14th International Conference on Modern Information Technology
in the Innovation Processes of the Industrial Enterprises
Budapest, Hungary, October 24–26, 2012

Detailed conference program

October 24: Proposers' Day sessions

12:00–13:00 Registration and Welcome reception

13:00–13:30 **Elisabeth Ilie-Zudor**
MTA SZTAKI
Overview of EU, trans-regional and bilateral country-specific calls

13:30–16:00 EC experts' talks on future funding opportunities, guidelines for good proposal preparation and specific evaluation procedures

Andrea Gentili
European Commission, Deputy Head of Unit "New Forms of Production"
NMP opportunities for research and innovation on Manu-facturing in 2013 and beyond

Erastos Filos
European Commission, Head of Sector "Intelligent Manufacturing Systems"
Next ICT Calls in Factories of the Future and Opportunities for Global Research under IMS

Márta Nagy-Rothengass
European Commission, Head of Unit "Data Value Chain"
Information management related funding opportunities

Ales Fiala
European Commission, Head of Unit "Future and Emerging Technologies"
Future and Emerging Technologies—Challenging Current Thinking

16:00–16:20 Coffee break

16:20–19:00 Proposal idea presentations and networking
PIP 1–30: Proposal idea presentations

Organized by

Supporting projects

http://www.mitip.org

October 25: Scientific sessions I.—Opening and sessions S1, S2

08:00– Registration

09:00–09:30 **László Monostori, Elisabeth Ilie-Zudor and Zsolt Kemény**
Opening speech

09:30–11:15

S1: Decision support and management in supply chains and logistics
Chair: Daniel Palm

Christopher Buckingham, Paul Buijs, Philip Welch, Ashish Kumar and Abu Ahmed
Developing a cognitive model of decision-making to support members of hub-and-spoke logistics networks

Roberto Pinto
A customers grouping problem with demand uncertainty and resource minimization

Daniel Palm, Florian Markus and Wilfried Sihn
Potential of logistic-oriented production scheduling in the automotive industry

Jose Ferreira, Miguel Ferro de Beca, Carlos Agostinho and Ricardo Goncalves
Monitoring Morphisms for advanced interoperability in Factories of the Future (FoF) platforms

S2: Design, planning and control of production systems I.
Chair: Tamás Bartha

Tamás Koltai
Supporting line configuration decisions with assemblyline balancing models: a practical case

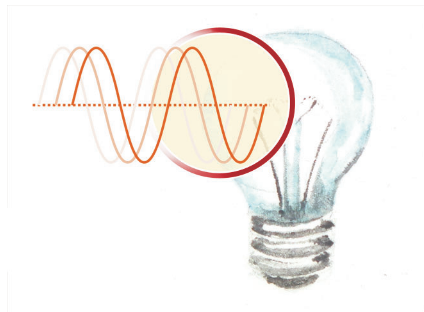
Anders Skoogh, Åsa Fasth and Johan Stahre
Information handling for reliability services in production systems

Philipp Spenhoff, Daryl Powell, Erlend Alfnes and Marco Semini
The application of lean production control methods within a iprocess-type ndustry: the case of Benteler Aluminium Systems Norway

Konstantinos Efthymiou, Maria Michalopoulou, Konstantinos Sipsas, Christos Giannoulis, Dimitris Mourtzis and George Chryssolouris
On plant reconfiguration following a collaborative engineering and knowledge management approach

11:15–11:45 Coffee break

October 25: Scientific sessions I.—Sessions S3, S4, S5



11:45–13:00 **S3: Product and process traceability, modelling and simulation**
Chair: Tamás Koltai

Gergely Popovics, Csaba Kardos, Dávid Gyulai and Lőrinc Kemény
Uniform data structure for production simulation

Milan Gregor, Silvia Palajova and Michal Gregor
Simulation metamodelling of manufacturing systems with the use of artificial neural networks

Flavio Tonelli, Lucia Cassettari, Fabio Rolando and Roberto Mosca
Simulation based analysis and optimization in the industrial sustainability domain

S4: Mobile and digital applications
Chair: Christopher Buckingham

Herwig Stockl
Local trends in m-commerce set the technical requirements on global solutions

Tamás Tettamanti and István Varga
Urban road traffic estimation based on cellular signaling data

Yuan Lu, Tomico Oscar, Matthijs Zwinderman, Guillaume Stollman, Andre Vermeulen and Edwin Noordman
Designing knowledge sharing opportunities in new product development

13:00–14:20 Lunch

14:20–14:50 **S5: Exhibition-related speeches**
Chair: Elisabeth Ilie-Zudor

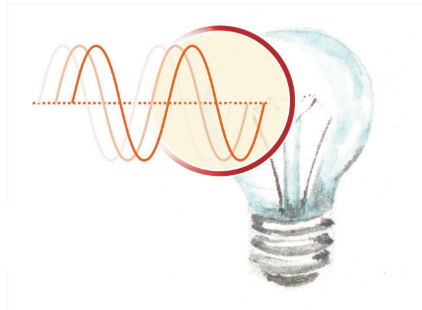
Holografika Kft.
First Full-angle 3D Light Field Display—HoloVizio 80WLT

Artklikk Plc.
Multimedia as Mobile Application: Introducing a Next Generation App Creation Platform

István Elek, János Roden, Thai Binh Nguyen
Spontaneous emergence of the intelligence in digital evolutionary machines

14:50–15:00 Coffee break

October 25: Scientific sessions I.—Sessions S6, S7



15:00–17:00

S6: Augmented and virtual reality in design and production
Chair: Frédéric Noël

Gabriela Candea, Ciprian Candea, Ciprian Radu, Walter Terkaj, Marco Sacco and Octavian Suciu
A practical use of the Virtual Factory Framework

Alessandra Caggiano and Roberto Teti
Improving the performance of a real manufacturing cell through advanced digital simulation

Frédéric Noël
VISIONAIR: An infrastructure for research with visualization and interaction technologies: design and manufacturing research oportunities

Loukas Rentzos, Konstantinos Smparounis, Dimitris Mavrikios and George Chryssolouris
An ontology for classifying advanced visualization infrastructures

Carmen Constantinescu and Joachim Lentes
Engineering apps for advanced manufacturing engineering to align the lifecycles of products and factories

S7: Energy, resource and IT efficiency
Chair: Herwig Stockl

Apostolos Fysikopoulos, Panagiotis Stavropoulos, Alexios Papacharalampopoulos, Paolo Calefati and George Chryssolouris
A process planning system for energy efficiency

Thomas Bauernhansl, Anja-Tatjana Braun, Peter Dürr and Frank Grossmann
Indicator-based method for increasing IT efficiency

Jadwiga Fangrat and Anna Pachman
Chosen aspects of energy efficiency in construction

Aitor Arnaiz and Egoitz Conde
Continuous improvement cycle to lead cost-effectiveness in maintenance strategies

Andreas Schlegel, Johannes Stoldt, Enrico Franz, Tino Langer and Marcel Tisztl
A framework for energy-sensitive production control in MES

19:30–22:30 Danube boat cruise and conference dinner

October 26: Scientific sessions II.—Sessions S8, S9

08:00– Registration

09:00–10:45

S8: Factory of the future, IT for Enterprise 2.0
Chair: Roberto Pinto

Walter Terkaj, Marcello Urgo, Botond Kádár, Gergely Popovics and Lőrinc Kemény
Modeling and simulation of production systems supported by a Virtual Factory Framework

Imad Chalfoun, Khalid Kouiss, Nicolas Bouton and Pascal Ray
Characterization of a Reconfigurable and Agile Manufacturing System (RAMS)

Ferenc Erdélyi, Tibor Tóth, Gyula Kulcsár and Péter Bikfalvi
Some new considerations for applying MES models to improve the effectiveness of production operations management in discrete manufacturing

Stefan Wiesner and Jens Eschenbächer
Challenges of requirements engineering for extended products in collaborative environments

S9: Value adding through modern software and information systems
Chair: Vidosav Majstorovic

Pavan Kumar Sriram, Erlend Alfnes and Emrah Arica
Engineering change management in the Engineer-to-Order environment: a literature review

Tomas Langer and Pavel Vaněček
Added value of agile methods in startup

Marcello Braglia, Davide Castellano and Marco Frosolini
Application of the QFD methodology to plant layout evaluation

Ljubisa Urosevic, Philip Reimer, Oliver Kotte, Aitor Elorriaga and Silvia Lopez
Decision support system for the initial phase of innovation processes in manufacturing SME

10:45–11:15 Coffee break

October 26: Scientific sessions II.—Sessions S10, S11

11:15–13:00

S10: Design, planning and control of production systems II.
Chair: Tibor Tóth

Imre Paniti and Ursula Rauschecker
Integration of incremental sheet forming with an adaptive control into cloud manufacturing

Frédéric Noël
From integrated to intuitive design thanks to new technologies

Christen Rose-Anderssen, James Baldwin, Keith Ridgway, Fabian Boettinger, Kwabena Agyapong-Kodua, Iván Brencsics and István Németh
Application of production system classifications in rapid design and virtual prototyping

István Németh, János Püspöki, Csaba Haraszkó and James S. Baldwin
Rapid layout design of manufacturing systems

S11: Reliability engineering and multicriteria optimization problems
Chair: Andreas Schlegel

Jose L. Salmeron and Ester Gutierrez
Fuzzy cognitive maps in FMEA

Tamás Bartha, András Vörös, Dániel Darvas and Attila Jámbor
Verification of an industrial safety function using coloured Petri nets and model checking

Vidosav Majstorovic and Tatjana Sibalija
Knowledge-based system for Taguchi's robust design model

Alfréd Csikós and István Varga
Nonlinear model predictive ramp control for multicriteria traffic optimization

13:00–14:30 Lunch

October 26: Scientific sessions II.—Sessions S12, S13

14:30–16:40

S12: Decision support and management in transport and logistics
Chair: Elisabeth Ilie-Zudor

Ádám Ludvig, Tamás Tettamanti and István Varga
Travel time estimation in urban road traffic networks based on radio signaling data

Rita Markovits-Somogyi
Verifying and applying traditional DEA and novel DEA-PC methodology in road freight transport

Cristina Mohora, Dorel Anania and Radu Chanarache
Material flow optimisation in an automotive industry logistic platform

Dávid Karnok and Zsolt Kemény
Framework for building and coordinating information flows in logistics networks

Dávid Karnok and Zsolt Kemény
Definition and handling of data types in a dataflow-oriented modelling and processing environment

S13: Digital Factories and Virtual Organizations
Chair: Marco Sacco

Mildred J. Puerto, Josu Larranaga, Alessandro Brusaferri and Marius Vanca
Factory image: knowledge driven real data integration in VFF

Marco Sacco, Walter Terkaj and Claudia Redaelli
VFF: a framework for interoperability

Cosmina Carmen Aldea, Anca Diana Popescu, Anca Draghici and George Draghici
Information technology solution for a collaborative environment dedicated to project virtual teams

Andreas Riel and Serge Tichkiewitch
E-learning and certification to face MITIP challenges

16:40–17:00 Coffee break and closing

POTENTIAL OF LOGISTIC-ORIENTED PRODUCTION SCHEDULING IN THE AUTOMOTIVE INDUSTRY

Palm, Daniel[1], Florian, Markus[2], Sihn, Wilfried[3]

[1]Fraunhofer Austria Research GmbH
Theresianumgasse 7, 1040 Vienna, Austria
daniel.palm@fraunhofer.at

[2]Fraunhofer Austria Research GmbH
Theresianumgasse 7, 1040 Vienna, Austria
markus.florian@fraunhofer.at

[3]Vienna University of Technology
Theresianumgasse 27, 1040 Vienna, Austria
wilfried.sihn@tuwien.ac.at

Abstract:

The integration of logistics aspects in the planning of the production sequence in the Automotive Industry was the focus of the research project InterTrans. The basic idea is to integrate logistics constraints in production scheduling of a vehicle manufacturer in order to improve inbound and outbound transportation processes in terms of CO2 emissions and transportation costs. The project results show, that the introduction of logistics constraints in production scheduling is possible and that logistics savings can be significant.

Keywords:

Logistics, Transportation; Automotive; Production Scheduling.

1 INTRODUCTION

Production scheduling in the Automotive Industry for sequenced assembly lines is the matching of the required capacities out of the production program with the existing fundamental factors of production. Workforce, equipment and material are three basic planning sectors. Their limitiations and availability can be defined as planning constraints in production scheduling as input, determining the output of the production system. Current planning algorithms try to create a valid production sequence under consideration of all given production constraints.

Such restrictions narrow the solution space by prohibiting certain events or sequences of events. By introducing additional logistics-oriented constraints to the production scheduling, an optimization of transport parameter like costs or CO_2-emissions can be achieved [1].

The project InterTrans, supported by the German Ministry of Economics and Technology, the Austrian Research Promotion Agency (FFG) and the European research initiative EUREKA, had the aim to research the possibilities in the European Automotive Industry to increase capacity utilization of transport means, to reduce kilometers traveled to supply Automotive production with parts (inbound transportation), to deliver finished cars to the customer (outbound transportation) and to determine the possibility to shift transports from truck to more eco-friendly transportation modes like ship or railway.

2 PRODUCTION CONSTRAINTS FOR SEQUENCED ASSEMBLY LINES

The Automotive Industry produces according to the principle of a high-variant line production [2]. The production sequence on the assembly line is a result of a constraint planning. There are two types of constraints: Inherent constraints which are balancing equations or conditions and are valid for the complete production system and second task related constraints which represent technological, organizational and economic characteristics of the production system [3]. Task related planning constraints are relevant for the planning of the production sequence on assembly lines. Hence the originators of planning constraints are generally classified within five groups: Equipment, Workforce, Material, Product and Market. These five groups build the branches of the Ishikawa-diagram in Figure 1. [4]

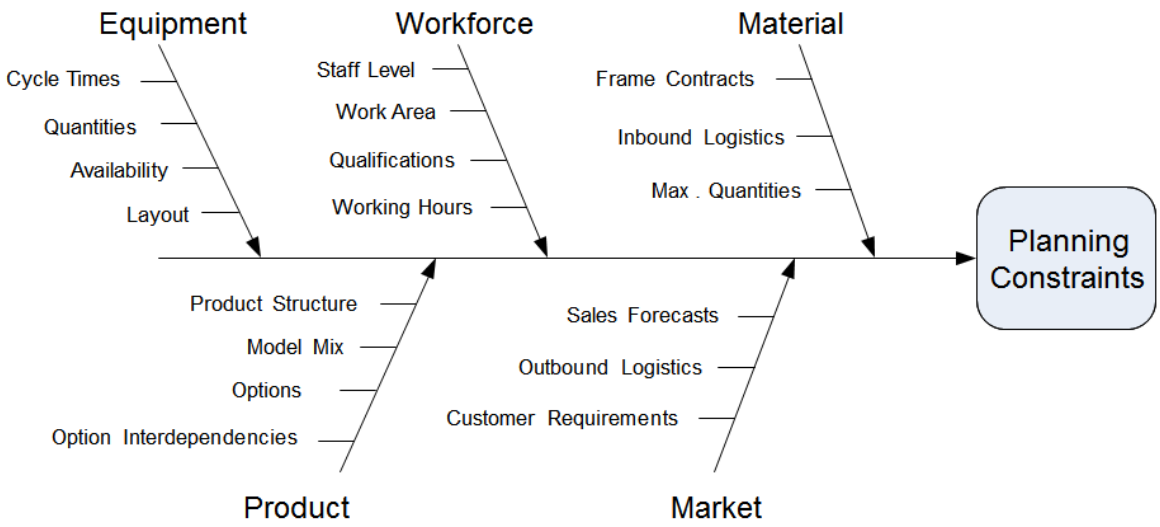


Figure 1: Originators of planning constraints [2]

The upper three branches represent the fundamental factors that describe the production system. They are essential to achieve the required output:

- Equipment
- Workforce
- Material

The output of the production system itself is characterized by the branch “Product”. It defines which brands, models and types are available for the customer and how those products can be configured. The last branch of the diagram – the “Market” branch – represents all customers and their requirements as well as the outbound logistics which became more important as minimization of transport is in focus [5]. All described constraints can be defined as absolute or relative Constraints [3]:

- Absolute constraints are quantity or time constraints. A quantity constraint has a variable quantity and fixed time period (e.g.: The weekly capacity is 1200 parts.). On the other hand time constraints have fixed quantities and a variable time period (e.g.: A product carrier has a capacity of ten components and it is just shipped when the carrier is full).
- A relative constraint is always characterized by a combination of at least two events. Such constraints are for example sequence or distance constraints. A sequence constraint for example prohibits that a white car body is followed by a black body in the paint shop. The distance constraint can define that there are three cycles required until the same option is allowed to be assembled again.

Relative constraints are mainly relevant in the short-term planning process (sequencing). In long- and mid-term planning the relative constraints have to be translated to quantity or time constraints.

It is possible that the limit of a constraint is flexible. Such constraints are also called soft constraints. Other restrictions that are often caused by technological limitations cannot be exceeded and must be seen as hard constraints and cannot be violated. An example for a soft restriction is a weekly delivery lot size of a supplier that can be exceeded under special conditions.

3 TRANSPORT PLANNING IN AUTOMOTIVE INDUSTRY

The task of the transport planning can be divided in the design of the network and the planning and control of the executed transport processes. The task can be segmented in: [6]

- Design of transport network (long-term)
- Planning of transport routes and means of transports (middle-term)
- Planning of vehicle usages (middle and short-term)

The design and the long-term planning define sources, nodes and drains of the automotive supply chain (suppliers, crossdocks, component factories, automotive plants, transshipment points, dealers etc.) and the transportation network of roads, rails and waterways. These networks are used to forward freight between origins and destinations of the production network. Shipments may be transshipped from road to road, from rail to rail, from water to road or vice versa using adequate facilities. [7]

The short term transport planning takes the result of the production scheduling and assigns the derived demand to the available transport capacities. This transport planning process is highly reactive. This is causing a mismatch between demand and availability what leads to inefficiencies like higher logistics costs or unnecessary CO_2 emissions. [8]

4 LOGISTICS RESTRICTIONS TO IMPROVE EFFICIENCY IN TRANSPORT LOGISTICS

In order to improve this transport planning process it is necessary to define strategies for a higher efficiency of transport logistics. Jin et. al. published an approach to minimize the costs for production and distribution by using an integrated planning model and showed, that savings can be achieved in comparison to a sequential planning of production and logistics. [9]

In general it can be distinguished between ecological and economical efficiency. Efficiency describes the extent to which effort is used for the intended task or purpose – economically in terms of total costs and ecologically in terms of external effects caused by the transport (ex. CO_2 emissions, pollution, noise). The aim to increase efficiency can be reached by:

- Shift of carrier or transportation mean (more ecological or more economical)
- Traffic reduction or avoidance
- Optimization of capacity utilization of the carrier

Ecological and economical aims can herby be conflicting (shift of carrier may be ecologically good but economically bad) or common (an increase in capacity utilization and traffic reduction or avoidance is ecologically and economically favorable; total costs and unwanted external effects are reduced). [10]

In order to reach the goals to increase efficiency, several measures in production sequencing can be taken to positively influence these three aims.

4.1 Shift of carrier or transportation mean

From an ecological point of view, rail or ship transports can be generally considered as more efficient than truck transports. The characteristic trait of these two transport modes is their higher capacity. For example the capacity in outbound logistics of a train is aprox. 200 cars whereas a truck capacity is 8 cars. To support the shift of carrier to rail or water, a planning strategy to bundle the car production from or for a specific destination according to their time schedule would be favorable.

4.2 Traffic reduction or avoidance

The bundling of cars for the same outbound destination or the bundling of parts for inbound logistics is also an appropriate strategy for the traffic reduction or avoidance. Inbound bundling means to concentrate the demand of certain parts into a shorter time span. By bundling parts, which are supplied over the same transport relation, high transport utilization and low inventory costs can be achieved. A traffic reduction can be realized by a consolidated transport instead of direct deliveries.

4.3 Optimization of capacity utilization of the carrier

The principle of bundling under consideration of the capacity of the carrier can optimize the capacity utilization of the carrier and as a result can reduce or avoid traffic. This should be combined with the smoothing of demand over several planning periods in order to optimize the capacity utilization and the planning process. A weekly train to supply the demand of a specific market for example can only be considered as ecologically efficient if the fluctuation of capacity demand does not exceed frequently the maximum capacity. The resulting disturbances and the need of additional transportation of the overrun may reduce or overcompensate the benefits.

A constant demand exists only for parts with a high installation rate. Typically these parts are frequently sourced from supplier parks or with lean JIT transports that are within close proximity [11]. Smoothing means realizing a steady demand of parts. The resulting constant stock movement and flow of parts provide a basis for a steady transport schedule [12].

4.4 Logistics restrictions to improve efficiency

To summarize, the following planning restrictions in the production scheduling would provide ecological and economical efficiency in transportation: [13]

- Capacity oriented bundling of parts from suppliers or regions (inbound; ex. parts for a specific option can be bundled)
- Capacity oriented bundling of cars for destinations or markets (outbound; cars for a specific region with the same ship carrier can be bundled)
- Smoothing over several periods
- Timing according to a schedule (timetable)

Occurring conflicts in ecological or economical aims in the case of a shift of carrier or transportation mean must be solved by a prioritization decision.

5 PROJECT PROCEEDING

Sequencing in the Automotive Industry is the planning process where assembly orders for a specific time period (ex. day or shift) are brought to an optimal sequence assuring a consideration of different lead times of orders as a result of different variants. The assembly order should not break any restrictions and should maximize the capacity utilization of every station. Exact optimization approaches are not applicable in practice due to long calculation times. Therefore several heuristics are used to find a practicable assembly sequence (see [14], [15], [16], [17]).

Most of the Western European car manufacturers use the car sequencing algorithm (car sequencing problem, CSP). CSP does not work with detailed car configuration information, but ban overloads of partial sequences with so-called “Ho:No-rules”. These rules determine that among “N” consecutive sequence positions at most “H” occurrences of a certain option “o” are allowed. A sequence which does not violate this rule also ensures the avoidance of a work overload at the several work stations. One example for a rule of Ho:No of 1:3 for the option sunroof says that from three sequenced orders only one order can contain a sunroof.

After the appliance of the algorithm on the entirety of the orders, from No sequenced variants, the maximum amount of Ho options can be included to assure no overloads.

One aim of the project InterTrans was to prove, that it is possible, to integrate logistics restrictions in the sequencing algorithm in addition to existing production oriented restrictions in order to improve the usage of transport means (short term). This will be shown with two examples. To optimize transports, a temporally adjustment of demand (bundling, smoothing) is necessary. To be able to define Ho:No-Rules for inbound transports it is necessary to do a bill explosion of the considered orders and to derive a part demand for each supplier. For smoothing, the tact time A for a specific part of a supplier must be related to the tact time B of the assembly line and the Ho:No-rule 1:(A/B) must be applied.

In the distribution logistics the time of departure of the transport mean is an important parameter to optimize. By introducing a latest completion time for orders, the optimization criteria: a) “minimize the amount of tacts between completion time and latest completion time” and b) “minimize the amount of orders with a completion time after the latest completion time” lead to a bulking of orders around the latest completion time. This can be considered as favorable for rail or ship transports and therefore for more ecological transportation. For smoothing, the planned production quantities for specific markets or outbound destinations over a certain time period must be constant.

6 PROJECT RESULTS

In the project InterTrans, the introduction of the logistics restrictions in the production program planning and sequencing process was examined and tested under realistic conditions with data sets from a European OEM. In order to include these logistics requirements in production planning, integrated information from production and logistics is necessary (see Figure 2). New processes for a dynamic transport planning and a logistics-integrated sequencing were developed and combined to an overall planning process. A software tool to dynamically plan the transportation was realized as a prototype.

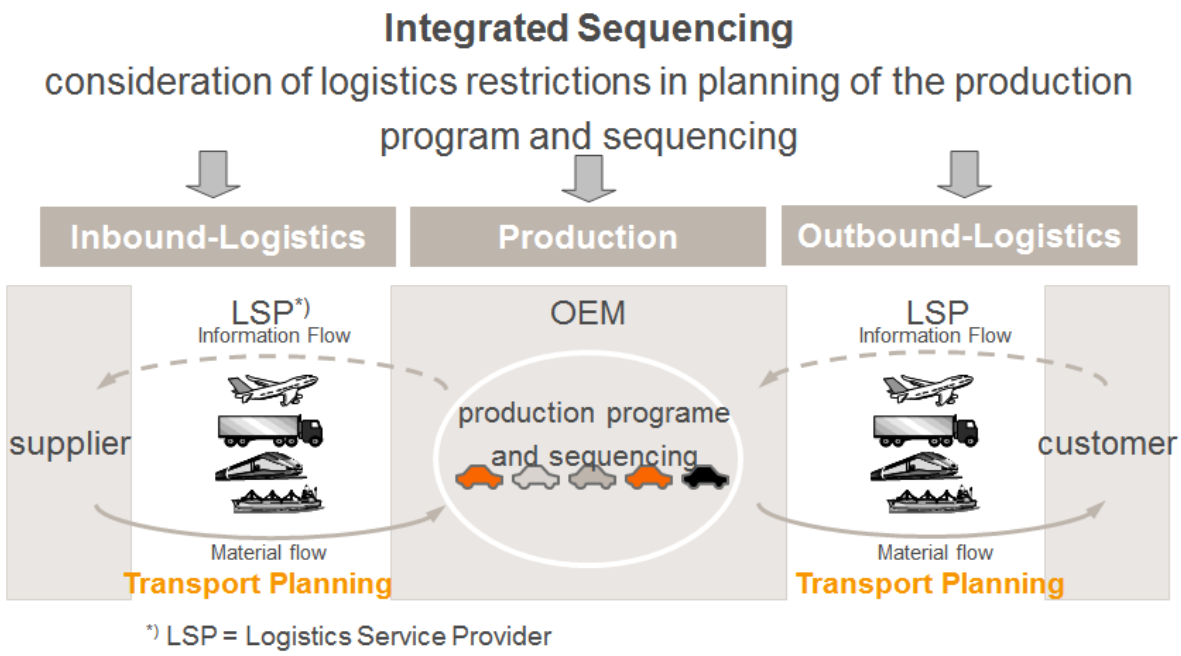


Figure 2: Solution approach of InterTrans: Integrated sequencing

The dynamic planning of transportation processes and capacities leads to an increase of efficiency and flexibility also in mid-term transportation planning aspects (see Figure 3) by opening up the possibility for example to dynamically assign a transport mean with appropriate shipping volume or to switch the transportation concept from a direct transport if the shipping volume decreases to a milk-run concept.

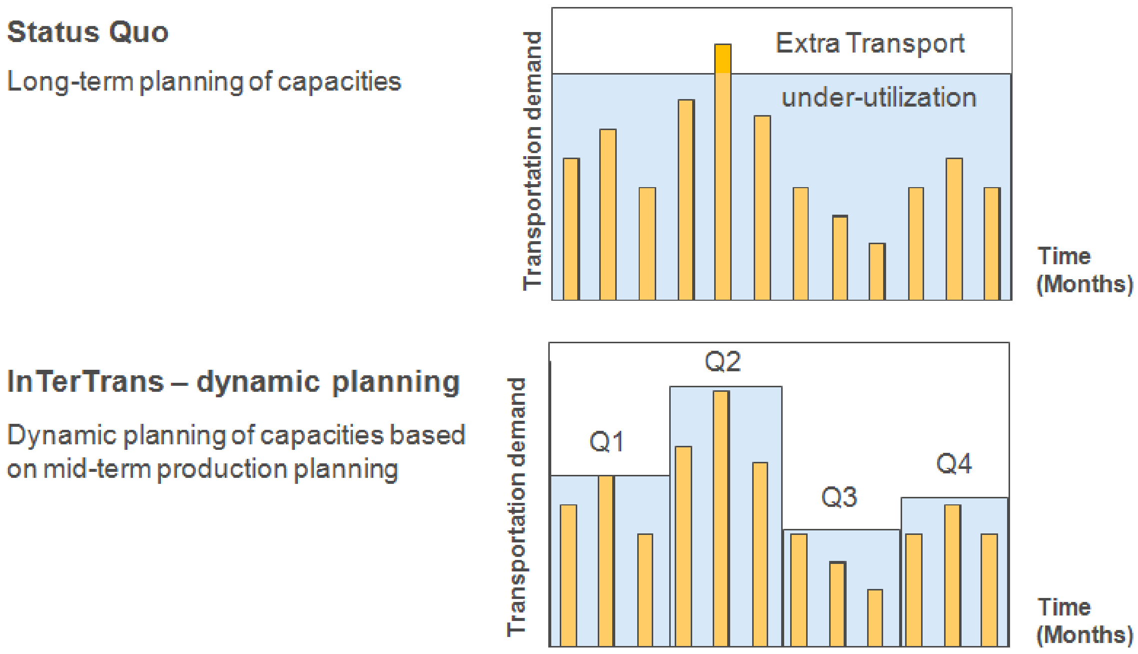


Figure 3: dynamic transport planning

6.1 Impact on Outbound Logistics

In the distribution logistics, finished cars are assigned directly to the transport device. The integrated planning of the sequence and the transport has the following overall aims (see Figure 4):

- Maximization of capacity utilization
- Preference for Transports with better ecological efficiency
- Minimization of stocks (to avoid additional handling after the end of the production process)
- Keeping the deadline of the customer order

In case studies a double-digit percentage rate for the relocation of truck transports towards train transports outbound could have been proven. Also the stock level of finished vehicles before distribution was reduced by over 20%. The customer service level was not reduced by the measures. Lead times where stable or reduced and the productivity of the plant and the output was not affected.

Based on the InterTrans principles of bundling, smoothing and timing according to a schedule, the following process optimizations could have been implemented:

1. quick load building for truck relations (small loads)
2. higher usage of bulk trains (middle loads) and dealer milk runs (main legs and subsequent legs)
3. ship-synchronized port delivery with reduced standstill time and reduced inventory in the ports

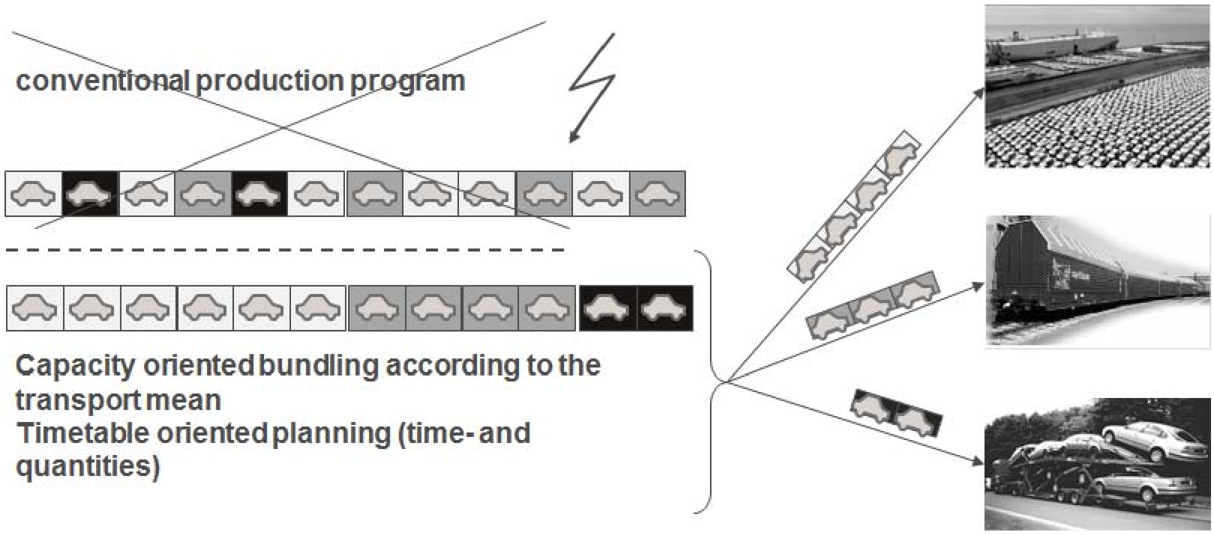


Figure 4: outbound transport planning

6.2 Impact on Inbound Logistics

The smoothing of the demand to eliminate fluctuations and to improve the quality of the transportation planning is the main driver on the supply side. The optimization of capacity utilization of the carrier can be reached by a timetable oriented planning due to consistent demand (see Figure 5).

The sole adaptation of the production sequence without adjusting the timetables and the consolidation of transports had no impact in the case studies of InterTrans. But with adjustments, a reduction of truck usage up to 9 % together with a higher capacity utilization rate could inbound have been achieved.

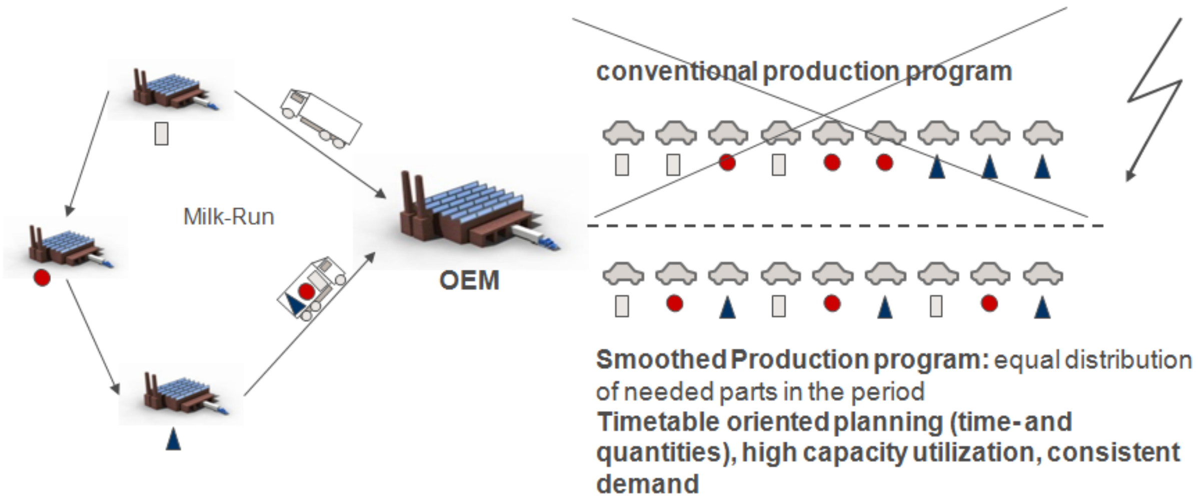


Figure 5: inbound transport planning

7 CONCLUSION

The project InterTrans proved that the introduction of logistics-oriented planning restrictions in the production planning and scheduling process has a very positive impact on the efficiency of the transportation logistics. The integrated planning of logistics and production in the Automotive Industry is not only feasible in practice but showed significant improvements in the logistics efficiency without affecting the production adversely. The dynamic transportation planning, the logistics-oriented planning constraints and the holistic planning process developed in InterTrans lead to a couple of improvement compared to the state of the art in the Automotive Industry.

Due to the specific production sequencing algorithm used in the automotiv industry, a portability of the developped solution to other industries is not given directely if they don’t use the CSP algorithm. But the project showed, that integrated planning of production and logistics has a high potential for economical and ecological improvement.

To summarize, the potentials of logistic-oriented production scheduling in the automotive industry achieved in the InterTrans-project are:

- Utilization of dynamic bundling capabilities (reduction of transports)
- Improved capacity utilization of the transport carriers (up to 9%)
- Relocation of transports towards ecological transportation means (reduction of truck kilometer up to 48%)
- Reduced distribution times
- Reduction of CO_2-emissions
- Reduced stock level of finished vehicles before distribution (up to 23%) and less handling costs
- Improved communication between all partners in the Automotive supply chain
- Improved planning quality and reliability

REFERENCES

[1] **Scholz-Reiter, B., u.a.** (2008): Transportorientierte Reihenfolgeplanung, PPS Management 13 (2008) 4, S. 15-17.
[2] **Freye, D.** (1997): Reihenfolgeplanung in einem variantenreichen Fließfertigungssystem, Dissertation Universität Göttingen.
[3] **Dangelmaier, W.** (2009): Theorie der Produktionsplanung und Steuerung, Springer.
[4] **Auer, S., März, L., Tutsch, H., Sihn, W.** (2011): Classification of interdependent planning restrictions and their various impacts on long-, mid- and short term planning of high variety production. CIRP, ICMS 2011.
[5] **Bong, H-B.** (2002): The Lean Concept or how to adopt production system philosophies to vehicle logistics, Survey on Vehicle Logistics, ECG – The Association of European Vehicle Logistics, Brussels, 321-324.
[6] **Arnold D., Isermann H., Kuhn A., Tempelmeier H., Furmans K.** (2008): Handbuch Logistik, Springer-Verlag Berlin Heidelberg, ISBN 978-3-540-72928-0, pp.14; 137.
[7] **M. Preuss1, B. Hellingrath (2010):** Tactical planning of sustainable transportation by logistics service providers for the automotive industry. CIRP, ICMS 2010.

[8] **Florian, M., Kemper, J., Sihn, W.** (2011): Concept To Optimize Inbound Logistics Traffic By A Transport Oriented Scheduling In The Automotive. Stuttgart, 21. international Conference on Production Research.

[9] **Jin, M.; Luo, Y.; Eksioglu, S. D.** (2007): Integration of production sequencing and outbound logistics in the automotive industry. In: International Journal of Production Economics.

[10] **Hermes, A., Preuss, M., Wagenitz, A., Hellingrath, B.** (2009): Integrierte Produktions- und Transportplanung in der Automobilindustrie zur Steigerung der ökologischen Effizienz. In: Inderfurth et.al., Sustainable Logistics, 2009, S. 183ff.

[11] **Jones, D.T. (**2006): Heijunka: Leveling Production, Manufacturing Engineering, 132/2: 7.

[12] **Liker, J.** (2004): The Toyota Way. 14 Management Principles, McGraw-Hill, New York, 364.

[13] **Zesch Felix et.al.** (2011): Integrierte Terminierung und Transportplanung für komplexe Wertschöpfungsstrukturen. Abschlussbericht des Verbundprojekts.

[14] **Boysen, N.; Fliedner, M.; Scholl, A.** (2006): Produktionsplanung bei Variantenfließfertigung Planungshierarchie und hierarchische Planung. Friedrich-Schiller-Universität Jena (Jenaer Schriften zur Wirtschaftswissenschaft, 22).

[15] **Boysen, Nils; Fliedner, Malte; Scholl, Armin** (2007): Level-Scheduling bei Variantenfließfertigung: Klassifikation, Literaturüberblick und Modellkritik. In: Journal für Betriebswirtschaft 57 (1), S. 37–66.

[16] **Boysen, Nils; Fliedner, Malte; Scholl, Armin** (2007): Produktionsplanung bei Variantenfließfertigung: Planungshierarchie und Elemente einer Hierarchischen Planung. In: ZfB 77 (7/8), S. 759–793.

[17] **Domschke, Wolfgang; Drexl, Andreas** (2007): Einführung in Operations Research. 7., Berlin, Springer.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the German Ministry of Economics and Technology, the Austrian Research Promotion Agency (FFG), the European research initiative EUREKA and the Project management agency TÜV Rheinland. The project consortium consisted of the partners 4flow AG (project coordinator), Fraunhofer IML, Schenker AG, Vienna University of Technology and Volkswagen AG.