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**ASME 2010 10th Biennial Conference on Engineering Systems Design and Analysis (ESDA2010)**
**July 12-14, 2010 • Istanbul, Turkey**



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# WELCOME FROM THE CONFERENCE CHAIR

Prof. Dr. Nilufer Egrican
Conference Chair
ESDA2010

Dear Colleagues,

On behalf of the organizing committee I would like to welcome you to Istanbul for the **ASME 2010 10th Biennial Conference on Engineering Systems Design and Analysis (ESDA2010)**. This three day conference of ASME is being organized by Yeditepe University and the ASME Turkey Section. The purpose of this letter is to give a brief overview of the current standing of the conference from an organizational viewpoint.

The conference organization started with the launch of conference website at http://www.asmeconferences.org/esda2010. An exhaustive effort aimed at announcing and publicizing the conference paid off well, indicated by the large interest received from the related academic and industrial circles. A record number of abstracts (topping 1200) were received, almost half of which (568 to be exact) being accepted as full papers. The accepted papers were categorized into a total of 15 tracks which are: Advanced Energy Systems (42), Advanced Materials and Tribology (56), Applied Mechanics (56), Automotive Engineering and Technologies (40), Bioengineering and Biomedical Technology (19), Computational Mechanics (41), Design Engineering (43), Dynamic Systems and Control (63), Fluids Engineering (30), Heat Transfer (49), Manufacturing Systems (32), Mechanisms and Robotics (34), Mechatronics (14), Micro and Nanotechnology (38), and Science, Engineering & Education (11), where the brackets indicate the number of papers for the respective track. We are expecting that authors of a vast majority of these papers will show up and present their work during the event.

There are five keynote lectures highlighting the conference. The speakers and their respective speech titles are, Dr. C. D. Mote, Jr. (President, University of Maryland): Nurturing Innovation; Dr. Nam Pyo Suh (President, KAIST): Innovative Engineering Systems; Dr. Nihat Berker (President, Sabanci University): Undergraduate Education with Focus on Research; Dr. Hugh Spikes (Professor, Imperial College): Recent Advances in Liquid Lubrication Research; and Dr. Adnan Akay (Vice President, Bilkent University): Dissipation and Irreversible Energy Transfer in Dynamics Systems.

In tandem with the conference there will be professional and student activities in conjunction with ASME. Prior to the conference, an ASME short course program is scheduled to take place between 7-11 July, 2010. This will be the first time such an event has ever been organized in Turkey. In addition, following the conference, the ASME District H Student Professional Development Conference (SPDC) will take place between 14-16 July, 2010. Highlighting this event, a Student Design Contest (SDC) will be held in the conference venue, on July 14, 2010.

A large selection of pre- and post-conference tours is being offered by Interium, the official travel agent for the conference. Social program of the conference includes a welcome reception following a "live documentary" presentation entitled "Istanbul: City of Cities"; a gala dinner at the social facilities of Istanbul Chamber of Commerce located in Cemile Sultan Woods; and a farewell boat cruise aboard a Bosphorus cruise ship.

I would like to take this opportunity to thank the keynote speakers for their participation, authors for submitting their valuable work to the conference, reviewers for taking time and reviewing papers, track chairs for leading their technical tracks, and the conference technical chair for his tremendous effort in organizing the technical content. In addition, to members of the organizing committee who have worked very hard to make **ESDA 2010** a highly successful conference both technically and socially: your tremendous efforts are highly appreciated.

I wish all participants a pleasant week during the conference and for our international guests, I wish you a favorable stay in Istanbul and Turkey. I hope that you spend a memorable time in the next few days and that this conference will produce fruitful results for all of you.

Thank you again!

**Prof. Dr. Nilufer Egrican**
Yeditepe University
Conference Chair

*Technical Tracks*

- **Advanced Energy Systems**
- **Advanced Materials and Tribology**
- **Applied Mechanics**
- **Automotive Engineering and Technologies**
- **Bioengineering and Biomedical Technology**
- **Computational Mechanics**
- **Design Engineering**
- **Dynamic Systems and Control**
- **Fluids Engineering**
- **Heat Transfer**
- **Manufacturing Systems**
- **Mechanisms and Robotics**
- **Mechatronics**
- **Micro and Nanotechnology**
- **Science, Engineering and Education**

Welcome to the ESDA2010 CD.

This CD contains the final papers of the ASME 2010 10th Biennial Conference on Engineering Systems Design and Analysis. To locate papers you can do one of the following:

1. Search. You can perform a fielded search of the title, author(s) name, affiliation or paper number.
2. Review the papers listed in the tracks.
3. Browse the Author Index.

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# DESIGN ENGINEERING

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# CONCEPTION AND EVALUATION OF SUSTAINABLE CROSS-COMPANY LOGISTICS MODELS

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## ABSTRACT

Business networking strategies and especially co-operation in logistics is gaining momentum for individual companies in order to survive in competitive markets. As cross-company transport bundling is a powerful approach to optimize cost structures, this publication deals with the conceptual design and evaluation of cross-company logistics models. For this purpose, a simulation and evaluation model is presented that supports the development of new logistics concepts. Therefore models for the calculation of emissions, costs and logistics competitiveness, have to be created and combined to holistically validate and evaluate the new approach. This combination between the three different target values distinguishes the developed model from already published methods. Based on the sustainable, company-wide approach, potentials for optimization in the areas emissions, costs, and logistic competitiveness can be detected and by means of these analysis results, new sustainable and energy efficient logistics models can be designed.

## INTRODUCTION

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 (AREE) not just to take advantage of the emerging market but also because of the low wage costs [1, 2]. These new production sites, which were established partly with the intention to transfer operations from existing Western European facilities or in order to provide a necessary growth of capacity, supplier and customer structures of the parent plants, were often just assumed. Approximately two thirds of suppliers as well as customers of Eastern European Tier 1 suppliers are still situated in Western Europe [3].

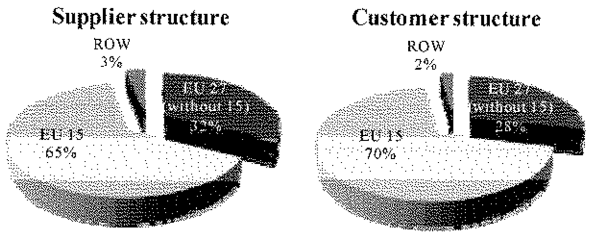



**Figure 1. Demonstration of supplier and customer structure of suppliers in the CEE region[1].**

The trend towards relocation has shown that the exchange of goods leads to new demands and challenges for transportation and logistics [4]. 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 [5].

[1] EU 15: member countries of the European Union prior to May 2004, EU27: current member countries of the European Union

Particularly transit countries like Austria suffer from increased traffic volumes and constantly rising environmental and infrastructural burden. Further, rising labor costs in Eastern Europe make it necessary to focus on efficient logistics processes. Business networking strategies and especially cross-company co-operation is one of the key factors to improve in production issues as well as in logistics and hence to survive in competitive markets [1, 6]. Based on this situation, a new simulation and evaluation model, which supports the development and evaluation of new logistics concepts, was developed. It is used for the validation and evaluation of cross-company logistics models. Due to the new, holistic evaluation approach potentials for optimization in the areas emissions, costs and logistical competitiveness are targeted on developing new sustainable and energy-efficient logistics models.

## CROSS-COMPANY LOGISTICS MODELS

The currently applied logistics processes, especially for the specific needs of individual enterprises do not appear optimal from a holistic point of view [7, 8]. Deficits might emerge from direct transport running far beyond capacity, use of small transport carriers, less-than container load (LCL) with long running times or multiple handling steps as well as bad transportation tariffs due to small quantities. High stocks and capital tied up are results of this inefficiency. Since many companies have a similar source-target-behavior the potential of cross-company bundling to optimize transport efficiency is high.

### Existing consolidation approaches

The relevant literature in the field of logistics and operations research knows only very few approaches for planning transportation networks which include the consolidation of transport flows from multiple shippers. Although operations research has been used for almost all types of typical decision situations in intermodal transportation planning, the number of studies carried out for each problem is still very limited and mainly at operational level. [9]

A basic approach to evaluate multiple consolidation strategies is proposed by Janic et al. [10] by employing multi-criteria methods and combining them in their Simple Additive Weighting (SAW) method. By doing so they evaluate 23 existing consolidation networks for favorable characteristics. In the case of rail transport they found out that the optimality of a rail consolidation network depends on its number of nodes as well as interconnecting routes and frequency.

Trip and Bontekoning [11] describe an approach for bundling small freight flows into a multimodal transportation network. The theoretical considerations are then illustrated by applying it to an intermodal terminal in the Netherlands.

Another approach proposed by Jourquin et al. [12] is built upon a geographic information system (GIS) which represents the modeling environment for transport bundling activities. Within this environment the user can map different bundling scenarios, whereupon these are evaluated by simulation for their optimality according to given criteria. The authors present a proof of concept by applying it to a trans-European transportation network.

Another direction of research is the optimization of traffic schedules as proposed for example by Newman and Yano [13]. They present a mathematical formulation for a train scheduling problem in centralized and decentralized environments. Their target function consists of minimizing "operating costs, including a fixed charge for each train, variable transportation and handling costs for each container and yard storage costs, while meeting on-time delivery requirements" [13].

Another scheduling-based approach is presented by Moccia et al. [14]. They assume that a network can consist of a mix of scheduled and flexible-time transportation services. Upon this they propose a modeling concept based on digraphs to map possible network structures. Column generation algorithms are applied to these models in order to identify optimal scenarios.

A recent approach for planning multimodal transports of hazardous materials based on lead-times is proposed by Verma and Verter [15]. The paper describes a bi-objective optimization model to plan and manage intermodal shipments.

As this brief literature review shows, most existing approaches resort to limiting the search for optimal scenarios to certain dimensions like lead-times or train schedules. As this reduces the flexibility of possible transport bundling methodologies, the need for optimization techniques which provide more degrees of freedom exists. One possible approach is using discrete-event simulation techniques. As Macharis et al. state, "simulation models offer the possibility to incorporate more realistic details into the model" [16]. However, one of the main limitations of simulation techniques is that they are not able to generate candidate scenarios for optimal transport bundling strategies [17]. Therefore the definition of optimal scenarios is one of the main challenges when developing logistics models.

### Logistics networks

There are various approaches for cross-company logistics models that conform to the general network model of logistics. These models represent networks transporting rights, goods, finance and information where spatial, quantitative, informational and temporal differences as well as company boundaries are crossed [18]. Parameters defining the structure of a logistics network are paramount [19]:

- Number, locations and functions of source points (= loading locations, making goods available),
- Number, locations and functions of target points (= unloading locations, points of reception),
- 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 [19].

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 where the network nodes serve as consolidation terminals where the flows of goods are collected and/or as break-bulk terminals where the flows are in turn distributed. (Figure 2)

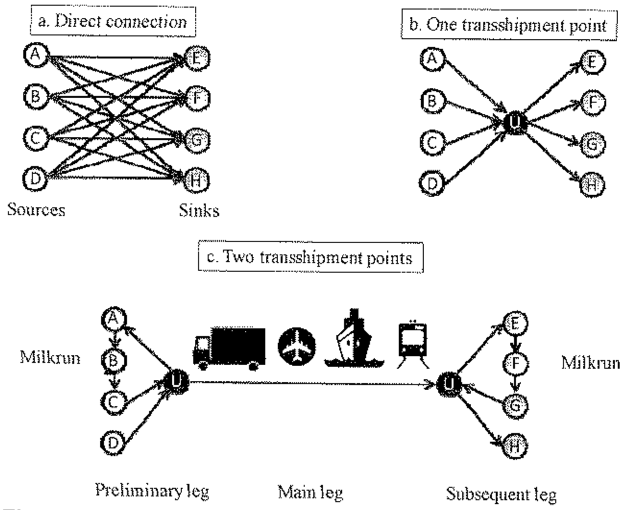



**Figure 2. Illustration of consolidation by means of transshipment points [20].**

The mixture of logistics systems made up from the given basic structures is decided in the logistical network structure. The processes are designed when the logistical capacities are superimposed on this. The logistical capacity can be subdivided into transport capacity, warehousing capacity and 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 [21]. 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.

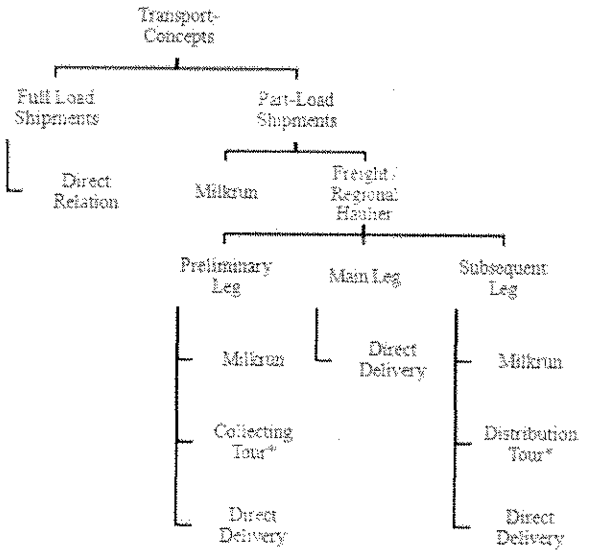
Summing up, the criteria logistics costs, supply service, adaptability, susceptibility to interference, transparency and time for planning and establishment of the system are important in the moment of developing and evaluation logistics models [21].

## CONSOLIDATION OF SHIPMENTS

As described in the initial situation, optimization of transports for individual businesses does not appear ideal; therefore companies can align with partners to a logistical co-operation and bundle transport volumes. Bundling, also referred to as consolidation, happens when transport volumes are combined to form larger transport batches in order to allow more efficient and more frequent shipping by concentrating large flows onto relatively few links between terminals, thus lowering transport unit costs and the unit costs of incoming or outgoing goods at their starting or target points. 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**, where 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**, **vehicle bundling** and **transshipment point** or **transit terminal bundling** as forms of spatial bundling (Figure 3). The number of transports between sources and targets can be reduced by the setup of transshipment points from m x n to m + n, m and n being the number of source and target points [22, 23].




*similar to milkrun but without 1:1 exchange of empty Cargo-carriers

**Figure 3. Overview of logistics models considered.**

Bundled transport over the long run between two transshipment points can raise high potentials due to low transport costs and efficient use of transport capacities [9]. Logistics performance is improved by the raised frequency of transports. Overall every bundling type must meet the requirements of savings through consolidation of synergy effects to cover higher transport costs, operation costs of handling points or longer distances of time frames in comparison with direct relations.

The goal to reduce logistics costs while keeping logistics quality at the same level or raising the quality (delivery times, adherence to delivery schedule) is the main focus when designing the transport network. An iterative method is needed to evaluate the impacts of modifications in logistics models regarding ecology, economy or logistic competitiveness.

Transport bundling or cross-company logistics networks are originally based on the idea of good distribution in urban centers. The different approaches can be summed up with the term city logistics [24]. Other known developments of transport bundling of different suppliers are area contract freight forwarders, bundling and delivering goods for one plant conjointly. Collaborative approaches and the logistics models in this case are mainly based on the following premises:

- Identification of route sections where transport volumes can be handled with efficient transport carriers
- Availability of adequate partner for transport bundling on route sections (legs)
- Possibility of individual businesses to efficient usage of carriers
- Distance from source to target of possible nodes considering impacts of variance from ideal path
- Prioritization from transport volumes given limited capacities of one carrier in the main run as a result of different impacts on target categories
- Possibility to change transport frequency

## DEVELOPING A HOLISTIC SIMULATION AND EVALUATION MODEL

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. Considering in number of parameters taken into account the complexity for setting up an optimization algorithm would be by far more effort and therefore cost.

As transferability of the model is one of the goals, mathematically optimal solutions for the logistics problem were abandoned for less expensive and time demanding robust solutions defined by experts.

The essential experts' know-how can be more easily incorporated in simulation models. Therefore simulation was chosen in this case to evaluate and support the decision process of defining new cross-company transport concepts for a given number of companies.

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 within 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. Combining the partial or universal bundling of goods for freight transport independent of the individual companies allows focusing 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.

### Evaluation model for logistics models

The starting point for the design and evaluation of new logistics models was the current state of the art with regard to known logistics models and structures that involve the organization of transport according to ecological principles. 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 good 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 the models' conceptual design. This should be performed in accordance with the main target dimensions - emissions, costs and competitiveness.

The **ecological evaluation** is a result of determining the impact of $CO_2$ and $NO_x$ as well as an estimation of the amount of particles 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.

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. 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.

The third criterion, **logistic competitiveness**, is made up of the 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 a 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) [25]. The resultant level of service is heavily dependent on the requirements placed on suppliers delivering 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 logistics costs and not on actual production requirements. This results in higher transport capacity utilization owing to the logistics service provider's improved costs but at the same time pressing the supplier to maintain 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 be contrasted with the transport costs involved.

Against this background, it becomes apparent that the cooperative planning of multimodal transport is affected by a multiplicity of factors. Numerous interdependencies between these parameters and the goal criteria such as costs, emissions, or flexibility exist. The evaluation model thus has to solve the conflict of goals like the trade-off between costs and guaranteeing competitiveness by applying stocks.

Beyond that, the identified parameters are often afflicted with uncertainty. These affects frequently influence the quality of material planning decisions and transport planning considerably.

Owing to dynamic interactions and taking stochastic phenomena into account, a static estimation of the behavior is difficult or almost impossible. Simulation has satisfactorily demonstrated its ability to illustrate and evaluate systems with dynamic behavior.

In order to provide a simulation model for logistics operators, the system-specific characteristics in a suitable simulation environment have to be illustrated. To achieve flexibility in planning regarding changes of logistics models or changes of the basic conditions, it is useful to provide a generic and easily adaptable model. For this purpose, the models of intermodal transport were illustrated within an application platform for simulation. This simulation environment permits the illustration of various technical models in a modeling environment adaptable to the planning domain. Furthermore, the environment permits an automatic derivation of simulation models and a return of the results to an economic or ecological level. In the next section, the fundamental methods of the application platform simulation and the development of a simulation model for the planning of multimodal transport are described.

## Application platform for simulation

Depending on which simulation tool is chosen from the set of tools with different universal validities and application references, the simulation expert can access more or less preconfigured building blocks. Special simulators contain solutions matched to the specific area of the domain of application, thus simplifying handling. The higher the degree of universality, the more varied the possibility of creating and depositing own functional building blocks becomes; however, the necessity of a simulation-specified training increases as well. The application environment developed by V-Research deals with simulation models in production and logistics [26].

To execute a conventional simulation study, a substantial amount of time and money has to be invested, which still prevents small and medium-sized businesses to apply those. To prevent a planner, who is usually well trained in his respective systems domain, from dealing with the simulation expertise itself, it is helpful to develop an instrument that lets him answer upcoming questions without specific simulation know-how in an accessible amount of time. Thus, the planner is able to define planning tasks, generate models, analyze results, and optimize those results by comparing different scenarios.

The core of the platform represent application related and technically oriented components that base on the utilization of open industry standards (.Net Framework 2008) and reliable, well-tested simulation software. The concept embraces the idea that each simulation study needs certain key functions and procedures; contains customer and project specific characteristics and requirements; should be expandable concerning detailing, functionality, and system boundaries; and lets other users (e.g. customers) enhance the model [27].

The separation between task specific and resource specific components is reflected in the structure of the application environment. Task specific components summarize all aspects concerning process logic of an application that are illustratable by a (production and/or logistic) system. Examples would be the definition of manufacturing technologies used for processing orders, process outcomes, product structure etc.; logistical sequencing strategies (push, pull, KANBAN, ...); organizational classifications (employees assigned to department and resources, shift schedules, ...); as well as an architecture for administering simulation runs, result data, and shift schedule data.

These components signify the applied level. The technical level comprises the structure of a production and logistics system. The resources (machines, means of transportation, tools, ...) are systematically described in predefined components. In order to create a complete model, these project specific resources are substantiated and incorporated into a basic model. The entire architecture thus differentiates between technical components, application oriented components, and the actual business application. The business application represents the simulation study, which can be made up of a number of simulation experiments. The component model is well suited for customer specific simulation applications within a short period of time.

### Simulation and model creation

The base of the simulation model is formed by individual logistical building modules (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 modules were created in the simulation environment Flexsim® based on the transport flows 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.

The individual phases starting with acquisition and preparation of data up to the analysis of the scenarios pass through the different stages as shown in the following figure:

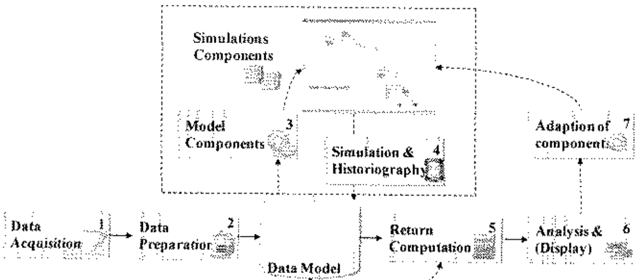



**Figure 4. Stages of the simulation and evaluation process [8].**

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

- **Product**: this building module 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 module 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 central technical construct in the domain transport planning is the route, which represents a given start-destination-relation, for example between a loader in Eastern Europe and a Western European production facility. This route is either being served by a direct relation or by intermodal transport, which is usually conducted through certain hubs. In any case, the chosen domain model displays the relations from start to destination between Eastern and Western production locations. The actual routes taken were tracked via GPS and then contributed into the system's data. The information includes not only kilometers driven for the running time calculation, but also other data such as altitude profiles. These profiles further refine the simulation model leading to consumption and emission data of the transport resources to be implemented in the model.

The system load of the simulation model is determined by the output of products on the loaders' side, which is being processed in form of a tabulated schedule. A profile of each originating plant is defined therein, stating which products are being put out in which amount at what time. The running time of the simulation is thus supplemented with the corresponding number of product objects that later undergo the defined transport process (stated below).

Transport resources are active parts when it comes to overcoming regional distances within the domain model. In the case of the afterwards presented application various types of trucks and trains are displayed in the model. Transport resources are matched with certain routes and characterized by a number of attributes. Besides loading and unloading times for the transport resource, triggers have to be defined when a transport resource leaves a location (e.g. every Monday 8 a.m.). Furthermore, additional data can be added to the model, such as cost, consumption, emissions, or any local- or time-specific data. Therefore, the model is formed in a way that specifies consumption data for different types of trucks and diesel locomotives. In case of electrified railways, the proportionate emissions for the necessary power are included as ecologic target factors in the simulation for each country.

In the domain model, a plant can serve as a starting point or as a destination, or even as a hub to add products to or discharge items from the transport. Product objects are created in the course of simulation, beginning at the starting plant with a time-amount-profile, and they are dissolved after reaching the destination.

The handling point describes a special location along the route, with incoming transports being unloaded and leaving transports prepared for the next trigger with their inherent loading and idle times (see transport resource).

In contrast to the handling point, no change of transport resource and no transshipping take place at a processing point. This simulation block simply represents a location where the transport is stopped for a certain handling time, calculated as a stochastic variable. This method enables the display and calculation of customs clearance at national borders. The handling itself is not directly calculated due to model simplification, and it is thus represented by idle time.

Beside of these simulation blocks, the transport process is an integral part of the simulation model. The later presented application includes a process that starts off with the production of products at a starting point and ends at the destination point, where the products are destroyed. On closer inspection, the transport starts, when a specified amount of products is available at a certain location or the starting trigger for a certain means of transportation is activated. Consecutively, the transport process is being planned according to the route; the products are loaded on the transport resource and then transported to the next stop on the route. If the next stop is a plant or handling point, the products are unloaded and, if needed, prepared for the next shipment. In case of the next stop being a handling point, the idle time is applied and the transport continues. Upon arrival and unloading of the transport, the respective products are destroyed in the simulation environment and the simulation run is ended.

Throughout this process, the running time and its contributing factors of each process entity, such as time needed for loading procedures, handling activities, driving times, and emissions depending on the road profile (distance, incline, street conditions), are logged. After the simulation, this logged data supplements the results analysis. A historiography of the granulated simulation data in a database enables detailed and flexible analyses and a deduction of key performance indicators. The (logistic) results drawn from the simulation can consequently be applied to calculations with data sources concerning emission behavior, for cost analyses, and for comparisons whether logistics targets have been met. The model structure simplifies changes made to the parameters (e.g. varied transport cycles, use of various traffic resources and carriers etc.), and a comparison of the effects on the three target areas economy, ecology, and competitiveness is enabled. Based on the opposed target dimensions, a decision can only be made through comparing different scenarios and considering the pros and cons of all compromises

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 is depicted in Figure 5.

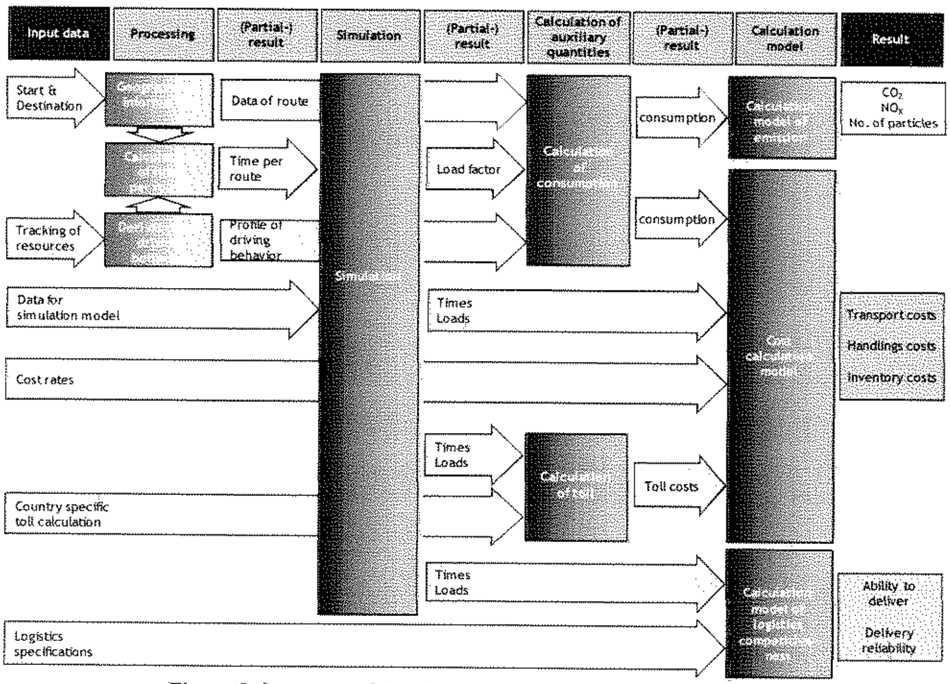



**Figure 5. Structure of the simulation and evaluation model.**

## APPLICATION OF THE MODELLING APPROACH TO A ROMANIAN AUTOMOTIVE CLUSTER

In a research project funded by the Federal Ministry for Transport, Innovation and Technology (BMVIT) as well as the Austrian Research Promotion Agency (FFG) 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.

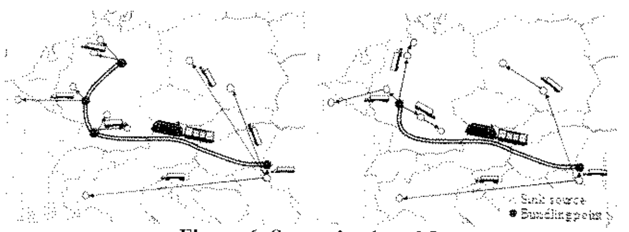


**Figure 6. Scenarios 1 and 2.**

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. 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 $CO_2$ 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 transport 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.

## CONCLUDING REMARKS

This paper visualized models to simulate and evaluate potentials of transport bundling for cross-company logistics networks. For an example region, the similar source-sink-behavior of companies within a specific region was demonstrated and the approach of cross-company bundling thus permits a shift to intermodal logistics concepts. The empirical analysis could give proof to the high potentials of cross-company logistic networks and showed a reduction of road traffic, emissions and costs.

Further the analysis showed the great complexity of the problem that was built in a simulation framework and the linked challenges for possible implementations which constitute further research developments. The problem of the simulations main limitation of not being able to generate to optimal scenario of a logistics network was addressed by developing a generic and easily adaptable model. It permits the illustration of various technical models and thus enables the application of an iterative, IT-supported procedure. The logistics specifications were adjusted step-by-step by means of heuristic methods in order to evaluate and optimize the different logistics models.

Optimization of the given set of problems would be a possible expansion keeping in mind the time and cost needed to set up the base and ensuring the transferability of a developed optimization model.

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