DYNAMIC AND SEAMLESS INTEGRATION OF PRODUCTION, LOGISTICS AND TRAFFIC & TRANSPORT (DYNAMO PLV) – BARRIERS FOR INTERDISCIPLINARY DECISION-MAKING

Hans-Christian Pfohl[1], Christian Zuber[2], Ulrich Berbner[3], Markus Ehrenhöfer[4]

[1,2,3,4]Technische Universität Darmstadt, Hochschulstr. 1, 64289 Darmstadt, Germany

Email for correspondence: pfohl@bwl.tu-darmstadt.de

ABSTRACT

The objective of the paper is to identify the barriers for interdisciplinary decision-making in production, logistics, and traffic & transport. The paper will give an answer to the question, why decision makers in production, logistics, and traffic & transport often do not include/consider affected parties of their value chain in their decision-making processes and how decision makers can be enabled to make more integrated decisions.
In this paper, a twofold research design is implemented. At first, the authors build basic knowledge about existing interdependencies by conducting a role-play with experts from the different disciplines production, logistics, and traffic & transport. Building upon the findings a case study is conducted again including parties from production, logistics, and traffic & transport in order to build theory about the barriers for interdisciplinary decision-making.
The results show that it can be distinct between four different types of relevant barriers for interdisciplinary decision-making: transparency, interest, information and data processability.
The identified barriers and the described measures provide a first insight into the challenges of decision makers in today's value chains. They further provide a solid foundation for developing tools for increasing cooperation along the value chain.

Keywords: Decision Science, Behavioral Operations, Interdisciplinary Decision-making, Supply Chain Management, Systems Theory.

1 TOPIC AND LEVELS OF ANALYSIS IN "DYNAMO PLV"

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 the research project "Dynamo PLV" 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 interdisciplinarities 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 Dynamo PLV:

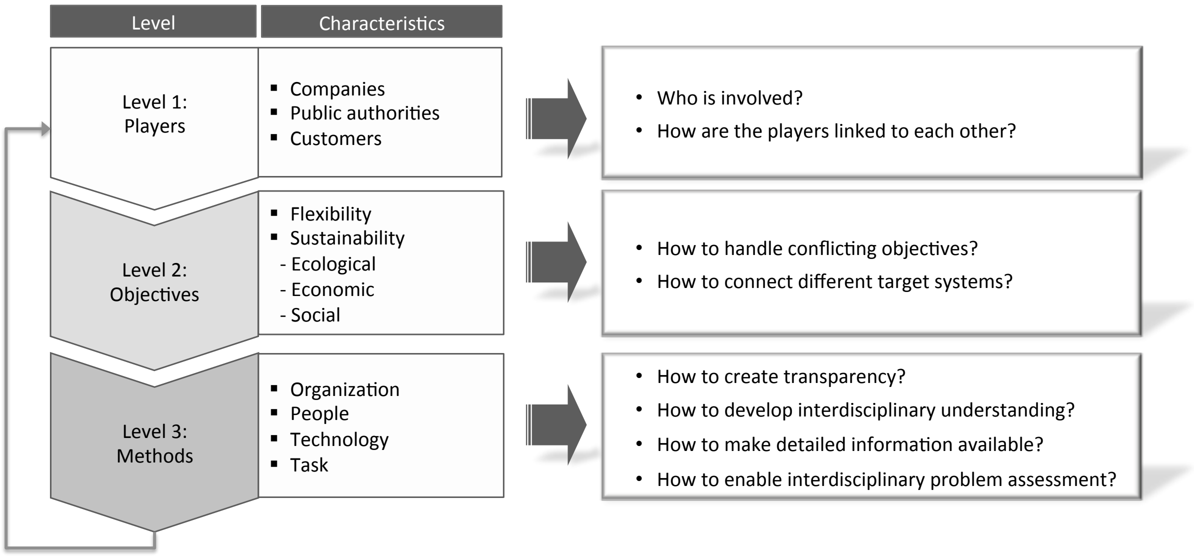

Figure 1 – Three levels of analysis

Level 1 (players' level) outlines and implements the businesses' flexibility as well as the public authorities' and the consumers' decision-making. 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. The utilization of method-mix at the next level is mandated when trying to resolve the stress-ratio and to reveal barriers for integrated decision-making in detail. Hence we are using and investigating methods within three configurable variables (organization, people and technology) to improve interdisciplinary decision-making (task) (cf. Leavitt 1978). These methods are the basis for 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 competiveness of an individual company, this project is set out to increase the competitive ability of the entire value added chain. Current developments as well as the previously outlined goals and challenges enable the definition of the key subjects: supply, 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.

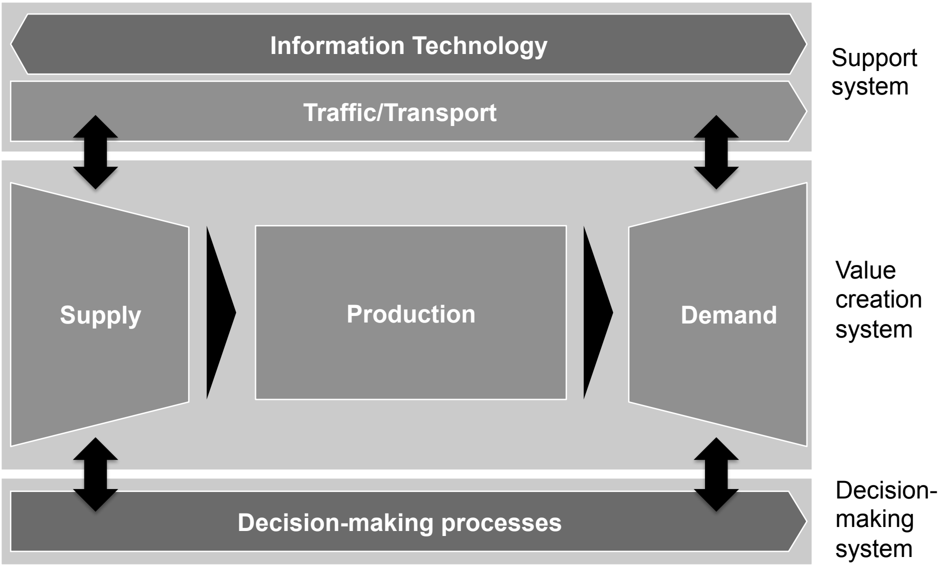

Figure 2 – Overall system of Dynamo PLV

A realization of interdisciplinary 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 (cf. 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 (cf. 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 (cf. Boltze 2011). There are neither detailed analysis on how traffic and transport measurements impact the production and logistics nor is there any information on how production and logistics measurements influence the traffic. Researches generally focus on freight traffic.

2 FOCUS AND RESEARCH OBJECTIVE IN THIS PAPER

In this paper we focus on interdisciplinary decision-making itself and the decision-making systems: First 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).

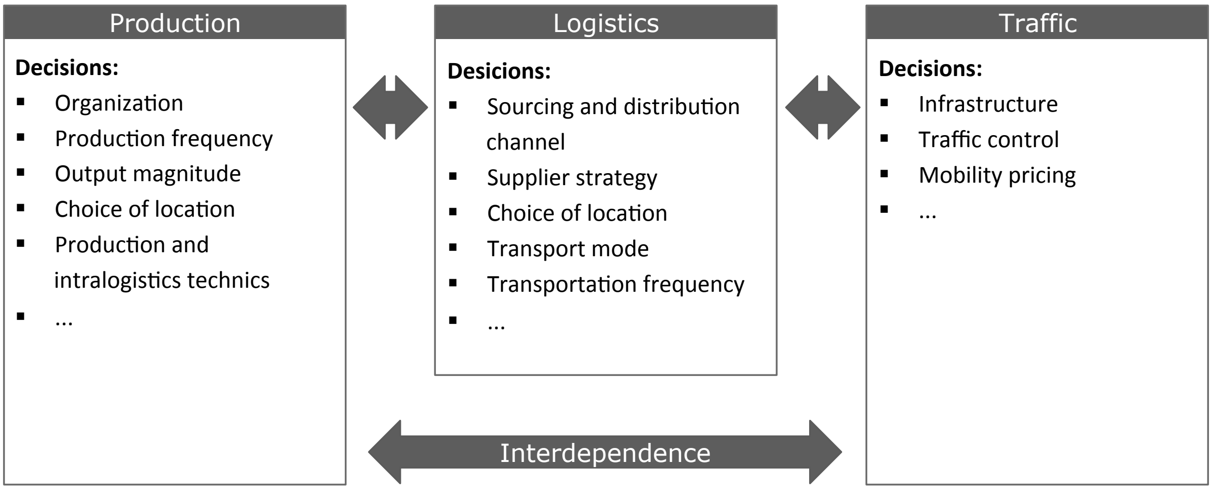

Figure 3 – Decision issues in production, logistics and traffic

We remain with the automotive example for an insight in interdisciplinary decision-making behavior; 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. Peek 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 and that we need a systems thinking approach including value creation and traffic & transport in the future.

We also see that current dynamic changes raise complexity and make quick and sustainable decisions (concerning the overall system) increasingly difficult. The need for cross-functional integration in the supply chain (intra-organizational as well as inter-organizational) has been recognized some time ago and is part of scientific research and theoretical concepts in the meantime. For example, Lambert (2008) describes in his partnership model an approach to build high-performance relationships in the supply chain. Nowadays decision-making in the logistics and supply chain is characterized by forecasts and early warning systems (cf. e.g. O'Donnell/Maguire/McIvor/Humphreys 2006; LeBlanc/Hill/Harder/Greenwell 2009). Insights regarding algorithm-controlled process optimization within the field of operations research are quite popular as well as widely accepted. But when improving the interfaces within the supply chain, the focus should not solely rely on the mechanistic improvement of physical and information-technical processes. It is more likely that the managers and their behavior determine the design of the interfaces and efficiency of the processes (cf. e.g. Knemeyer/Naylor 2011, Kaufmann/Michel/Carter 2009). This assumption is characterized by the high degree of complexity, which is a result of comprehensive logistical issues and decision-making problems (cf. e.g. Fleischmann/Meyr 2004 or Feige/Klaus 2008).

In addition, most of the decision support models have been specifically designed for accurately defined application scenarios. But the benefits to decision makers decrease, if conditions vary only slightly. Decreasing product life cycles, greatly increasing demographic change, high volatility in the market as well as the progression of digitization are seen as the most important megatrends of global added value. These trends lead to frequent, if not even continuous change of decision premises of logistics interfaces' design in the supply chain and subsequently increasing the significance of the decision makers' behavior (cf. Pfohl/Ehrenhöfer/Zuber 2012 and Straube/Pfohl 2008).
However, in practice, companies are still far away from an ideal partnership, which could be based mainly on the lack of interdisciplinary decision-making. But what are major barriers and how to overcome these challenges in decision-making? Addressing these questions and the increased (interdisciplinary) decision-making challenges described above; the objective of this paper is to analyse barriers to interdisciplinary integration in decisions and challenges for each discipline to admit integrated decision support systems. Therefore we characterize different types of barriers occurring in interdisciplinary decision-making, focusing on an integrated system of *production*, *logistics* and *traffic & transport*. Further we use our findings to set up a first toolbox to overcome the identified barriers.

3 DECISION THEORY AND INTERDISCIPLINARY DECISION-MAKING

The field of decision theory is divided in two main research sections (cf. e.g. Bell/Raiffa/Tversky 1988; Laux 2012). *Prescriptive/normative decision models* are based upon certain premises and generally provide a clear recommendation of action, calculated by means of a model algorithm (cf. Braybrook/Lindblom 1969; Kassouf 1970; 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 (cf. Alexis/Wilson 1967; Feige/Klaus 2008). Therefore prescriptive decision models represent a simplification of the reality and show a certain distance to practice (cf. Neumann/Morgenstern 1953; Mezias/Starbuck 2008; Schön 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 (cf. Hodgkingson/Starbuck 2008; Schön 2009). Decision-making processes and organizational behavior in enterprises are described and explained by means of descriptive decision models (cf. 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 (cf. Pondy 1983; Sadler-Smith/Shefy 2004; Feige/Klaus 2008). Therefore we choose a descriptive approach of (real) problematic issues in interdisciplinary decision-making for our investigation, which will be introduced in the next section.
Our systematic analysis of interdisciplinary decision-making includes *individual* as well as *collective decision-making*, which in many companies plays an increasingly important role due to the prevalent rising complexity of decision-making (cf. Laux 2012). In case of collec-

tive decision-making, multiple decision-making individuals are participating in a single decision-making process. In this case the individuals' decisions are connected to and affected by each other, resulting in communication and interaction becoming increasingly important (cf. Laux 2012). We use the term *decision maker* in the following in order to describe both, an individual (individual decision-making), as well as a collective (group decision-making; e.g. a division, committee, working group etc.) (cf. Gäfgen 1968; Pfohl 1977).
The description of the decision-making process differs vaguely among the existing literature in decision science, but usually contains the four different steps, which are illustrated in Figure 4 (cf. Andler 2010). Step one can be seen as the decision makers' *identification of the need for action* or the expression of the decision maker's initial problem (cf. Laux 2012; Schiemenz/Schönert 2005). A problem can be seen as a condition, where the as-is state deviates from a certain target state (cf. Pfohl 1977). This initial step is followed by step two that is called the *search for relevant alternatives,* in which the decision maker selects all those alternatives from the set of total alternatives, whatever in his opinion might lead to a preferred solution if implemented. In step three, the decision maker *evaluates the previously selected alternatives* in order to *make a final decision* and to *implement the selected alternative* in step four. In the literature, the control of a decision's implementation is sometimes also seen as part of the decision-making process (step five) (cf. Andler 2010; Schiemenz/Schönert 2005).

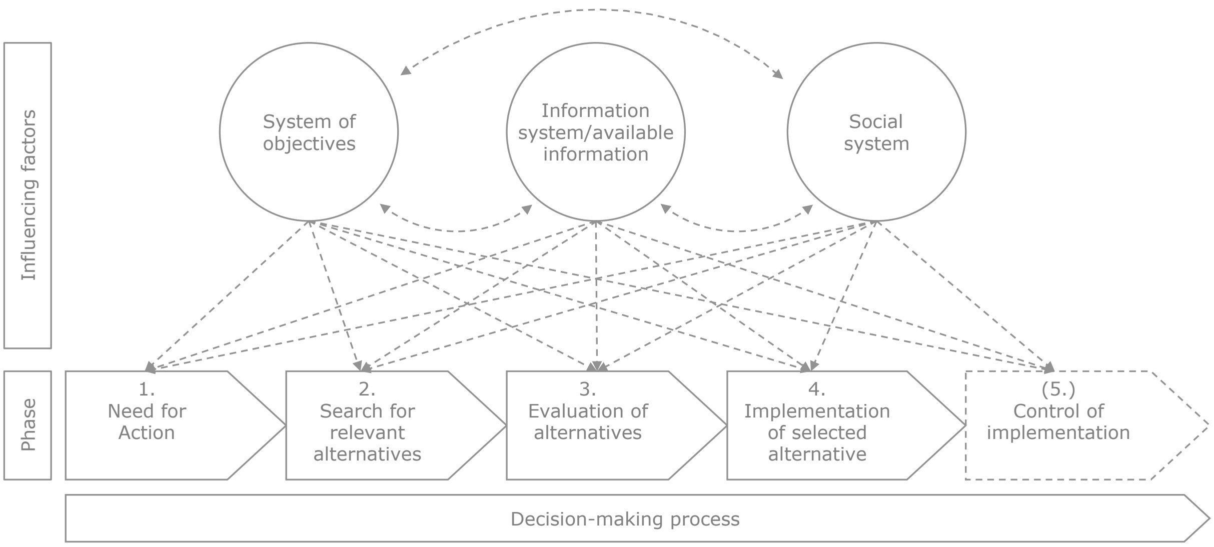

Figure 4 – Decision-making process (based on Schiemenz/Schönert 2005)

Three different types of factors usually influence the actor making the decision as illustrated in figure 4 (cf. Schiemenz/Schönert 2005). In literature, the decision maker's goals are often distinct in success objectives, security objectives, growth objectives and power objectives (cf. Schiemenz/Schönert 2005). The different objectives' relations can usually be described as neutral, complementary or competing (cf. Klein/Scholl 2011). In addition to the decision maker's objectives the degree and quality of available and processable information also has an impact on a decision's outcome. Decision makers will normally use all available information

in order to shape their set of alternatives and evaluate those alternatives in order to make a decision (cf. Pfohl 1977). And also the social system (community) of the decision-maker plays an important role in form of information and knowledge transfer and the interchange of experiences. Especially interdisciplinary decisions e.g. along the supply chain, require decision makers from different functions or disciplines to interact with each other. Decisions made by one actor will in most cases lead to a problem/need for action concerning one or more other actors. Improved level of coordination concerning interdisciplinary decisions thus might lead to better solutions concerning the whole supply chain e.g. from a total cost perspective.
Interdisciplinary decision-making is already subject of research activities. Research focuses however predominantly on general aspects, e.g. the underlying process of interdisciplinary decision-making (cf. Harrison 1993; Koutsoukis/Mitra 2003), or is related to typical application fields like the health sector (cf. Elwyn/Edwards 2009; Strausa/Tetroeb/Grahamb 2011). An investigation of (barriers in) interdisciplinary decision-making along the value network regarding the interactions between production, logistics, and traffic & transport did not take place so far.

4 RESEARCH METHODOLOGY AND DATA

As variables for describing the systems state of production, logistics and traffic, we use the existing organizational structure, the company's employees, the technology employed and the tasks carried out which can be also interpreted as the four basic configurable variables of the management (cf. Leavitt 1978, Leavitt 1965). The characteristics of those configurable variables are determined by systems specific decisions and the accrued *tasks*. That leads to *organizational* centralized or fragmented subunits production, logistics, and traffic, which are influenced by other respective subsystems and further environment.
The structural couplings between the subsystems determine if and to what degree decision makers and other subsystems can confuse the subsystem. The subsystems' structures, derived out of the system differentiation, limit the number of compatible operations in form of communicated decisions and the selection of the communication channels (cf. Luhmann 2008). The remaining environment in terms of other functional areas is particularly determined by its assignment and e.g. for the subsystems logistics includes also the areas of the subsystem's context variables, such as suppliers, customers, competitors or the logistical infrastructure. The four design variables are used to stretch the subsystems state. The characteristics of the variables are nominal so that different types of each variable can be defined.
To investigate interdisciplinary interdependencies and the barriers for integrated decision-making, a combined research approach grounded on a *role-play based research method* and *case study research* was applied. While the former method allows examining the reaction of individuals on dynamically changing situations (cf. Nienhaus/Ziegenbein/Schoensleben 2006), the latter permits building theories based on observation and interpretation (cf. Eisenhardt 1989; Yin 2009).

Role-play based research method

In the field of supply chain management, role-games are often utilized to increase the participant's cross-functional understanding of supply chain mechanisms (cf. Korhonen/Pekkanen/Pirttilä 2007). But role-play approaches may also be used to study human behavior in decision-making process (cf. Nienhaus/Ziegenbein/Schoensleben 2006). In case of the present study, a role-play approach was utilized to gather knowledge about the existing interdependencies between the different disciplines, in order to build a solid foundation for the case studies conducted afterwards. In a first step, PhD students majoring in the areas of *logistics (strategic distribution, demand fulfillment, global sourcing, supply chain management)*, *production* (production management, materials handling), and *traffic & transportation (transport management, commercial transport)* had to build multiple typologies (cf. Knoblich 1972) based on a deductive, literature based approach, describing the object of interest of their research area and typical fields of actions of decision makers in the disciplines.

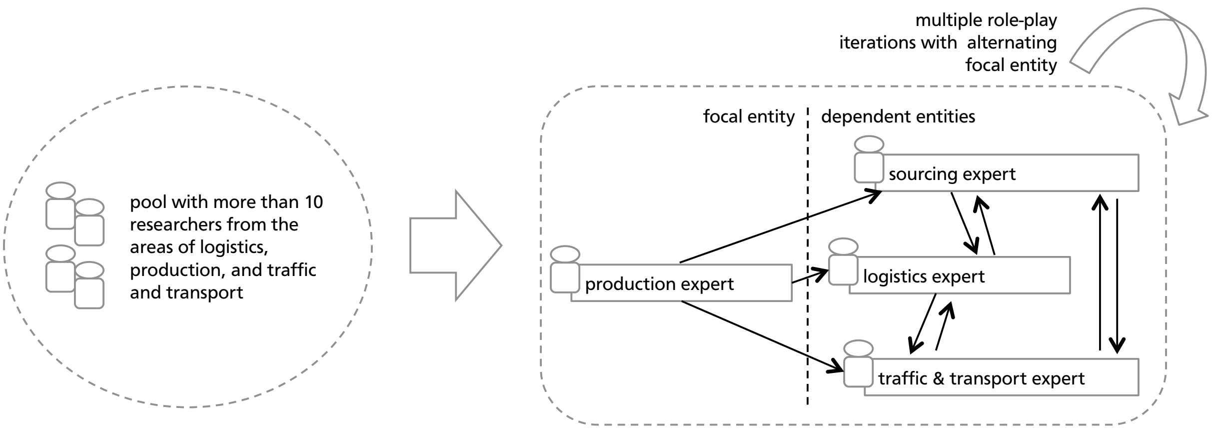

Figure 5 - Role-play based research approach

After the typologies had been created, two workshops with 10 to 12 participants each have been conducted (figure 5). The group was separated into teams of four to five PhD students from different research areas. Each PhD student was then, depending on his field of study, assigned to one of the systems *sourcing*, *production*, *materials handling*, *distribution,* and *traffic & transport*. In multiple rounds, one of the researchers assumed the role of the focal system and challenged the other participants by setting up different configurations of the focal system. For example, if the focal system was logistics, the researcher in charge could change the delivery method from standard delivery to just in time delivery. The other researchers had to react on this new configuration. For example, different transport vehicles needed to be utilized in the illustrated case. The outcome of the workshops was a system showing interdisciplinary interdependencies and detailed information on the requirements for implementing system-wide decisions.

Case Study Research Design

The role-play based research approach provided the researches with basic knowledge on how different decisions from different disciplines might be interconnected with each other and what types of barrier could theoretically occur. In order to study the relevance of those interconnections in practice, a multi case study (Yin 2009) was conducted among different companies.

According to Schramm (1972) "the essence of a case study (…) is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result." Hence, the case study method seems to be adequate in order to describe interconnections between the different disciplines, the underlying decisions and barriers. Yin (2003) describes four different types of case studies, among which one type follows the so-called embedded multi-case design. This type of design was implemented in the present study in order to achieve a higher level of robustness than with a single-case design. The case study was prepared, conducted and evaluated by following these eight steps: 1. definition of the research question, 2. case selection, 3. preparation, 4. field entrance, 5. data analysis, 6. shaping hypotheses, 7. literature comparison, 8. reaching closure (cf. Eisenhardt 1989).

Definition of the case study's research question and case selection: We derived the following research question based on the insights we gained from literature review and the role-play:

> *Why do decision makers in production, logistics, and traffic & transport often not include/consider affected parties of their value chain in their decision-making processes and how can decision makers be enabled to make more integrated decisions?*

Answers to this question led us to problematic fields in supply chain management and enabled us to build up a structured theory about relevant barriers for interdisciplinary decision-making.

We have conducted three main cases (automotive, spare parts/engineering, regional traffic management) and gathered input from about 55 experts (companies, science, public authorities). The entities selected for conducting the case study represented different market segments and industries (B2B/B2C, logistics/production). The case study's objective was mainly, to study decision-making processes in the supply chain, hence companies from different supply chain depths (OEM/Tier 1 supplier) were selected and are rounded up by the public sector. Concerning each individual case, again decision makers from the areas of production and logistics were selected for interviews. In the process, we tried to include decision makers that could also give insight about existing decisions' impact on traffic and transport. The interviewees' job definitions varied, among them were logistics managers, sourcing and purchasing experts, production planners and production steerers. Adding the public sector entity to the sample allowed gaining additional knowledge about the potential impact of companies' decisions on the transport infrastructure. Cases/entities were added sequentially during the research process in order to replicate but also to extend our emergent theories in the area of interdisciplinary decision-making. Saturation was reached after investigating existing processes in the eleven different entities listed in table 1.

Case	Entity	Industry	Firm size (No. of employees)	Experts		
				production	logistics	traffic
1	1	Automotive	160.000	x	x	
	2	Logistics Service Provider (Automotive)	90.000		x	
	3	Automotive	60.000	x	x	
	4	Automotive	6.500	x	x	
	5	Automotive	80.000	x	x	
2	1	Engineering	40.000	x	x	
	2	Wholesale (Engineering)	60.000		x	
	3	Logistics Service Provider	250.000		x	
	4	Engineering	15.000	x	x	
	5	Engineering	700	x	x	
3	1	Traffic Management	-			x

Table 1 – Selected samples for the conducted case study

Preparation and field entrance: Before visiting the companies, the researchers collected available data, created interview guidelines based on the results from the role-play based research approach and defined requirements concerning data and information to be collected from the different contact persons. Data was collected through semi-structured interviews and documents provided by the different companies, like process flow diagrams or organization charts.

Data analysis: After visiting the different companies the core barriers in the existing decision-making processes were identified and characterized. For quality assurance, the results were discussed with a selection of interview partners representing the entities where the case studies took place and with an interdisciplinary plenum of researchers from the areas of production, logistics, and traffic & transport.

Shaping hypotheses: Hypotheses concerning possible reasons for disciplinary decision-making have already been shaped in the early research process by conducting the role-play described above with other researchers. The Hypotheses were then expanded based on the interviews' results.

Literature Comparison: Literature in the area of barriers in interdisciplinary decision processes in value networks is rare. However, existing literature could give a general insight about reasons for barriers in interdisciplinary decision-making. The relevant literature is presented in part 3 and 4 of this article and was used to support the theory building process.

Reaching closure: Based on the different research steps described above and the repeated discussion of the research results with other researchers from the fields of production, logistics, and traffic & transport, four core propositions, presented in the following part of the article, were developed.

5 RESEARCH FINDINGS

Our investigations 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 subsystem only. Effects on other subsystems, respectively the overall system, are usually not considered (silo thinking) or left to the partners within the value network. The case studies' also revealed that the barriers for interdisciplinary decision-making are directly interconnected with the factors *system of objectives*, *available information, and social system* shown in figure 4. Table 2 gives samples drawn from the case studies concerning decision situations where decisions were not the result of an interdisciplinary process but made in disciplinal or functional silos:

Example		Decision makers involved (decision makers main objectives), actual decision maker marked bold
E1	Dual sourcing concept is implemented concerning just in sequence components and causes increase in process complexity.	▪ **Purchase department OEM** (risk mitigation) ▪ Logistics department OEM (reduction of process complexity) ▪ Logistics department supplier (reduction of process complexity) ▪ Production management supplier (capacity utilization)
E2	Parts are sourced from overseas even so this causes higher supply risks.	▪ **Purchase department OEM** (Cost reduction) ▪ Logistics department OEM (Reduction of process complexity)
E3	Specific type of reusable containers are used for ergonomic reasons even so this causes low transport capacity utilization.	▪ **Production OEM** (optimization of container ergonomics) ▪ Logistics OEM (capacity utilization) ▪ Transport operator (capacity utilization)
E4	Goods have to be repacked before storage since packaging is incompatible with storage system.	▪ **Logistics department supplier** (reduction of cost of packing material) ▪ Logistics department OEM (reduction of process complexity)
E5	Truck drivers are not well equipped with navigation equipment by their employer.	▪ **Transport operator** (cost reduction) ▪ Truck drivers (process optimization)
E6	Delivery trucks are blocked by passenger traffic.	▪ **Logistics department OEM** (optimum road usage) ▪ Different public entities (political objectives)
E7	Truck drivers do ignore regulations concerning the inner-city infrastructure use.	▪ **Transport operator/Truck drivers**

		(using shortest routes) ▪ Different public entities (reduction of congestion in inner cities)
E8	Truck drivers/transport operators do not interchange information about when a delivery reaches its destination what may cause congestion at the destination site due to ramp overload.	▪ Logistics department OEM (optimum ramp utilization) ▪ Truck driver/transport operator (reduction of loading/unloading times)
E9	Production is sometimes surprised by out-of-stock situations that occur due to late deliveries.	▪ Truck driver/transport operator (tour optimization) ▪ Logistics department OEM (on-time replenishment)
E10	Transport service providers are aggregating data from different sources in order to get reliable traffic information.	▪ Transport operator (circumnavigate congested areas) ▪ Different types of data providers

Table 2 – Exemplary field observations

It became evident that in some cases decision outcomes concerning one entity were not transparent to the decision-making entity. This can also mean that the objectives of the affected entities are not transparent to the decider. This situation is illustrated by example 4 in table 2, which could be observed in two different cases. Here, the supplier decides on a type of packaging to package all its goods in order to standardize the packaging process and to save packaging costs. The supplier *does not know* that the receiver of the goods (the OEM) needs to repack the goods in the incoming goods department manually since the packaging is not compatible with its automated storage system. If the supplier was informed, he would probably be interested in changing his packaging processes, probably coming along with higher fees what could easily be absorbed by the receiver due to his decreased handling efforts taking the former repacking incoming goods into account.

It also became apparent that in some cases, the decision-making entity is just *not interested* in considering objectives of other parties involved. An example for this case is example 3, where the production department decided to use a dedicated type of container for ergonomic reasons. In this case, the deciders were aware of the difficulties this may cause for the other parties involved, like the transport operator or the logistics department, but had the power to enforce their preferred solution.

Of course there were cases observed, where the decision makers were interested in finding interdisciplinary solutions, which might be beneficial for all parties involved. In example 8, the parties involved would like to reduce congestion caused by the mismanagement of delivery trucks at the ramp. But since there is *no information system available* that holds the required information and provides access for all relevant decision makers, it is not possible to make system-wide or interdisciplinary decisions.

Example 6 shows that even if the relevant information is available, decisions might still be made in silos. The sample illustrates a case were all parties involved are interested in finding an optimized solution, have all the information necessary to do so, but are not provided with any tools or method to do so. In the sample, delivery trucks are regularly blocked by passenger traffic. This happens at regular hours each day due to shift changeovers at the nearby

production site. In order to resolve the problem, different stakeholders from industry and public entities would need to find an integrated solution.
Based on those findings, a systematic overview of barriers for interdisciplinary decision-making is presented in figure 6 while the following core propositions can be verbalized:

P1: In interdisciplinary contexts, decisions focus on sub-systems since not all outcomes and effects of decisions are transparent to the decision maker.

P2: In interdisciplinary contexts, decisions focus on sub-systems since the decision maker is not interested in the impact his decisions might have on other systems.

P3: In interdisciplinary contexts, decisions focus on sub-systems since not all the relevant information/data is available to the decision maker in a sufficient depth of detail.

P4: In interdisciplinary contexts, decisions focus on sub-systems since the available information/data is not processable.

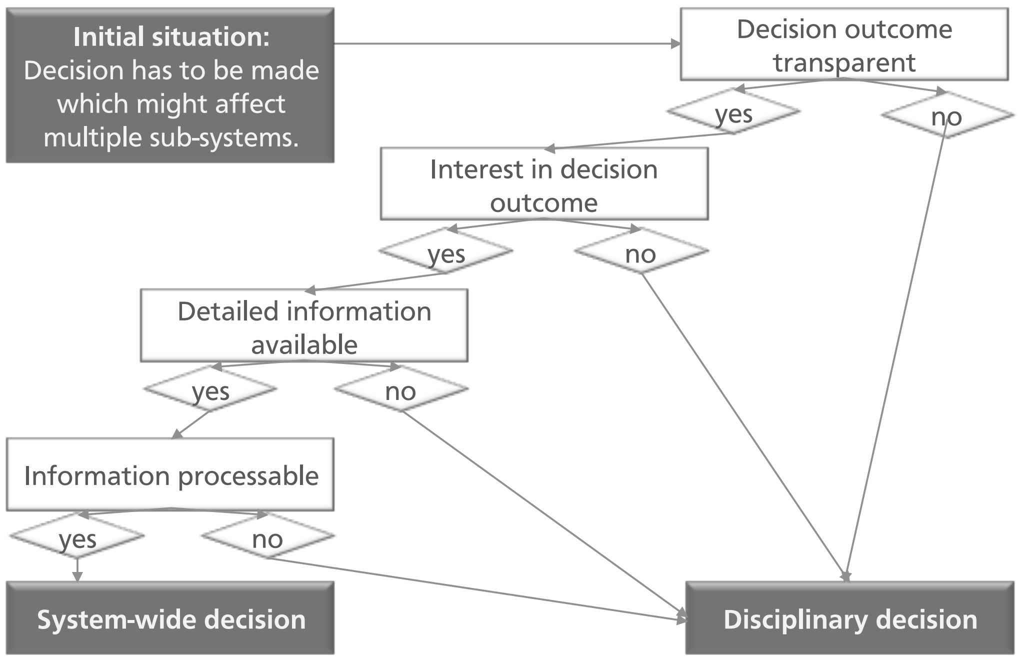

Figure 6 – Barriers for interdisciplinary decision-making

The four types of barriers for integrated decision-making described above can occur in each step of the (earlier mentioned) decision-making process and again be broken down in a number of sub-reasons. For example non-transparent decision outcomes might result from missing interdisciplinary education or the nonexistence of process documentation, while a lack of interest in system-wide decision outcomes might result from differing objectives of the decision-making entities or from linguistic barriers among interdisciplinary groups. The amount of identified (and theoretical derived) sub-reasons can be structured into three interconnected operationally systems; *organization, people*, *technology*, which influence the decision-making process. This approach is lend on the former mentioned scheme of Harold J. Leavitt, which describes an organization as an interconnected dynamic system with four basic configurable variables of the management, namely the company's employees (people), the technology employed, the organizational structure, and the tasks carried out or as we see it, the decision-making processes (figure 7) (cf. Leavitt 1965; Leavitt 1978).

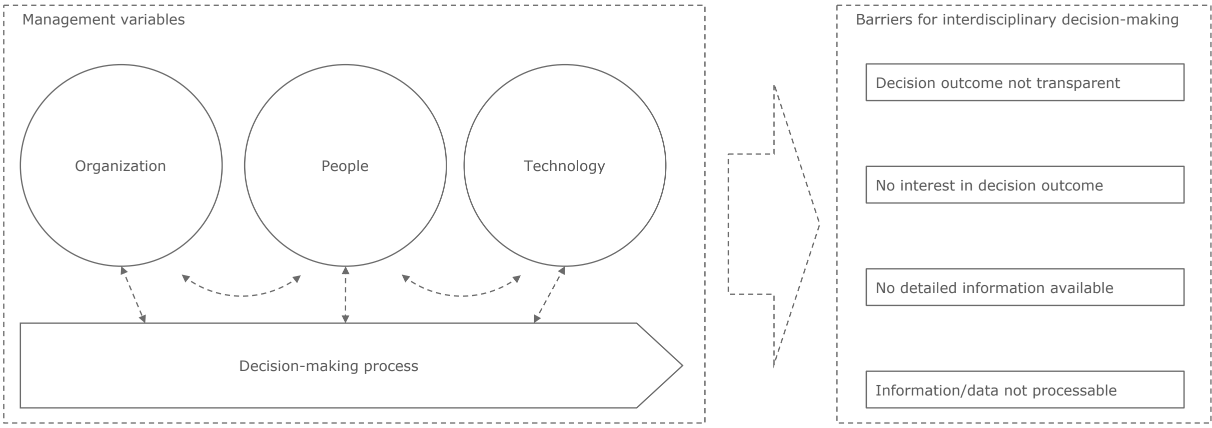

Figure 7 – Basic management variables that can influence interdisciplinary decision-making (based on Leavitt 1978)

The research results show, that barriers for interdisciplinary decision-making arise from each dimension of the Leavitt diamond. Concerning the dimension *organization*, existing structures are often not laid out to support interdisciplinary decision-making. E.g. interdisciplinary workshops or attempts to support informal learning in the area of interdisciplinary knowledge do not exist in practice. Also, due to the lack of appropriate incentives, interdisciplinary decision-making, meaning taking into account the affection of other systems when making a decision, is not encouraged. Further, existing processes that describe the information flow inside the organization, do not allow detailed information to pass the bounds of functional silos or subsystems. The processing of interdisciplinary information is usually hampered due to the lack of cross-functional integration and the resulting absence of possibilities for interdisciplinary problem assessment.

Concerning the *people* who are in charge of making decisions, skills for understanding the interdisciplinary consequences of disciplinary decisions are not well developed. But even if decision makers know about existing dependencies, they are not educated in a way to understand or even quantify the affection of the dependent systems. The case studies also revealed, that even in seldom cases, where people in charge of making decisions understand the impact to interlinked systems, they either have no detailed information in order evaluate the relevant factors of the decision situation, which would be beneficial for the affected systems, or they do not have the right skills in order to process the available information.

The last managerial variable affecting interdisciplinary decision-making is the *technology* used to support the decision-making process. Subsystems like production, logistics and traffic need to be interlinked through adequate information systems which guarantee transparency over the whole decision-making process, e.g. by implementing an event based system, which is sending messages to all affected parties if an affecting decision is made. Prominent systems for supporting interdisciplinary decision-making are so called Interorganizational Systems (IOS) (cf. Cash 1985). Those IT systems not only need to show decision makers that their decision might have certain impacts on other systems, they also need to support the understanding of the meaning of the underlying linkage. Providing the right information at the right time to the right destination is getting an increasingly difficult task with constantly growing amounts of data shared among the members of value added networks, but is essential for interdisciplinary decision-making. Only with technologies that ensure decision makers have all relevant information for making a decision and enabling the decision maker to process the available information, truly interdisciplinary decision-making can be achieved.
Table 3 shows adequate methods derived from the identified barriers, which can support interdisciplinary decision-making processes. Organizational measures, e.g. concerning the organizational structure or process definitions, might help to integrate decision makers among the value chain and sensitize them to the impact their decisions might have on other parties. Measures in the area of the employees or people might contain extensive trainings in different disciplines in order to support the development of an interdisciplinary understanding of existing cross-functional or cross-company interrelations. New technologies, e.g. in the area of intercompany communication, can help to implement integrated decision processes that go beyond company borders. Table 3 gives an insight in possible fields of action and measures that are adequate in order to deal with the problems that are object of the article.

Management variables	Barriers for interdisciplinary decision-making	Areas of action (toolbox, extract)
Organization	**P1: Insufficient transparency** In order to identify and trigger the need of action,. the decision-maker has to have access to sufficient data (information) at the right time.	▪ Company organization structure (Interdisciplinary workshops/ working groups/project teams) ▪ Flow-orientated planning (Specification of interdisciplinary process of coordination) ▪ Interdisciplinary Project-/Process management
	P2: Insufficient interest Interdisciplinary decisions should be supported by establishing comprehensible structures and processes.	▪ Company organization structure (hierarchy structure, leadership range, form of organization…) ▪ Flow-orientated planning (Specification of interdisciplinary process of coordination) ▪ Interdisciplinary Project-/Process management
	P3: Insufficient information The data-exchange is supported by a greater interdisciplinary, respectively cross-functional integration of the organizational structures.	▪ Company organization structure (Interdisciplinary workshops/ working groups/project teams…) ▪ Flow-orientated planning (Specification of interdisciplinary process of coordination) ▪ Interdisciplinary Project-/Process management ▪ Personnel communication (information- knowledge management, meeting points, collaboration…)
	P4: Insufficient data processability Greater interdisciplinary, respectively crossfunctional integration of organizational structures have to be available and should support the assessment and interpretation of interdisciplinary information.	▪ Company organization structure (Interdisciplinary workshops/ working groups/project teams…) ▪ Flow-orientated planning (Specification of interdisciplinary process of coordination) ▪ Interdisciplinary Project-/Process management
People (Human)	**P1: Insufficient transparency** Decision makers need to possess skills to identify interdisciplinary consequences that result out of their own actions (particularly the functional and mental maturity).	▪ Human resource development (interdisciplinary measure for further education and training, cultural/social acclimatization) ▪ Personnel planning/deployment (interdisciplinary allocation of expenditure, competent, job, rotation…)
	P2: Insufficient interest Decision makers need to be more alerted to the importance of their own decisions and thus for the entire value added network.	▪ Human resource development (interdisciplinary measure for further education and training, cultural/social acclimatization) ▪ Personnel planning/deployment (interdisciplinary allocation of expenditure, competent, job, rotation…) ▪ Human resource management (incentive system, intrinsic/extrinsic management motivation, identification, culture…)
	P3: Insufficient information It is mandated that the decision makers possess the necessary skills to obtain the data (information) from multidisciplinary value creation chain sources.	▪ Human resource development (interdisciplinary measure for further education and training, cultural/social competent, soft skills) ▪ Personnel planning/deployment (interdisciplinary competent, Networker…)
	P4: Insufficient data processability Decision makers must understand and evaluate the data (information) from other disciplines.	▪ Human resource development (interdisciplinary measure for further education, trainings…) ▪ Personnel planning/deployment (interdisciplinary allocation of expenditure, competent, job rotation… …)
Technology	**P1: Insufficient transparency** The existence of a technical solution for the transmission of action triggers throughout the value added chain is required.	▪ IT standards (Communication standards throughout the value-adding network) ▪ IT Systems (Event-based IT allowing the context-sensitive processing of the events from production, logistics and transport, push/pull systems…)
	P2: Insufficient interest Companywide systems must enable the exchange of communication between diverse units of value creation networks.	▪ IT standards (Communication standards throughout the value-adding network) ▪ IT Systems (smart interfaces, clear/easy operation, high creditableness/depth, interface enclosure…)
	P3: Insufficient information The data-exchange between the various/different units (people) of the value-added networks is realized in cross-company systems.	▪ IT standards (Communication standards throughout the value-adding network) ▪ IT systems (Data-warehouse-solutions and BI-solutions throughout the value added network, providing the context sensitive data preparation of production, logistics and transport information) ▪ Social business (interdisciplinary cross-linking/collaboration, social software…)
	P4: Insufficient data processability Systems allowing the interpretation and evaluation of interdisciplinary relationships should be established and utilized allowing proper decision support.	▪ IT standards (Communication standards throughout the value-adding network) ▪ IT systems (hardware/software accouterments, tools and methods necessary for the coupling, visualization, interpretation and evaluation of all the data derived from different disciplines,…)

Table 3 - Fields of action in order to support interdisciplinary decision-making

It becomes evident, that there are manifold fields of action that might support interdisciplinary decision-making along the value chain. Those fields of actions apparently lay across the different variables of management. A close look on the measures reveals, that most of them cannot be implemented on their own but need to be well orchestrated with other matching actions. This can be illustrated by consulting the example already mentioned above, where goods needed to be repacked in order to fit to the automated warehouse system. Implementing a cross functional or cross-company workgroup would help to raise awareness about the problem, but decision makers responsible for the packing process might still not be interested in finding an improved solution that is beneficial for all parties affected by the decision. In this case, also the decision maker's objectives might need adjustment or the decision maker probably needs to be sensitized concerning his decisions' consequences.

Another example is drawn from the current discussion about cross company decision support systems or business intelligence solutions. Those systems can only be successful, if their implementation is part of a well-orchestrated strategy that considers relevant changes concerning employees, organization, and additional dependent technical solutions. In this picture, we see the human as the key factor, since he is the decision-making entity. The other systems should be built according to the humans' requirements.

6 CONCLUSIONS

Growing complexity of value networks will increase the need for system-wide decision-making approaches in the future. Experiences from production, logistics, and traffic & transport show, that interdependencies exist and need to be managed, that system-wide decision-making is not implemented in practice and that there are four major barriers for interdisciplinary decision-making.

The developed hierarchy of barriers for interdisciplinary decision-making represents a first approach to identify and systemize the causes that detain companies from implementing interdisciplinary decision approaches that most likely would lead to more efficient and more effective value networks. Further, the provided systematization builds a solid foundation for developing adequate methods to overcome these barriers and to increase the quality of decision outcomes. Based on this foundation and by utilization of the scheme of Leavitt a toolbox could be developed including a first set of methods, that if applied in the right manner, can support interdisciplinary decision-making processes. Most of these methods and their underlying principles are not new (e.g. interdisciplinary workgroups, need for collaboration, self-organization), but there are at the present time, for example through the use of Social Software and mobile devices, new technical and organizational opportunities to come a little closer to the goal of quick and flexible system-wide decision-making.

7 IMPLICATIONS

Theoretical implications

As already outlined in this paper, existing research in the area of interdisciplinary decision-making is either focused on general aspects of interdisciplinary decision-making processes or related to some niche application fields. Thus, the paper represents a first approach to illuminate barriers of interdisciplinary decision-making and their reasons concerning decision-making in value networks.
The barriers identified in the paper are usually not subject of the discussions in decision science; even so through the listed barriers it became apparent, that the human-factor plays an important role in interdisciplinary decision-making. Evidently, the human factor has considerable potential to increase the efficiency of decision processes. The different requirements arising from the systems state spaces require different types of decision makers within the company. But these requirements are versatile so that purely technocratic and mechanistic decision-making aids are not useful. Better solutions based on associated models could be developed, particularly for times of uncertainty or unstable environment. For academics it is necessary to understand boundaries, connection and effects of specific decisions. To make the results of decisions more efficient, it is necessary to combine heuristic and algorithm based decision-making. One important point for academics as well as for practitioners is the interdisciplinary influence of many decisions made in operations and value chains. The challenge here is to identify different mind-sets, meanings and decision-making processes to generate interdisciplinary approaches that are constrained by different levels and parameters of (disciplinary) decision-making processes.

Managerial implications

Due to ideas like Supply Chain Management or Supplier Relation Management, collaboration was no foreign term to the companies that were subject to our case study. Nonetheless, the applied case study proved that companies are often far away from a high degree of supply chain integration. Even simple decision processes, like for example the decision to use a certain type of container, are not coordinated even so this type of decision affects multiple parties among different companies, e.g. supplier, transport operator, and the OEM. Repacking the goods in this case does not only increase the process complexity thus causing a higher error rate and longer procession times but of course also increases the costs for at least one party due to additionally required resources.
Having this in mind, the barriers for interdisciplinary decision-making identified in this paper and the developed toolbox are of high value to practitioners. They profit by gaining knowledge about what might be the reasons for inefficiencies or complex processes in their companies or value networks and they are provided with some basic tools that can help them in overcoming existing problems.

Furthermore, the result implies that the human factor has considerable potential to increase the efficiency of processes. This happens when not only one's own process, but also up-stream and downstream steps are considered. It will be essential that employees develop an awareness of the implications of their actions for other parts of the process chain. This re-quires an interdisciplinary understanding. In addition to adequate education and training in this area, it also lacks on decentralized decision-support systems, which relieve it for em-ployees and decision makers to make the right decisions for the overall process in terms of efficiency and existing conflicting goals.

8 RESEARCH LIMITATIONS AND FUTURE RESEARCH DIREC-TIONS

This article presents a first idea on the barriers, which detain companies from making more integrated decisions. The research was limited preliminary to production companies and lo-gistics service providers and included only one public sector entity. In order to better under-stand impacts of decisions made in the private sector on parties from the public sector and the other way around, the existing case study would need to be expanded.
Concerning the case study's findings, numerous questions evolved during the interpretation of the case study's results:

1. How are the given barriers interrelated? Does in fact exist a hierarchical dependence matching the illustration in figure 6?
2. Can the identified barriers be applied to all steps of the decision-making process illus-trated in figure 6?
3. The findings show that the solely implementation of measures from table 3 might not be beneficial; how can those methods be implemented in an orchestrated way in or-der to catalyze interdisciplinary decision-making in value chains?
4. The case study showed, that the lack of interdisciplinary decision-making might have negative impacts, e.g. on supply chain efficiency and supply chain effectiveness; how can this impact be quantified or measured?

In addition to those questions, which need to be the object of further research, the conducted case studies revealed, that purely technocratic decision-making aids are often not useful, especially if they are not understood or not even used by the decider. 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 ex-ists, in order to find an explanation approach for interdisciplinary decision-making in the add-ed value network.

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