling problems of the production system. Then, each pair of problem and its schedule is analyzed by an analysis heuristic. Training data in the form of production system state, then dispatching rule are generated that denotes for one given state of a previous problem which dispatching rule is selected by its schedule. Afterwards, a machine learning process is applied on these training data to acquire knowledge about the relationship between system states and dispatching rules in the considered production system.

In the online phase, when this production system has an unexpected event (e.g., delay of the arrival of raw materials due to a transportation delay) and the current production schedule has to be updated, the rescheduling approach considers the current system state and dynamically selects the most appropriate dispatching rule for this state, based on the acquired knowledge. The approach iteratively updates the system state and selects the best dispatching rule for each state, until the whole new schedule is completed.

[2] The set of active schedules is a subset of feasible schedules for a scheduling problem. Giffler and Tompson (1960)proved that at least one optimal schedule is active schedule. Their work also presents a heuristics, which can generate all possible active schedules. Dispatching rules are usually used to lead the search directions in this heuristics to generate active schedules.

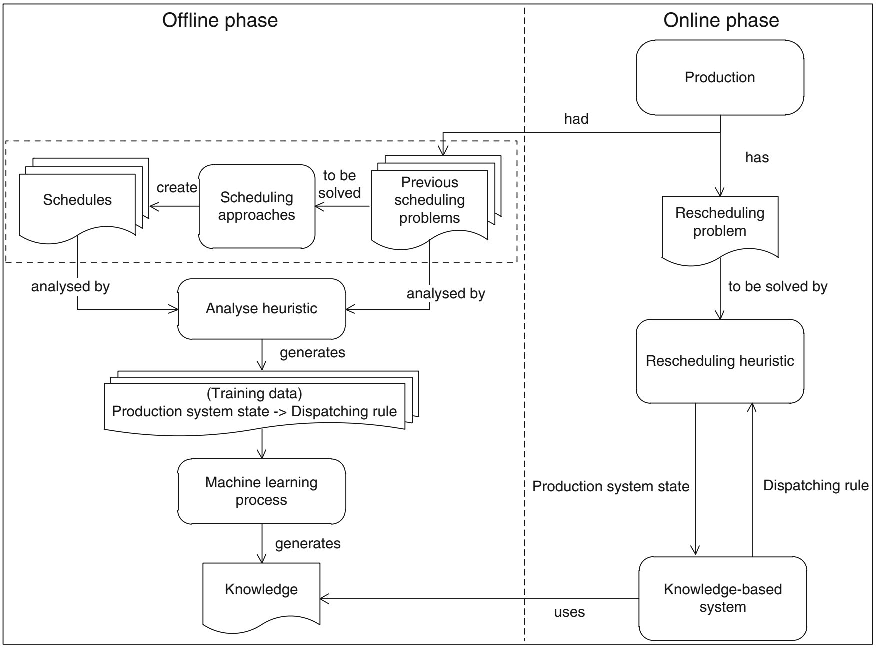

Fig. 1 The knowledge-based rescheduling concept for dynamically selecting dispatching rules of Tan and Aufenanger (2011)

Tan and Aufenanger (2011) reported this knowledge-based rescheduling approach outperforms all single dispatching rules that they studied. In addition, the offline knowledge acquisition phase saves the computational time of the online phase and ensures the efficiency (near real-time) of the rescheduling.

Event Management for Uncertainties in Transportation Planning

A broad view of transportation management's role in an integrated SC is a must nowadays because it is the key to improving the SC performance. Traditionally, the focus of managing uncertainty has been on production operations, with little attention paid to the causes and consequences of uncertainty within freight transport operations. Consequently, there has been little integration of transport in supply chains (Rodrigue et al. 2007).

Transport planning is influenced by the uncertainties. The transport represents an important part of the supply chain due to the dynamics of the current business environment, which is characterized by short products life cycles and large varieties of the products. Performance of transport can impact the wider supply chain (Larsen et al. 1999). Therefore, effective and efficient logistic management has become a requirement rather than a competitive advantage under these complex and dynamic environment. Accordingly, increased flexibility in transport services to meet a variety of customer demands, and the involvement of the shipper, carrier and customer as part of a logistics trade are highly required.

The design of transport network has to consider a number of requirements:

1. *Sustainability*: It is increasingly seen as essential to delivering long-term profitability. The targeted benefits include shorter product life cycles, faster product development cycles, globalization and customization of product offerings, and higher overall quality (Fortes 2007). Construct automated decision support system helps the decision maker in determining the optimal distribution schedules and the optimal distribution sequences (Bonfill et al. 2008).
2. *Flexibility*: The increase of structural and dynamic complexity of production and logistics systems could be observed. Companies should be able to respond to diversity or change of environment.
3. *Visibility*: It is about measuring time and accuracy of information transfer. The transfer of information between operational levels could be delayed or inaccurate, therefore affect the efficiency of the whole network.
4. *Reliability*: It affects customers trust through different levels of the supply chain. The importance is the supplier's performance, how consistent suppliers deliver raw materials on time in good condition.

Uncertain events can affect the ability of transport operations to satisfy customers' requirements. The customer satisfaction could associate with the service before or after purchasing products or service as well as with service elements directly involved in the physical products distribution (Li and Schulze 2011). Thus, there is a need to identify the sources of transport uncertainty as a mean of improving the effectiveness of management (Sanchez-Rodrigues et al. 2010a). From transport perspective, various sources of uncertainty can exist within logistics networks. Uncertainty can be initiated from one source and can possibly affect many of the logistics processes (Sanchez-Rodrigues et al. 2008). The uncertainty sources are mainly categorized into five types which are (Sanchez-Rodrigues et al. 2010a):

1. *Shipper*: any uncertainty originating from the sender of products in the logistics trade, which directly impacts transport performance. These may relate to raw material sourcing, the production processes or the activities involved in the dispatching process such as: shipment time variability, loss or damage of materials in the shipping operation and lack of integration with production.
2. *Customer*: any uncertainty that is produced by the receiver of products. Examples include forecasting and ordering products or any delivery restrictions. Uncertainties could be caused by variations in customer demand for transport, rigid delivery window, equipment breakdowns, or lack of integration within SCs.

3. *Carrier*: any anomalies that can be originated from the carrier and directly affect the delivery process, such as transport delays due to internal reasons like: vehicle failure or a lack of drivers, insufficient fleet capacity, lack of carrier flexibility in terms of time, lack of integration between transport modes and providers or lack of flexibility of shipment and transport schedule.
4. *Control systems*: any problems caused by inadequate and fragmented information and communications technology systems within the logistics trade such as lack of integration when SC companies assess, transport and inventory systems are not properly integrated, lack of visibility of information regarding inventories or work in process, capacity, order status within the SC, or the lack of physical monitoring systems such as poor auditing or quality control systems.
5. *External uncertainty*: any disruption caused by uncontrollable transportation factors, including congestion, labor shortages, unexpected repairs for preferred transport routes and volatility of fuel prices or even problems that cannot be predicted in any way, such as political and natural disasters.

SCEM has tools that can reduce or eliminate uncertainties when they applied. The most important tools that are: strategic optimization (such as network modeling software), which ensures that the distribution networks are robust to disruptions, operational optimization (such as vehicle scheduling), which allows businesses to respond to uncertainty as quickly as possible while minimizing the overall impact, quality management (like total quality management), which allows to address the causes of uncertainty, to reduce their frequency and to impact in the longer term, and demand forecasting, which are designed to improve accuracy and, therefore, reducing uncertainty (Sanchez-Rodrigues et al. 2010b).

Event Management in Collaborative Production and Transportation Planning

In a collaborative environment of SC the requirement for synchronization of production and transport planning is characterized by the breadth of effects of unexpected events of one process in the other. For example, an urgent customer order (rush order) leads changes in the production planning, and consequently generates a delay in the loading operation of the vehicle, which causes another event affecting the transportation planning.

This mutual influence of unexpected events in production and transport system requires planning makers to consider the production and transport planning in an integrated way, where the visibility of the two simultaneous processes is provided. Scholz-Reiter et al. (2011) presents a mathematical model to describe the integrated production and transportation scheduling problem. Their model considers one production facility and its associated transportation along the SC.

Based on an integrated production and transportation planning model at the operational level, strategies and methods of event management for uncertainties in production planning can be extended to transportation planning, and reversely. Hence, an integrative event management for uncertainties in production and transportation planning can be achieved.

Conclusions and Future Work

This paper introduced the event management for uncertainties for collaborative production and transportation planning at the operational level. That adds value to SCs in a dynamic environment. Considering uncertainties of SC processes simultaneously leads to maximize the benefit of reducing or eliminating risks.

For future research, more review related to integration between production and transportation is required. In addition risk based planning and scheduling approach is one of the possible research directions. This approach combines the features from a simulation model that generates a detailed resource-constrained deterministic schedule and a probability-based risk analysis considering the deviations from SC process. Furthermore, global supply network aspects such as culture aspects and specific regulations should be taken into account.

Sustainability in the supply chain is increasingly seen as essential to delivering long-term profitability. Achieving a level of integration between production and distribution decisions will yield these benefits. These benefits include shorter product life cycles, faster product development cycles, globalization and customization of product offerings, and higher overall quality (Fortes 2007).

Acknowledgments This research was supported by the International Graduate School for Dynamics in Logistics (IGS) at the University of Bremen, by Capes as part of the Brazilian-German Collaborative Research Initiative on Manufacturing Technology (BRAGECRIM) and by Deutscher Akademischer Austausch Dienst (DAAD) and the Egyptian Government under Grant GERLS 2010.

References

Bonfill A, Espuna A, Puigjaner L (2008) Decision support framework for coordinated production and transport scheduling in SCM. Comput Chem Eng 32:1206–1224

Chen CC, Yih Y (1996) Identifying attributes for knowledge-based development in dynamic scheduling environments. Int J Prod Res 34:1739–1755

Christopher M, Mena C, Khan O, Yurt O (2011) Approaches to managing global sourcing risk. Supply Chain Manag: Int J 16(2):67–81

Fortes J (2007) Green supply chain management: a literature review. Otago Manag Graduate Rev 7:51–62

Giffler B, Tompson GL (1960) Algorithms for solving production-scheduling problems. Oper Res 8:487–503

Khan O, Burnes B (2007) Risk and supply chain management: creating a research agenda. Int J Logistic Manag 18(2):197–216

Larsen ER, Morecroft JDW, Thomsen JS (1999) Theory and methodology: complex behavior in a production-distribution model. E J Oper Res 119:61–74

Li L, Schulze L (2011) Uncertainty in logistics network design: a review. In: Proceedings of the international multi conference of engineers and computer scientist II, IMECS 2011

Manuj I, Mentzer JT (2008) Global supply chain risk management strategies. Int J Phys Distrib Logistics Manag 38(3):192–223

Otto A (2003) Supply chain event management: three perspectives. Int J Logistics Manag 14(2): 1–13

Pfund ME, Mason SJ, Fowler JW (2006) Semiconductor manufacturing scheduling and dispatching. In: Herrmann JW (ed) Handbook of production scheduling. Springer, New York

Priore P, De La Fuente D, Gomez A, Puente J (2001) A review of machine learning in dynamic scheduling of flexible manufacturing systems. Artif Intell Eng Des Anal Manuf 15:251–263

Ritchie B, Brindley C (2007a) Supply chain risk management and performance: a guiding framework for future development. Int J Oper Prod Manag 27(3):303–322

Ritchie B, Brindley C (2007b) An emergent framework for supply chain risk management and performance measurement. J Oper Res Soc 58(11):1398–1412

Rodrigue VS, Stantche D, Potte A, Naim M, Whitein A (2007) Establishing a transport operation focused uncertainty model for the supply chain. In: 14th international annual Euroma conference

Sanchez-Rodrigues V, Potter A, Naim M (2010a) Evaluating the causes of uncertainty in logistics operations. Int J Logistics Manag 21(1):45–64

Sanchez-Rodrigues V, Potter A, Naim M (2010b) The impact of logistics uncertainty on sustainable transport operations. Int J Phys Distrib Logistics Manag 40(1):61–83

Sanchez-Rodrigues V, Stantchev D, Potter A, Naim M, Whiteing A (2008) Establishing a transport focused uncertainty model for the supply chain. Int J Phys Distrib Logistics Manag 38(5):388–411

Stank TP, Dittmann JP, Autry CW (2011) The new supply chain agenda: a synopsis and directions for future research. Int J Phys Distrib Logistics Manag 41(10):1–25

Scholz-Reiter B, Novaes AGN, Makuschewitz T, Frazzon EM (2011) Dynamic scheduling of production and inter-facilities logistic systems. Dynamics in logistics. Springer, Berlin

Tan Y, Aufenanger M (2011) A real-time rescheduling heuristic using decentralized knowledge-based decisions for flexible flow shops with unrelated parallel machines. In: Proceedings of the 9th IEEE international conference on industrial informatics. pp. 431–436

Tang CS (2006) Perspectives in supply chain risk management. Int J Prod Econ 103:451–488

Vieira GE, Herrmann JW, Lin E (2003) Rescheduling manufacturing systems: a framework of strategies, policies, and methods. J Sched 6:39–62