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**DYNAMIC AND SEAMLESS INTEGRATION
OF PRODUCTION, LOGISTICS,
AND TRAFFIC/TRANSPORT (DYNAMO PLV)
– CHALLENGES OF AN INTERDISCIPLINARY
RESEARCH PROJECT**

1. The project setting: Disciplinarity and interdisciplinarity of production, logistics, and traffic/transport

Production, logistics, and traffic/transport face particular challenges in regards to their specialist disciplines. The multidimensionality of the problems calls for an interdisciplinary study of all the specialist disciplines. This is the only way to deliver new approaches, which will then in turn lead to a sustainable increase in the value added chain. The aim and challenge of this research project is, to transfer existing interfaces between the disciplines into a conjunction, enabling a more thorough scientific penetration. With globalization, production companies are increasingly confronted with globally distributed value added chains. As a consequence thereof and due to the freight traffic's strong growth our transport systems come close to their capacity limits. This in turn hampers our mobility, turning transport from an enabling to a limiting factor for all production and logistics processes. Traffic related decisions made by public authorities have to be considered as well, for they similarly influence production and logistics. When striving for a solid decision-making foundation, with an integrated manufacturing, logistics and traffic model, it is essential that a seamless view of all interdisciplinarity is conducted instead of the commonly used optimization of the sub systems. The need for the dynamic adaption of changes (such as new technologies), coupled with the high responsiveness due to the lack of the demands' predictability, are the reason for the complexity of such an integrated production, logistics and traffic model. This can easily be derived from megatrends such as "shortening product life cycle" and "quickly changing customer requirements in small market segments". Businesses as well as governance levels need to make decisions quickly. The knowledge of the sub systems' general conditions, their quantified description as well as their future predictability, are essential when trying to achieve high dynamics and maximum responsiveness. This in turn will allow the consideration of uniformed system design dimensions.

Taking all economic, ecological, and social sustainability into account will lead to a conflicting goal management. The stress ratio between flexibility and the sustainability's three goal destinations for all individual topics needs to be taken into account. The below outlined objectives and topic models are to provide businesses and politics alike with models, methods and instruments enabling fast decision making processing. This in turn will lead to the seamless development of product and information flow in manufacturing, logistics and traffic/transportation.

Figure 1 shows the stress ratio by analyzing the three levels in the sub projects of Dynamo PLV.

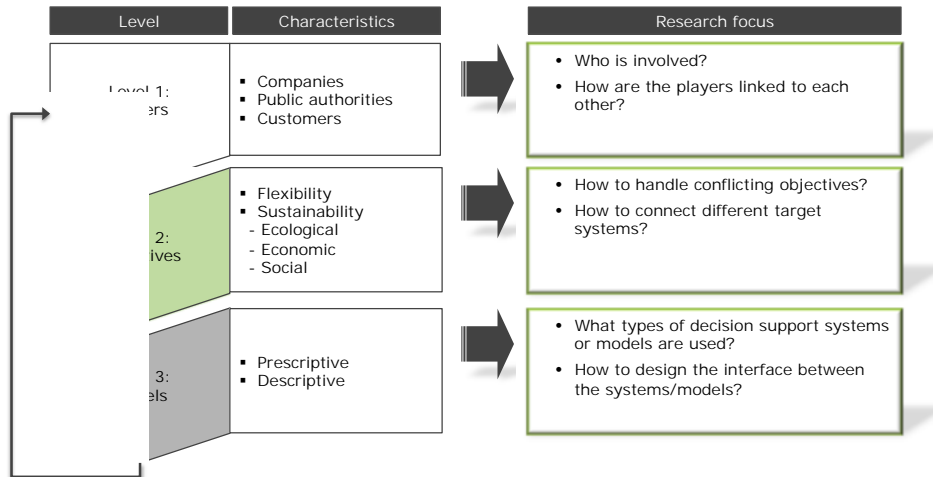


Figure 1. Three levels of research

Level 1 (players' level) outlines and implements the businesses' flexibility as well as the public authorities' and the consumers' decision-making. This is the foundation for the sub-projects' flexibility within the production as well as the consolidated depicted sub project of freight-transportation. The above-mentioned stress-ratio between flexibility and sustainability in its three dimensions is outlined in level 2. Each player in a decision making process is exposed to this stress-ratio.

All of the outlined sub projects play its part to resolve the stress-ratio as a whole instead of shifting it to another level of the value added chain. The utilization of model-mix at the next level is mandated when trying to resolve the stress-ratio. Hence, we are using prescriptive models to derive optimal decision alternatives as well as descriptive models to describe and explain existing and future decision-making contexts. These models are the basis for the decentralized decision support systems that can be used by all players.

This project's interdisciplinary consideration is genuinely innovative at world level. Processing such a fundamental and comprehensive topic mandates the bundling of expertise, which in turn is embodied in the interdisciplinary focus of the outlined subjects. Instead of improving the competitiveness of an individual company, this project is set out to increase the competitive ability of the entire value added chain. Once the concept for a decision support system is developed it should be made available to the decision it makes in business and politics alike.

Current developments as well as the previously outlined goals and challenges enable the definition of the key subjects: supply (global sourcing), production, and demand. In this context one has to distinguish between strategic distribution logistics and operative demand fulfillment. This stands in sharp contrast to freight traffic, whereas the strategic distribution is bridging between productions' and transport systems. The framework for the overall aim of Dynamo PLV, namely the development of decision making systems, is being established by priorities derived from the analysis on the role of information technology and the decision-making of an interdisciplinary system. Figure 2 shows the overall system with its key subjects, which are covered by sub projects.

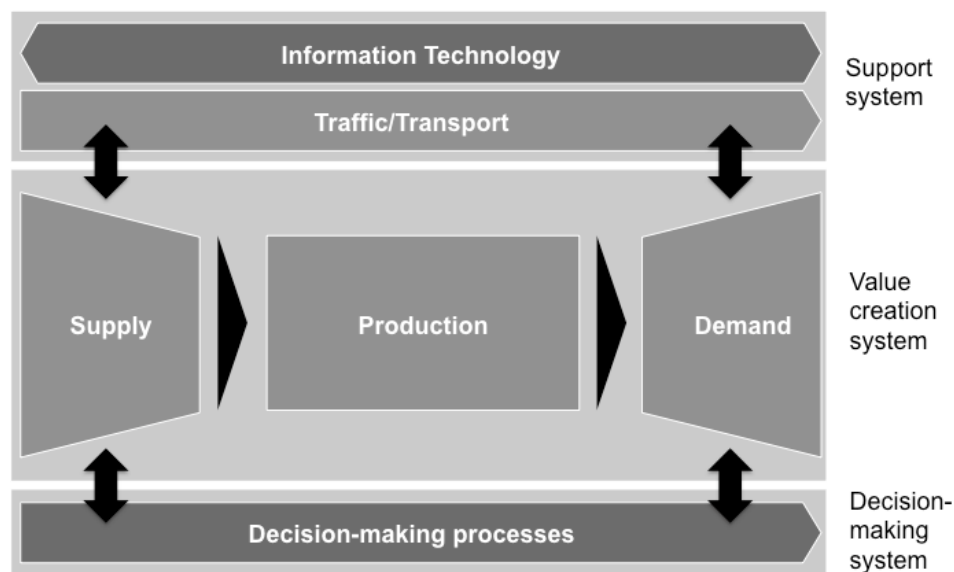


Figure 2. Overall system of Dynamo PLV

A realization of decision-making systems mandates the consideration of the entire value added chain. Hence, it is essential to consider the freight and information flow, in accordance to the *logistics'* meaning of overall-flow, which includes production- stock- and transport processing (Pfohl, 2004). A thorough perspective of adding value mandates the consideration of production as well as the upstream and downstream of value added activities. According to the *production's* perspective, there is quite a research gap between plant traffic, respectively transport processing as part of manufacturing (Abele, Brungs, 2009). However, this is a core element in the all-in consideration of logistics and traffic within the value added process. The third and essential element for a seamless consideration of a system-wide decision-making process is characterized by the

traffic. In this context it is important to understand the significance of economic trade, something not sufficiently represented in the existing research environment (Boltze, 2011). There are neither detailed analysis on how traffic and transport measurements impact the production and logistics nor are there any information on how production and logistics measurements influence the traffic. Researches generally focus on freight traffic.

Along the value added chain we give a detailed description of “supply, production, demand” as the heart of the logistics system followed by the accompanying topics represented by “traffic” and “information technology” to outline the goals and work package individually. Decision-making processes, which form the thematic framework of this project’s overall goal, are presented in detail in the following section “interdisciplinary decision making”.

1.1. Supply*

Global Sourcing describes the targeted integration and coordination of global procurement and production strategies, in order to optimize the company’s added value. Between 1995 and 2004 the world trade volume doubled, indicating sustainable growth of global sourcing, as shown by the development of “emerging markets” such as China and India.

Records show that added value is increasingly relocated abroad – so-called Offshoring (Lockström, 2007). One of the companies’ key issues are how and where to increase added value, whether to manufacture in own production plants at home or abroad and last but not least if purchasing is undertaken in alternative regions. The companies rarely meet the complexity of global sourcing decisions. On one hand it mandates the coordination of the inter-dependent decisions of procurement (e.g. selection of the suppliers, price and quantity structure), production (e.g. manufacturing in-house vs. external production, product design, components’ standardization) and logistics (choice of carriers, delivery time, stock). On the other hand there is a growing need to include aspects of sustainability and risks in the decision-making process. Flexibility is of particular interest, as this is taken into account by the management as a risk factor, whilst it may also have a negative effect in regards to sustainability (e.g. unutilized means of transportation, respectively special shipment). This sub-project’s objective is to develop innovative methods for the analysis and assessment of global-sourcing alternatives. These methods in turn will consider all interdependent partial aspects derived out of procurement, production and logistics as well as the previously mentioned targeted dimension.

* Project owner: Ass. Prof. Kai Förstl, Global Sourcing, EBS Wiesbaden.

A decision-making support system will then be developed out of an innovative global sourcing typology, which in turn will meet the decisions' outlined complexity, tackling two main issues: (1) Allowing for restrictions in regards to transportation and other requirements (risk, sustainability) should the production be executed abroad or should the products be bought in from external suppliers? (2) How to distribute the production and purchase capacities to the individual countries, whilst integrating the individual country characteristics (such as transport infrastructure, risks, sustainability)? The heart of this decision-making support system is the (yet to develop) multiple target decision model. This project's practice and application orientation is secured by representative analysis of German industries with intensive global sourcing intensive expertise.

1.2. Production*

The adjustment and optimization of flexibility activities within the production, logistics, and transportation are this sub-project's objective, "Flexible production". The integration of information in regards to logistics availability, taking into account traffic forecasts in existing flexibility strategies of production and intra-logistics, are of particular interest in this analysis. A flexibility strategy serves as the definition of multiple production scenarios over a period of time that set a suitable combination of organizational, technical, and personnel activities depending on quantities and mix of variants (Abele, Rumpel, Kuhn, 2008; Reinhart, Dürrschmidt, Krüger, 1999). In this context flexibility describes the ability to switch quickly between the pre-defined various scenarios, whereas existing approaches concentrate on singular view of the players. When developing a scenario, this sub-project is set out to develop a flexibility optimum that includes models, strategies, and activities along the entire value-added chain, starting at the supplier all the way up to the customer. This mandates that all flexibility activities of all players are synchronized, in line with the stringent optimal strategy starting with the production. This is to be accomplished by the classification of the existing production, respectively intra-logistics into one typology, allowing a selection of suitable optimization models. These optimization models include the targeted objective of logistics and transportation, resulting in a minimization of potential target conflicts. A necessary degree of flexibility on production, logistics and transportation is to be ensured by the development of activities, respectively strategies that are based on optimization. Flexibility requirements for example derive from the logistics of machine tools.

* Project owner: Prof. Eberhard Abele, Institute of Production Management, Technology and Machine Tools, TU Darmstadt.

The alignment of general traffic conditions is to translate the interface between intra-logistics and external logistics into one joint. This enables the supply flexibility from the company's point of view, whilst determining the impact of the company's decisions on the public authorities' activities. The comparison is to point out energy consumption, respectively emissions as well as general costs and on-time delivery, which will arise when choosing a production scenario with the related internal and external means of transportation and the intensity of their utilization. Furthermore this research will show how the capacity and qualification requirements of the factory personnel for the production and intra-logistics will affect the flexibility. This alignment is made possible by adequate information processing through IT systems as well as the customization of decision-making models in regards to target conflicts and interaction.

1.3. Demand*

The strategic distribution logistics takes into account all long-term income-related decisions, which can only be revised over a long-term period, respectively when accepting a substantial profit reduction. The distribution-logistics fundamental choice includes the definition of traceable service policy as well as the definition of a basic structure on a distributional logistics system and last but not least the micro and meta-logistical infrastructure for the freight- and information flow between supplier and reception point. All relevant aspects in regards to the basic structure of the distribution-logistical networks are strategic decisions on (1) a centralized vs. a decentralized distribution system, (2) postponement vs. speculation (definition of the de-coupling point) (3) direct vs. indirect delivery, i.e. use of just-in-time benefits vs. use of bundling effects (4) integration vs. loose coupling of interacting elements of distribution systems.

The scientific goal of the sub-project's "strategic distribution" in the sense of the logistics' flow orientation consists of the integration of the production's flexibility strategies into a sustainable (economic, ecological and social) design of distribution-logistical systems; taking into account all supplying transport systems.

In addition of the fulfillment of customer orders at the operational level, the sub project "demand fulfillment" considers the distribution's strategic level. As a result the logistics' decision makers are given recommendations in regards to the design of flexible, seamless production and traffic integrated distribution systems. Demand fulfillment (DF) making a significant contribution within the

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realms of supply chain planning and providing decision support in regards to integrated procurement, production, logistics and sales planning to manufacturing industries with the help of modern software-systems, so called advanced planning systems (APS). DF portrays the typical short-term sales-side processes of delivery date commitment and fulfillment of customer orders. Depending on the interface between the forecast based and mission-oriented processes this concerns not only the delivery (“make-to-stock”, MTS), but also the final assembly (“assembly-to-order”, ATO) or even the direct production process (“make-to-order”, MTO). This is why the DF attempts to achieve a flexible integration between short-term production and distribution logistics within a company. Due to the growing globalization DF increasingly refers to global networks, including several production alternatives as well as potential distribution channels. Hence the DF requires both the reflection of individual local production and distribution networks and the decision-making within a complex network of locations with a variety of locational and transport-related alternatives for the fulfillment of customer orders.

Different modes of transport (e.g. truck, train, ship, aircraft) and transport systems pose a significant cost determination and can provide an additional resource in regards to short-term delivery that needs to be investigated. Transport conditions (e.g. custom duties, infrastructure, distance-related tolls and time based user charges, particulate matters and CO₂ limits), which are generally set by public authorities in line with the social, economic and ecological interests, have an important impact on decisions within the DF.

1.4. Traffic/Transport*

Requirements of flexible production and logistics as well as transport offer in regards to production planning and logistics have to be included into the freight traffic planning (Clausen, Iddink, Naumann, 2007). This helps to reduce target conflicts whilst improving the efficiency in regards to transport requirements and the transport planning’s fundamental objectives.

This mandates firstly the identification of information gaps on interactions and secondly its closure through the application of different methodological approaches, whilst developing the appropriate tools to model those interactions and customize, respectively develop new measures in compliance with the various interactions. The relevant offer properties and the characteristics of the

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freight transport are transport-specifically drawn up. This is generated with the help of a system- theoretical analysis and a survey of experts and users and the subsequent comparison of freight-transport-related characteristics of flexible production and logistics of interactions between the individual segments and standardized into structured matrices. Interactions in relevance to the decisions with an impact of the freight transport are supported by in-depth interviews and evaluated in regards to the production and logistics and described on the basis of qualitative and quantitative parameters that have been identified by thorough literature research, system theoretical analysis and interviews. The main objectives are the determination as well as the evaluation of those parameters by decision makers. The determination of the influencing factors on this research (including the inspection of non-linearities) and last but not least the relevance of the dispersion of the parameters on the performance of decision makers. The modeling of the freight demand includes the segments traffic generation, traffic distribution, choice of transportation and traffic assignments, which must be applied to all modes of transportation. Possibilities of simultaneous or sequential modeling are carefully considered. The illustration of parameters and the underlying interactions in existing traffic freight modeling systems are analyzed. The existing research and development requirements with regards to the modeling of individual interactions and the resulting need to define models (e.g. temporal distribution of demand) as well as the data requirements for the models' calibration and validation is specified. This is the basis for the development of an overall concept of a comprehensive modeling of the freight transport with linkage to the production and logistics under consideration of different modeling approaches – such as individual or aggregate models, logic models, gravitational models (Steierwald, Künne, Vogt, 2005).

The developed theoretical approaches are accompanied by case studies and checked on its practical feasibility whilst drawing conclusions for future work. Based on the developed matrices of the interactions as well as the described parameters are structured in an analytical approach, using existing infra structural, regulatory, financial, and informational activities that influence transport offer and transport. The measurement catalogue, which is being supplemented by creativity techniques as well as new activities, allows the identification of measures relevant to freight traffic, which has a positive impact on the (above mentioned) parameters and the underlying interactions. With the help of impact assessments, like existing or reasonable further developmental transport demand models, existing traffic measures are exemplarily improved and new measures developed.

1.5. Information technology*

Integrated production, logistics and transport chains, require a continuous flow of information as a necessary crosscutting function. On one hand, the relevant information includes the product memory (including the components used), which is required for the maintainability of the products, the availability of spare parts to the environmentally sound disposal and recycling. On the other hand, details of the transport and logistics chains are required, in order to ensure the traceability of transport routes and conditions, for example cold chain for food and pharmaceuticals or strong vibration in glass and electronics. Here, the transitions between modes of transport and businesses must be seamlessly covered. The proposed approach includes event-based systems and “Event Warehouses” for the long-term storage of event information for analysis and traceability, needed in decision-making processes. The information technology has interfaces to all thematic areas as crosscutting issue and is needed for the decision-making technology. One of the most important objectives is to ensure the uninterrupted flow of information by integration of heterogeneous information on many levels of production, logistics and transport processes. The second objective is to offer approaches for the automated and seamless product tracing across all areas. These should be based on event-based systems and support the objectives of the analysis, optimization and governance together with “Event Warehouses”. In this context it is the main objective to enable decision-making processes and the resulting dynamics and responsiveness through high-quality and timely information.

2. Special focus: Interdisciplinary decision-making**

Private enterprises, public authorities and also customers are increasingly confronted with complex decision situations. An example: From a customer’s point of view it is getting more and more difficult to order a car in Europe. This is at least caused by the unbelievable high number of models, editions and equipment components: For a middle-class car we can choose between more than 100.000 options. Regarding to this, there is no other way than having a complex operational system to address the customer’s differentiated needs. The decisions that have to be made to produce such a car are as difficult as the system itself. To be aware of the processes lots of solutions have been developed by practitioners and scientists. But those solutions are mostly disciplinary. They do not consider that decisions made in one discipline affect other disciplines as well (see Figure 3).

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** Project owner: Prof. Hans-Christian Pfohl, Supply Chain and Network Management, TU Darmstadt.

To stay at the car-example for an insight in interdisciplinary decision behaviour, a rush increase of sales (or decrease like in 2008) directly impacts the production rate. Doubled the sales connotes double the production, requiring additional resources, workers and machines. But a closer look e.g. to the distribution side of the supply chain shows that also a modification of logistics services is necessary: Should we transport a higher number of products at one time or do we have to increase the transport frequency? In both cases the traffic itself is an enabler and must be considered by the logistics service providers. Peak time traffic or weight restrictions for streets and bridges are additional decision parameters. It is easy to see that this example can be complicated in any order.

Actually dynamic changes increase complexity and make quick and sustainable decisions more difficult. The problem of the increasing flexibility need is not solved yet. In this regard the automotive industry is indeed a useful example and source for partial solutions. But compared to other industries – like pharmaceutical sector or spare parts business in the machinery and equipment industry – the required flexibility and the demands on the decision-making are not as high.

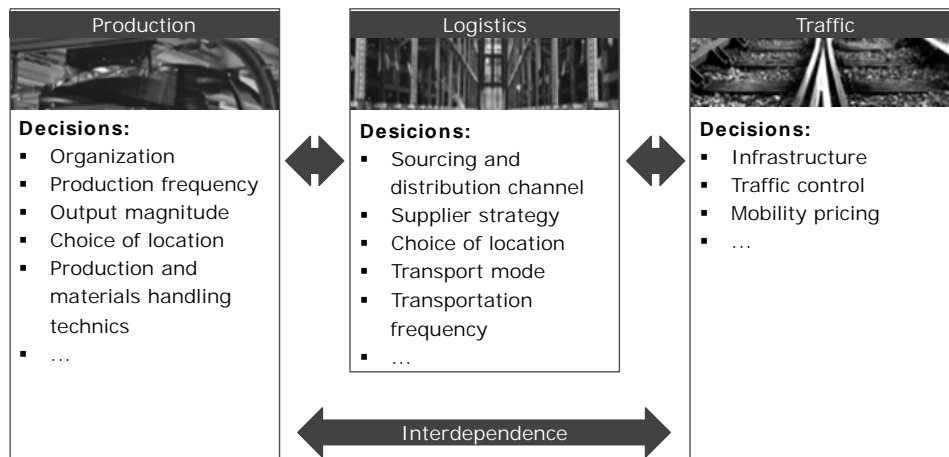


Figure 2. Decision issues in production, logistics, and traffic

In order to cope with the challenge of interdisciplinary decisions, all decision players have to be identified and their decision involvement regarding the goal conflicts closely examined. This is done via the above-mentioned three study levels (players, objective, models). The approach enables to draw conclusions on the utilization of decision supporting models and mandates the development of model typology that relates to the respective disciplines, respectively sub-projects systemizing the utilization of models supporting the decisions of value added in regards to traffic planning and traffic control. This enables the

development of specialized model types for different situations such as changed framework conditions in regards to the value added due to changing megatrends, respectively the implementation of traffic restrictions or changes within the distribution strategy. Once the development of the model types has been realized one can then start to define the required interfaces. This yields a decentralized decision support system for each player, based on his/her conflict of interest. Another unique characteristic is derived out of the circumstance that collective decisions as well as individual decisions are both made rationally as well as intuitively. The more persons and organizations are involved the larger is the complexity of the decision-making processes. Based on this we are aiming to derive first modeling approaches of decentralized, interdisciplinary decision support system by means of a holistic model. Therefore, real decision-making processes must be examined, especially seizing and categorizing the methods, instruments and models available for decision support and in the next step further developed for an interdisciplinary support of a decision-making process. In particular it is to be examined to what extent the methods and models offer better solutions identified for decision support compared with heuristic, experience-based decision rules (Wübben, von Wangenheim, 2008). The objective is to ascertain which technological, personnel and organizational conditions are relevant for a corresponding decision model and its practical application: this demands a technical arranged model, providing the user with comprehensible decision proposals whilst being most user-friendly. On the personnel side it has to be ensured that the abilities for handling models are present. Additionally set incentives may motivate the use of the model. By guidance an appropriate behavior influence must be made if necessary (Schulte-Zurhausen, 2010). On the organization side it is to be examined, which organizational structures connect technological and personnel aspects most efficiently (Pfohl, Stöltzle, 1997).

The employment of model mix is required for the dissolution of this transitional field. Thus, both prescriptive models for the derivative of optimal decision alternatives as well as descriptive models for the description and explanation of existing and future decision behavior are used.

Prescriptive decision models are based upon certain premises and generally provide a clear recommendation of action, calculated by means of a model algorithm (Kim, Yang, Kim, 2008). Modeling full complexity of real decision situations is impossible due to reduced computer capacities as well as to the cost, complexity, and availability of data (Feige, Klaus, 2008). Therefore prescriptive decision models represent a simplification of the reality and show a certain distance to practice (Schön, 2009; Mezas, Starbuck, 2008). For this reason partial simulation models and assistance systems are used, for they characterized by

a larger flexibility, whilst learning effects can be installed/updated (Wadhwa, Saxena, Chan, 2008; Pfohl, 2004; Toth, Wagenitz, 2009). In recent times however a shift from research focus to descriptive decision models is happening, mainly due to the addressed weaknesses of prescriptive decision models (Schön, 2009). Decision-making processes and organizational behavior in enterprises are described and explained by means of descriptive decision models (Rowland, Parry, 2009). They are to measure up to the complexity of real decision-making processes, whilst orientating itself more strongly at the “planning humans” and less at (rational) task of planning (Feige, Klaus, eds., 2008).

There are hardly any research approaches combining both decision theories due to the very different research directions. However, a consolidation of decision models into real decision-making processes particularly during the implementation phase is important.

Purely technocratic decision-making aids are not useful, when they are not understood or not even used by the decider. Better solutions based on associated models could be developed, particularly for times of uncertainty, like the current financial and economic crisis (Kotler, Caslione, 2009). Hence, we are looking at two identified academic voids. On the one hand at the combination of existing decision-making aids to support interdisciplinary decision-making processes and on the other hand the study of practice-oriented decision-making aids for intuitive decision behavior.

Conclusions

First investigations in form of case studies confirm that in practice decisions are made disciplinary, despite increased requirements. Enterprises simplify complex decision situations, by not including certain aspects (like external logistics or traffic influences within production decisions), allowing to focus on a sub-system only. Effects on other sub-systems respectively the overall system are usually not considered (silo-thinking) or left to the partners within the value network. However, if for e.g. company-wide consignment stores are to be operated, progressive and unusual paradigms and decision-making processes are needed. Currently such interdisciplinary approaches are constrained by different levels and parameters of (disciplinary) decision-making processes as well as cultural and linguistic barriers. At first it is necessary to form a (linguistic) meta-level, which assists the interdisciplinary exchange between the players and brings them on a common dominator.

In order to manage fast and flexibly complex decision situations, an additional approach could be the combination of analytical and intuitive procedure

decision making. Informal networks and cooperation are two aspects, we consider particularly important. However, substantial research need still exists, in order to find an explanation approach for interdisciplinary decision making in the added value network.

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