Energieeffiziente Produkt- und Prozessinnovationen in der Produktionstechnik

Energy-Efficient Product and Process Innovation in Production Engineering

1. Internationales Kolloquium des Spitzentechnologieclusters eniPROD

1st International Colloquium of the Cluster of Excellence eniPROD

Tagungsband/Proceedings

Technische Universität Chemnitz
Fraunhofer IWU

Herausgeber/Editor:
Prof. Dr.-Ing. habil. Prof. E.h. Dr.-Ing. E.h. Dr. h.c.
Reimund Neugebauer

Verlag
Wissenschaftliche
Scripten

Impressum

Energieeffiziente Produkt- und Prozessinnovationen in der Produktionstechnik

Energy-Efficient Product and Process Innovation in Production Engineering

1. Internationales Kolloquium des Spitzentechnologieclusters eniPROD

1st International Colloquium of the Cluster of Excellence eniPROD

Herausgeber:

Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. Dr. h. c.
Reimund Neugebauer

Verlag Wissenschaftliche Scripten
www.verlag-wiss-scripten.de

ISBN: 978-3-942267-00-7

Inhaltsverzeichnis

K.-J. Matthes
Grußwort des Rektors der Technischen Universität Chemnitz 21

Plenarvorträge
Plenary Papers

H. Rauen
Maschinen- und Anlagenbau – Innovationsmotor
für Energie- und Umwelttechnologien 27

R. Neugebauer, A. Sterzing, H.-J. Koriath
Vision einer energieautarken Fabrik – Beitrag des
Spitzentechnologieclusters eniPROD 33

S. T. Newman, A. Nassehi, R. Imani-Asrai
Energy Efficient Process Planning for CNC Machining 57

J. R. Duflou, K. Kellens
Unit Process Impact Assessment for Discrete Part Manufacturing:
A State of the Art 81

E. Abele, B. Kuhrke, S. Rothenbücher
Entwicklungstrends zur Erhöhung und Bewertung
der Energieeffizienz spanender Werkzeugmaschinen 99

W. Hufenbach, M. Gude, F. Adam
Mehrkomponentenwerkstoffe für Hightech-Anwendungen
im Maschinen- und Fahrzeugbau 121

D. Rafaja
Centre of Excellence "Functional Structure Design of
Novel High-Performance Materials via Atomic Design
and Defect Engineering (ADDE)" 131

Energiebedarfsarme intelligente Produktionssysteme
Intelligent Production Systems with Low Energy Demand

J. Beyer
Energieeffiziente Servopressen – Energieeinsparung durch ServoDirekt-Technologie 139

U. Götze, H.-J. Koriath, A. Kolesnikov, R. Lindner, J. Paetzold, C. Scheffler
Energetische Bilanzierung und Bewertung von Werkzeugmaschinen 157

A. Dietmair, A. Verl
Energieeffizienter Betrieb von Produktionsanlagen 185

R. Neugebauer, M. Wabner, H. Rentzsch, P. Kocourek, S. Ihlenfeldt
Structure Principles of Energy Efficient Machine Tools 207

L. Kroll, P. Blau, M. Wabner, U. Frieß, J. Eulitz, M. Klärner
Leichtbaukomponenten für energieeffiziente Werkzeugmaschinen 231

W.-G. Drossel, A. Hellmich, J. Quellmalz, M. Rehm, H. Schlegel
Strategie zur optimierten Regelung mechatronischer Achsen 259

Energieoptimierte und ressourcenschonende Werkstoffe und Strukturen
Energy-Optimized and Resource-Saving Materials and Structures

B. Wielage, G. Paczkowski, T. Grund, C. Rupprecht
Entwicklung lavalähnlicher Expansionsdüsen für thermische Beschichtungssysteme in Abhängigkeit vom Eigenschaftsprofil des Spritzzusatzwerkstoffs 285

B. Wielage, S. Hausner, I. Hoyer
Niederenergetische Verbindungsverfahren – Metall-Keramik-Aktivlöten 307

M. Klärner, V. Bayreuther, C. Kuprin, A. Czech, M. Kausch, L. Kroll, B. Wielage, D. Nestler, M. Wagner
Ressourcenschonende Verbundstrukturen und Technologien durch Ultraleichtbau 325

S. Stark, P. Schulze, T. Lampke, T. Halle
Modellbildung des thermomechanischen
Umwandlungsverhaltens von Stählen 349

Gestaltung hochintegrativer, energiearmer Prozessketten (Powertrain)
Design of Highly Integrative Process Chains with Low Energy Demand
(Power Train)

G. Byrne
Energy und Resource Efficient Cutting Processes 373

J. Fleischer
Fallbeispiele zur Ressourceneffizienz von Werkzeugmaschinen 389

U. Götze, C. Helmberg, G. Rünger, A. Schubert,
S. Goller, B. Krellner, A. Lau, R. Sygulla
Integrating Energy Flows in Modeling Manufacturing Processes
and Process Chains of Powertrain Components 409

R. Neugebauer, A. Schubert, H. Bräunlich,
M. Dix, A. Rennau, B. Reichmann
Ressourceneffizienz in Haupt-, Neben- und Endformgebungsprozessen
für Präzisionskomponenten in Antrieben 439

A. Schubert, R. Neugebauer, D. Sylla, M. Avila, M. Hackert
Fertigungs- und Oberflächentechnologien für
anforderungsgerechte, tribologisch effiziente Oberflächen
von Umformwerkzeugen und Powertrain-Bauteilen 461

K.-J. Matthes, M. Putz, M. Todtermuschke, J. Böhme, A. Hälsig
Methods and Characteristic Values in Energy Analysis
of Handling, Assembling and Joining Processes 483

Energieeffiziente Systeme und Prozesse der Logistik und Fabrikplanung
Energy-Efficient Systems and Processes in Logistics and Factory Planning

K. Matyas, F. Meizer, D. Palm, W. Sihn
Sustainable and Energy-Efficient Logistics – Design and Evaluation of Cross-Company Logistics Models 505

E. Müller, A. Schütz, U. Götze, C. Helmberg, N. Rösch, S. Nizielski, L. Meynerts, A. Lau
Planung energieeffizienter Fabriksysteme 519

E. Müller, U. Götze, S. Fischer, T. Veit, J. Strauch, S. Krönert
Auswirkungen von Lean Logistikstrategien auf energieeffiziente Fabriksysteme 551

M. Putz, B. Leischnig, A. Schlegel, A. Golle, T. Riedel
Energiesensitive, VR-basierte Steuerung der Variantenfließfertigung 573

K. Nendel, F. Richter, S. Weise, M. Schreiter, A. Schumann, Z. Stryhal, H. Kupfer
Entwicklung energieeffizienter Zug- und Tragmittel durch die Verwendung von Verbundbauweisen und Beschichtungen 597

W.-G. Drossel, L. Kroll, M. Schreiter, J. Strobel, H. Kaden, K. Wolf
Lagerbestückungssystem mit massereduziertem Lastaufnahmemittel und energieführenden Zahnriemen 619

Virtuelle Produktentwicklung für energieeffiziente Produkte und Prozesse
Virtual Product Development for Energy-Efficient Products and Processes

J. Gausemeier, S. Kahl, R. Radkowski
Selbstoptimierende Produkte - neue Perspektiven zur Steigerung der Energieeffizienz 641

R. Neugebauer, V. Wittstock, J. Glänzel, M. Pätzold, M. Schumann
VR-Tools for the Development of Energy-Efficient Products 657

G. Rünger, U. Götze, M. Putz, A. Bierer, S. Lorenz
T. Reichel, D. Steger, K. Wenzel, H. Xu
IT Systems Integration for the Development
of Energy-Efficient Products 677

V. Wittstock, W.-G. Drossel, H. Schlegel,
P. Klimant, A. Hellmich, J. Quellmalz
Virtual Prototypes for an Energy-Optimized Product
Development Process via Hardware in the Loop Simulation 697

Gestaltung hochintegrativer, energiearmer Prozessketten (Zellstrukturen)
Design of Highly Integrative Process Chains with Low Energy Demand (Car Body)

G. Ingarao, R. di Lorenzo, F. Micari
Energy and Resource Efficient Forming Processes 717

A. Göschel, A. Sterzing, J. Schönherr
Systembetrachtungen von Prozessketten der Blechwarmumformung
in Hinblick auf Energie- und Ressourceneffizienz 747

R. Neugebauer, F. Schieck, A. Rautenstrauch, M. Bach
Gezieltes Temperaturmanagement bei der werkzeuggebundenen
und derinkrementellen Formgebung in der Blechwarmumformung zur
Einstellung gradierter Bauteileigenschaften... 769

F. Schieck, C. Hochmuth, S. Polster, A. Mosel
Moderne Werkzeuggestaltung zur Bauteilgradierung
unter Einbindung von Simulationsmodellen, effizienten
Werkzeugkühlkonzepten und Werkzeugbeschichtungssystemen 789

Sustainable and Energy-Efficient Logistics - Design and Evaluation of Cross-Company Logistics Models

Matyas, K.; Meizer, F.; Palm, D.; Sihn, W.

Abstract

In this paper the results of a research project that deals with the conceptual design and evaluation of cross-company logistics models are presented. For this purpose a simulation model is designed that enables the development and evaluation of new logistics concepts. Therefore models for the calculation of emissions, of costs and of logistic competitiveness, have to be created and combined.

Based on the sustainable, inter-company approach, potentials for optimization in the areas emissions, costs, and logistic competitiveness can be detected and based on these analysis results, new sustainable and energy efficient logistics models can be designed and evaluated.

1 Approaches for Cross Company Logistics Models

In the last few years many car manufacturers and component suppliers have set up new production sites in or moved existing locations to the Automotive Region Eastern Europe not just to take advantage of the emerging market there but also because of the low wage costs [1].

The trend towards relocation has shown that the exchange of goods leads to new demands and challenges for transportation and logistics. At an economic level, one of the main areas of focus for logistics in this context is how to plan and manage transport capacities to cope with the transport flows and the related planning and management of logistics networks for goods, services and information [2].

Taking this situation as a starting point, a new simulation and evaluation model has been developed as part of the "Trans Austria" research project that supports the development and evaluation of new logistics concepts and that differs quite radically from the classical models published so far. This is being used to validate and evaluate cross-company logistics models. Thanks to its holistic, cross-company approach, opportunities for improvement in the areas of emissions, costs and logistical competitiveness can be identified and new, sustainable and energy-efficient logistics models can be developed.

There are various approaches for cross-company logistics models that conform to the general network model of logistics [3]. These models represent networks carrying rights, goods, finance and information where spatial, quantitative, informational and temporal differences as well as company boundaries are crossed. Parameters defining the structure of a logistics network are paramount [4]:

- Number, locations and functions of source points (= loading locations, making goods available)
- Number, locations and functions of target points (= unloading locations, points of reception, utilization of goods)
- number, locations, functions of connections or nodes between sources and targets

The network nodes are called transshipment terminals. This implies that only transshipment but not storage in general (no inventory) is foreseen at these locations. Transshipment terminals serve as consolidation terminals where the flows of goods are collected and/or as break-bulk terminals where the flows are in turn distributed [4].

The basic structure of transportation links can be represented either as direct connection ("point-to-point" transport) in its simplest form (single-stage, uninterrupted transport chain) or as a multi-stage system with preliminary leg, main leg and subsequent leg with transshipment terminals for consolidation and break bulk (Figure 1).

This multi-stage transportation chain is further divided up into

- Broken transport, where the load units are broken up and if necessary recombined and where interim storage is usual, and
- Combined transport, which is performed without any change to the transport container. In addition, integrated systems also include

- Piggyback transport, where the complete transport means, or a part thereof, is shipped (roll on-roll off/swim on-swim off, bimodal semi-trailers etc.), and
- Container transport, which, as the name indicates, carries the transport container.

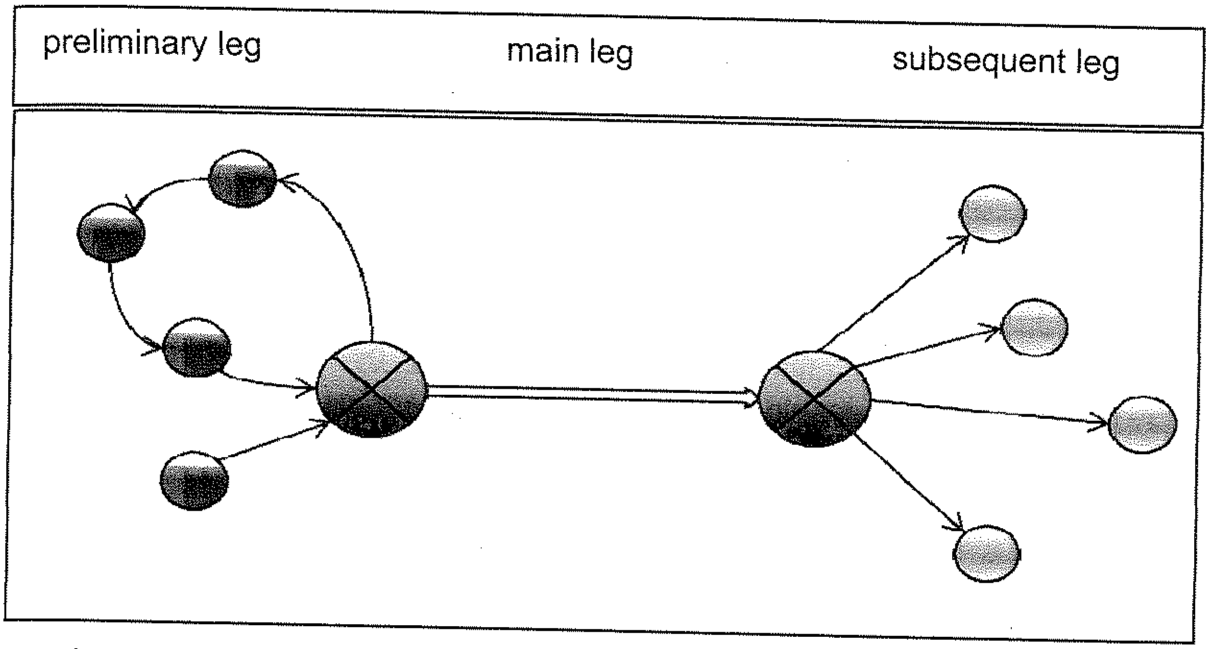


Figure 1: *Integrated Structure*

The mixture of logistics systems made up from the given basic structures is decided in the logistical network structure. The logistical capacity can be subdivided into the following points:

- Transport/transshipment capacity
- Warehousing capacity
- Information capacity

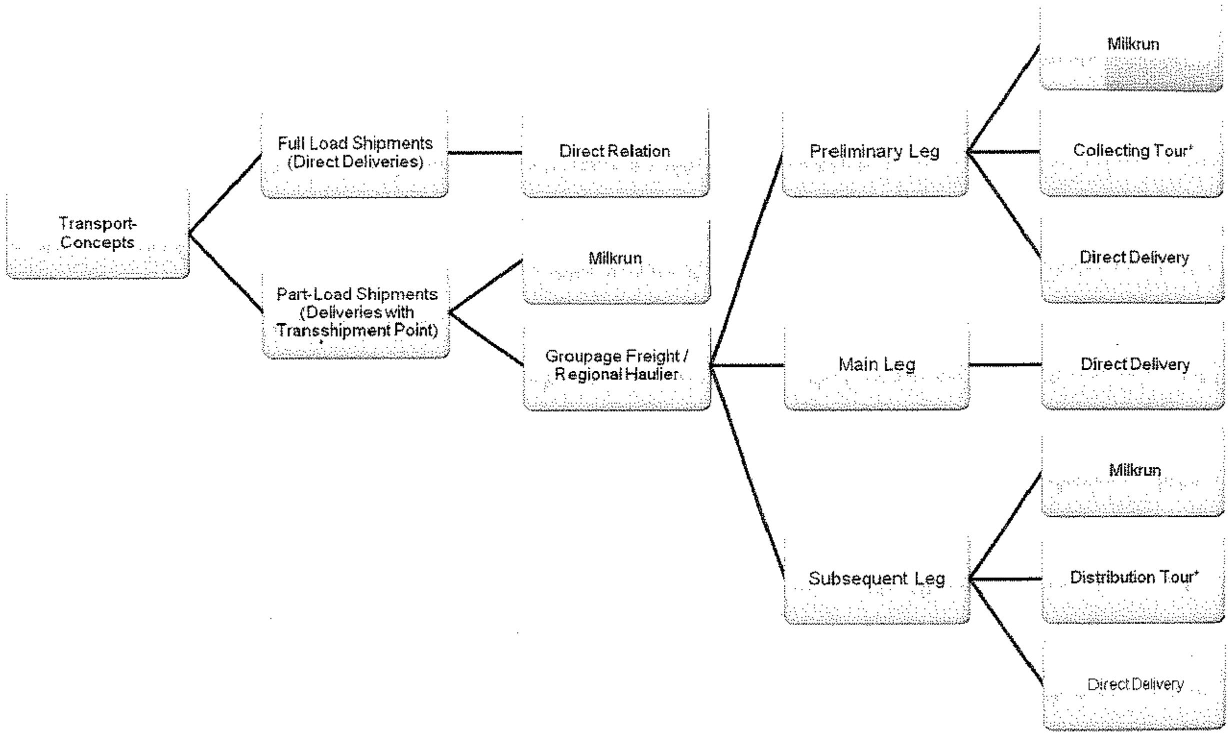
In addition to the basic structure of the systems, the speed of traffic flowing between the individual points in the system must be taken into account [5]. The network strategy is also based on geo-economic considerations such as the long-term development of customer demand or the development of the required delivery time.

Logistical cooperation between different companies is characterized by the bundling of transport volumes. Bundling, also referred to as consolidation, happens when transport volumes are combined to form larger transport batches in order to lower transport unit costs and the unit costs of incoming goods at the target point or of outgoing goods at the source point.

The starting points for the scenarios for transport bundling are the individual parameters of the logistical network structure. The following forms may thus be used:

- Source-point bundling often following the principle of the "milk run" (the shipments intended for a particular destination are collected from several places of shipment, from neighboring places of shipment or from a shipment region and processed together)
- Target-point bundling (shipments from one place of shipment intended for several destinations or for a delivery region are processed jointly and transported together) and
- Transport bundling, where shipments are collected and delivered in one tour.

Further forms of bundling can be inventory bundling or temporal bundling, and vehicle bundling and transshipment point or transit terminal bundling as forms of spatial bundling (Figure 2).



*) similar to Milk run but without 1:1 exchange of empty Cargo-Carriers

Figure 2: *Overview of logistics models considered*

2 Design and Evaluation of Logistics Models

The current state of the art with regard to known logistics models and structures that involve the organization of transport according to ecological principles was the starting point for the design and evaluation of new logistics models.

The control variables required to achieve the objectives (minimize emissions, reduce costs of logistics and increase logistical competitiveness) are the following:

- Traffic avoidance: organize transport more efficiently (improve vehicle utilization, cut down on transport capacity)
- Bundling of goods flows: consolidate in order to optimize the substitution relationship between transport and inventory costs
- Switching freight transport to other means of transport: inter-modal transport

It is also necessary in the long term to validate the results of model's conceptual design. This should be performed in accordance with the main target dimensions - emissions, costs and competitiveness.

2.1 Emission Model

It is in particular the intermodality aimed for in the models that plays an important role in the evaluation of this target dimension. In this point only a selection of the most harmful emissions - CO2, NOX and amount of particulates - are analyzed that are mainly accounted for in the dominant means of transport - road haulage. The emission levels are mainly dependent on the journey, i.e. distance covered by the predefined journey profile and on the allocated transport resource. Diesel or electrical power consumption also plays a decisive role in the output of emissions.

2.2 Cost Model

The cost calculation model is somewhat more extensive and can be subdivided into three different categories (Transport costs, transshipment costs and inventory costs).

With transport costs it is important that the model is based on the actual costs incurred, i.e. the overhead costs, road charges, customs clearance and wage costs and not on the transport tariffs charged by shipping companies.

The road charges are particularly difficult to determine due to the differing systems in the individual countries and play a considerable role in fixing the route.

2.3 Competitiveness Model

The third criterion in evaluating optimization models is logistic competitiveness, which is made up of ability to deliver (a measure of the extent to which the company can guarantee the logistical service requested by the customer - short delivery times compared to the competition are especially important for high ability to deliver) and delivery reliability (delivery reliability rates the service provision of the logistics process - it indicates the proportion of the complete and punctual deliveries compared to all delivery orders) [6].

2.4 Consolidating the Evaluation Models

The evaluation models are populated with data from actual surveys or based in part on assumptions and research findings and then analyzed, or are the result of simulated models. The development of a holistic model of simulation and evaluation is described in the next chapter.

3 *Development of a Holistic Simulation and Evaluation Model*

In order to evaluate freight transport according to economic, ecological and competitive criteria, the most significant influential factors in the process chain must first be identified. The most significant factors such as determining the means of transport and route influence each other and can conflict with the different target criteria. For example, ensuring competitiveness through short transport times and high time contingency can be achieved, but at higher cost.

Transport processes are subject to random fluctuations whose characteristics can influence the subsequent processes. The correlations are not linear and can have a volatile effect on costs, environmental impact and transport times.

Waiting times for customs clearance can thus be subject to fluctuations and can, for example, lead to increased road charges if a surcharge has to be paid due to the delayed continuation of the journey. The reciprocal effects can be manifold and make it more difficult to create a mathematical model and its analytical solution.

Owing to dynamic interactions and taking stochastic phenomena into account, simulation offers a good solution for evaluation. By describing the behavior and the possibility of providing process cycle time fluctuations using distribution functions, so-called confidence intervals can be determined through a number of replications (simulation runs with independent random variables) which allow a prediction to be made as to the bandwidths where the target dimensions are likely to be with a given level of probability. The user gains a feeling for the robustness of the solution through the range between the upper and lower limits of the output values. This prediction serves as the basis for a comparison with other transport chains using alternative means of transport or other routes.

Usually there are only a limited number of alternatives available for a transport assignment from A to B. Additional scenarios are conceivable in the context of a cross-company examination of transport, Combining the partial or universal bundling of goods for freight transport independent of the individual companies allows the focus to be placed on concepts for modes of transport that would not be sufficiently profitable or flexible for the individual companies. The comparison of the universal scenario of cross-company freight transport processing with individual company scenarios allows predictions to be made concerning the potential for savings, reduced environmental impact and the consequences of logistical delivery ability and reliability (Figure 3).

The determination of the output values is based on various calculation steps whose central element is logistical (discrete-event) simulation.

The ecological evaluation is a result of determining the impact of CO2 and NOx as well as an estimation of the amount of particulates released into the environment. Basic information includes data about the route (distance, elevation profile), journey time and driving behavior. The simulation returns information about capacity utilization of the transport means, with consumption being derived as a basic measurement that serves as an input value for calculating emissions.

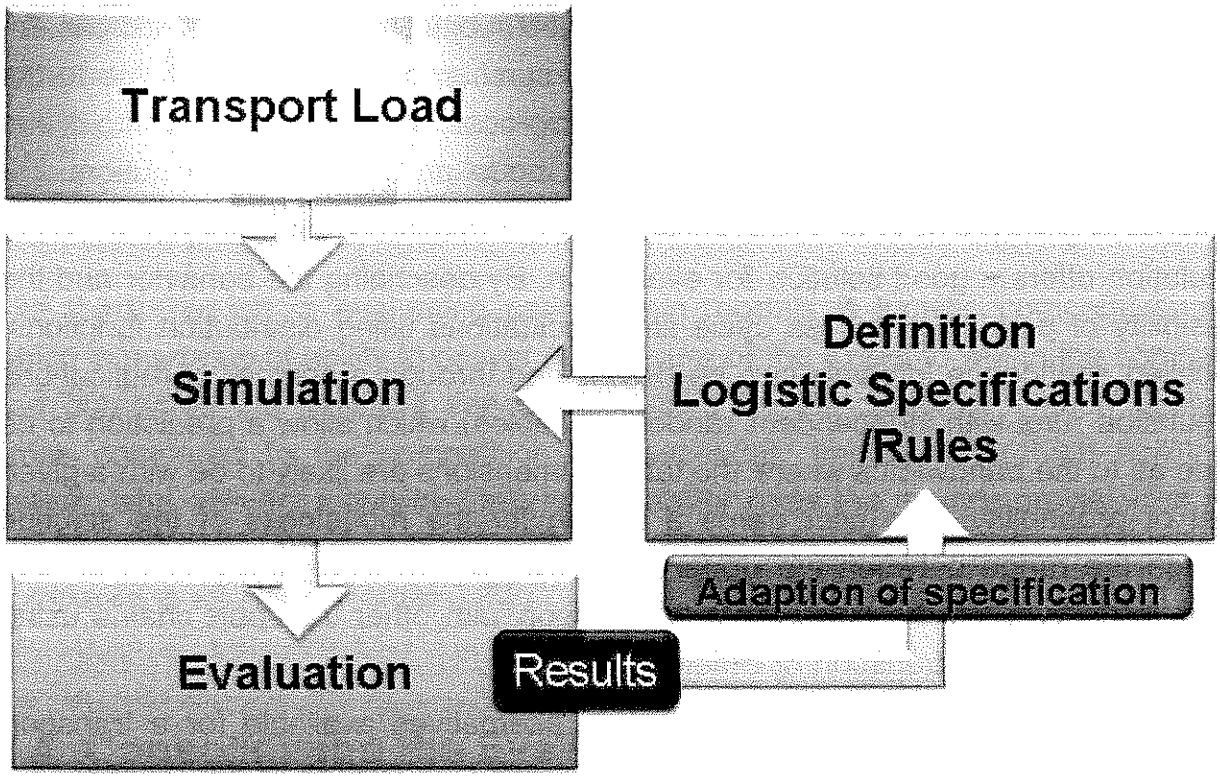


Figure 3: *Simulation and Calculation Model*

Fuel consumption is also an input value for part of the transport costs in the economic evaluation. The total costs are the sum of the transport, transshipment and differential inventory costs. Transport and transshipment costs are calculated using the simulation's process information (time, quantities) multiplied with the relevant cost rates, e.g. road charges. Differential inventory costs take account of the changes in inventory levels in the factories in order to show the quantitative advantage of lower capital commitment and warehousing costs when transport cycle frequencies increase.

Competitiveness is measured by level of service. This is heavily dependent on the requirements placed on supplies to the factories. The logistical demands placed on freight transport are usually fixed time targets with contingency margins. This is justified by the fact that the currently selected transport times and quantities are based on available transport logistics and costs and not on actual production requirements. This results in higher transport capacity utilization owing to the logistics service provider's improved costs but on the other hand the supplier maintains a high level of inventory due to drastic penalties incurred in the event of delays in delivery. Sufficient improvement potential can only be expected from the evaluation of alternative transport concepts if the actual logistical requirements of the target factories can be fully disclosed.

In this case, different scenarios can be evaluated and compared based on the target criteria. Due to the conflicting target dimensions, the results should be viewed as compromise proposals that can be regarded as the basis for decisions. For example, increased delivery frequency might increase flexibility and reduce susceptibility to failure due to shorter reaction times but should really be contrasted with the transport costs involved.

The aim of the evaluation of different scenarios is to determine robust transport logistics chains that are available depending on the current transport situation in question. Thus in a certain week delivery can be effected to the factories by the suppliers independently of one another, and in the following week the cross-company use of an alternative means of transport such as rail can be more expedient owing to the volume that has to be transported.

The decision is based on the alternative logistics models that were examined beforehand and which have taken account of the random factor thanks to the dynamic evaluation of stochastic influences. This evaluation must be conducted continually in order to track changes in costs, times and other basic factors (e.g. emission characteristics of modes of transport) and to assess their effects on the transport logistics chain, and if necessary to develop alternative, new logistics models.

4 Model creation using simulation building classes

The basis for the simulation model is formed by individual logistical building classes (factory, transshipment centre etc) that can be combined with one another to represent any desired logistics concept (point-to-point transportation, consolidation terminals, milk run). These building classes were created in the simulation environment Flexsim® based on the transport streams analyzed and then stored in a library. The generation of the simulation model is therefore effected automatically: the simulation objects are created on the basis of the structural and load data held in the database, their parameters are set and then they are linked to each other via transport relationships.

Structural, procedural and resource-related data are required in order to model with the simulation system. By modeling with building classes, it is possible to describe both the structure and the behavior of individual resources independently and their interaction with other building classes. This inherent knowledge contained in the individual building classes is used and extended by configuring the building classes to form an overall model.

- Product: this building class describes a system load in the form of a schedule indicating what quantities of products are available at the initial location and when.
- Factory: the initial and target locations must be entered for every route.
- Vehicle: the alternative transport resources used must be assigned to the route.
- Handling point: this building class describes a transshipment point where incoming goods are completely unloaded and distributed over outgoing shipments.
- Processing point: a route consists of one or more legs that are interrupted by processing points entailing a time lag. So, for example, the onward journey of the transport resource is delayed by the wait at border customs.

The building classes have predefined default values that they read via the link to the database at the time of configuration. The user can accept or modify these values.

For the simulation, the schedules of the starting points are analyzed and the shipments determined using the stored rules of behavior. This can be explained on the basis of the general code of practice (Fig. 4).

The volume of products that must be transported on the assigned route are scheduled and loaded at the departure times of the transport resources. In addition, a load can be initiated if a predefined minimum quantity is exceeded. The transport resource is simulated over the configured route, i.e. the time shares for each leg and the time overhead for handling and processing points are calculated. The process takes into account, for example, the information on the journey profiles (distance, elevation and road profile) when calculating the journey times on the legs. The model also takes into account that products may be unloaded at various target destinations so that concepts such as a milk run may also be represented.

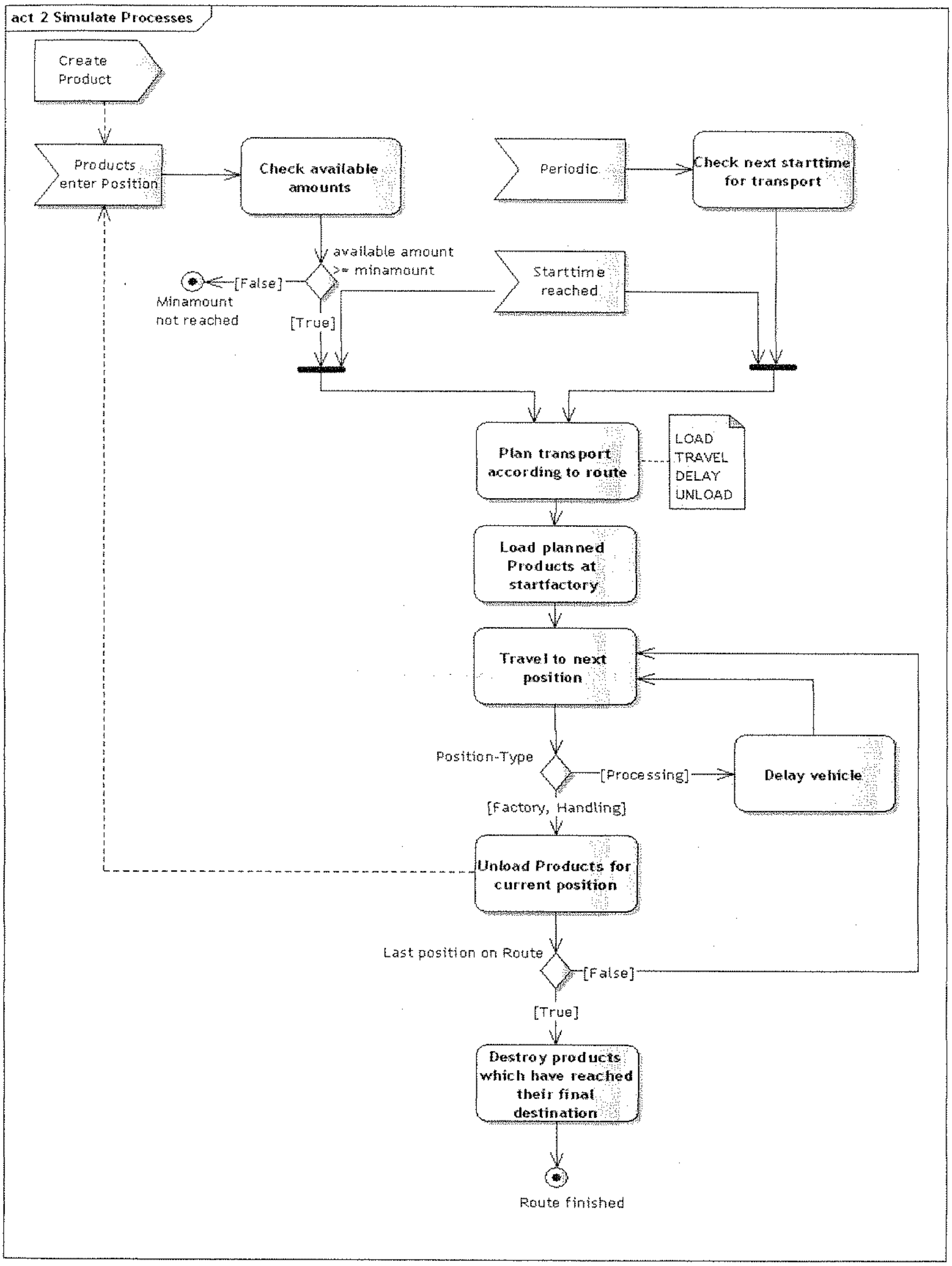


Figure 4: *UML model of the process "Effect transport"*

At the time of simulation all data are continuously time-stamped and written to a database. The (logistical) results gained from the simulation can be subsequently drawn on by assigning them to data sources for emission behavior, cost evaluation and to compare whether the logistical aims have been met. Since the modeling system is simple to use, changes can easily be made to system parameters (e.g. modified transport cycles, use of different transport sources and modes etc.) and allow the effects to be compared on the three target dimensions of economy, ecology and competitiveness. The simulation and evaluation model developed with the procedure described in Figure 5.

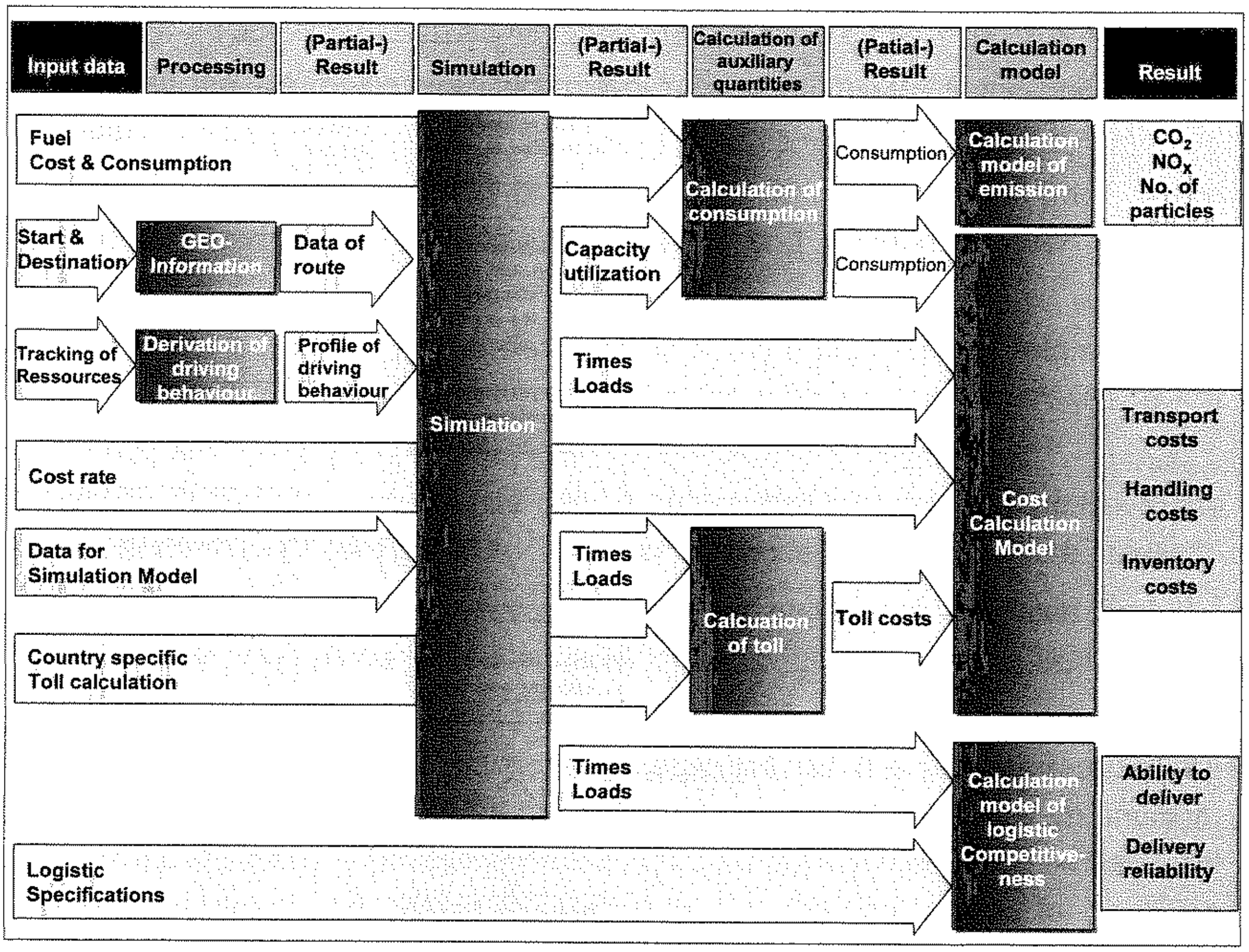


Figure 5: *Structure of the simulation and evaluation model*

With each scenario, the key figures are provided as output in the target fields mentioned of ecology, economy and competitiveness. Owing to the conflicting objectives, decision-making process can be represented by comparing different scenarios and considering the advantages and disadvantages of different compromise solutions. Therefore, in a specific case meeting logistical requirements may have absolute priority over economic and ecological considerations.

The simulation and evaluation model makes it possible to represent dynamic behavior and thus provides the user with the basis for reaching a decision.

5 Status of Research

In the research project "Trans Austria" the developed logistics models are demonstrated by means of the region Timis in Romania. Focusing on 7 automotive companies volumes of outgoing transports were analyzed. Starting from the current state of individual transports, different scenarios were defined. The scenarios are aimed at cost reduction and sustainability in using modes of transport for high transport volumes like rail traffic.

Figure 6 shows 2 defined scenarios of transport bundling for the Timis Region. Scenarios 1 using block train with 3 stops and direct relations from the end of the train not considering locations in Poland and Italy that cannot profit from consolidation with the block train. Scenario 2 limits the block train to one stop but bundles transports further leaving the train to their final destinations.

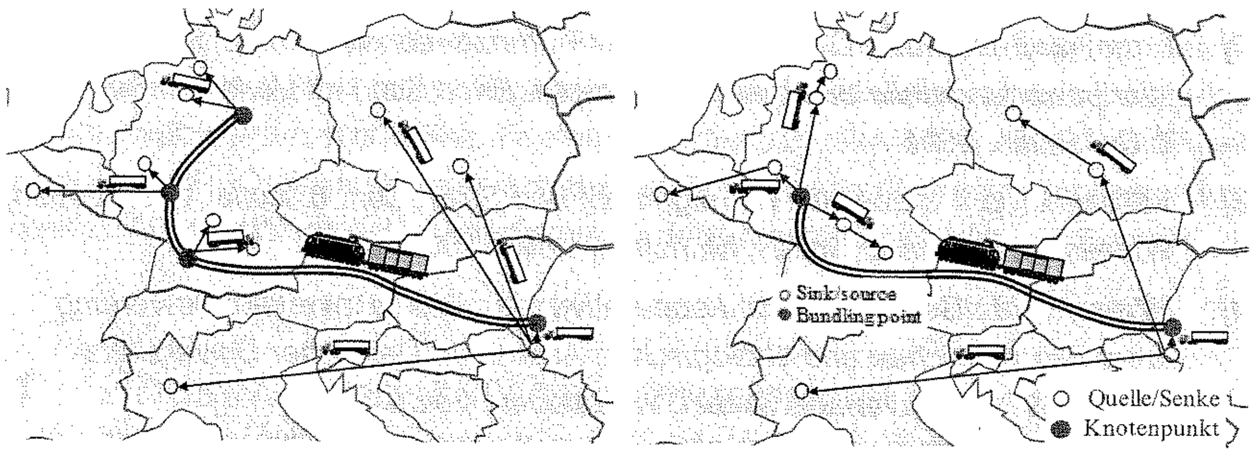


Figure 6: *Scenarios 1 and 2*

Destinations not considered in the main leg bundling were consolidated as well. Shifting the main leg to railway and optimizing the collection and distribution of goods from and to transshipment points costs could be reduced by 15 % in the given case. The ecological impact in reduction of CO2 emissions by 40 %, cutting fuel consumption in half, shows the success in more than one target dimension. The main deficit of the models is overcoming the doubled lead time coming from the ceteris paribus inspection of transports.

In addition to the simulation and evaluation of scenarios a sensitivity analysis was executed to cover the ecological and economical results. Therefore the evaluated scenarios indicated were simulated with lower basic loads keeping all other factors stable. At a level of 70 % of the load, block train concepts as well as the transfer of 66 % of transports to railroad could be maintained. Negative effects of the change in basic loads were determined in the capacity utilization of transport capacities and the flexibility especially for block trains. Nevertheless the developed logistics concepts and cross-company models can stand up to the actual transport handling. Economic considerations show lower costs of scenarios compared to the actual situation. Therefore the model indicated shows full functionality even with fluctuation of volumes and prices.

References

[1] Sihn, W.; Palm, D.; Matyas, K.; Kuhlang, P.: Automotive Region Eastern Europe - AREE: Chancen und Potentiale des "Detroit des Ostens" für Automobilzulieferer, Vienna, 2006

[2] Engelhardt-Nowitzki, C.; Oberhofer, A. F.: Innovationen für die Logistik-Wettbewerbsvorteile durch neue Konzepte, Erich Schmidt Verlag GmbH & Co, Berlin, 2006

[3] Vahrenkamp, R.: Logistik: Management und Strategien, 6. Auflage, Oldenburg Wissenschaftsverlag GmbH, München, Wien, 2007

[4] Rösler, O.M.: Gestaltung von kooperativen Logistiknetzwerken: Bewertung unter ökonomischen und ökologischen Aspekten, Deutscher Universitäts-Verlag/GWV Fachverlage GmbH, Wiesbaden, 2003

[5] Pfohl, H.-C.: Logistikmanagement: Konzeption und Funktionen, 2., überarbeitete und erweiterte Ausgabe, Springer-Verlag, Berlin, Heidelberg, New York, 2004

[6] Wiendahl, H.-P.: Erfolgsfaktor Logistikqualität, Springer, Heidelberg, 1996